Department of Defense
Legacy Resource Management Program

PROJECT NUMBER (04-1703)

Development of a Categorized List of Invasive Non-native Plants That Threaten Wildlands in Arizona: Individual Plant Assessments by Species

Final Report of the Arizona Wildland Invasive Plant Working Group
Vol 2. *Hordeum murinum* to *Vinca major*

F. Northam, Consulting Biologist, Tempe AZ.
D. Backer, National Park Service, Tucson AZ.
J. Hall, The Nature Conservancy, Tucson AZ.

SEPTEMBER 2005

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Hordeum murinum* L. (USDA 2005)
Synonyms:	*Hordeum murinum* L.: *Hordeum leporinum* Link; *Hordeum murinum* spp. *glaucum*: *Critesion glaucum* (Steud.) A. Löve, *Critesion murinum* (L.) A. Löve ssp. *glaucum* (Steud.) W.A. Weber, *Hordeum glaucum* Steud., *Hordeum stebbinsii* Covas; *Hordeum murinum* spp. *leporinum*: *Critesion murinum* (L.) A. Löve ssp. *leporinum* (Link) A. Löve, *Hordeum leporinum* Link; *Hordeum murinum* ssp. *murinum*: *Critesion murinum* (L.) A. Löve (USDA 2005).
Common names:	*Hordeum murinum* L.: Mouse barley; *Hordeum murinum* spp. *glaucum*: Smooth barley; *Hordeum murinum* spp. *leporinum*: Leporinum barley, hare barley, wild barley, barely grass; *Hordeum murinum* ssp. *murinum*: Wall barley.
Evaluation date (mm/dd/yy)**:**	05/21/04
Evaluator #1 Name/Title:	Dennis J. Casper/Biological Technician
Affiliation:	National Park Service, Organ Pipe Cactus National Monument
Phone numbers:	(520) 387–7661 ext. 7118
Email address:	Dennis_Casper@nps.gov
Address:	10 Organ Pipe Drive, Ajo, Arizona 85321–9626
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	05/21/04: D. Backer, D. Casper, D. Foster, P. Guertin, J. Hall, C. Laws, F. Northam 09/24/04: D. Backer, J. Brock, D. Casper, J. Cotton, R. de la Torre, J. Hall, K. Klementowski, H. Messing, B. Munda, F. Northam, J. Ward
Committee review date:	5/21/04 and 09/24/04
List date:	09/24/04
Re-evaluation date(s):	

Taxonomic Comment: See the Red Flag Annotation section.

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Observational	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**B**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**C**	Other published material		
1.4	Impact on genetic integrity	**U**	Observational		
2.1	Role of anthropogenic and natural disturbance	**B**	Reviewed scientific publication	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **15 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Other published material		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Other published material		
2.6	Potential for natural long-distance dispersal	**A**	Other published material		
2.7	Other regions invaded	**C**	Other published material		 Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Red Flag Annotation

Some authorities recognize *Hordeum glaucum, H. leporinum*, and *H. murinum* as separate species; however, based on the use of the U.S. Department of Agriculture Plants Database [USDA 2005] as the authority for reconciling taxonomic questions, *H. murinum* is recognized herein as the valid species taxon and *H. m. glaucum, H. m. leporinum*, and *H. m. murinum* are recognized as subspecies.

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes	*Score:* **B** *Doc'n Level:* **Obs.**
Identify ecosystem processes impacted: Dense stands may increase fire frequency and intensity though this species is not promoted by fire; it competes successfully for light, water, and nutrients due to its ability to start growth early in the season.	
Rationale: Direct information on wildland fires fueled by *Hordeum murinum* are lacking, however it is well established that high density stands of exotic winter ephemeral grasses have supported damaging fires in the Sonoran desert (Esque and Schwalbe 2001). In California *H. m. leporinum* was found to be the annual grass most sensitive to burning. When grassland contained up to 90% of *H. m. leporinum*, this percentage was reduced to less than 5% after burning. The early maturation of *H. m. leporinum* enables it to complete its life cycle ahead of later-maturing associated annual and perennial species (Dean 1990). Early germination and establishment also provides these plants an advantage in capturing needed resources (light, water, and nutrients) (Guertin and Halvorson 2003). **Note:** Little research has been conducted on *H. m. leporinum* in natural areas (Dean 1990).	
Sources of information: See cited literature. Score based on inference drawn from the literature.	

Question 1.2 Impact on plant community composition, structure, and interactions	*Score:* **B** *Doc'n Level:* **Rev. sci. pub**.
Identify type of impact or alteration: Can become dominant over native plants, particularly where livestock is grazed and where soil nitrogen is high.	
Rationale: Some native annuals may have density-dependent germination (Inouye 1980 in Burgess et al. 1991) whereby the presence of established plants on a site prevents others from germinating. *Hordeum murinum* does not suppress germination at high densities. After good rains, mass germination in these species produces dense stands that suppress other ephemerals (Burgess et al. 1991). *Hordeum m. leporinum* is a successful invader species, particularly where land has been disturbed (i.e. continuous grazing) and where soil nutrient levels are high and nitrogen rich. Under climatic conditions similar to the Mediterranean (warm, dry summers and cool, moist winters that are relatively frost free), the species can become dominant over native plants (Dean 1990). This species does particularly well in areas with high nitrogen leaf litter such as mesquite bosques in Sonoran riparian and Sonoran desertscrub (i.e., Hassayampa River Preserve and Catalina State Park). It is in these areas where impact on plant community dynamics could be significant, particularly when climatic conditions are favorable (D. Casper, personal observation, 2004).	
Sources of information: See cited literature. Also considered personal observations by D. Casper (Biological Technician, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 2004). Score based in part on inference drawn from the literature and observations by D. Casper.	

Question 1.3 Impact on higher trophic levels	*Score:* **C** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Seed awn could harm wildlife, the forage produced is of high quality before seed heads develop.	
Rationale: Because the seed awn is often so damaging to stock animals, it is possible that the species could be harmful to wildlife (Dean 1990). *Hordeum murinum* is generally a localized species in favored environments that grow a host of other native and non-native species; therefore, its impact on higher trophic levels is probably small. More research is needed on the impact of *H. murinum* on higher trophic levels. It was suggested during Working Group member discussions that the presence of dense stands of *H. murinum* could affect foraging patterns of animals because of the presence of the mechanical deterrent of seed awns in dense stands.	
Sources of information: See cited literature. Also considered Working Group member discussions on May 21, 2004).	

Question 1.4 Impact on genetic integrity	*Score:* **U** *Doc'n Level:* **Obs.**
Identify impacts: Unknown; not likely significant because barely grass usually has closed flowers.	
Rationale: Native congeners occur in Arizona (Kearney and Peebles 1960). No studies were found that address whether *Hordeum murinum* (and all of its subspecies) can hybridize with native barleys. The flowers can be wind pollinated, but mostly are cleistogamous and are self-fertilized (Giles and Lefkovitch 1986, Weiller et al. 1995 in Guertin and Halvorson 2003).	
Sources of information: See cited literature. Score based on inference drawn from the literature.	

Question 2.1 Role of anthropogenic and natural disturbance in establishment	*Score:* **B** *Doc'n Level:* **Rev. sci. pub.**
Describe role of disturbance: This species thrives in ruderal habitats associated with grazing and human habitation, it can establish in the absence of disturbance.	
Rationale: *Hordeum murinum* typically grows in disturbed, ruderal sites or cultivated fields (Burgess et al. 1991). In Arizona *H. m. leporinum* is common on disturbed soil of roadsides, irrigation ditches, vacant lots, and lawns (Dean 1990). This species is widespread throughout Arizona and is locally present in relatively undisturbed natural areas. It's important to note that cattle grazing has occurred or continues to occur in many natural areas throughout the state and creates suitable site for *Hordeum murinum* establishment (D. Casper, unpublished data, 2004).	
Sources of information: See cited literature. Also considered unpublished information of D. Casper (Hordeum Occurrence in Local Floras of Arizona. Worksheet produced for AZ-WIPWG meeting [see table following Worksheet B]. Research conducted online May 7, 2004 at: http://seinet.asu.edu/bioExplorer/ChecklistChoices.jsp.).	

Question 2.2 Local rate of spread with no management	*Score:* **B** *Doc'n Level:* **Other pub**.
Describe rate of spread: The rate of spread will vary with climatic conditions, in years with the appropriate weather regimes the rate of spread can be locally high	
Rationale: *Hordeum murinum* can rapidly colonize areas when environmental conditions are good (i.e. no hard freeze and good moisture) because of its early germination, early rapid growth rate, high seed production, and efficient dispersal mechanisms (Biddiscombe et al. 1954, Smith 1972 in Dean 1990). No research was located on the local rate of spread within Arizona.	
Sources of information: See cited literature. Score based on inference drawn from the literature.	

Question 2.3 Recent trend in total area infested within state	*Score:* **C** *Doc'n Level:* **Obs.**
Describe trend: Not known with certainty, but inferred to be fairly stable considering how long it has been within the state.	
Rationale: It is thought to have been introduced to North and South America, and to Australia, by the early nineteenth century (Smith 1972, Cocks et al. 1976 in Dean 1990). *Hordeum murinum* has a nearly complete germination of its seeds. Because of this life-history strategy, little evidence exists for large seed banks to develop for this species (Popay and Sanders 1974 in Guertin and Halvorson 2003).	
Sources of information: See cited literature. Score based on inference drawn from the literature.	

Question 2.4 Innate reproductive potential	*Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: See Worksheet A.	
Rationale: Life-history strategy: an annual, C3 graminoid. Reproduces by seed (Guertin and Halvorson 2003). Growth to seed maturation is rapid, and ripe seed production is copious. Halloran and Pennell (1981) found 19 to 29 seeds produced per head. In a study conducted on pasture in Austrailia, Smith (1968) found an average seed set of 1166 seeds per 64 inches square (>28,000 seeds m^2) under three different grazing regimes and natural rainfall conditions. The flowers can be wind pollinated, but mostly are cleistogamous and are self-fertilized (Giles and Lefkovitch 1986, Weiller et al. 1995 in Guertin and	

Halvorson 2003). *Hordeum m. leporinum* flowers from March to April in the lower elevations in Arizona, and until October in the higher elevations (Parker 1972 in Guertin and Halvorson 2003). In any one location *Hordeum murinum* produces seed for a relatively short period of time 1 to 2 months (D. Casper, personal observation, 2004). A viable, 200 year-old seed (*H. m. leporinum*) was found in adobe brick in southwest North America (Mexico) (Mabberley 1997, Spira and Wagner 1983). Generally, after a short dormancy, almost 100% germination occurs, with a few seed remaining dormant (Guertin and Halvorson 2003). Little evidence exists for large seed banks to develop for this species (Popay and Sanders 1974 in Guertin and Halvorson 2003). Heavy grazing…increased tillering and heads produced (Smith 1968 in Dean 1990).
Sources of information: See cited literature citations. Also considered personal observations by D. Casper (Biological Technician, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 2004).

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Other Pub.**
Identify dispersal mechanisms: Seed is transported in the fur of domesticated grazing animals
Rationale: These seeds easily disperse when long awn attaches to stock (Dean 1990). In Arizona *H. m. leporinum* is common on disturbed soil of roadsides, irrigation ditches, vacant lots, and lawns (Dean 1990). Livestock probably account for much of the dispersal of this species. Disturbed conditions associated with agriculture provide areas for *H. murinum* to thrive and spread along roadway corridors is common. *Hordeum murinum* is often a contaminant in the early cut of alfalfa, so it could be transported in hay (F. Northam, personal communication, 2004).
Sources of information: See cited literature. Also considered personal communication with F. Northam (Weed Biologist [former Arizona Department of Agriculture, Noxious Weed Coordinator], Tempe, Arizona, 2004).

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Other Pub.**
Identify dispersal mechanisms: Wind; birds; long-awned seed can be transported in the fur of animals; also seed is highly viable.
Rationale: Seed is distributed by wind, birds, or when the awns of the seeds attach to the wool or fur of animals (Ridley 1930 in Guertin and Halvorson 2003). *Hordeum m. leporinum* showed 92% mean fertility of seed heads (Halloran and Pennel 1981).
Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Other Pub.**
Identify other regions: *Hordeum murinum* has invaded elsewhere but only in ecological types that it has already invaded in Arizona
Rationale: Extremely widespread genus; from western Asia; introduced to North and South America, Africa, and to Australia.
Sources of information: See Guertin and Halvorson (2003) and Dean (1990).

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: *Hordeum murinum* invades seven major ecological types in Arizona (See Worksheet B). *Hordeum m. leporinum* is found from 275 to 2750 m in Arizona (Dean 1990). Earliest record found was 1902 for *H. m. glaucum* (SEINet 2004). In Arizona this species has invaded all major ecological types with the exception of alpine and dunes (See Worksheet B and subsequent table). In North America, *Hordeum murinum* can be found from Maine and British Columbia to northern Mexico; it is absent in most Midwestern states (Dean 1990, USDA 2005).

Rationale: *Hordeum murinum* is thought to have been introduced to North and South America, and to Australia, by the early nineteenth century (Smith 1972, Cocks et al. 1976 in Dean 1990). As early as 1901, McClatchie (1901) warned that *H. m. glaucum* would become a "problem invasive" in the Salt River floodplain if no measures were taken to halt its spread (cited in Stromberg and Chew 2002).
Sources of information: See cited literature. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed September 2004), unpublished information of D. Casper (Hordeum Occurrence in Local Floras of Arizona. Worksheet produced for AZ-WIPWG meeting [see table following Worksheet B]. Research conducted online May 7, 2004 at: http://seinet.asu.edu/bioExplorer/ChecklistChoices.jsp.), and Working Group member observations.

Question 3.2 Distribution	*Score:* **A** *Doc'n Level:* **Obs.**
Describe distribution: *Hordeum murinum* is present in Arizona in every county except Navajo, Apache, and Greenlee (Guertin and Halvorson 2003).	
Rationale: *Hordeum m. leporinum* is indigenous to the Mediterranean region where it typically occurs in disturbed areas. In North America it is found from Maine and British Columbia to northern Mexico; it is absent from most Midwestern states (Dean 1990). *Hordeum murinum* is rated A for Sonoran Riparian. It is a common understory plant in mesquite bosques of Arizona's Hassayampa River (observations by H. Richter cited in Dean 1990).	
Sources of information: See cited literature. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed September 2004) and Working Group member observations.	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 8 Total unknowns: 0		
	Score : A		
Note any related traits:			

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	**C**
Desertlands	Great Basin desertscrub	**C**
	Mohave desertscrub	**C**
	Chihuahuan desertscrub	**D**
	Sonoran desertscrub	**C**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	**U**
	semi-desert grassland	**C**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	**C**
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**A**
	southwestern interior riparian	**B**
	montane riparian	**D**
Woodlands	Great Basin conifer woodland	**D**
	Madrean evergreen woodland	**D**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	**D**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Hordeum murinum **(and included subspecies): Occurrence in Local Floras in Arizona**			
Location	**Occurrence****	**Major Ecol. Type**	**Minor Ecol. Type**
Buckeye Hills Recreation Area	P	Desertlands	Sonoran desertscrub
Canyon De Chelly N.M.	P	Desertlands	Great Basin desertscrub
Castle Dome Mountains	A	Desertlands	Sonoran desertscrub
Chiricahua National Monument	A	Forests/Woodlands	montane conifer forest/ Madrean evergreen woodland
Hassayampa River Preserve	P	Riparian	Sonoran Riparian
Lake Pleasant Regional Park	P	Desertlands/ Freshwater Systems	Sonoran desertscrub/ lakes ponds, reservoirs
McDowell Mountains Regional Park	P	Desertlands	Sonoran desertscrub
Organ Pipe Cactus N.M.	P	Desertlands	Sonoran desertscrub
Buenos Aires N.W.R.	P	Grasslands	semi-desert grassland
Sierra Ancha	P	Woodlands/ Scrublands/Forests	Great Basin conifer woodland & Madrean evergreen woodland/ southwestern interior chaparral/ montane conifer forest
San Pedro Riparian Conservation Area	P	Desertlands/ Riparian	Chihuahuan desertscrub/ Sonoran riparian
West Fork Oak Creek Canyon	P	Riparian/ Woodlands/Forests	southwestern interior riparian/ Great Basin conifer woodland & Madrean evergreen woodland/ montane conifer forest
Pinal Mountains	A	Woodlands/ Scrublands/Forests	Great Basin conifer woodland & Madrean evergreen woodland/ southwestern interior chaparral/ montane conifer forest
San Tan Semi-Regional Park	P	Desertlands	Sonoran Riparian
Seven Springs	P	Desertlands/ Scrublands/ Grasslands/ Riparian	Sonoran desertscrub/ southwestern interior chaparral/ semi-desert grassland/ Sonoran Riparian
Sierra Estrella Regional Park	P	Desertlands	Sonoran desertscrub
South Mountain	P	Desertlands	Sonoran desertscrub
Superstition Mountains Wilderness	P	Desertlands/ Scrublands/ Grasslands	Sonoran desertscrub/ southwestern interior chaparral/ semi-desert grassland
White Tank Mountains Regional Park	P	Desertlands	Sonoran desertscrub

*Based on information at http://seinet.asu.edu/ and knowledge of the ecological types.
**A = absent; P = present.

Literature Cited

Biddescombe, E., E. Cuthbertson, and R. Hutchings. 1954. Autoecology of some natural pasture species at Trangie, New South Wales. Australian Journal of Botany 2:69−98.

Bowers, J.E. and S.P. McLaughlin. 1987. Flora and Vegetation of the Rincon Mountains, Pima County, Arizona. Desert Plants 8:50−95.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burgess, T.L., J.E. Bowers, and R.M. Turner. 1991. Exotic plants at the desert laboratory, Tucson, Arizona. Madroño 38:96−114.

Cocks, P., K. Boyce, and P. Kloot. 1976. The *Hordeum murinum* complex in Australia. Australian Journal of Botany 24:651−662.

Dean, S.A. 1990. *Hordeum murinum* spp. *leporinum*—wild barley. Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documnts/hordmu1.html; accessed May 2004.

Esque, T., and C. Swalbe. 2000. Non-native grasses & fires create double jeopardy. People, Land, and Water. July/August 2000. Available online at: http://www.usgs.gov/invasive_species/plw/grassfire.html; accessed May 2004.

Giles, B.E., and L.P. Lefkovitch. 1986. A taxonomic investigation of the *Hordeum murinum* complex (Poaceae). Plant Systematics and Evolution 153:181−197.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Halloran, G.M., and A.L. Pennel 1981. Regenerative Potential of Barley Grass (*Hordeum leporinum*). Journal of Applied Ecology 18:805−813.

Inouye, R.S. 1980. Density-dependent germination response by seeds of desert annuals. Oecologia 46:235−238.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Mabberley, D.J. 1997. The Plant-Book: A Portable Dictionary of the Vascular Plants. 2nd edition., Cambridge University Press, Cambridge, United Kingdom. 858 p.

McClatchie, A.J. 1901. Wild barley. Univ. Ariz. Agric. Exp. Stn. Bull. 38:287−290.

Parker, K.F. 1972. An Illustrated Guide to Arizona Weeds. The University of Arizona Press, Tucson. 338 p. Available online at: http://www.uapress.arizona.edu/online.bks/weeds/.

Popay, A.I., and P. Sanders. 1974. Effect of depth of burial on seed germination and seedling emergence of barley grass (*Hordeum murinum* L.). New Zealand Journal of Experimental Agriculture 3:77−80.

Ridley, H.N. 1930. The Dispersal of Plants throughout the World. L. Reeve and Co., Ltd., Ashford, Kent. 744 p.

Rondeau, R.J., T.R. Van Devender, C.D. Bertelsen, P.D. Jenkins, R.K. Van Devender, and M.A. Dimmit. 2000. Flora and Vegetation of the Tucson Mountains, Pima County, Arizona. Available online at: http://eebweb.arizona.edu/herb/TUCSONS/tucsons.html#veget; accessed September 23, 2004.

Smith D.F. 1968. The growth of barley grass (*Hordeum leporinum)* in annual pasture 4. The effect of some management practices on barley grass content. Australian Journal of Animal Husbandry 8:706−711.

Smith, D. 1972. *Hordeum* species in grasslands. Herbage Abstracts 42:213−223.

Spira, T.P., and L.K. Wagner. 1983. Viability of seeds up to 211 years old extracted from adobe brick buildings of California and northern Mexico. American Journal of Botany 70:303−307.

Stromberg, J.C., and M.K. Chew. 2002. Foreign visitors in riparian corridors of the American Southwest: is xenophytophobia justified? Pages 195−219 in B. Tellman (ed.), Invasive Exotic Species in the Sonoran Region. The University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson, Arizona.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Weiller, C.M., M.J. Henwood, J. Lenz, and L. Watson. 1995 [and onwards]. Pooideae (Poaceae) in Australia—descriptions and illustrations. Available online for:
Hordeum [*m.*] *glaucum*: at http://muse.bio.cornell.edu/delta/pooid/www/descr204.htm;
Hordeum [*m.*] *leporinum*: at http://muse.bio.cornell.edu/delta/pooid/www/descr206.htm;
Hordeum [*m.*] *murinum*: at http://muse.bio.cornell.edu/delta/pooid/www/descr208.htm.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Hydrilla verticillata* (L.f.) Royle (USDA 2005)
Synonyms:	None identified in USDA (2005)
Common names:	Hydrilla, water thyme, Florida elodea
Evaluation date (mm/dd/yy)**:**	03/26/04
Evaluator #1 Name/Title:	Dr. Francis E. Northam
Affiliation:	Freelance weed biologist
Phone numbers:	(480) 947–3882
Email address:	fnortham@msn.com
Address:	216 E. Taylor St., Tempe, Arizona 85281
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	03/26/04: D. Backer, K. Brown, P. Guertin, J. Hall, B. Munda, F. Northam, M. Quinn, J. Ward 05/21/04: D. Backer, K. Brown, D. Casper, G. Ferguson, D. Foster, P. Guertin, J. Hall, C. Laws, D. Madison, F. Northam, J. Ward
Committee review date:	03/26/04 and 05/21/04
List date:	05/21/04
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

<table>
<tr><th colspan="2">Question</th><th>Score</th><th>Documentation Level</th><th>Section Scores</th><th>Overall Score & Designations</th></tr>
<tr><td>1.1</td><td>Impact on abiotic ecosystem processes</td><td>A</td><td>Other published material</td><td rowspan="4">“Impact”

Section 1 Score:

A</td><td rowspan="11">“Plant Score”

Overall Score:

Evaluated but not listed

Alert Status:

None</td></tr>
<tr><td>1.2</td><td>Impact on plant community</td><td>A</td><td>Other published material</td></tr>
<tr><td>1.3</td><td>Impact on higher trophic levels</td><td>B</td><td>Other published material</td></tr>
<tr><td>1.4</td><td>Impact on genetic integrity</td><td>D</td><td>Other published material</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2.1</td><td>Role of anthropogenic and natural disturbance</td><td>A</td><td>Other published material</td><td rowspan="7">“Invasiveness”

For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:

11 pts

Section 2 Score:

B</td></tr>
<tr><td>2.2</td><td>Local rate of spread with no management</td><td>U</td><td>No information</td></tr>
<tr><td>2.3</td><td>Recent trend in total area infested within state</td><td>C</td><td>Observational</td></tr>
<tr><td>2.4</td><td>Innate reproductive potential</td><td>A</td><td>Other published material</td></tr>
<tr><td>2.5</td><td>Potential for human-caused dispersal</td><td>C</td><td>Other published material</td></tr>
<tr><td>2.6</td><td>Potential for natural long-distance dispersal</td><td>C</td><td>Other published material</td></tr>
<tr><td>2.7</td><td>Other regions invaded</td><td>B</td><td>Other published material</td><td rowspan="4">
Something you should know.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.1</td><td>Ecological amplitude</td><td>U</td><td>Observational</td><td rowspan="2">“Distribution”

Section 3 Score:

U</td></tr>
<tr><td>3.2</td><td>Distribution</td><td>U</td><td>Observational</td></tr>
</table>

Red Flag Annotation

Although based on its question and section scores related to Impact and Invasiveness *Hydrilla verticillata* potentially could have been ranked as a High, Alert taxon, it was assigned an **Evaluated but not listed** designation to reflect its current distribution status: present in the state but only in human-constructed water bodies. If inadvertently introduced into natural, low-elevation water bodies in Arizona, *H. verticillata* easily could establish and flourish in Arizona's wildlands.

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n Level:* **Other pub.**

Identify ecosystem processes impacted: *Hydrilla verticillata* restricts water flow in streams, increases sediment and organic matter deposition, reduces availability of light to submerged plants and animals, and alters water quality.

Rationale: No populations are known to be established in Arizona's natural waters. No impacts on Arizona's natural fresh water habitats have been documented; however, research in other areas has documented definite impacts. First, hydrilla colonies fill water columns of streams with dense, tangled mats that physically impede (slow) water flow and increases sedimentation (Godfrey 2000). Second, as vertical hydrilla stems grow from the mud/sediment toward the water surface, shoots branch laterally and create a dense vegetative layer within the top 0.5 m of water column. These dense mats severely reduce sunlight penetration below 1.0 m (Langeland 1996). Third, because hydrilla's photosynthetic system can function at low light intensities (<1% of sunlight), this species can colonize deeper areas of water bodies (9 to 15 meters) than most aquatic macrophytes. As a result, this species can occupy portions of aquatic habitats that have no native submerged plant life (Batcher Undated). Fourth, in situations where hydrilla is the predominate macrophyte biomass, pH is raised, dissolved oxygen concentrations decrease, and water temperature increases (Invasive Plant Atlas of New England Undated).

Sources of information: See cited literature. Also considered information from the Invasive Plant Atlas of New England. Undated. *Hydrilla verticillata* (available online at: http://webapps.lib.uconn.edu/ipane/browsing.cfm?descriptionid=22; accessed March 2004).

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Other pub.**

Identify type of impact or alteration: *Hydrilla verticillata* displaces native species and reduces native seed production. In addition, biomass production is reduced by hydrilla, as it excludes light from native plants.

Rationale: No *H. verticillata* populations have been reported in natural aquatic habitats in Arizona, but this species' detrimental effects in natural areas of the southeastern U.S. indicate it poses a direct threat to Arizona lakes and streams. Hydrilla has been shown to have the capability to replace native species of *Potamogeton* and *Vallisneria* in the southeastern U.S. (Haller and Sutton 1975, Spencer and Ksander 2000). Colonies of hydrilla have been shown to reduce seed banks of native species in lake sediments de Winton and Clayton 1996). Hydrilla's mat-forming ability at water surfaces intercept (block) light to other submerged plants (Batcher Undated)..

Sources of information: See cited literature.

Question 1.3 Impact on higher trophic levels *Score:* **B** *Doc'n Level:* **Other pub.**

Identify type of impact or alteration: *Hydrilla verticillata* increases mosquito habitat, provides substrate for epiphytic cyanobacteria (bluegreen algae) that produce neurotoxins that are lethal to waterfowl, and provides non-native forage for water fowl. In addition, dense infestations are detrimental to fish habitat.

Rationale: Streams clogged with dense hydrilla populations stagnate to the point that mosquito larvae survive in previously unsuitable habitat. These increases in mosquito habitat become potential breeding sites for vectors of arthropod borne diseases such as West Nile virus, malaria and encephalitis (Invasive Plant Atlas of New England Undated). Largemouth bass populations are adversely affected when hydrilla coverage exceeds 30% (Colle and Sherman 1980). Waterfowl in the southeastern U.S. feeding on hydrilla during November 2001–2003 died of avian vacuolar myelinopathy (AVM; Thomas et al. 1998, Rocke et al. 2002, Fischer et al. 2003). Bald eagles feeding on sick coots also died from the disease. Wildlife pathologists are currently investigating a hypothesis that an undescribed

Stigonematales species is the toxin source. Southeastern U.S. wildlife biologists have detected waterfowl utilizing hydrilla as a forage plant (Johnson and Montalbano 1984, Esler 1989). The impact on higher trophic levels was given a B and not an A (which was the case for *Myriophyllum spicatum*), because hydrilla is not present in natural areas and in the unnatural areas (golf courses) they are few and often not associated with the wildlife mentioned above.
Sources of information: See cited literature. Also considered information from the Invasive Plant Atlas of New England. *Hydrilla verticillata* (Undated; available online at: http://webapps.lib.uconn.edu/ipane/browsing.cfm?descriptionid=22; accessed March 2004).

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: No known hybridization.
Rationale: No known native congeners in Arizona (Kearney and Peebles 1960).
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **A** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Habitat disturbance is not necessary for establishment of this species.
Rationale *Hydrilla verticillata* grows in a wide range of water quality conditions, including oliogotrophic near-pristine habitats (Langeland 1996). Water quality is rarely a limiting factor for establishment (Batcher Undated). Initial establishment of pioneer colonies in an ecosystem requires direct human intervention or waterfowl transport from another ecosystem.
Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **U** *Doc'n Level:* **No info.**
Describe rate of spread: Rate of spread with no management is unknown as current populations (in artificial environments) are managed and contained.
Rationale: No known infestations in natural freshwater habitats in Arizona. Two golf course ponds, one in Phoenix and one in Tucson, are the only presently known infestations in Arizona (Arizona Department of Agriculture 2001−2003). No documentation of dispersal from these sites has been detected during the past 3.5 years. Land owners are applying treatments to keep growth under control.
Sources of information: See Arizona Department of Agriculture, Noxious Weed Distribution Records, 2001−2003. No information on local rate of spread with no management.

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n Level:* **Obs.**
Describe trend: Stable.
Rationale: No known infestations in natural freshwater habitats in Arizona as of March 2004. Two golf course ponds, one in Phoenix and one in Tucson, are the only presently known infestations in Arizona. No dispersal from these sites has been detected during the past 3.5 years. Land owners are applying treatments to keep growth under control. Several examples of small populations becoming established in Arizona irrigation canals and backyard ponds since the 1980s are present in Arizona Department of Agriculture, Noxious Weeds files. All of these hydrilla populations were eradicated and no indication exists of hydrilla returning. Likewise, a few retail sales outlets of hydrilla were detected and halted by Arizona Department of Agriculture inspectors during the past 3.5 years.
Sources of information: See Arizona Department of Agriculture, Noxious Weed Distribution Records, 2001−2003. Also considered statewide observations by F. Northam (Weed Biologist, Tempe, Arizona, 2004) while serving as Arizona Noxious Weed Program Coordinator from July 2000 to Dec 2003.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: Rapid vegetative growth; new infestations easily started by small fragments of stem; both turions and tubers are produced asexually; asexual reproduction occurs in Arizona; seed production is possible but seed have a minor impact on dispersal of new infestations; asexual propagule production can be extensive.
Rationale: Field research has documented hydrilla stem growth rate of one inch per day in the southeastern U.S. (Langeland 1996). *Hydrilla verticillata* vegetative growth experiments demonstrated nearly 50% of stems fragments with one whorl of leaves (one node) were able to sprout roots and establish a new plant (Langeland and Sutton 1980). As a result, dispersal of small segments of hydrilla plants can establish new infestations. *Hydrilla verticillata* plants produce vegetative propagules in leaf axils (turions) and on roots (tubers). These asexual structures contain buds that will sprout new plants once they are detached from parent plant and tubers may remain viable and dormant for at least 3-5 years in moist sediment (Godfrey 2000). Field observations by Arizona Department of Agriculture inspectors confirmed hydrilla plants are capable of producing turions and tubers in Arizona (F. Northam, personal observation, 2004). Both monoecious and dioecious biotypes exist in U.S. waters; however, seed production seems to be a minor source of propagule dispersal (Batcher Undated). Asexual propagule densities of 2000 turions and 6000 tubers per sq. meter have been recorded in southeastern U.S. (Batcher Undated).
Sources of information: See cited literature. Also considered statewide observations by F. Northam (Weed Biologist, Tempe, Arizona, 2004) while serving as Arizona Noxious Weed Program Coordinator from July 2000 to Dec 2003.

Question 2.5 Potential for human-caused dispersal *Score:* **C** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Vegetative fragment transport via watercraft and trailers; ornamental plant in aquarium trade and by backyard pond hobbyists; contaminate of other commercially traded aquatic ornamental species including aquarium plants.
Rationale: All authors cited in previous questions acknowledge the threat of new infestation being established by moving hydrilla fragments on boats, boat trailers, bait buckets/boxes, fishing gear, anchors, swamp buggies, etc., and they similarly affirm these human activities are the primary source of extant infestations in the U.S. During the period of July 2000 to December 2003, hydrilla retail sales were stopped and fishpond infestations started from purchased hydrilla plants were abated in Arizona (F. Northam, personal observation, 2004).
Sources of information: See cited literature in previous questions. Also considered statewide observations by F. Northam (Weed Biologist, Tempe, Arizona, 2004) while serving as Arizona Noxious Weed Program Coordinator from July 2000 to Dec 2003.

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Downstream movement of stem fragments, turions or tubers; waterfowl transport of stem fragments, turions, or tubers.
Rationale: Once initial human-induced hydrilla populations are established in non-infested regions, natural transport mechanisms are effective dispersers because of the ease with which stem fragments produce roots; see question 2.4 rationale (Batcher Undated). Turions and tubers can survive ingestion by waterfowl (Batcher Undated).
Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: Wide amplitude of aquatic conditions are infested in North America.
Rationale: *Hydrilla verticillata* can infest any freshwater aquatic system in California from desert waters to upper estuaries to mountain lakes (Godfrey 2000). *Hydrilla verticillata* also infests the cool

temperate waters of Washington (Seattle area), Connecticut, and Cape Cod, Massachusetts (Washington State Department of Ecology Undated, Invasive Plant Atlas of New England Undated), and the warm temperate and humid subtropical areas of the southeastern U.S. (USDA 2005). *Hydrilla verticillata* rarely establishes in swift-flowing water (Batcher Undated)**.** Because of the asexual perennial reproductive traits of hydrilla, this species appears to be adapted to any permanent freshwater system in the U.S. where tubers can survive winter freezing. All freshwater systems—lakes, ponds, reservoirs, rivers, and streams—in Arizona are susceptible to invasion by hydrilla.
Sources of information: See cited literature. Also considered information from the Washington State Department of Ecology, Water Quality website: General Information About Hydrilla (Undated; available online at: http://www.ecy.wa.gov/programs/wq/plants/weeds/*Hydrilla*.html; accessed March 2004) and Invasive Plant Atlas of New England. *Hydrilla verticillata* (Undated; available online at: http://webapps.lib.uconn.edu/ipane/browsing.cfm?descriptionid=22; accessed March 2004).

Question 3.1 Ecological amplitude *Score:* **U** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Limited to permanent freshwater habitats. See question 2.7 rationale.
Rationale: Based on hydrilla's distribution in temperate regions of North America, it seems capable of colonizing any Arizona aquatic site that has a permanent source of water; however, distribution records since its first discovery in west Phoenix during the early 1980s are in the elevation range of 900 to 2500 feet, with none of the infested sites natural water bodies (F. Northam, personal observation, 2004).
Sources of information: Statewide observations by F. Northam (Weed Biologist, Tempe, Arizona, 2004) while serving as Arizona Noxious Weed Program Coordinator from July 2000 to Dec 2003.

Question 3.2 Distribution *Score:* **U** *Doc'n Level:* **Obs.**
Describe distribution: Man-made ponds, water storage structures, irrigation water delivery canals, and retail aquatic plant culture tanks. At present, unknown from natural freshwater systems.
Rationale: Examination of collection records (SEINet 2004; F. Northam, personal observation, 2004) did not uncover any records of hydrilla established in natural waters.
Sources of information: Statewide observations by F. Northam (Weed Biologist, Tempe, Arizona, 2004) while serving as Arizona Noxious Weed Program Coordinator from July 2000 to Dec 2003 and information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed March 2004).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**Yes**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**[Yes]**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 6	**Total unknowns: 3**	
	Score : A		

Note any related traits: Seed production is not considered an important part of hydrilla reproduction.

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	**U**
	rivers, streams	**U**
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Batcher, M.S. Undated. *Hydrilla verticillata* (L.F.) Royle. Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documnts/hydrver.rtf; accessed March 2004.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Colle, D.E., and J.V. Shireman 1980. Coefficients of condition for largemouth bass, bluegill and redear sunfish in *Hydrilla*-infested lakes. Trans. Amer. Fish. Soc. 109:521−531

de Winton, M.D., and J.S. Clayton. 1996. The impact of native submerged weed species on seed banks in lake sediments. Aquatic Botany 53:31−45.

Esler D. 1989. An assessment of American coot herbivory of *Hydrilla*. Journal of Wildlife Management 53: 1147−1149.

Fischer, J.R., L.A. Lewis-Weis, and C.M. Tate. 2003. Experimental vacuolar myelinopathy in red-tailed hawks. Journal Wildlife Diseases 329:400−406.

Godfrey, K. 2000. *Hydrilla verticillata*. Pages 218−221 in C.C. Bossard, J.M. Randall, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Haller, W.T., and D.L. Sutton. 1975. Community structure and competition between *Hydrilla* and *Vallisneria*. Hyacinth Control Journal 13:48−50.

Johnson, F.A., and F. Montalbano. 1984. Selection of plant communities by wintering waterfowl on Lake Okeechobee, Florida. Journal of Wildlife Management 48:174−178.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Langeland, K.A. 1996. *Hydrilla verticillata*…."The Perfect Aquatic Weed." Castena 61:293−304. Available online at: http://aquatic1.ifas.ufl.edu/hydcirc.html.

Langeland, K.A., and D.L. Sutton. 1980. Regrowth of *Hydrilla* from axillary buds. Journal of Aquatic Plant Management 18:27−29

Rocke, T.E., N.J. Thomas, T. Augspurger, and K. Miller. 2002. Epizootiologic studies of avian vascular myelinopathy in waterbirds. Journal of Wildlife Diseases 38:678−684.

Spencer, D.F., and G. G. Ksander. 2000. Interactions between American pondweed and monoecious hydrilla grown in mixtures. Journal of Aquatic Plant Management 38:5−13.

Thomas, N.J., C.U. Meteyer, and L. Sileo. 1998. Epizootic vacuolar myelinopathy of the central nervous system of bald eagles and American coots. Veterinary Pathology 35:479−478.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Lepidium latifolium* L. (USDA 2005)
Synonyms:	*Cadaria latifolia* (L.) Spach (USDA 2005)
Common names:	Perennial pepperweed, tall whitetop, perennial peppercress (or peppergrass), broadleaved peppergrass (or pepperweed), peppergrass, slender perennial peppercress, dittander, giant whiteweed, ironweed
Evaluation date (mm/dd/yy)**:**	01/15/04
Evaluator #1 Name/Title:	Katy Brown
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 327–6862
Email address:	kbrown321@cox.net
Address:	4357 E. Monte Vista; Tucson, Arizona 85712
Evaluator #2 Name/Title:	Dana Backer
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell, Tucson, Arizona 85719

List committee members:	03/26/04: D. Backer, K. Brown, P. Guertin, J. Hall, B. Munda, F. Northam, M. Quinn, K. Umeda, J. Ward 03/01/05: D. Backer, D. Casper, J. Filar, E. Geiger, J. Hall, H. Messing, B. Munda, F. Northam
Committee review date:	03/26/04 and 03/01/05
List date:	03/26/04; revised 03/01/05
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**A**	Other published material	**"Impact"** **Section 1 Score:** **A**	**"Plant Score"** **Overall Score:** **High** **Alert Status:** **Alert**
1.2	Impact on plant community	**A**	Other published material		
1.3	Impact on higher trophic levels	**U**	No information		
1.4	Impact on genetic integrity	**U**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **14 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**A**	Observational		
2.3	Recent trend in total area infested within state	**U**	No information		
2.4	Innate reproductive potential	**A**	Other published material		
2.5	Potential for human-caused dispersal	**B**	Other published material		
2.6	Potential for natural long-distance dispersal	**B**	Observational		
2.7	Other regions invaded	**B**	Other published material		 Something you should know.
3.1	Ecological amplitude	**B**	Other published material	**"Distribution"** **Section 3 Score:** **C**	
3.2	Distribution	**D**	Observational		

Red Flag Annotation

Lepidium latifolium is not widely distributed in Arizona. Established populations occur mostly near the northern borders of the state. Land managers should be on the alert for isolated plants or small nascent populations that can be eradicated before they can spread. *Lepidium latifolium* is a difficult species to eradicate so addressing infestations while they are small is critical.

Table 3. Documentation

Note: *Lepidium latifolium* is widespread through many of New Mexico *Tamarix* spp patches and much concern exists for *Tamarix* spp. management causing increases in the spread of perennial pepperweed (M. Renz, personal communication, New Mexico State Noxious Weed Coordinator, Albuquerque, New Mexico, 2005).

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n Level:* **Other pub**.
Identify ecosystem processes impacted: *Lepidium latifolium* grows large monotypic stands that reduce light to the soil surface. It can alter the soil salinity and chemistry. Its root system allows erosion to occur along river banks.
Rationale: All of the information that follows is based on studies in California and Nevada. These studies show that *L. latifolium* grows large monotypic stands that reduce light to the soil surface by both the dense upper foliage and a layer of senesced woody stems. Soil salinity is altered by roots that draw salt ions from deep in the soil to deposit on the surface. Soil stability is decreased on riverbanks by an extensive root system that fragments easily. The dense stands of *L. latifolium* reduce light to the soil surface in more than one way. "Structurally, a stand consists of from 4 to 8 stems per 0.1 m^2 resulting in nearly complete foliar crown closure…" (Young et al. 1995a). "Old stems take several years to degrade, and can form a layer impenetrable to light…upwards of 10 cm in depth which prevents the emergence of annual plants in these areas (Renz and DiTomaso 1998 in Renz 2000). "Few plants besides *L. latifolium* have enough stored energy to grow through this dense litter layer." (Renz 2000). It forms "tall dense stands, with the surface soil packed with creeping stems" (Young et al. 1995a). *Lepidium latifolium* acts as a "salt pump" transporting salt ions from deeper soil to the surface, which favors halophytes over other species (Blank and Young 1997 in Renz 2000). Annual biomass production by perennial pepperweed builds a dense organic layer on the soil surface, which may have a significant consequence on carbon-nitrogen ratios over time (Washington State Noxious Weed Control Board 1999). *Lepidium latifolium* has both surface and penetrating roots. However, "the combination of the low root density and perennial roots fragmenting easily allows soil erosion to occur more frequently along riverbanks that they infest" (Renz 2000).
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: *Lepidium latifolium* can grow large monospecific stands, which can displace native plants or interfere with regeneration. It competes with other plants for resources. It alters the soil to favor more halophytic plants. It also adds structure of dense senescent and persistent material that prevents emergence of annual plants.
Rationale: *Lepidium latifolium* appears to successfully compete with other plant species for moisture, nutrients, and light (Young et al. 1995a). Large colonies replace native grasses, sedges, and rushes (Washington State Noxious Weed Control Board 1999). From Renz (2000): Young and others (1995b) have also shown that *L. latifolium* interferes with the regeneration of plant species such as willows and cottonwoods. Studies from California and Nevada show that *L. latifolium* populations displace and/or interfere with the regeneration of native plants through competition, exclusion, and possibly allelopathy. *Lepidium latifolium* allelopathic research so far has failed to isolate the substance (Young et al. 1995a). It also alters the soil to favor more halophytic plants (Young et al. 1995b).

Its ability to act as a "salt pump" can shift plant composition toward more halophytic plants (Blank and Young 1997), thereby decreasing diversity. "Experimental evidence suggests that plants extract salts from deep soil and deposit them on the soil surface with leaf litter, inhibiting the germination and growth of other species (DiTomaso and Healy 2003). In the Suisun Marsh (Grizzly Island Wildlife Area in California) it is encroaching on rare plant populations in salt marshes (Skinner and Pavlik 1994 in Howald 2000). *Lepidium latifolium* "spreads by creeping underground roots which may grow to a length of ten feet, sending up shoots and enabling dense monocultures to form" (Krueger and Sheley 1999).
Sources of information: See cited literature.

Question 1.3 Impact on higher trophic levels *Score:* **U** *Doc'n Level:* **No info.**
Identify type of impact or alteration: Potentially reduces habitat and frequency of nesting waterfowl; alters forage.
Rationale: Trumbo (1994) documented that at Suisun Marsh (Grizzly Island Wildlife Area in California), perennial pepperweed competes with pickleweed, which supports populations of endangered salt marsh harvest mouse. The tall stature and dense growth pattern of perennial pepperweed make it unsuitable use for waterfowl as nesting cover. In addition to the endangered salt marsh harvest mouse, Howald (2000) also suggests it poses a threat to habitat to California black rail and California clapper rail. In waterfowl nesting areas, it outcompetes grasses that provide food for waterfowl. *Lepidium latifolium* displaces native forage and nesting vegetation (Krueger and Sheley 1999). Because Arizona has limited salt marshes and coastal wetlands, it is unknown how *L. latifolium* impacts Ariizona's higher trophic levels.
Sources of information: See cited literaure.

Question 1.4 Impact on genetic integrity *Score:* **U** *Doc'n Level:* **Other pub.**
Identify impacts: The potential to hybridize does exist but it is not know whether it can or does hybridize with Arizona's native *Lepidium*.
Rationale: Young et al (1995a) mention that there are approximately 75 native Lepidium in North America. Arizona has several native *Lepidium* (Kearney and Peebles 1960). *Lepidium* species can hybridize (Lee et al. 2002, A. Salywon, personal communication, 2005).
Sources of information: See cited literature. Also considered personal communication with A. Salywon (Research Geneticist, U.S. Department of Agriculture, Agricultural Research Service, Water Conservation Laboratory, Phoenix, Arizona, 2005).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Populations of *L. latifolium* have not been known to establish without some form of disturbance. Prior disturbance may facilitate the colonization.
Rationale: Various sources suggest (see below) that disturbance, prior or current, human or natural, is required for *L. latifolium* to establish. Disturbance that moves root stock from one location to another will more likely result in colonization than will opportunism by seeds in newly opened land. Studies in California and Nevada indicate that many of the places that *L. latifolium* invades are already not in good ecological condition (e.g., overgrazed, abandoned crop land) (Young et al. 1995a, Washington State Noxious Weed Control Board 1999). In western Nevada, investigators had "difficulty finding high condition areas without perennial pepperweed to serve as experimental controls" (Young et al. 1995a). "Perennial pepperweed will have a difficult time encroaching upon a healthy, functioning ecosystem in which few niches are left unoccupied" (Krueger and Sheley 1999).

Washington State Noxious Weed Control Board (1999) states that *L. latifolium* readily invades disturbed areas and bare soils. It also states that "in addition to natural areas, dense colonies are formed in disturbed areas such as roadsides, rangelands, pastures, agricultural fields, and irrigation canals." Populations have not been observed in Arizona where some sort of disturbance has not occurred (Working Group discussion).

Sources of information: See cited literature; also see Renz (2000), DiTomaso and Healy (2003), and Trumbo (1994). Also considered Working Group discussion.

Question 2.2 Local rate of spread with no management *Score:* **A** *Doc'n Level:* **Obs.**

Describe rate of spread: Doubling in <10 years.

Rationale: Based on observations by L. Stevens and G. Rink contained in SEINet (2004) around the 1990s and those of L. Makarick and C. Deuser in the last few years, populations have been doubling in less than ten years (L. Makarick, personal communication, 2005). Makarick was unaware *of L. latifolium* infestations until recent years (2003 and 2004) that were documented along the upper stretches of the Colorado River below Lee's Ferry (personal communication, 2005).

At three sites in California, *L. latifolium* infestations spread clonally 1 to 2 m per year, expanding 44% to 129% over a two-year time period (Renz 2002). Once established, in an optimum location, a plant can spread 1 to 2 m (sometimes 3 m) per year; in a less optimum location, spread rate will be less (M. Renz, personal communication, 2004 and 2005).

Trumbo (1994) stresses the need to eradicate small populations quickly before they have a chance to spread.

Sources of information: See cited literature. Also considered personal communications with L. Makarick (Below the Rim Vegetation Program Manager, Grand Canyon National Park, Science Center Flagstaff, Arizona, 2005) and M. Renz (New Mexico State Noxious Weed Coordinator, Albuquerque, New Mexico, 2004 and 2005).

Question 2.3 Recent trend in total area infested within state *Score:* **U** *Doc'n Level:* **No info.**

Describe trend: Unknown

Rationale: Individuals familiar with this species are not comfortable making an estimate in the total area infested within the state.

Sources of information: Personal communication with L. Makarick (Below the Rim Vegetation Program Manager, Grand Canyon National Park, Science Center Flagstaff, Arizona, 2005) and Working Group discussion.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Other pub.**

Describe key reproductive characteristics: *Lepidium latifolium* is a prolific seed producer however, it relies heavily upon regeneration by offshoots from the root structures.

Rationale: Perennial pepperweed reproduces from seed, as well as vegetatively from intact root systems or from pieces of rootstock (Howald 2000). Seedlings are extremely rare in established stands. Plants form large spreading clones, with new stems arising from creeping root system (Young et al. 1995a).

Flowering is from May to July, lasting for several weeks, and seeds mature by June or July. Seedlings grow rapidly and can produce flowering stems the first year. (Howald 2000). Others state it as shorter flowering periods of late June to early July (Young et al. 1995a); mid spring to early summer with flowering and fruit set occurring for several months (Renz 2000). Plants can self- and cross-pollinate (M. Renz, personal communication, 2005 and A. Salywon, personal communication, 2005).

Seeds have a high rate of germination following winter periods of fluctuating temperatures; however, "seeds lack a hard seed coat and do not seem to be capable of surviving long periods in the soil, thus seed viability may be short. This suggests that reinfestations from the seed bank may not be a problem once control is achieved" (Miller et al. 1986 in Renz 2000). Seed production highly variable: measured to be as high as 1.6 x 10^{10} seeds/ha (unpublished research, U.S. Department of Agriculture, Agricultural Research Service, Reno, Nevada in Renz 2000). Krueger and Sheley (1999) report seed production of six billion seeds per acre of infestation. California studies have indicated that perennial pepperweed can produce over 16 million seeds per hectare (Young et al. 1997 in Washington State Noxious Weed Control Board 1999). From Renz (2000): Plant can fragment easily (usually through disturbance along water courses) and can establish elsewhere. Mowing is not an effect means of control. Burning does not appear to harm below-ground perennial roots (Trumbo 1994). Biomass of resprouting stems may even increase in subsequent years due to the removal of the litter layer (Renz and DiTomaso 1998).
Sources of information: See cited literature. Also considered personal communications with M. Renz (New Mexico State Noxious Weed Coordinator, Albuquerque, New Mexico, 2005) and A. Salywon (Research Geneticist, U.S. Department of Agriculture, Agricultural Research Service, Water Conservation Laboratory, Phoenix, Arizona, 2005).

Question 2.5 Potential for human-caused dispersal *Score:* **B** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Dried flower arrangements; movement of root or seed in contaminated dirt, machinery, feed, straw or other materials; hay and seed contaminate.
Rationale: Moving dirt or machinery that are contaminated with root fragments can initiate an invasion. Hay, feed stock, dried flowers arrangements, and straw used in stabilization projects can also be contaminated with weed seed and/or rhizomes (Washington State Noxious Weed Control Board 1999). Krueger and Sheley (1999): Flood irrigation carries plant propagules into hay meadows, pastures and other irrigated lands. Also carried in contaminated topsoil used as fill for construction and landscaping. Often used by florists in fresh and dried flower arrangements. Once established, *L. latifolium* follows water routes to other areas (could be irrigation ditches and canals) (Young et. al. 1995a). It is said to be able to reach fields from riparian areas via irrigation ditches (Washington State Noxious Weed Control Board 1999).
Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **B** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Seasonal flooding or bank erosion, wind, and waterfowl.
Rationale: *Lepidium latifolium* typically invades along riparian areas and other water courses and wet areas (Renz 2000). When flooding events or natural flow occur, roots can breaks off and colonize downstream. Distribution corresponds to river systems and riparian zones, which are the primary areas of invasion in most states though not limited to these areas. Travels in rivers and irrigation systems as seeds and rhizomes from eroded banks. (Krueger and Sheley 1999). Howald (2000) states that the small seeds have no special adaptations for long-distance dispersal, but they are capable of being transported by wind, water, and possibly waterfowl.
Sources of information: See cited literature. Working Group members used inference to assign the score.

Question 2.7 Other regions invaded	*Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: Great Basin grasslands and Chihuahuan desertscrub.	
Rationale: The draft California plant assessment for *Lepidium latifolium* by C. Roye and J. DiTomaso (reviewed by the California list committee on March 19, 2004) listed ecological types invaded in California. A number of these, riparian scrub (desert washes), riparian woodlands, riparian forests, and Great Basin grasslands, likely have ecological equivalents in Arizona. Based on this information, the plains and Great Basin shrub-grassland type and at least one of the riparian types in Arizona seem to be equivalent ecological types invaded in California but not yet invaded in Arizona. In addition, in New Mexico *L. latifolium* can be found in Chihuahuan desertscrub along Rio Grande (M. Renz, personal communication, 2004) and along the south side of the San Juan River, between Slickhorn Canyon and Grand Gulch (collection by D. Roth 2003 in SEINet 2005). *Lepidium latifolium* is currently in Utah on the Arizona border in the Arizona Strip area (L. Walker, personal communication, 2004). Also exists along the San Juan River, Utah (see above) and in the Chuska Mountains, New Mexico on the Navajo Nation (D. Roth, personal communication, 2005). "In New Mexico it is prevalent in riparian areas and high elevation spots with a very high water-table. I have seen it in Nevada (Las Vegas) established in a floodplain area with a high water-table, so it can withstand hot temps, the establishment conditions likely need to be ideal, causing infrequent establishment" (D. Roth, personal communication, 2005). Chihuahuan desertscrub is thus another ecological type invaded elsewhere that is not yet invaded in Arizona. From the Washington State Noxious Weed Control Board (1999): Native range of perennial pepperweed extends from the Mediterranean basin, to temperate Europe, and east to the Middle East, Asia and the Himalayas (Kloot 1973). In North America it has been introduced to diverse locations from New England to Mexico (Miller et al. 1986) and now covers thousands of acres across the West. (Young et al. 1997). Infestations in North America have been reported in coastal New England and throughout all of the states west of the Rocky Mountains. California lists it widespread throughout (Howald 2000).	
Sources of information: See cited literature. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed February 2005), the draft California *Lepidium latifolium* plant assessment by C. Roye and J. DiTomaso (available online at: http://www.cal-ipc.org/list_revision/completed_pafs.html; information current as of March 19, 2004), and personal communications with M. Renz (New Mexico State Noxious Weed Coordinator, Albuquerque, New Mexico, 2004), L. Walker (Weed Specialist, Bureau of Land Management, Arizona Strip, St. George, Utah, 2004), and D. Roth (Botanist, Navajo Natural Heritage Program, Flagstaff, Arizona, 2005).	

Question 3.1 Ecological amplitude	*Score:* **B** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: First sighted in California in 1936 sugar beet seed (Bellue 1936 in Howald 2000). First herbarium record in Arizona (as of February 2005) was collected by L. Stevens in 1987 along the Colorado River in the Grand Canyon (river mile 194-left, SEINet 2005). *Lepidium latifolium* is adapted to sites that are at least seasonally moist in riparian and wetland areas. *Lepidium latifolium* is particularly adapted to salt affected soils. (Young et al 1995a, Howald 2000).	
Rationale: Observations of *L. latifolium* have occurred in southwestern interior riparian, in "scattered locations along the Colorado River beaches and shoreline from river mile 24.5 to 170" (L. Makarick, personal communication, 2005). Great Basin desertscrub and Mohave desertscrub (L. Walker, personal communication, 2004) populations were treated and no longer exist. *Lepidium latifolium* is currently in Utah on the Arizona border in the Arizona Strip area (Walker, personal communication, 2004). Also exists in San Juan River, Utah and Chuska Mountains, New Mexico on the Navajo Nation (D. Roth, personal communication, 2005).	

Collections in Arizona herbaria include include two from L.E. Stevens, in 1991 and 1987, along the Colorado River in the Grand Canyon National Park and G. Rink in 2000 at the high water mark (river mile 31) just above South Canyon (SEINet 2005).
Sources of information: See cited literature. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed February 2005) and personal communications with L. Makarick (Below the Rim Vegetation Program Manager, Grand Canyon National Park, Science Center Flagstaff, Arizona, 2005), L. Walker (Weed Specialist, Bureau of Land Management, Arizona Strip, St. George, Utah, 2004), and D. Roth (Botanist, Navajo Natural Heritage Program, Flagstaff, Arizona, 2005).

Question 3.2 Distribution	*Score:* **D** *Doc'n Level:* **Obs.**
Describe distribution: *Lepidium latifolium* is not currently widely distributed in Arizona nor does it occupy any one ecological type more than 5%.	
Rationale: Based on communications with several individuals who are familiar with the species, *L. latifolium* does not yet seem to have taken a permanent hold in Arizona. However, there are established populations near the northern borders (L. Walker, personal communication, 2004). One important note: pepperweed is widespread through many of New Mexico *Tamarix* spp. patches and much concern exists for *Tamarix* spp. management causing increases in the spread of perennial pepperweed. (M. Renz, personal communication, 2005)	
Sources of information: Personal communications with L. Walker (Weed Specialist, Bureau of Land Management, Arizona Strip, St. George, Utah, 2004) and with M. Renz (New Mexico State Noxious Weed Coordinator, Albuquerque, New Mexico, 2004).	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**[Yes]**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 9	**Total unknowns: 1**	
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	**D** (Virgin River)
	Mohave desertscrub	**D**
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	**D** (Colorado River-Grand Canyon)
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Bellue, M.K. 1936. *Lepidium latifolium* L., a new perennial peppergrass. California Department of Agriculture Bulletin. 25:359.

Blank, R.R., and J.A. Young. 1997. *Lepidium latifolium:* Influences on soil properties, rate of spread, and competitive stature. Pages 69–80 in J.H. Brock, M. Wade, P. Pysek, and D. Green (eds.), Plant Invasions: Studies from North America and Europe. Backhuys Publishers, Leiden, The Netherlands.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

DiTomaso, J.M., and E.A. Healy. 2003. Aquatic and Riparian Weeds of the West. Publication 3421. University of California, Agriculture and Natural Resources, Davis. 442 p.

Howald, A. 2000. *Lepidium latifolium.* Pages 222–227 in C.C. Bossard, J.M. Randall, and M. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Kloot, P.M. 1973. Perennial peppercress…a warning. Journal of Agriculture South Australia 76:72–73.

Krueger, J., and R. Sheley 1999. Montguide MT 9906 Agriculture-perennial pepperweed (*Lepidium latifolium*). Montana State University Extension Service, Bozeman. Available online at: http://www.montana.edu/wwwpb/pubs/mt9906.html; accessed March 2003.

Lee, J.-Y., K. Mummenhoff, and J.L. Bowman. 2002. Allopolyploidzation and evolution of species with reduced floral structures in *Lepidium* (Brassicaceae). Proceedings of the National Academy of Science 99:16835–16840.

Miller, G.K., J.A. Young, and R.A. Evans. 1986. Germination of seeds of perennial pepperweed (*Lepidium latifolium*). Weed Science 34:252–255.

Renz, M.J., and J.M. DiTomaso. 1998. The effectiveness of mowing & herbicides to control perennial pepperweed (*Lepidium latifolium*) in rangeland & roadside habitats. Proceedings from the 1998 California Weed Science Conference.

Renz, M.J. 2000. *Lepidium latifolium* L. Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs; accessed March 2003.

Renz, M.J. 2002. Biology, Ecology and Control of Perennial Pepperweed (*Lepidium latifolium* L.). Doctoral dissertation. University of California, Davis.

Skinner, M.W., and B.M. Pavlik. 1994. Inventory of Rare and Endangered Vascular Plants of California. Special Publication No. 1. 5th ed. California Native Plant Society, Sacramento.

Trumbo, J. 1994. Perennial pepperweed: A threat to wildland areas. CalEPPC Newsletter 2:4–5.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Washington State Noxious Weed Control Board. 1999. Perennial Pepperweed (*Lepidium latifolium* L.). Available online at: http://www.nwcb.wa.gov/weed_info/pepperweedwf.html; accessed February 2005.

Young, J.A., D.E. Palmquist, R.S. Blank, and C.E. Turner. 1995a. Ecology and control of perennial pepperweed (*Lepidium latifolium* L.). California Exotic Pest Plant Council 1995 Symposium Proceedings:1–3.

Young, J.A., C.E. Turner, and L.F. James. 1995b. Perennial pepperweed. Rangelands 17:121–123.

Young, J.A., D.E. Palmquist, and S.O. Wotring. 1997. The invasive nature of *Lepidium latifolium:* A review. Pages 59–68 in J.H. Brock, M. Wade, P. Pysek, and D. Green (eds.), Plant Invasions: Studies from North America and Europe. Backhuys Publishers, Leiden, The Netherlands.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Leucanthemum vulgare* Lam. (USDA 2005)
Synonyms:	*Chrysanthemum leucanthemum* L., *Chrysanthemum leucanthemum* L. var. *boecheri* Boivin, *Chrysanthemum leucanthemum* L. var. *pinnatifidum* Lecoq & Lamotte, *Leucanthemum leucanthemum* (L.) Rydb., *Leucanthemum vulgare* Lam. var. *pinnatifidum* (Lecoq & Lamotte) Moldenke (USDA 2005)
Common names:	Oxeye daisy, field daisy, white daisy
Evaluation date (mm/dd/yy)**:**	4/15/04
Evaluator #1 Name/Title:	Dana Backer, Conservation Ecologist
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85719
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	04/16/04: W. Albrecht, D. Backer, J. Crawford, J. Hall, F. Northam, T. Olson, K. Watters 06/23/04: W. Albrecht, D. Backer, J. Brock, J. Busco, J. Hall, C. Laws, B. Phillips, K. Watters
Committee review date:	04/16/04 and 06/23/04
List date:	06/23/04
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**D**	Observational	**"Impact"** **Section 1 Score:** **C**	**"Plant Score"** **Overall Score:** **Low** **Alert Status:** **None**
1.2	Impact on plant community	**C**	Other published material		
1.3	Impact on higher trophic levels	**D**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**C**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **12 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**A**	Other published material		
2.5	Potential for human-caused dispersal	**B**	Other published material		
2.6	Potential for natural long-distance dispersal	**C**	Other published material		
2.7	Other regions invaded	**C**	Other published material		 Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **B**	
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **D** *Doc'n Level:* **Obs.**
Identify ecosystem processes impacted: Negligible perceived impact on ecosystem processes.
Rationale: Ecological, environmental, economical and sociological impacts are not well documented (Olson and Wallander 1999, Krueger and Sheley 2002). "Bare soil is more prominent in areas with high densities of oxeye daisy so the potential for soil erosion is increased" (Olson and Wallander 1999). Because of a relatively small tap root compared to fibrous roots of grasses, a heavy infestation may reduce the amount of organic matter contributed belowground annually, and in turn slow the rate of nutrient cycling (Olson and Wallander 1999). This information is speculative and no empirical studies in the literature suggest this to be the impact. This plant has been in the U.S. since the early 20th century and appears to be most associated with human-engineered systems (agriculture, pastures, waste areas, etc.); therefore the score assigned is negligible impact (**D**) and not unknown. Mitchell White (personal communication, 2004) conducted research on grassland communities on the Apache-Sitgreaves National Forests and observed no abiotic impacts that could be directly attributed to oxeye daisy other than inter-species competition.
Sources of information: See cited literature. Also considered personal communications with M. White (Rangeland Ecologist, U.S. Department of Agriculture, Forest Service, Apache-Sitgreaves National Forest, Springerville, Arizona, 2004). Score based on inference based on the literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **C** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Potential to compete with natives and form dense stands.
Rationale: Ecological, environmental, economical and sociological impacts are not well documented (Olson and Wallander 1999, Krueger and Sheley 2002). Yet the preceding authors both state that oxeye daisy has become an aggressive competitor and often forms dense patches especially in areas grazed by cattle (not specifically stated where this has occurred but Olson's research has been predominantly in southwest Montana and Idaho, and Krueger and Sheley are from Montana State University). Oxeye daisy is a common weed of disturbed areas but is increasingly becoming a problem in western rangelands (including pastures and meadows), particularly in Montana (Krueger and Sheley 2002). In California oxeye daisy displaces native plant species, growing so densely it excludes other vegetation (Alvarez 2000). In Colorado at Rocky Mountain National Park, the infestation forms dense mats and it is likely to be displacing native forbs (J. Knudson, personal communication, 2004). Can not compete with established vegetation on more fertile soils (Olson and Wallander 1999). Ground cover (litter or vegetation) can prevent establishment (Reader 1991 in Alvarez 2000). Has low shade tolerance (Olson and Wallander 1999). Mitchell White (personal communication, 2004) conducted research on grassland communities on the Apache-Sitgreaves National Forests and observed no abiotic impacts that could be directly attributed to oxeye daisy other than inter-species competition. His research suggested that oxeye daisy was a "secondary species" based on frequency of occurrence, cover and relative composition, in mesic montane grasslands and mesic meadows along riparian bench communities (below 8500 feet) but it did not seem to be altering or impacting plant communities in any noticeable way other than site occupation.
Sources of information: See cited literature. Also considered personal communications with J. Knudson (Exotic Biological Tech, National Park Service, Rocky Mountain National Park, 2004) and M. White (Rangeland Ecologist, U.S. Department of Agriculture, Forest Service, Apache-Sitgreaves National Forest, Springerville, Arizona, 2004).

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n Level:* **Obs.**

Identify type of impact or alteration: Negligible

Rationale: Ecological, environmental, economical and sociological impacts are not well documented (Olson and Wallander 1999, Krueger and Sheley 2002). Although cattle may not eat the species, other livestock do but it is unclear if native ungulates use it for forage. Horse, sheep and goats graze on oxeye daisy but cows and pigs tend not to (Howarth and Williams 1968 in Olson and Wallander 1999). Cattle avoid grazing oxeye daisy thus enhancing its natural competitive abilities to occupy sites and ultimately decreasing other forage available for grazing ungulates.

Sources of information: See cited literature. Score based on inference based on the literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**

Identify impacts: No known hybridization

Rationale: No native congeners

Sources of information: Kearney and Peebles (1960).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **C** *Doc'n Level:* **Other pub.**

Describe role of disturbance: First requires an anthropogenic disturbance before it will establish in naturally areas.

Rationale: Abundance is partly related to intensity of cutting or grazing of associated species, suggesting that oxeye daisy requires reduced competition from existing vegetation by grazing or possible a disturbance to establish (Olsen and Wallander 1999). In Rocky Mountain National Park only known in two places, both of which were anthropogenically disturbed (J. Knudson, personal communication, 2004). In areas of the Apache-Sitgreaves National Forests, oxeye daisy establishes in areas where there has been a history of long-term livestock grazing and fire suppression (M. White, personal communication, 2004).

Sources of information: See cited literature. Also considered personal communications with J. Knudson (Exotic Biological Tech, National Park Service, Rocky Mountain National Park, 2004) and M. White (Rangeland Ecologist, U.S. Department of Agriculture, Forest Service, Apache-Sitgreaves National Forest, Springerville, Arizona, 2004).

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**

Describe rate of spread: Increasing but less rapidly than doubling in <10 years.

Rationale: Starts at roadside or at some other human-caused disturbance and then moves into natural areas from there; one example is from Kachina Village (B. Phillips, personal communication, 2004). Lauren Johnson (personal communication, 2004) hasn't observed it below the rim on the portion of the Kaibab National Forest south of the Grand Canyon. In the White Mountains area, oxeye daisy has been increasing over the years as a result of grazing and fire suppression, but oxeye daisy has not been doubling its area of infestation (M. White, personal communication, 2004). At Rocky Mountain National Park, there is no one present that knows the history of the two populations in the park (J. Knudson, personal communication, 2004).

Sources of information: Score based on Working Group consensus and personal observations/ communications by/with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, Flagstaff, Arizona, 2004), L. Johnson (U.S. Department of Agriculture, Forest Service, Kaibab National Forest, 2004), M. White (Rangeland Ecologist, U.S. Department of Agriculture, Forest Service, Apache-Sitgreaves National Forest, Springerville, Arizona, 2004), and J. Knudson (Exotic Biological Tech, National Park Service, Rocky Mountain National Park, 2004).

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**
Describe trend: Increasing in area infested.
Rationale: Mitchell White (personal communication, 2004) has observed oxeye daisy increasing in range as a function of increased vehicular traffic, road maintenance, and road construction.
Sources of information: Personal communication with M. White (Rangeland Ecologist, U.S. Department of Agriculture, Forest Service, Apache-Sitgreaves National Forest, Springerville, Arizona, 2004). Communication with White took place on August 3, 2004. Although this was after the date the Working Group "signed off" on the scores, they deferred to White for additional comments and rationale relative to question 2.3.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: High reproductive potential.
Rationale: See Worksheet A.
Sources of information: See Worksheet A.

Question 2.5 Potential for human-caused dispersal *Score:* **B** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Sold as ornamental; in seed mixes; contaminated hay/seeds, and along transportation corridors.
Rationale: Sold as an ornamental mainly in seed packets; hay and grain seed contaminant (Olson and Wallander 1999). Has been noted in seed packets in Phoenix nurseries (F. Northam, personal observations, 2004). First cutting of hay in southwest Montana coincides with the beginning of seed set of this species. *Leucanthemum vulgare* is not common in Arizona's agriculture/hay field (Working Group comments). Was once cultivated for natural medicine and used in salads (Krueger and Sheley 2002).
Sources of information: See cited literature. Also considered personal observations by F. Northam (Weed Biologist, Tempe, Arizona, 2004).
Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Animals and water.
Rationale: Seeds dispersed by wind fall close to the parent plant because the seed lacks a pappus (Olson and Wallander 1999). Seeds are small and fall to the ground up to 2 m from parent plant (Alvarez 2000). Seeds may be carried by animals (Olson and Wallander 1999), water, earth-moving machinery, and human traffic (Alvarez 2000). If the seed head is eaten, less than 40% passing through a cow are viable. Olson suggests that other large ungulates may intentionally or incidentally ingest oxeye daisy and pass the seeds in their feces.
Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Other pub.**
Identify other regions: Same ecological types as in Arizona.
Rationale: Native to Europe; introduced in northeastern U.S. Introduced in contaminated seed and as an ornamental. Common along roadsides, waste grounds, and pastures in Montana (Dorn 1984 in Olson and Wallander 1999) and Pacific Northwest (Taylor 1990 in Olson and Wallander 1999). Occurs in meadows, native grasslands, pastures, waste grounds and along railway embankments (Olson and Wallander 1999; don't provide specific regions). In the West *Leucanthemum vulgare* is considered a noxious weed in Colorado, Montana, Washington, and Wyoming (USDA 2005). In California it is found in both the North Coast Range and northern Sierra Nevada from sea level bluffs and canyons to alpine mountain meadows to 7000 feet and from central California into Oregon (Alvarez

2000). Commonly found in disturbed areas and former homesteads (Cowell 1973 and Peck 1961 [reported as 1993] in Alvarez 2000). Rapidly spreads into wildlands and is found in a variety of plant communities including prairie, scrub, wet meadows, riparian forests, and open-canopy forests (Alvarez 2000; mostly likely this is from California).

Julie Knudson (personal communication, 2004) and M. Margo (personal communication, 2004) both noted that oxeye daisy is on the western slopes of Rocky Mountain National Park in two known areas: along a shoreline and in a meadow, both at approximately 8000 feet in elevation. As a result, the plant is in areas that have wet soils and have been disturbed by humans. Maria Alvarez (personal communication, 2004) indicated the plant is plastic, has broad environmental tolerances, and is not limited by elevation. She commented that the plant will adapt to whatever environment it is in (for example, growing a six foot flower stalk in a cottonwood-willow forest). Moreover, she has observed dense patches in riparian areas and open wetland areas (with sedges and rushes) in Yosemite Valley.

Sources of information: See cited literature. Also considered personal communications with J. Knudson (Exotic Biological Tech, National Park Service, Rocky Mountain National Park, 2004), M. Margo (National Park Service, Rocky Mountain National Park, 2004), and M. Alvarez (Natural Resources, National Park Service, Golden Gate National Recreation Area. California, 2004).

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Obs.**

Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: See below. Earliest record in Arizona herbaria (SEINet 2004) is 1936 in Navajo County, Lakeside.

Rationale: Based on the limited current data for Arizona, the response is based primarily on the herbaria collection records and personal observations of Working Group members.

Locations taken from Arizona herbaria records (SEINet 2004): Lockwood Draw, Coconino County ; Grand Canyon, North Rim, Swamp Ridge, Kaibab National Forest, Coconino County; Upper Ash Creek (below mill site and above Slick Rock), Graham County; Hannigan Meadows, White Mountains, Greenlee County; Apache National Forest on west bank of Black River, White Mountains; Apache County; Lakeside Ranger station in wet meadow near lake shore; Navajo County; 4 miles west of Coronado Trail along Beaver creek, Apache County. Two of these collections were taken from mixed conifer forests (University of Arizona collections) and three from open area near lake or stream. In the Grand Canyon National Park, on the south rim at Grandview Junction (Makarick 1999).

Has a wide edaphic tolerance; more often found on basic or neutral soils (Howarth and Williams 1968 in Olson and Wallander 1999) and has a moderate requirement for nitrogen (Ellenburg 1950 in Olson and Wallander 1999). Unaffected by light frost and tolerates drought well, though it is usually found in more moist areas (Olson and Wallander 1999).

Personal observations: Kachina Village (B. Phillips, personal communication, 2003) and North Rim near Route 64 (K. Watters, personal communication, 2004). At the Apache-Sitgreaves National Forests, observed in research plots in isolated abundance in mesic montane grasslands, mesic meadows, along montane riparian bench communities, and large open grasslands within Ponderosa Pine (M. White, personal communication, 2004).

Sources of information: See cited literature. Also considered personal communications with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, Flagstaff, Arizona, 2004), K. Watters (Research Technician, National Park Service, Southern Colorado Plateau Network, Flagstaff, Arizona, 2004), and M. White (Rangeland Ecologist, U.S. Department of Agriculture, Forest Service, Apache-Sitgreaves National Forest, Springerville, Arizona, 2004) (June 2004; B. Phillips, June 2004; and M. White, August 2004) and information from

SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed April 15, 2004). Working Group applied inference based on the literature, herbaria records, and personal observations considered.

Question 3.2 Distribution *Score:* **D** *Doc'n Level:* **Obs.**
Describe distribution: Limited (less than 5% of any ecological type invaded).
Rationale: Oxeye daisy in the montane conifer forest is in the opening between the ponderosa pines (Working Group member's comments). Information is limited to the few known occurrences and no significant "infestation" occurs in Arizona. The Working Group member consensus was that the distribution was limited.
Sources of information: Score based on Working Group member observations and inference.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**[Yes]**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 9	**Total unknowns: 1**	
	Score : A		

Note any related traits: From Olson and Wallander (1999): resprouts when mowed; reproduces vegetatively; robust plants produce about 26,000 seeds and smaller plants produced from 1300 to 4000 seeds per plant (Dorph-Peterson 1925 in Olson and Wallander 1999). Most seeds (82%) remain viable for at least six years (Toole and Brown 1946 in Olson and Wallander 1999) and by some estimates viability can extend to 20 years (Parsons 1992 in Alvarez 2000). Flowers late spring through late summer (Alvarez 2000).

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	**D**
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	**D**
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	**D**
	montane riparian	**D**
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	**D**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Alvarez, M. 2000. *Leucanthemum vulgare* Lam. Pages 227−231 in C.C. Bossard, J.M. Randall, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Cowell, W.S. 1973. Wildflowers of the U.S. Vol 5: The Northwestern States. Cowell LTD, Butter Market, Ipswich, United Kingdom.

Dorn, R.D. 1984. Vascular Plants of Montana. Mountain West Publishing, Cheyenne, Wyoming.

Dorph-Petersen, K. 1925. Examinations of the occurrence and vitality of various weed seed species under different conditions, made at the Danish State Seed Testing Station during the years 1896−1923. Rep. 4th Int. Seed Test. Congr. 4:128−138.

Ellenburg, H. 1950. Unkrautgemeinschaften als Zeiger fur Klima und Boden. Stuttgart.

Howarth, S.E. and J.T. Williams. 1968. Biological flora of the British Isels. J. Ecology 56:585−595.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Krueger, J.M., and R.L. Sheley. 2002. Oxeye daisy (*Chrysanthemum leucanthemum*). Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, Montana.

Makarick, L.J. 1999. Draft Exotic Plan for Grand Canyon National Park. National Park Service, Grand Canyon National Park, Arizona.

Olson B.E., and R.T. Wallander. 1999. Oxeye daisy. Pages 282−289 in R.T. Sheley and J.K. Petroff (eds.), Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis.

Parsons, J. M. 1992 (ed.) Australian Weed Control Handbook. Inkata Press, Melbourne, Australia.

Peck, M.E. 1961. A Manual of the Higher Plants of Oregon. 2nd ed. Binfords and Mort, Portland, Oregon.

Reader, R.J. 1991. Relationship between seedling emergence and species frequency on a gradient of ground cover density in an abandoned pasture. Canadian J. of Botany 69:1397−1404.

Taylor, R.J. 1990. Northwest Weeds: The Ugly and Beautiful Villains of Fields, Gardens, and Roadsides. Mountain Press Publishing, Missoula, Montana.

Toole, E.H., and E. Brown. 1946. Final results of the Duvel buried seed experiment. Journal of Agriculture Research 72:201−210.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Linaria dalmatica* (L.) P. Mill. (USDA 2005)
Synonyms:	*Linaria genistifolia* (L.) P. Mill. ssp. *dalmatica* (L.) Maire & Petitm. (USDA 2005)
Common names:	Dalmatian toadflax, butter and eggs, broad-leaved toadflax
Evaluation date (mm/dd/yy)**:**	05/05/03
Evaluator #1 Name/Title:	Laura P. Moser, Botanist & SFPWMA Coordinator
Affiliation:	Coconino National Forest
Phone numbers:	(928) 527–3423
Email address:	lmoser@fs.fed.us
Address:	1824 S. Thompson Rd, Flagstaff, Arizona 86001
Evaluator #2 Name/Title:	Dana Backer, Conservation Ecologist
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85719

List committee members:	W. Albrecht, D. Backer, J. Brock, J. Busco, J. Hall, C. Laws, L. Moser, B. Phillips, K. Watters
Committee review date:	06/23/04
List date:	06/23/04
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

Question		Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Other published material	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**A**	Other published material		
1.3	Impact on higher trophic levels	**B**	Other published material		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **14 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Other published material		
2.6	Potential for natural long-distance dispersal	**C**	Observational		
2.7	Other regions invaded	**C**	Observational		 Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Red Flag Annotation

Linaria dalmatica occurs within a variety of ecosystems/plant communities that experience different natural fire regimes. *Linaria dalmatica*, however, established in these various ecological types after the onset of habitat alteration and fire exclusion that characterizes these types today. Because *L. dalmatica* was not present when historic (natural) fire regimes were functioning, it is unclear how the presence of *L. dalmatica* might affect the ability to restore a natural fire regime. Little empirical evidence exists to enable anticipating these potential effects. The expanding wildland-urban interface and projected increases in the intensity of forest restoration/fuel treatments may provide new opportunities for *L. dalmatica* to spread into forested areas. Only a portion of *L. dalmatica* seeds may germinate in any given year. As a result, dormant seeds may germinate at sites following herbicide applications or other site disturbances that reduce native plant competition.

Table 3. Documentation

Note: Several sources describe *Linaria dalmatica* and *L. vulgaris* collectively. Although these species may be similar in some aspects, they were not evaluated collectively here particularly because they have different distributions in Arizona. When referring to information not specific to *L. dalmatica* (Dalmatian toadflax), but *Linaria* in general, which includes *L. vulgaris*, the term *Linaria* (toadflax) will be used.

Grieshop and Nowierski (2002 in Zouhar 2003) found, under the field conditions of their two-year study, that Dalmatian toadflax populations filled most "safe seedling emergence sites" and seedling recruitment of Dalmatian toadflax was limited more by interspecific resource competition than by seed numbers. Because Dalmatian toadflax can produce enough seeds to exceed potential emergence sites, and because Dalmatian toadflax plants reproduce vegetatively, it appears that individual seedling recruitment in Dalmatian toadflax is more important for establishing new populations than it is for maintaining established populations (Grieshop and Nowierski 2002).

Question 1.1 Impact on abiotic ecosystem processes *Score*: **B** *Doc'n Level*: **Other pub.**
Identify ecosystem processes impacted: Soil moisture; altered fire regime.
Rationale: Mature toadflax plants have extensive, well-developed root systems. Taproots of a mature Dalmatian toadflax plant may reach depths of 4 to 10 feet (1.3 to 3 m), and lateral roots can extend 12 feet (3.6 m) from the parent plant (penetrating horizontally into several soil profiles). Vegetative buds were found as deep as 6 feet (1.8 m) in coarse soil. However, most Dalmatian toadflax plants produced from vegetative buds occur on lateral roots that are found in the upper 2 to 12 inches (5 to 30 cm) of soil (Alex 1962, Robocker 1974). While this may help stabilize soil in sparsely vegetated areas, it can increase soil erosion , surface runoff and sediment yield in sod-forming or bunchgrass communities that re replaced with toadflax (Saner et al. 1995, Lajeunesse 1999). The extensive root systems allows toadflax to exploit water resources efficiently (Zouhar 2003). The adventitious buds on roots allow for *L. dalmatica* to form dense colonies (Zouhar 2003) Presence of *L. dalmatica* in the understory may disrupt the surface fire patterns (J. Springer, personal communication, 2004) currently surface fire is a patchy occurrence but with fuel reduction treatments this could have a larger impact and more continuous surface fire patterns. Response of toadflax to fire may depend on site characteristics and the fire adaptations of other species in the plant community. Most reviews suggest that toadflax is likely to increase or to be unaffected by fire. Several studies provide examples of toadflax establishment following fire. See Zouhar (2003) for several examples of each.
Sources of information: See cited literaure. Also considered personal communication with J. Springer Senior Research Specialist, Ecological Restoration Institute, Northern Arizona University, Flagstaff, Arizona, 2004).

Question 1.2 Impact on plant community composition, structure, and interactions *Score*: **A** *Doc'n Level*: **Other pub.**
Identify type of impact or alteration: Severe alteration of composition and interactions; formation of patches dominated by the species (>75% relative cover).
Rationale: Seedlings are considered ineffective competitors of soil moisture with established perennials and winter annuals. Mature plants of *L. dalmatica* are particularly competitive with winter annuals and shallow-rooted perennials (Robocker 1974). Once established *Linaria* suppresses other

vegetation mainly by intense competition for limited soil water (Carpenter and Murray 1998) primarily as a function of its deep tap root and extensive lateral roots (roots can grow 20 inches deep or more nine weeds after seedlings have emerged), which efficiently exploit water. Personal observations by B. Phillips and L. Moser in Coconino National Forest (2002 to 2003) agree with these findings The roots of *L. dalmatica* (and *L. vulgaris*) are colonized by vascular-arbuscular mycorrhizal fungi, probably less in cultivated soils than in less disturbed areas. (Harris and Clapperton 1997 in Zouhar 2003). An aggressive invader that is capable of forming colonies through adventitious buds from creeping root system (Carpenter and Murray 1998, Zouhar 2003). This has also been observed in National Forests in northern Arizona (B. Phillips, L. Moser, and other Working Group members, personal observations, 2002 to 2003). Seeds are vulnerable to dehydration and competition from other species (Zouhar 2003). *Linaria dalmatica* establishment and survival depends on favorable precipitation or lack of competition from other plants (Robocker 1970). From Zouhar (2003) and verified in Robocker (1970, 1974): "Dalmatian toadflax seedlings died following rapid or extreme temperature changes or dehydration in field and greenhouse studies. When Dalmatian toadflax seeds germinate in autumn, seedling survival the next year depends on sufficient spring and early summer precipitation, or a lack of competition from other plants. Dalmatian toadflax seedlings are easily outcompeted by established plants, especially perennial species (Robocker 1970) and also by cheatgrass [*Bromus tectorum*] on fertile soils. Conversely, cheatgrass does not compete well with established Dalmatian toadflax plants (Robocker 1974). Cultivation or soil disturbance that removes perennial plants may increase Dalmatian toadflax seedling survival (Robocker 1970)." Once established in an area it is aggressive and crowds out native species and wildlife forage (L. Moser and B. Phillips, personal observations, 2002 to 2003)
Sources of information: See cited literature. Also considered personal observations by L. Moser (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2002 to 2003) and B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2002 to 2003).

Question 1.3 Impact on higher trophic levels Score: *Score*: **B** *Doc'n Level*: **Other pub.**
Identify type of impact or alteration: reduces native forage
Rationale: May become a problem by crowding out desirable wildlife forage (Burril et al. 2002); cattle avoid *L. dalmatica* and have preferential selection for native forage (thus further reducing natives for competition) (Lajeunesse 1999). Some species of birds and rodents may feed on seeds yet not heavily used by native species (Robocker 1970) or use it for cover (Lajeunesse 1999).
Sources of information: See cited literature.

Question 1.4 Impact on genetic integrity *Score*: **D** *Doc'n Level*: **Other pub.**
Identify impacts: No known hybridization.
Rationale: Although Kearney and Peebles (1960) list *L. texana* Scheele as a native annual species in Arizona, the taxonomy has changed it to *Nuttallanthus texanus* (Scheele) D.A. Sutton (USDA 2005). There is no evidence that *L. dalmatica* (a perennial) will hybridize across genera. From Saner et al. (1995): Hybridization did occur between *Linaria* dalmatica and *L. vulgaris* in a laboratory (Bruun 1937) and according to Sutton (1988) the occurrence of this hybrid in nature cannot be excluded. *L. vulgaris* is also a non-native plant to Arizona.
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score*: **B** *Doc'n Level*: **Other pub.**
Describe role of disturbance: Disturbance promotes toadflax invasion and may be necessary for establishment. However, once established, toadflax can spread into adjacent non-disturbed areas (Beck 2001).
Rationale: In North America, toadflax are most commonly found on disturbed sites such as roadsides, fencelines, areas near dwellings, vacant lots, cemeteries, gravel pits, croplands, clearcuts, pastures, waste areas, and other disturbed sites where removal of vegetation allows toadflax seedlings to establish (Carpenter and Murray 1998, Lajeunesse 1999). Toadflax can also establish and spread in sparsely vegetated areas and sites with naturally occurring disturbances, small openings, and/or little competition between species. Examples of such sites include dry, open areas in grassland and bunchgrass communities, sagebrush, open coniferous forests, sand dunes, riparian areas, and borders of woods (e.g. numerous authors see Carpenter and Murry 1998 and Zouhar 2003). *Linaria dalmatica c*olonizes open spaces (Rocky Mountain National Park 1998) and exhibits a positive response to pre-monsoon prescribed burning but not post-monsoon prescribed burning (Phillips and Crisp 2001). *Linaria* increased in stem density, number of flowering stalks and percent cover one to three years following the Leroux Fire in 2003 under all fire severity categories and did so significantly in areas of high fire severity (R. Dodge, unpublished data, 2004). In the San Francisco Peaks, establishment has been observed due to small disturbances from elk (bedding down, migration) and birds (B. Phillips and L. Moser, personal observations, 2004). Toadflax most commonly invades disturbed plant communities typical of cultivated areas, roadsides, and other "waste places." It also invades communities with naturally-occurring disturbances or small openings (Arnold 1982 in Zouhar 2003, Lajeunesse 1999)
Sources of information: See cited literature. Also considered unpublished data of R. Dodge (Master's student, Northern Arizona University, presented at San Francisco Peaks Cooperative Weed Management Area meeting, August 26, 2004) and personal observations of L. Moser (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2004) and B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004).

Question 2.2 Local rate of spread with no management *Score*: **B** *Doc'n Level*: **Obs.**
Describe rate of spread: Increases rapidly, but does not double in <10 years.
Rationale: Because Dalmatian toadflax can produce enough seeds to exceed potential emergence sites, and because Dalmatian toadflax plants reproduce vegetatively, it appears that individual seedling recruitment in Dalmatian toadflax is more important for establishing new populations than it is for maintaining established populations (Grieshop and Nowierski 2002). Roots of Dalmatian toadflax seedlings grow an average of about 2 inches (6 cm) per week, with the uppermost primary branch tending to grow horizontally at depths of 0.8 to 4 inches (2 to 10 cm) (Robocker 1974). Growth models are in the process of being developed from data collected in the Coconino National Forest (R. Dodge, unpublished data, 2004). Dodge's observations during her field study 2002 to 2004 suggested that *Linaria* populations are increasing but not doubling in <10 years (R. Dodge, personal communication, 2004). In Raymond Mountain Wilderness Study Area (Border Junction, Wyoming), D. Wilde (Undated) with the Lincoln County Weed and Pest District reported an infestation of Dalmatian toadflax has more than

quadrupled since 1991. In Colorado, shoot density increased over 1200% in six years at one location and 190% over three years at another location. Dalmatian toadflax plants are thought to live an average of 3 to 5 years. Dalmatian toadflax patches can persist for 13 years or more under favorable conditions. Dalmatian toadflax stands sometimes disappear for several years then re-establish, either from buried seeds or perhaps from vegetative root buds (Robocker 1974).
Sources of information: See cited literature. Also considered unpublished data and personal communication with R. Dodge (Master's student, Northern Arizona University, 2004) and report by D. Wilde (Lincoln County Weed and Pest District, available online at http://www.denix.osd.mil/denix/Public/ES-Programs/Conservaion/Invasive/natural.html, Undated).

Question 2.3 Recent trend in total area infested within state *Score*: **B** *Doc'n Level*: **Obs.**
Describe trend: Increasing but not doubling in <10 years in total area infested.
Rationale: *L. dalmatica* is increasing in its range within Arizona but not rapidly.
Sources of information: Observations by L. Moser (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2004) and Working Group consensus.

Question 2.4 Innate reproductive potential *Score*: **A** *Doc'n Level*: **Rev. sci. pub.**
Describe key reproductive characteristics: See Worksheet A.
Rationale: Reproduces by seed and extensive horizontal roots; prolific seed producer.
Sources of information: See Worksheet A and cited literature in the accompanying notes.

Question 2.5 Potential for human-caused dispersal *Score*: **A** *Doc'n Level*: **Other pub.**
Identify dispersal mechanisms: Equipment, human recreation, cattle (post digestion), horticulture industry.
Rationale: Equipment used in moving soil and gravel disperse vegetative root fragments that will establish elsewhere. Fuel reduction treatments (by humans), trail maintenance, and recreational use of the back country have the potential to spread seed and root fragments. Seed dispersal via farm equipment is likely an important mode of dispersal in agricultural areas. Still being use as an ornamental (plant and seed) and people have a tendency to pick it because it is pretty. Formerly used as a folk remedy and fabric dye; do not know the current status of this. Dalmatian toadflax may also be dispersed by cattle, deer and other browsing animals; seeds can remain viable after passing through the gastrointestinal tracts of cattle, and possibly deer (Robocker 1970).
Sources of information: See Carpenter and Murray (1998). Also considered Working Group member observations.

Question 2.6 Potential for natural long-distance dispersal *Score*: **C** *Doc'n Level*: **Obs.**
Identify dispersal mechanisms: Rare dispersal of more than 1 km
Rationale: Irregular wings on tiny seeds aid in wind dispersal and oily seed coats to enhance water and granivore dispersal. Nadeau and King (1991) observed that over 80% of yellow toadflax seeds fell within an 18-inch (50 cm) radius of the parent plant, and "very few" seeds fell more than 5 feet (1.5 m) from the parent plant. Average seed size is similar for yellow and Dalmatian toadflax. Dalmatian toadflax seeds are slightly heavier (Robocker 1970), and the papery wing surrounding the seeds is less developed on Dalmatian toadflax. This suggests that Dalmatian toadflax seeds probably also fall within short distances of the parent plant (Zouhar 2003). Yellow toadflax seeds may also be dispersed by

natural causes such as water, ants, birds, and rodents (Saner et al. 1995). It is inferred that this is true for Dalmatian toadflax as well.
Sources of information: See cited literature. Working Group also applied inference.

Question 2.7 Other regions invaded *Score*: **C** *Doc'n Level*: **Obs.**
Identify other regions: only in areas invaded in AZ
Rationale: Ecological distribution in Colorado typically found between 5000 to 6500 feet in oak, aspen, sagebrush, mountain brush and riparian communities (Rocky Mountain National Park 1998). Dalmatian toadflax is said to be highly invasive and competitive in sagebrush (*Artemisia* spp.) ecosystems (Pyke 2000) and is often invasive in open ponderosa pine (*Pinus ponderosa*), bunchgrass, and riparian communities. Dalmatian toadflax may displace natives in shrub-steppe communities in Washington (Rice and Randall 2003). It was found in trace amounts in ponderosa pine-bluebunch wheatgrass (*Pseudoroegneria spicata*) and ponderosa pine-Thurber needlegrass (*Achnatherum thurberianum*) habitat types in Washington and Idaho in the late 1960s (Daubenmire and Daubenmire 1968). In Oregon Dalmatian toadflax is found in bluebunch wheatgrass-Sandberg bluegrass (*Poa secunda*), Idaho fescue (*Festuca idahoensis*)-bluebunch wheatgrass communities, and on gravel bars in riparian communities (Rice and Randall 2003). In Montana Dalmatian toadflax forms large colonies in dry mountain grasslands of valleys and foothills Lackschewitz 1991), on sites formerly dominated by native prairie species such as Idaho fescue and bluebunch wheatgrass. These sites are now dominated by Dalmatian toadflax, leafy spurge (*Euphorbia esula*), spotted knapweed (*Centaurea maculosa*), cheatgrass (*Bromus tectorum*) (Marler et al. 1999) and sulphur cinquefoil (*Potentilla recta*) (L. Moser, personal observation, 2003). In Glacier National Park, Montana, Dalmatian toadflax occurs in rough fescue (*Festuca altaica*)-Idaho fescue habitat types along roadsides (Tyser and Worley 1992). In Yellowstone National Park, Wyoming Dalmatian toadflax was found at Mammoth Campground in a big sagebrush (*Artemisia tridentata*)/bluebunch wheatgrass habitat type. It was not found at campgrounds at higher elevations (Allen and Hansen 1999). Along the Yampa River area in Colorado, Dalmatian toadflax spreads in from adjacent upland areas and along the river. It is found in gravel bars, riparian pastures, and open meadows, and may compete with cottonwood seedlings for establishment sites on gravel bars. In Phantom, Colorado the river and trails are conduits to dispersal of Dalmatian toadflax. It may also invade mountain-mahogany (*Cercocarpus* spp.) shrubland and shortgrass prairie communities adjacent to riparian corridors (Rice and Randall 2003). In Utah, Dalmatian toadflax is found in oak (*Quercus* spp.), quaking aspen (*Populus tremuloides*), sagebrush, mountain brush, and riparian communities (Welsh et al. 1987)
Sources of information: See cited literature.

Question 3.1 Ecological amplitude *Score*: **A** *Doc'n Level*: **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Widespread, invades 10 minor ecological types in Arizona.
Rationale: Dalmatian toadflax is a native of the Mediterranean region from the coast of Croatia northeastward to Transylvania and Moldavia in northern Romania, southward and eastward around the Black Sea in the countries of Bulgaria, Albania, Greece, Crete, Turkey, Syria, Iran, and Iraq (Alex 1962 in Carpenter and Murray 1998). According to Saner et al. (1995) *Linaria* has a tolerance for low temperatures and coarse textured soils. In addition, can adapt their growth to fit a number of habitats

primarily occurring on sandy or gravely soil on roadsides, railroads, pastures, cultivated fields, rangelands and clear cuts From Zouhar (2003): the latitudinal range of Dalmatian toadflax in North America is from about 33° N to about 56° N (Alex 1962). Dalmatian toadflax is most common in western North America, especially in California, Oregon, Washington, Idaho, Montana, Wyoming, Alberta, and British Columbia (Carpenter and Murray 1998, Lajeunesse 1999), and it is spreading in the Southwest. For example, it is estimated to have invaded 200,000 acres (80,000 ha) on the Coconino National Forest in northern Arizona as of 2001 (Phillips and Crisp 2001). First reported in North America as an ornamental in 1894 (Alex 1962 in Carpenter and Murray 1998); earliest authentic specimen collected in California in 1920 (Alex 1962 in Zouhar 2003). Persistent and aggressive invader in Colorado from 6000 to 8500 feet mostly on the Western Slope (Beck 2001). Earliest AZ record is 1955 (SEINet 2004). Dalmatian toadflax is found, though rare, in sandy soils and washes in oak woodland in Fort Bowie National Historic Site in southeastern Arizona (Warren et al. 1992). It is also found in northern Arizona in Bebb willow (*Salix bebbiana*) wet meadow, fescue (*Festuca* spp.)-muhly (*Muhlenbergia* spp.) grassland, and mixed conifer understory communities(Rice and Randall 2003).
Sources of information: Observations by several of the Working Group members. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed June 2004) and Southwest Exotic Plant Mapping Program (SWEMP) 2003 records (available online at: http://www.usgs.nau.edu/swepic/swemp).

Question 3.2 Distribution	*Score*: **A** *Doc'n Level*: **Obs.**
Describe distribution: Largest frequency of occurrence is in tundra (only one ecological type of tundra)	
Rationale: See Worksheet B.	
Sources of information: Observations by several of the Working Group members.	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	[Yes]	No	1 pt.
Dense infestations produce >1,000 viable seed per square meter	[Yes]	No	2 pt.
Populations of this species produce seeds every year.	[Yes]	No	1 pt.
Seed production sustained for 3 or more months within a population annually	[Yes]	No	1 pt.
Seeds remain viable in soil for three or more years	[Yes]	No	2 pt.
Viable seed produced with *both* self-pollination and cross-pollination	Yes	[No]	1 pt.
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	[Yes]	No	1 pt.
Fragments easily and fragments can become established elsewhere	[Yes]	No	2 pt.
Resprouts readily when cut, grazed, or burned	[Yes]	No	1 pt.
	Total pts: 11 Total unknowns: 0		
	Score : A		

Note any related traits: According to Robecker (1974), with minimal competition and good moisture availability a Dalmatian toadflax plant with 10 stems could potentially produce 500,000 seeds and remain dormant for up to 10 years. Over 90% germination has been obtained with 2 to3 year-old seeds in a laboratory (Rocky Mountain National Park 1998). Vegetative buds give rise to new shoots as early as nine weeks (Robocker 1974). According to Zimmerman (1996), vegetative reproduction from root buds can occur as early as 2 to 3 weeks after germination. Root buds are not killed by fire and removal of top growth can stimulate production of vegetative shoots (Lajeunesse 1999). Self-incompatible and rely on insects for pollinations (Vujnovic 1997 in Zouhar 2003). Life span is up to five years with an average of 3.8 years (Robocker 1974).

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	**C**
	southwestern interior chaparral scrub	**D**
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	**C**
	plains and Great Basin shrub-grassland	**D**
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	**C**
	montane riparian	**C**
Woodlands	Great Basin conifer woodland	**C**
	Madrean evergreen woodland	**D**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	**C**
	montane conifer forest	**B**
Tundra (alpine)	tundra (alpine)	**A**

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

The following table provides some elevation ranges for Dalmatian toadflax by geographic area (from Zouhar 2003)

Area	Elevation	References
Nevada	3,000 to 7,000 feet (900 to 2,100 m)	Kartesz (2002)
New Mexico	5,000 to 6,000 feet (1,500 to 1,800 m)	Martin and Hutchins (1981)
Utah	4,400 to 10,000 feet (1,300 to 3,100 m)	Welsh et al. (1987)

Literature Citations

Alex, J.F. 1962. The taxonomy, history, and distribution of *Linaria genistifolia* ssp. *dalmatica*. Canadian Journal of Botany 40:295–307.

Allen, K., and K. Hansen. 1999. Geography of exotic plants adjacent to campgrounds, Yellowstone National Park, USA. The Great Basin Naturalist 59:315–322.

Arnold, R.M. 1982. Pollination, predation and seed set in Linaria vulgaris (Scrophulariaceae). American Midland Naturalist 107:360–369.

Beck, K.G. 2001. Biology and Management of the Toadflaxes. No. 3.114. Colorado State University, Cooperative Extension.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Bruun, H.G. 1937. Genetical notes on *Linaria*, I-II. Hereditas 22:395–401.

Burrill, L.C, S.A. Dewey, D.W. Cudney, B.E. Nelson, R.D. Lee, and R. Parker. 2002. Weeds of the West. The Western Society of Weed Science and University of Wyoming.

Carpenter, A.T., and T.A. Murray. 1998. *Linaria dalmatica and Linaria vulgaris.* Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documnts/linadal.html.

Daubenmire, R.F., and J.B. Daubenmire. 1968. Forest Vegetation of Eastern Washington and Northern Idaho. Technical Bulletin 60. Washington State University, Agricultural Experiment Station, Pullman. 104 p.

Grieshop, M.J., and R.M. Nowierski. 2002. Selected factors affecting seedling recruitment of dalmatian toadflax. Journal of Range Management 55:612–619.

Harris, P., and M.J. Clapperton. 1997. An exploratory study on the influence of vesicular-arbuscular mycorrhizal fungi on the success of weed biological control with insects. Biocontrol Science and Technology 7:193–201.

Kartesz, J.T., and C.A. Meacham. 1999. Synthesis of the North American Flora (Windows Version 1.0), [CD-ROM]. Available from the North Carolina Botanical Garden. In cooperation with the Nature Conservancy, Natural Resources Conservation Service, and U.S. Fish and Wildlife Service.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Lackschewitz, K. 1991. Vascular Plants of West-Central Montana—Identification Guidebook. Gen. Tech. Rep. INT-227. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah. 648 p.

Lajeunesse, D. 1999. Dalmatian and yellow toadflax. Pages 202–216 in R.L. Sheley and J.K. Petroff (eds.), Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis.

Marler, M.J., C.A. Zabinski, T. Wojtowicz, and R.M. Callaway. 1999. Mycorrhizae and fine root dynamics of *Centaurea maculosa* and native bunchgrasses in western Montana. Northwest Science 73:217–224.

Martin, W.C., and C.R. Hutchins. 1981. A Flora of New Mexico. Volume 2. J. Cramer, Germany. 2589 p.

Nadeau, L.B., and J.R. King. 1991. Seed dispersal and seedling establishment of *Linaria vulgaris* Mill. Canadian Journal of Plant Science 71:771–782.

Phillips, B.G., and D. Crisp. 2001.Dalmatian toadflax, an invasive exotic noxious weed, threatens Flagstaff pennyroyal community following prescribed fire. In Southwestern Rare and Endangered Plants: Proceedings of the Third Conference. September 25–28, 2000, Flagstaff, Arizona. RMRS-P-23.

Pyke, D.A. 2000. Invasive exotic plants in sagebrush ecosystems of the Intermountain West. Pages 43–44 in P.G. Entwistle, A.M. DeBolt, J.H. Kaltenecker, and K. Steenhof (compilers), Sagebrush Steppe Ecosystems Symposium: Proceedings. June 21–23, 1999, Boise, Idaho. Publication No. BLM/ID/PT-001001+1150. U.S. Department of the Interior, Bureau of Land Management, Boise State Office, Boise, Idaho.

Rice, B.M., and J. Randall (compilers). 2003. Weed report: *Linaria dalmatica*--Dalmatian toadflax. In Wildland Weeds Management and Research: 1998–99 Weed Survey. The Nature Conservancy, Wildland Invasive Species Program, Davis, California. 7 p. On file with: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, Montana.

Robocker, W.C. 1970. Seed characteristics and seedling emergence of Dalmatian toadflax. Weed Science 18:720–725.

Robocker, W.C. 1974. Life History, Ecology, and Control of Dalmatian Toadflax. Technical Bulletin No. 79. Washington Agricultural Experiment Station.

Rocky Mountain National Park. 1998. An Assessment of *Linaria dalmatica ssp.dalmatica* (L.). Available online at: http://www.npwrc.usgs.gov/resource/othrdata/explant/linadalm.html; accessed February 7, 2004.

Saner, M.A., D.R. Clements, M.R. Hall, D.J. Doohan, and C.W. Crompton. 1995. The biology of Canadian weeds. 105. *Linaria vulgaris* Mill. Canadian Journal of Plant Science 75: 525–537.

Sutton, D.A. 1988. A Revision of the Tribe Antirrhineae. British Museum (Natural History), Oxford University Press, London. 575 p.

Tyser, R.W., and C.A. Worley. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). Conservation Biology 6:253–262.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Vujnovic, K., and R.W. Wein. 1997. The biology of Canadian weeds. 106. *Linaria dalmatica* (L.) Mill. Canadian Journal of Plant Science 77:483–491.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Warren, P.L., M.S. Hoy, and W.E. Hoy. 1992. Vegetation and Flora of Fort Bowie National Historic Site, Arizona. Tech. Rep. NPS/WRUA/NRTR-92/43. The University of Arizona, School of Renewable Natural Resources, Cooperative National Park Resources Studies Unit, Tucson, Arizona. 78 p.

Welsh, S.L., N.D. Atwood, S. Goodrich, and L.C. Higgins (eds.). 1987. A Utah Flora. The Great Basin Naturalist Memoir No. 9. Brigham Young University, Provo, Utah. 894 p.

Zimmerman, J.A.C. 1996. Ecology and distribution of *Linaria vulgaris* (L.) Miller, Scrophulariaceae. U.S. Geological Survey, Biological Resources Division, Colorado Plateau Field Station-Flagstaff, Arizona. Available online at: http://www.nbsc.nau.edu/FNF/Vegetation/Exotics/Linariatitle.html.

Zouhar, K. 2003. *Linaria* spp. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Linaria vulgaris* P. Mill. (USDA 2005)
Synonyms:	*Linaria linaria* (L.) Karst. (USDA 2005)
Common names:	Yellow toadflax, butter and eggs, common toadflax, ramsted, flaxweed, wild snapdragon, Jacob's ladder
Evaluation date (mm/dd/yy)**:**	05/17/04
Evaluator #1 Name/Title:	Kate Watters
Affiliation:	Northern Arizona University, National Park Service I & M Network
Phone numbers:	(928) 523–8518
Email address:	Kw6@dana.ucc.nau.edu
Address:	P.O. Box 5765 Flagstaff, Arizona 86011–5765
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	06/24/03: W. Austin, D. Backer, J. Busco, P. Guertin, J. Hall, R. Haughey, L. Moser, F. Northam, R. Paredes, B. Phillips, K. Thomas, K. Watters 06/23/04: W. Albrecht, D. Backer, J. Brock, J. Busco, J. Hall, C. Laws, L. Moser, B. Phillips, K. Watters
Committee review date:	06/24/03 and 06/23/04
List date:	06/23/04
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

Question		Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Other published material	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **Alert**
1.2	Impact on plant community	**A**	Other published material		
1.3	Impact on higher trophic levels	**B**	Other published material		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **16 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**A**	Other published material		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Other published material		
2.6	Potential for natural long-distance dispersal	**C**	Other published material		
2.7	Other regions invaded	**B**	Other published material		 Something you should know.
3.1	Ecological amplitude	**B**	Observational	**"Distribution"** **Section 3 Score:** **C**	
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Other pub.**
Identify ecosystem processes impacted: Yellow toadflax populations have the potential to alter fire characteristics depending on the ecosystem. Yellow toadflax is capable of both increasing and preventing soil erosion surface runoff and sediment yield depending on the site and vegetation type.
Rationale: Yellow toadflax may alter fire intensity or slightly modify an existing fire regime in ecosystems where it replaces plants with similar fuel characteristics. However, it has the potential to completely alter the fire regime if yellow toadflax offers unique characteristics to the invaded ecosystem (D'Antonio 2000). There are no specific examples of fire regimes altered by toadflax invasion described in the available literature, however, it is thought that yellow toadflax populations interrupt grassland/surface fire regimes as yellow toadflax was not widespread in these communities when historic fire regimes were functioning, but has established since habitat alteration and fire exclusion began. It is unclear how historic fire regimes might affect toadflax populations, and it is unclear how the presence of toadflax in native ecosystems might affect fire regimes. Dalmatian toadflax (*L. dalmatica*) occurs in ecosystems with historic fire regimes of varied frequency and severity; from frequent, low-severity fires in ponderosa pine ecosystems, to less frequent and more severe fires in bunchgrass and sagebrush ecosystems, to frequent and severe fires in plains and prairie grassland ecosystems (Zouhar 2003). Where sod-forming or bunchgrass communities are replaced by yellow toadflax, soil erosion, surface runoff, and sediment yield are likely to increase. Yet, yellow toadflax can actually help stabilize soil on steep, eroding banks and devegetated sites (Lajeunesse 1999).
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Dense and established stands of yellow toadflax compete with native vegetation for resources and nutrients and can change the composition of a natural plant community.
Rationale: Yellow toadflax is a persistent, aggressive invader and capable of forming dense colonies through adventitious buds from creeping root systems. Yellow toadflax seedlings are considered ineffective competitors for soil moisture with established perennials and winter annuals, though mature plants are particularly competitive with winter annuals and shallow-rooted perennials (Morishita 1991). Colonies of mature, established yellow toadflax often outcompete native grasses and other perennials, and alter the species composition of natural communities. Mature yellow toadflax plants are considered strong competitors with an extensive root system. Taproots of a mature Dalmatian toadflax (*L. dalmatica*) plant may reach depths of 4 to 10 feet (1.3 to 3 m), and lateral roots can extend 12 feet (3.6 m) from the parent plant. Vegetative buds were found as deep as 6 feet (1.8 m) in coarse soil. However, most Dalmatian toadflax plants produced from vegetative buds occur on lateral roots that are found in the upper 2 to 12 inches (5 to 30 cm) of soil (Alex 1962, Robocker 1974). Mature yellow toadflax taproots may grow 3.3 feet (1 m) deep, and lateral roots can be several meters long. Once plants are established they can be capable of suppressing other vegetation mainly by intense competition for limited resources (Zouhar 2003).
Sources of information: See cited literature.

Question 1.3 Impact on higher trophic levels *Score:* **B** *Doc'n Level:* **Other pub**.
Identify type of impact or alteration: Yellow toadflax can displace plant communities and associated animal life. This can result in a loss of forage in pastures and rangelands that can impact livestock and some big game species, especially on winter ranges.
Rationale: Although deer have been observed to graze Dalmatian toadflax (*L. dalmatica*), toadflax seed is used by some species of birds and rodents, and it can provide cover for small mammals, it is not

known to be heavily used by any native animal species (Lajeunesse 1999, Robocker 1974). A review by Saner and others (1995) points out that several secondary compounds present in yellow toadflax may explain why cattle avoid it. This review also indicates that cattle eat dried yellow toadflax, and that yellow toadflax is not generally poisonous to livestock, as it has been used as a medicinal plant for cattle that cannot ruminate. Occasional cases of mild poisoning from yellow toadflax have been reported for cattle, who sometimes browse flowering shoots, but such cases are rare because cattle usually avoid toadflax (Mitich 1993, Lajeunesse 1999). Because cattle exhibit grazing preference and avoid toadflax, and by browsing on native plants and removing competition, this enables the yellow toadflax to establish readily. Heavy grazing creates more open areas with disturbance for toadflax to spread. Yellow toadflax is pollinated mostly by bumblebees and it is only of minor importance for honeybees (Saner et al. 1995).
Sources of information: See cited literature. Score also based on inference drawn from the literature as some of the information considered applied to *L. dalmatica*.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub**.
Identify impacts: According to Kearney and Peebles (1960), *Linaria texana* (Scheele), or Texas toadflax, is found in Graham, Gila, Maricopa, Pinal, Cochise and Pima counties from 1,500 to 5,000 feet. The current scientific name for this species is *Nuttallanthus texanus* (Scheele) D.A. Sutton (USDA 2005). It is unlikely that this could hybridize with *Linaria vulgaris* as they have completely different ranges and now have been separated into separate genera.
Rationale: No known hybridization.
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub**.
Describe role of disturbance: Disturbance promotes toadflax invasion and may be necessary for establishment to occur. However once established, toadflaxes readily spread into adjacent non-disturbed areas. Much of this spread is by vegetative means, reflecting a vigorously-growing root system. Toadflax invasion is favored by disturbance and they invade degraded areas such as roadsides, abandoned lots and fields, gravel pits, clearings, and overgrazed rangeland. Toadflax invasion after fire may also be related to soil disturbances brought about by fire suppression activities.
Rationale: Toadflax evolved in areas where much of the land is cultivated and are adapted to the periodic disturbances of agriculture. In North America, they are most commonly found on disturbed sites such as roadsides, fencelines, areas near dwellings, vacant lots, cemeteries, gravel pits, croplands, clearcuts, pastures, waste areas, and other disturbed sites where removal of vegetation allows toadflax seedlings to establish. Similarly, typical yellow toadflax habitats in Europe include vineyards, woodland clearings, and clearcuts. In Europe, large populations of yellow toadflax were observed on fields where competing vegetation was depressed by grazing or fire, and on some sites (e.g. between trees in orchards or in train yards) that had been subject to regular application of broad-action herbicides (Saner et al. 1995, Carpenter and Murray 1998, Lajeunesse 1999). Toadflax can also establish and spread in sparsely vegetated areas and sites with naturally-occurring disturbances, small openings, and/or little competition between species. Examples of such sites include dry, open areas in grassland and bunchgrass communities, sagebrush, open coniferous forests, sand dunes, riparian areas, and borders of woods (Lajeunesse 1999, Tyser and Worley 1992).
Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **A** *Doc'n Level:* **Other pub.**

Describe rate of spread: Vegetative propagation can allow a stand of toadflax to spread rapidly. In one study, a stand of *L. vulgaris* increased by 418% in a single season, and a patch that was originally one acre in size expanded to cover 85 acres in a five-year period.

Rationale: Increases rapidly, populations doubling in less than 10 years. For five of the yellow toadflax sites reported in the Southwest Exotic Plant Mapping Program (SWEMP; 2004) for 2003 in Arizona (including the ones near Lake Mary), three sites had doubled in size since the original reports, one was ~25% bigger, and the other ~40-50% bigger. All five sites also were infested with *L. damatica*.

Sources of information: Carpenter and Murray (1998). Also considered information from the SWEMP-Cain Crisis map (available online at: http://cain.nbii.gov/cgibin/mapserv?map=../html/cain/crisis/crisismaps/crisis.map&mode=browse&layer=state&layer=county; accessed online on February 10, 2004).

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**

Describe trend: Increasing, but less rapidly than doubling in total area infested in <years.

Rationale: Lake Mary population in Coconino National Forest may be near the edge of *L. vulgaris*'s southern range in Arizona, but it still has the capability to invade areas south and east along the Mogollon Rim and in the White Mountains.

Sources of information: Personal communication with L. Moser (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2004).

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci.pub.**

Describe key reproductive characteristics: Yellow toadflax is a deep-rooted, short-lived, herbaceous perennial that reproduces by seed, and can form colonies by means of adventitious buds on roots.

Rationale: Average number of seeds produced per yellow toadflax stem may range from 165 to 5,584. Nadeau and King (1991) found that seed production of 210,000 seeds per m^2 within a 0.5 m radius around yellow toadflax parent plants. Many seed studies fail to differentiate between viable and nonviable seeds. Seeds remain viable in the soil for 10 years. Yellow toadflax plants typically produce 90 to 100 secondary shoots from the root system in the 1st year and 200 to 250 shoots by the 2nd year. Nadeau and King (1991) found 40 to 51% average seed viability (by tetrazolium chloride test) in yellow toadflax seed collected throughout the season in Alberta).

Clements and Cavers (1990) observed seasonal differences in number of viable seeds produced by yellow toadflax and attributed these differences to differential seed development in response to variable resource availability. Capsules formed later in the growing season tend to produce more viable seed. Some populations of yellow toadflax may never produce more than 25% viable seed (Cements and Cavers 1990). However, vegetative reproduction in yellow toadflax is more important than seedling establishment for maintaining populations. Yellow toadflax plants typically produce 90 to 100 secondary shoots from the root system in the 1st year and 200 to 250 shoots by the 2nd year (Zouhar 2003).

Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* *A* *Doc'n Level:* **Other pub.**

Identify dispersal mechanisms: There are numerous opportunities for dispersal to new areas. Yellow toadflax is spread via fire suppression and thinning activities and trail construction. Yellow toadflax continues to be sold in nurseries and seed catalogs. For example, one publication lists "*Linaria vulgaris* (common toadflax or butter-and-eggs)" as a plant that is well suited for xeriscaping (Gutknecht 1989). The spread of toadflax was facilitated by its use as an ornamental, medicinal, magical, and dye plant,

although accidental introduction and distribution along roads and railway corridors, or in crop seed, baled hay, ship ballast, and clothing likely increased its spread.
Rationale: Seed dispersal via farm equipment is likely an important mode of dispersal in agricultural areas. Cutting equipment in forest thinning projects can transport yellow toadflax populations via root fragments. It is planted as an ornamental. Because of its propensity to establish in dry, open areas with little plant competition, toadflax has high potential for establishing after fire (when competition from other vegetation is removed or reduced) either by seed imported to the site by fire suppression equipment or by soil-stored seed. Disturbance associated with trail construction has also created new infestations of yellow toadflax.
Sources of information: See cited literature; also see Carpenter and Murray (1998) and Zouhar (2003). Also considered the observations of Working Group members.

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: A review by Saner and others (1995) suggests yellow toadflax seeds may also be dispersed by water, ants, birds, and rodents. Vegetative structures in a riparian system can easily result in transplant populations established downstream; however, dispersal of more than 1 km via natural events is rare.
Rationale: Although the seeds are winged, and wind has not been considered a major means of seed dispersal for toadflax species (Robocker 1970, Allen and Hansen 1999).Nadeau and King (1991) observed that over 80% of yellow toadflax seeds fell within an 18-inch (50 cm) radius of the parent plant, and "very few" seeds fell more than 5 feet (1.5 m) from the parent plant. Toadflax is also capable of establishing either from on-site seed, or seed dispersed into a burned area. Seed may be dispersed by animals into recently burned areas where it is adapted to establish under conditions of reduced competition (Zouhar 2003).
Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: Yellow toadflax is native to the steppes of southeastern Europe and southwestern Asia. The present world distribution includes most of Europe and Asia, and it has been introduced to Japan, Australia, New Zealand, South Africa, Jamaica, Chile and North America. In North America yellow toadflax is found throughout the continental United States and in every Canadian province and territory (Saner et al. 1995). The worst-infested western states are Idaho, Montana, Oregon, and Washington. *Linaria vulgaris* is listed as a noxious weed in Arizona and New Mexico. Both species have been cultivated as ornamentals for centuries and are widely distributed throughout the world. Yellow toadflax is most common in northeastern North America and is localized in other parts of the continent, particularly the western Canadian provinces (Lajeunesse 1999, Zouhar 2003). The northern limits of yellow toadflax's North American range are approximately 55° N to 65° N. In Utah yellow toadflax is found from 1270 to 3050 m in the central counties (Welsh et al. 2003). In Colorado yellow toadflax is found at elevations from 5,000 feet to over 10,000 feet. Yellow toadflax in particular has spread into high mountain valleys, river banks and parks. In Rocky Mountain National Park yellow toadflax is found at Upper Hollowell Park and is common around the Beaver Point, utility area and especially around old homesites. There are several widespread and dense populations in the park totaling an area of 11 to 50 hectares, including high quality areas with no known disturbance for last 100 years (Rutledge and McLendon 1996). Yellow toadflax infests over 40,800 acres in Colorado, with heaviest concentrations in Grand, Eagle, Pitkin, Garfield and Rio Blanco counties, also occurring in Gunnison, San Miguel, La Plata and Montezuma counties and often occurs in riparian areas in Colorado.

It is found, for example, on gravel bars in the south fork of the San Miguel River that are flanked by riparian forests of cottonwood (*Populus* spp.) and spruce (*Picea* spp.). In New Mexico yellow toadflax is found from 6000 to 7500 feet in northern counties of Rio Arriba and Sandoval (Martin and Hutchins 1981).
Rationale: In Arizona yellow toadflax is not known to occur in montane riparian or rocky mountain subalpine ecotypes.
Sources of information: See cited literature. Also considered information from the Colorado State University Cooperative Extension, Quadmapping project (available online at: http://www.ext.colostate.edu/pubs/natres/03114.html; accessed online on May 17, 2004) and the Atlas of the Vascular Plants of Utah (available online at: http://www.gis.usu.edu/Geography-Department/utgeog/utvatlas/ut-vascatlas.html; accessed February 10, 2004).

Question 3.1 Ecological amplitude *Score:* **B** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Yellow toadflax was introduced to New England in the late 1600s as an ornamental. The first collection of yellow toadflax in Arizona was by Thornber in 1930 from Coconino County (SEINet 2004). Toadflax is most commonly found in cultivated fields, roadsides, railways, "waste areas," clearcuts, overgrazed pastures and rangeland, and in plant communities that are typically open or disturbed. Neither *L. dalmatica* nor *L. vulgaris* occurs as frequently in intact wildlands and natural areas (Lajeunesse 1999). In central Europe, yellow toadflax prefers dry to moderately humid sandy loam soils that are moderate to rich in nutrients and minerals. Yellow toadflax may exhibit heavy metal tolerance. Yellow toadflax is more commonly associated with relatively summer-moist, coarse soils in the northwestern and north-central U.S. Yellow toadflax may grow well in moist areas of high fertility, but is more likely to be displaced by other species than on drier, less fertile sites. Yellow toadflax plants growing on dry sites are stunted but tend to be comparatively more persistent (Saner et al. 1995).
Rationale: Arizona populations of this species are confirmed from herbarium specimens in Ponderosa pine ecotype at Lake Mary in Coconino county. Earlier collections from 1938 and 1950 are from waste areas from Country Club in Coconino county. Distribution information is further complicated by the difficulty in distinguishing this species from *L. dalmatica*.
Sources of information: See cited literature. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed February 10, 2004).

Question 3.2 Distribution *Score:* **D** *Doc'n Level:* **Obs.**
Describe distribution: Arizona records are from Coconino County at Lake Mary Road.
Rationale: Limited observations in wildlands.
Sources of information: Kearney and Peebles (1960). Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed February 10, 2004).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**Yes**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**Yes**	**[No]**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**[No]**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**[Yes]**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 9	**Total unknowns: 1**	
	Score : A		

Note any related traits

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	**D**
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	**D**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Alex, J.F. 1962. The taxonomy, history, and distribution of Linaria dalmatica. Canadian Journal of Botany 40:295−307.

Allen, K., and K. Hansen. 1999. Geography of exotic plants adjacent to campgrounds, Yellowstone National Park, USA. The Great Basin Naturalist 59:315−322.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Carpenter, A.T., and T.A. Murray. 1998. *Linaria dalmatica and Linaria vulgaris.* Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/linadal.html; accessed May 17, 2004.

Clements, D.R., and P.B. Cavers. 1990. Seasonal seed viability patterns and the role of incomplete seed development in the life history strategy of *Linaria vulgaris*. Naturaliste Canadien 117:189−198.

D'Antonio, C.M. 2000. Fire, plant invasions, and global changes. Pages 65−93 in H.A. Mooney and R.J. Hobbs (eds.), Invasive Species in a Changing World. Island Press, Washington, DC.

Gutknecht, K.W. 1989. Xeriscaping: an alternative to thirsty landscapes. Utah Science 50:142−146.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Lajeunesse, S. 1999. Dalmatian and yellow toadflax. Pages 202–216 in R.L. Sheley and J.K. Petroff (eds.), Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis.

Martin, W.C., and C.R. Hutchins. 1981. A Flora of New Mexico. Volume 2. J. Cramer, Germany.

Mitich, L.W. 1993. Yellow toadflax. Weed Technology 7:791−793.

Morishita, D.W. 1991. Dalmatian toadflax, yellow toadflax, black henbane, and tansymustard: importance, distribution, and control. Pages 399−408 in L.F. James, J.O. Evans, M.H. Ralphs, and R.D. Child (eds.), Noxious Range Weeds. Westview Press, Boulder, Colorado.

Nadeau, L.B., and J.R. King. 1991. Seed dispersal and seedling establishment of *Linaria vulgaris* Mill. Canadian Journal of Plant Science 71:771−782.

Robocker, W.C. 1970. Seed characteristics and seedling emergence of Dalmatian toadflax. Weed Science 18:720–725.

Robocker, W.C. 1974. Life History, Ecology, and Control of Dalmatian Toadflax. Technical Bulletin 79. Washington State University, College of Agriculture, Agricultural Experiment Station, Pullman. 20 p.

Rutledge, C.R., and T. McLendon. 1996. An Assessment of Exotic Plant Species of Rocky Mountain National Park. Department of Rangeland Ecosystem Science, Colorado State University. 97 p. Available online from the Northern Prairie Wildlife Research Center, Jamestown, North Dakota at: http://www.npwrc.usgs.gov/resource/othrdata/explant/explant.htm. (Version 15Dec98). Go to the Abstracts for Exotic Plant Species of Concern—Final Assessment, and then click on *Linaria vulgaris.*

Saner, M.A., D.R. Clements, M.R. Hall, [and others]. 1995. The biology of Canadian weeds. 105. *Linaria vulgaris* Mill. Canadian Journal of Plant Science 75:525–537.

Tyser, R.W., and C.A. Worley. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). Conservation Biology 6:253–262.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Welsh, S.L., N.D. Atwood, S. Goodrich, and L.C. Higgins. 2003. A Utah Flora. 3rd edition. Brigham Young University Press, Provo, Utah. 912 p.

Zouhar, K. 2003. *Linaria* spp. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed May 17, 2004.

Other References of Interest Not Cited in the Text

Pauchard, A., P.B. Alaback, and E.G. Edlund. 2003. Plant invasions in protected areas at multiple scales: *Linaria vulgaris* (Scrophulariaceae) in the West Yellowstone area. Western North American Naturalist 63:416–428.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Lolium perenne* L. (USDA 2005)
Synonyms:	*Lolium perenne* L.: *Lolium multiflorum* Lam., *Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot; *Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot: *Lolium multiflorum* Lam., *Lolium multiflorum* Lam. var. *diminutum* Mutel, *Lolium multiflorum* Lam. var. *muticum* DC, *Lolium perenne* L. var. *aristatum* Willd. and *Lolium perenne* L. var. *multiflorum* (Lam.) Parnell; *Lolium perenne* L. ssp. *perenne*: *Lolium multiflorum* Lam. var. *ramosum* Guss. ex Arcang., *Lolium perenne* L. var. *cristatum* Pers. ex B.D. Jackson (USDA 2005)
Common names:	*Lolium perenne* L.: Perennial ryegrass; *Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot: Italian ryegrass, annual ryegrass; *Lolium perenne* L. ssp. *perenne*: Perennial ryegrass
Evaluation date (mm/dd/yy)**:**	02/25/04
Evaluator #1 Name/Title:	Kate Watters
Affiliation:	Northern Arizona University
Phone numbers:	(928) 523–8518
Email address:	Kw6@dana.ucc.nau.edu
Address:	P.O. Box 5765 Flagstaff, Arizona 86011–5765
Evaluator #2 Name/Title:	Wade Albrecht
Affiliation:	University of Arizona, Coconino County Cooperative Extension
Phone numbers:	(928) 774–1868 x25
Email address:	walbrech@ag.arizona.edu
Address:	2304 N. 3rd St. Flagstaff, Arizona 86001

List committee members:	12/17/04: W. Albrecht, D. Backer, J. Crawford, D. Crisp, S. Harger, S. Masek-Lopez, F. Northam, T. Olson, B. Phillips 03/02/05: W. Albrecht, S. Harger, L. Moser, F. Northam, T. Olson
Committee review date:	12/17/04 and 03/02/05
List date:	03/02/05
Re-evaluation date(s):	

Taxonomic Comment

Kearney and Peebles (1960) lists two perennial ryegrasses that have been introduced to Arizona: *Lolium perenne* and *L. multiflorum*. According to USDA (2005), however, *L. multiflorum* is a subspecies of *L. perenne* (*L. perenne* ssp. m*ultiflorum*) and can be an annual, biennial, or perennial. Another subspecies taxon, *L. perenne* ssp. p*erenne*, is listed as a perennial. Besides Kearney and Peebles (1960), some authors also distinguish annual ryegrass (*L. perenne* ssp. *multiflorum*) and perennial ryegrass (*L. perenne* ssp. *perenne*) as separate species because of their distinct structural characteristics, even though annual ryegrass was derived artificially from perennial ryegrass and they readily hybridize (Gould and Shaw 1983 in Sullivan 1992). Other authors in addition to USDA (2005) consider *L. multiflorum* to be a variety or subspecies of *L. perenne* (Welsh et al. 1987, Gleason and Cronquist 1991). For this assessment the taxonomy of USDA (2005) is followed and the various taxa included under *Lolium perenne* will be treated collectively.

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Other published material	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**B**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**C**	Other published material		
1.4	Impact on genetic integrity	**U**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **15 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Other published material		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**A**	Other published material		
2.5	Potential for human-caused dispersal	**A**	Other published material		
2.6	Potential for natural long-distance dispersal	**C**	Observational		
2.7	Other regions invaded	**B**	Other published material		 Something you should know.
3.1	Ecological amplitude	**A**	Other published material	**"Distribution"** **Section 3 Score:** **B**	
3.2	Distribution	**C**	Observational		

Table 3. Documentation

Note: Much of the literature refers to studies of *Lolium perenne* as a pasture grass and its response under different variables, however, some of this information is derived from references to *L. perenne* as a turfgrass component species.

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Other pub.**
Identify ecosystem processes impacted: Increased fire frequency in areas where seeded. The relatively sufficient fibrous root system can affect the soil water table level as well as stabilize soil.
Rationale: Dense stands of dry ryegrass burn readily and have the potential to increase the fire frequency (Care 1995). An example of this occurred in Otay Mountain, California where a natural fire burned chaparral vegetation and was reseeded with *L. perenne*. With near record precipitation, the ryegrass did exceptionally well. A second fire occurred the following year killing nearly all of the shrubs (Zedler et al. 1983). One of the reasons *L. perenne* is used in postfire seeding is because the fibrous root system appears to effectively stabilize surface soil (Barro and Conard 1987). Robichaud et al. (2000) conducted an extensive literature review of post fire rehabilitation using various seeding treatments. In general, a negative relationship exists between ryegrass cover and erosion (see Blanford and Gunter 1972, Krammes and Hill 1963). Gautier (1983) measured less erosion from plots in which ryegrass seeding increased total plant cover. On the other hand, Taskey et al. (1989) found no effect of ryegrass on first-year postfire erosion with average rainfall and no intense storms, despite higher average cover on seeded plots. In a more extensive study in chaparral (Beyers et al.1998a, b, Wohlgemuth et al. 1998) postfire erosion was greatest during the first year after fire and was not significantly affected by ryegrass seeding (Wohlgemuth et al. 1998). In later postfire years, some sites had significantly less erosion on seeded than on unseeded plots, but this happened only after erosion rates had dropped to prefire levels, which occurred in as little as two years on some sites (Wohlgemuth et al. 1998). The Working Group assumed similar affects apply in Arizona
Sources of information: See cited literature. Working Group members also applied inference.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **B** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: Dense stands of ryegrass, especially where it is reseeded, can cause changes in species composition. Ryegrass can quickly colonize a site, but cannot tolerate shade and can be succeeded by perennial species and shrubs.
Rationale: From Robichaud et al. (2000): most of the studies of *L. perenne* impact on native plant communities come from studying chaparral in California. An inverse relationship between ryegrass cover and native herbaceous plant cover was observed. Cover or biomass of native chaparral vegetation, especially herbaceous species, tended to be lower on plots with high ryegrass cover, both in operationally seeded areas (Keeley et al. 1981, Nadkarni and Odion 1986) and on hand-seeded experimental plots (Gautier 1983, Taskey et al. 1989). Native plant species richness was lower on plots containing ryegrass (Nadkarni and Odion 1986, Taskey et al. 1989). Native herbaceous plant cover and species richness were lower on seeded plots when ryegrass cover was high (Beyers et al. 1994, 1998b). Taskey et al. (1989) also noted bare areas appearing in seeded plots where ryegrass died out after three years, resulting in lower cover than on unseeded plots. These studies suggested that ryegrass grows at the expense of native vegetation. Several studies (see Schultz et al. 1955, Gautier 1983, Taskey et al. 1989) demonstrated that higher seeded grass cover and seeded plots found lower density of shrub seedlings, especially species killed by fire and warned that longterm chaparral species composition could potentially be affected by grass

seeding. However, Beyers et al. (1998a) did not find significantly lower shrub seedling density on seeded plots. Amaranthus et al. (1993) reported significantly lower survival of planted sugar pine (*Pinus lambertiana*) seedlings in plots heavily seeded with annual ryegrass than in unseeded controls during the first postfire year in southern Oregon. The soil moisture was significantly lower and pine seedlings showed significantly greater water stress in the seeded plots. *Lolium perenne* reduced growth of ponderosa pine seedlings in tests conducted in California (Baron 1962). Field studies on aerial seeded sites in California found low pine seedling densities on most plots with annual ryegrass cover higher than 40 percent (Griffin 1982, Conard et al. 1991). By the second year, planted pine seedlings had significantly greater survival and lower water stress on seeded plots than on controls. By then, dead ryegrass formed dense mulch on the seeded plots, but no live grass was found. Native shrub cover was significantly greater on the unseeded plots the second year and soil moisture was lower (Amaranthus et al. 1993). Ryegrass thus acted as a detrimental competitor to tree seedlings the first year after fire, but provided a beneficial mulch and reduced competition from woody plants the second year.

From Wardle et al. (1999): in an experimental removal study where different functional groups were removed (conducted in New Zealand). "C3 perennial grass, consisting almost entirely of *L. perenne*, was responsible for many of the treatment effects. *Lolium perenne* clearly exerted a disproportionate effect on the other components of the flora, meaning that the ecophysiological traits of this species presumably conferred some competitive advantage. …removal of all C3 grasses resulted in a highly significant enhancement of the total shoot mass to root mass ratio in the gaps….Removing *L. perenne* enables greater C4 grass seedling establishment, inducing greater C4 grass growth during periods in the summer when other species are suppressed by moisture limitation. This study provides clear evidence that removal of *L. perenne* enhanced spatial variability and biomass of C4 species. Removal of *L. perenne* also enhanced the species richness of the dicotyledonous weeds and, in the early summer period that of the C4 grasses. This means that at the within-gap scale, some plant species are simply excluded by competition from *L. perenne*."

From McKell et al. (1969): in an experimental (lab) study, ryegrass when seeded with other species (*Poa pratensis*, *Phalaris tuberosa* var. *stemoptera*, *Bromus mollis*, and *Avena fatua*) produced significantly larger plants than any other species (except *Avena fatua* which responded similarly) regardless of the planting combinations. The author considers this a large factor in their success as aggressors since a rapid increase in size is important in dominating a given micro-environment. In addition, ryegrass produced plants with greater mass of surface roots than any of the other grasses (Similar results for the field study indicated, ryegrass was suppressed more by itself than by any other species or combination of species and was most productive when grown with *P. pratensis*. In a third experiment, ryegrass plants were planted in alternating rows with *P. pratensis*, *Festuca arundinacea*, *P. tuberosa* var. *stemoptera*, *A. fatua,* and *Triflorium hirtum*. The growth of these species planted between rows of ryegrass was considerably less than growth of the same species planted without the influence of ryegrass. The reduction of the stand of perennial species may well be considerable (McKell et al. 1965) and is a probably cause of lowered production in succeeding years. In the same study, McKell et al (1965) found that after 11 years *L. perenne* was a very minor component of the seeded pastures.
A postfire study (tributary of Ventura River in southern California) where *L. perenne* was seeded, the first year of growth resulted in ryegrass dry biomass dominated the plant communities. Overall species richness of annals decreased in the second year after the fire due to the predominance of ryegrass, although perennials took over the riparian zone to a larger extant (Davis et al. 1989).

From Sullivan (1992): In Arizona seedings that included *L. perenne* had low initial cover values immediately following wildfire. By the seventh or eighth year, cover values had increased to nearly three times the values on unburned control plots, after which there was a slight drop in cover values (Lowe et al. 1978)

Sources of information: See cited literature.

Question 1.3 Impact on higher trophic levels *Score:* **C** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Positive impacts-forage value; negative impacts- poor habitat cover.
Rationale: *Lolium perenne* is considered good forage for livestock and wildlife (Frakes 1973 in Sullivan 1992). *Lolium perenne* is highly nutritious (Smoliak et al. 1981 in Carey 1995). In Montana *L. perenne* is considered poor cover for some mammal and waterfowl species (Dittberner and Olson 1983 in Carey 1995). Cover values in North Dakota rate *L. perenne* as poor for mule deer, white-tailed deer and pronghorn; and fair for upland game birds and waterfowl (Dittberner and Olson 1983 in Sullivan 1992). Pocket gophers increase in areas seeded with *L. perenne* possibly because of increased cover. Meadow mice and white-tailed deer graze *L. perenne* (Taskey et al. 1989 in Carey 1995). According to the draft California plant assessment for the taxon identified as *Lolium multiflorum* by J. DiTomaso (reviewed by the California list committee on August 1, 2003 and revised in September 2005), ryegrass outcompetes *Plantago erecta,* which is the sole source of food for the larvae of bay checkerspot butterflies in California. Suppression of native plant regeneration could potentially reduce browse species for wildlife (Keeley et al. 1981, Conard et al. 1991, Keeler-Wolf 1995, Loftin et al. 1998); however, no peer-published research was found that quantifies this.
Sources of information: See cited literature. Also considered the draft California *Lolium multiflorum* plant assessment by J. DiTomaso (available online at: http://www.cal-ipc.org/list_revision/completed_pafs.html; information current as of September 2005). Note: DiTomaso apparently considered *L. multiflorum* a distinct species from *L. perenne*.

Question 1.4 Impact on genetic integrity *Score:* **U** *Doc'n Level:* **Other pub.**
Identify impacts: No known native species in the genus *Lolium* occur in Arizona (Kearney and Peebles 1960).
Rationale: There are no native *Lolium* species in Arizona; however, there are several native species in the genus *Festuca* in Arizona (Kearney and Peebles 1960). Ryegrass is closely related to the genus *Festuca*; as a result, numerous natural hybrids between ryegrasses and European species of *Festuca* have been reported. Natural hybrids have resulted in great variation in the characteristics of ryegrass species (Gould and Shaw 1983 in Sullivan 1992). So the potential impacts on genetic integrity are still largely unknown.
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Moderate invasive potential-occasionally establish in undisturbed areas.
Rationale: The practice of seeding ryegrass for erosion control after fires provides a ready means for establishing this species. It is generally found in disturbed sites, but can move into relatively undisturbed grasslands (DiTomaso and Healy In Press). Colonization of disturbed sites and adjacent areas can take place by seed dispersal (Thompson 1979 in Sullivan 1992).
Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Other pub.**
Describe rate of spread: Increasing, but less rapidly than doubling in <years.
Rationale: Still being used in postfire seed mixes (Robichaud et al. 2000). Still used in lawn mixes. **Note:** The use of *L. perenne* for soil stabilization and rangeland conversion is becoming more questionable, because the effect of such species on the community structure of native plants is still poorly understood. Management considerations must take into account both the benefits of erosion

control, shrub control, and the reduction of shrub competition with conifers and the negative aspects of competition for space and soil moisture with native herbs and shrubs (Gross et al. 1989).
Sources of information: See cited literature.

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**
Describe trend: Increasing, but less rapidly than doubling in total area infested in <10 years.
Rationale: Development codes often encourage seeding. *Lolium perenne* is often a major component of seed mixes. Irrigation is required to ensure the survival of ryegrass in prolonged periods of drought (Beard 1973). Given climatic trends over the past 10 years, this suggests that statewide doubling of range seems improbable. Increased urbanization adjacent to wildlands provides opportunities for invasion.
Sources of information: See cited literature. Score based on inference drawn from the literature.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: Ryegrass is an annual, biennial, and perennial. Reproduces by seed.
Rationale: Ryegrass produces many seeds per year, and is cross- and self-pollinated, and seed is relatively short-lived in the soil. Longevity of buried *L. perenne* seed is not known (Carey 1995). High germination rate and initial rapid growth (Sullivan 1992, Carey 1995). Ryegrass is large seeded and possesses a rapid rate of seed germination, establishment, and vertical leaf extension (Beard 1973). Seedbanks of ryegrass are limited and transient and tend to germinate as soon as moisture conditions permit (Sullivan 1992). The lack of a persistent seedbank explains the tendency of ryegrass to be replaced by native grasses with persistent seedbanks in the more northerly latitudes (Thompson 1979 in Sullivan 1992). Flowering of ryegrass occurs April to August, depending on environmental conditions (Frakes 1973 in Sullivan 1992). In lawns or pastures ryegrass may be entirely dependent on vegetative reproduction (probably because the flowering stems are removed before seed production can occur; Grime 1979 in Sullivan 1992).
Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Ryegrass seed is present in hay and turf grass seed mixes and is used in lawns, as forage, for erosion control, and for revegetation.
Rationale: *Lolium perenne* is a quick, effective groundcover for erosion control and as a winter cover crop. Although ryegrass is one of the most commonly used grasses for revegetating burned sites, its use is controversial. Ryegrass is used as turf grass in the southern U.S. and is grown for winter pasture, hay, and silage (Carey 1995). Perennial ryegrass is widely planted in North America for range, pasture, hay and turf (Sullivan 1992). Available in turf mixes throughout the U.S.
Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Obs**.
Identify dispersal mechanisms: Most seeds fall close to parent plant (large seed). Natural long distance dispersal is rare.
Rationale: Small mammals may transport the seeds. Ryegrass does not have a long distance dispersal mechanism for the transport of seed.
Sources of information: Inference drawn from the literature

Question 2.7 Other regions invaded *Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: From Carey (1995): *Lolium perenne* ssp. *multiflorum* is native to Europe. Records of its cultivation in Italy date back to the thirteenth and fourteenth centuries. Ryegrass has been

introduced throughout the temperate regions of the world as a commercial species. *Lolium perenne* ssp. *multiflorum* occurs throughout the U.S., including Alaska and Hawaii, and in adjacent Canadian provinces. Difficulties in distinguishing *Lolium perenne* ssp. *multiflorum* from *Lolium perenne* ssp *perenne* make knowing the full range difficult. *Lolium perenne* ssp. *multiflorum* is reported to grow at less than 3,280 feet (1,000 m) in California, at 6,400 feet (1,350 m) in Utah, 6,500 feet (1,380 m) in Montana, and 4,000 to 8,000 feet (1,220 to 2,440 m) in Colorado. *Lolium perenne* is native to Eurasia and North Africa. It is widely planted in North America for lawns and has many agricultural uses. It occasionally escapes and becomes naturalized, mostly in waste places and roadsides (several authors cited by Sullivan 1992).
Rationale: In California, ryegrass occurs in coastal prairie, valley and foothill grassland, Great Basin grassland, meadows and seeps, and pinyon-juniper woodland. As a result, plains and Great Basin shrub-grassland and Great Basin conifer woodland are two minor ecological types in Arizona that invasion by *L. perenne* has not yet been documented but have been invaded elsewhere.
Sources of information: See cited literature. Also considered information from the Utah State University herbarium (available online at: http://www.herbarium.usu.edu/) and the draft California *Lolium multiflorum* plant assessment by J. DiTomaso (available online at: http://www.cal-ipc.org/list_revision/completed_pafs.html; information current as of September 2005). Note: DiTomaso apparently considered *L. multiflorum* a distinct species from *L. perenne*.

Question 3.1 Ecological amplitude	*Score:* **A** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: First record of ryegrass (*L. perenne multiflorum*) in Arizona is from 1884 along the Colorado River in the Grand Canyon. The next earliest record, for *L. perenne*, is 1913 in Tucson (SEINet 2004). Ryegrass invades at least four major and six minor ecological types in Arizona (see Worksheet B).	
Rationale: Perennial ryegrass is adapted to a wide range of soil types and drainage (Sullivan 1992). It does not thrive where there are extended periods of low temperatures or drought. Perennial ryegrass will do well in areas that are too wet for other grasses, and short periods of flooding will not severely reduce good stands (Wheeler and Hill 1957, Frakes 1973).	
Sources of information: See cited literature. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed May and November 2004) and the personal observations of Working Group members.	

Question 3.2 Distribution	*Score:* **C** *Doc'n Level:* **Obs.**
Describe distribution: Occurs in Grand Canyon National Park mainly in waste places and disturbed ground, as well as in the riparian corridor of the Colorado River. Also noted at the mouth of Bright Angel Creek and along the Colorado River (river mile 20.5) under tamarisk (L. Makarick, personal communication, 2004). It occurs in the Huachuca Mountains, Catalina Mountains., San Pedro River floodplain , Oak Creek Canyon, Hassayampa River Preserve. In Cibecue Ridge Watershed No. 1, 60+ acres cleared of trees and seeded with *L. perenne* in 1967.	
Rationale: In each minor ecological type in which it occurs, its distribution within the type is limited. See Worksheet B.	
Sources of information: Information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed May and November 2004) and personal communication with L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center, Flagstaff, Arizona, 2004).	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]** No	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]** No	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]** No	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]** No	**1 pt.**
Seeds remain viable in soil for three or more years	Yes **[No]**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]** No	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**[Yes]** No	**1 pt.**
Fragments easily and fragments can become established elsewhere	Yes **[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]** No	**1 pt.**
	Total pts: 8 Total unknowns: 0	
	Score : A	
Note any related traits:		

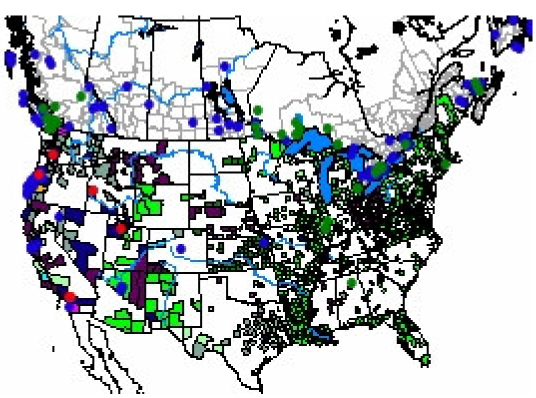
Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	Dunes	
Scrublands	Great Basin montane scrub	**U**
	southwestern interior chaparral scrub	**U**
Desertlands	Great Basin desertscrub	**U**
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	**D**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	**U**
	semi-desert grassland	**U**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	**U**
	Playas	
Riparian	Sonoran riparian	**D**
	southwestern interior riparian	**C**
	montane riparian	**D**
Woodlands	Great Basin conifer woodland	**U**
	Madrean evergreen woodland	**D**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	**D**
	montane conifer forest	**D**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

From Grass Manual on the Web (http://www.herbarium.usu.edu/webmanual/default.htm)

Lolium perenne



Literature Cited

Amaranthus, M.P., J.M. Trappe, and D.A. Perry. 1993. Soil moisture, native revegetation, and *Pinus lambertiana* seedling survival, growth, and mycorrhiza formation following wildfire and grass seeding. Restoration Ecology 1:188−195.

Baron, F. J. 1962. Effects of different grasses on ponderosa pine seedling establishment. Res. Note PSW-199. U.S.Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Barro, S.C., and S.G. Conard. 1987. Use of ryegrass seeding as an emergency revegetation measure in chaparral ecosystems. Gen. Tech. Rep. PSW-102. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. 12 p

Beard, J.B. 1973. Turfgrass Science and Culture. Prentice-Hall. Englewood Cliffs, New Jersey

Beyers, J.L., S.G. Conard, and C.D. Wakeman. 1994. Impacts of an introduced grass, seeded for erosion control, on postfire community composition and species diversity in southern California chaparral. Pages 594−601 in Proceedings of the 12th International Conference on Fire and Forest Meteorology. October 26−28, 1993, Jekyll Island, Georgia. Society of American Foresters, Bethesda, Maryland.

Beyers, J.L., C.D. Wakeman, P.M. Wohlgemuth, and S.G. Conard. 1998a. Effects of postfire grass seeding on native vegetation in southern California chaparral. Pages 52−64 in Proceedings, Nineteenth Annual Forest Vegetation Management Conference: Wildfire Rehabilitation. January 20−22, 1998, Redding, California.

Beyers, J.L., P.M. Wohlgemuth, C.D. Wakeman, and S.G. Conard. 1998b. Ryegrass seeding for postfire erosion control in chaparral—does it work? Fire Management Notes 58:30−34.

Blanford, R.H., and L.E. Gunter. 1972. Emergency revegetation—a review of project evaluations 1956−1970. Forest, Range and Watershed Management Section, California Division of Forestry, Sacramento, California. 21 p.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Carey, J.H. 1995. *Lolium multiflorum*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed November 2004.

Conard, S.G., J.C. Regelbrugge, and R.D. Wills. 1991. Preliminary effects of ryegrass seeding on postfire establishment of natural vegetation in two California ecosystems. Pages 314–321 in P.L. Andrews and F. Donald (eds.), Proceedings, 11th Annual Conference on Fire and Forest Meteorology. April 16–19, 1991, Missoula, Montana. SAF Publication 91–04. Society of American Foresters, Bethesda, Maryland.

Davis, F.W., E.A. Keller, A. Parikh, and J. Florsheim. 1989. Recovery of the chaparral riparian zone after wildfire. In Proceedings from California Riparian Systems Conference. September 22–24, 1988, Davis, California. GTR, PSW-110. U.S. Department of Agriculture, Forest Service.

DiTomaso, J.M., and E.A. Healy. In Press. Weeds of California. Division Nat. Agr. Res., University of California.

Dittberner, P.L., and M.R. Olson. 1983. The plant information network (PIN) data base: Colorado, Montana, North Dakota, Utah, and Wyoming. FWS/OBS-83/86. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC. 786 p.

Frakes, R.V. 1973. The ryegrasses. Pages 307–313 in M.E. Heath, D.S. Metcalfe, and R.F. Barnes (eds.), Forages: the Science of Grassland Management. Iowa State University Press, Ames.

Gautier, C.R. 1983. Sedimentation in burned chaparral watersheds: is emergency revegetation justified? Water Resources Bulletin 19:793–802.

Gleason, H.A., and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. 2nd edition. New York Botanical Garden, New York. 910 p.

Gould, F.W., and R.B. Shaw. 1983. Grass Systematics. 2nd edition. Texas A&M University Press, College Station. 397 p.

Griffin, J.R. 1982. Pine seedlings, native ground cover, and *Lolium multiflorum* on the Marble-Cone burn, Santa Lucia Range, California. Madroño 29:177–188.

Grime, J.P. 1979. Plant Strategies & Vegetation Proceses. John Wiley & Sons, Chichester, England. 222 p.

Gross, E., I. Steinblums, C. Ralston, and H. Jubas. 1989. Emergency watershed treatments on burned lands in southwestern Oregon. Pages 109–114 in N.H. Berg, (tech. coord.), Proceedings of the Symposium on Fire and Watershed Management. October 26–28, 1988, Sacramento, California. Gen. Tech. Rep. PSW-109. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Keeler-Wolf, T. 1995. Post-fire emergency seeding and conservationin southern California shrublands. Pages 127–139 in J.E. Keeley and T. Scott (eds.), Brushfires in California Wildlands: Ecology and Management. International Association of Wildland Fire, Fairfield, Washington.

Keeley, J.E., and S.C. Keeley. 1988. Chaparral. Pages 165–207 in M.G. Barbour and W.D. Billings (eds.), North American Terrestrial Vegetation. Cambridge University Press, Cambridge.

Keeley, S.C., J.E. Keeley, S.M. Hutchinson, and A.W. Johnson. 1981. Postfire succession of herbaceous flora in southern California chaparral. Ecology 62:1608–1621.

Krammes, J.S., and L.W. Hill. 1963. “First aid” for burned watersheds. Res. Note PSW-29. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. 7 p.

Loftin, S., R. Fletcher, and P. Luehring. 1998. Disturbed area rehabilitation review report. Unpublished report on file at: U.S. Department of Agriculture, Forest Service, Southwestern Region, Albuquerque, New Mexico. 17 p.

Lowe, P.O., P.F. Ffolliott, J.H. Dieterich, and D.R. Patton. 1978. Determining potential wildlife benefits from wildfire in Arizona ponderosa pine forests. Gen. Tech. Rep. RM-52. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 12 p.

McKell, C.M., C. Duncan, and C.H. Muller. 1969. Competition in annual ryegrass. Ecology 50:653–657.

McKell, C.M., V. Brown, C. Walker, and R.M. Love. 1965. Species composition changes on chaparral areas converted to grasslands. J. Range Management 18:321–326.

Nadkarni, N.M., and D.C. Odion. 1986. Effects of seeding an exotic grass *Lolium multiflorum* on native seedling regeneration following fire in a chaparral community. Pages 115–121 in J.J. DeVries (ed.), Proceeding of the Chaparral Ecosystems Research Conference. May 16–17, 1985, Santa Barbara, California. Report No. 62. California Water Resources Center, University of California, Davis.

Robichaud, P.R., J.L. Beyers, and D.G. Neary. 2000. Evaluating the Effectiveness of Postfire Rehabilitation Treatments. Gen. Tech. Rep. RMRS-GTR-63. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado. 85 p.

Schultz, A.M., J.L. Launchbaugh, and H.H. Biswell. 1955. Relationship between grass density and brush seedling survival. Ecology 36:226–238.

Smoliak, S., D. Penney, A.M. Harper, and J.S. Horricks. 1981. Alberta Forage Manual. Alberta Agriculture, Print Media Branch, Edmonton, Alberta. 87p.

Sullivan, J. 1992. *Lolium perenne*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed November 2004.

Taskey, R.D, C.L. Curtis, and J. Stone. 1989. Wildfire, ryegrass seeding, and watershed rehabilitation. Pages 149–161 in N.H. Berg, (tech. coord.), Proceedings of the Symposium on Fire and Watershed Management. October 26–28, 1988, Sacramento, California. Gen. Tech. Rep. PSW-109. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Thompson, K., and J.P. Grime. 1979. Seasonal variation in the seed banks of herbaceous species in ten contrasting habitats. Journal of Ecology 67:893–921.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Wardle, D.A., K.L. Bonner, G.M. Barker, [and others]. 1999. Plant removals in perennial grassland: vegetation dynamics, decomposers, soil biodiversity, and ecosystem properties. Ecological Monographs 69:535−568.

Welsh, S.L., D.N. Atwood, S. Goodrich, and L.C. Higgins (eds.). 1987. A Utah Flora. Great Basin Naturalist Memoir No. 9. Brigham Young University, Provo, Utah. 894 p.

Wheeler, W.A., and D.D. Hill. 1957. Western grasses. Pages 525−529 in Grassland Seeds. D. Van Norstrand, Princeton, New Jersey.

Wohlgemuth, P.M., J.L. Beyers, C.D. Wakeman, and S.G. Conard. 1998. Effects of fire and grass seeding on soil erosion in southern California chaparral. Pages 41−51 in Proceedings, Nineteenth Annual Forest Vegetation Management Conference: Wildfire Rehabilitation. January 20−22, 1998, Redding, California.

Zedler, P.H., C.R. Gautier, and G.S. McMaster. 1983.Vegetation change in response to extreme events: the effect of a short interval between fires in California chaparral and coastal scrub. Ecology 64:809−818.

References of Interest Not Cited in the Text

Donald, C.M. 1958. The interaction of competition for light and nutrients. Australian J. Agr. Res. 9:421−432.

Gartner, F.R., A.M. Schultz, and H.H. Biswell. 1957. Ryegrass and brush seedling competition for nitrogen on two soil types. J. Range Management 10:213−220.

Halpern, C.B., P.M. Frenzen, J.E. Means, and J.F. Franklin. 1990. Plant succession in areas of scorched and blown-down forest after the 1980 eruption of Mount St. Helens, Washington. Journal of Vegetation Science 1:181−194.

Hellmers, H., and W.C. Ashby. 1958. Growth of native and exotic plants under controlled temperatures and in the San Gabriel Mountains California. Ecology 39:416−428.

Schultz, A.M., and H.H. Biswell. 1952. Competition between grasses reseeded on burned brushlands in California. Journal of Range Management 5:338−345.

Sullivan, J., P.N. Omi, A.A. Dyer, and A. Gonzales-Caben. 1987. Evaluating the economics efficiency of wildfire rehabilitation treatments. Western Journal of Applied Forestry 2:58−61.

Wohlgemuth, P.M., S.G. Conard, and J.L. Beyers. 1995. Impacts of postfire grass seeding on chaparral ecosystems—what do we know and where do we go from here? Pages 149−161 in J.E. Keeley and T. Scott (eds.), Brushfires in California Wildlands: Ecology and Resource Management. International Association of Wildland Fire, Fairfield, Washington.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial):	*Melilotus alba* Medikus; *Melilotus officinalis* (L.) Lam. (USDA 2005)
Synonyms:	*Melilotus alba*: none identified in USDA (2005); *Melilotus officinalis*: *Melilotus albus* Medik., *Melilotus albus* Medik. var. *annuus* Coe (USDA 2005)
Common names:	*Melilotus alba*: white sweetclover; *Melilotus officinalis*: yellow sweetclover
Evaluation date (mm/dd/yy):	06/15/2004
Evaluator #1 Name/Title:	William J. Litzinger
Affiliation:	Prescott College
Phone numbers:	(928) 778–2090, extension 2233
Email address:	wlitzinge@prescott.edu
Address:	220 Grove Ave., Prescott, Arizona 86301
Evaluator #2 Name/Title:	Dana Backer, Conservation Ecologist
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85719

List committee members:	D. Backer, G. Ferguson, J. Hall, C. Laws, M. Van Glider, P. Warren
Committee review date:	07/16/04
List date:	07/16/04
Re-evaluation date(s):	

Taxonomic Comment

Different authorities address the taxonomy of *Melilotus alba* and *M. officinalis* differently. The taxonomy followed here is that of USDA (2005), which identifies these two taxa as separate species.

Table 2. Scores, Designations, and Documentation Levels

<table>
<tr><th colspan="2">Question</th><th>Score</th><th>Documentation Level</th><th>Section Scores</th><th>Overall Score & Designations</th></tr>
<tr><td>1.1</td><td>Impact on abiotic ecosystem processes</td><td>C</td><td>Other published material</td><td rowspan="4">“Impact”
Section 1 Score:
C</td><td rowspan="12">“Plant Score”
Overall Score:
Medium
Alert Status:
None</td></tr>
<tr><td>1.2</td><td>Impact on plant community</td><td>C</td><td>Other published material</td></tr>
<tr><td>1.3</td><td>Impact on higher trophic levels</td><td>D</td><td>Observational</td></tr>
<tr><td>1.4</td><td>Impact on genetic integrity</td><td>D</td><td>Other published material</td></tr>
<tr><td colspan="4"></td><td></td></tr>
<tr><td>2.1</td><td>Role of anthropogenic and natural disturbance</td><td>B</td><td>Other published material</td><td rowspan="7">“Invasiveness”
For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:
14 pts
Section 2 Score:
B</td></tr>
<tr><td>2.2</td><td>Local rate of spread with no management</td><td>B</td><td>Observational</td></tr>
<tr><td>2.3</td><td>Recent trend in total area infested within state</td><td>C</td><td>Observational</td></tr>
<tr><td>2.4</td><td>Innate reproductive potential</td><td>A</td><td>Other published material</td></tr>
<tr><td>2.5</td><td>Potential for human-caused dispersal</td><td>B</td><td>Other published material</td></tr>
<tr><td>2.6</td><td>Potential for natural long-distance dispersal</td><td>A</td><td>Observational</td></tr>
<tr><td>2.7</td><td>Other regions invaded</td><td>C</td><td>Other published material</td><td rowspan="4">
Something you should know.</td></tr>
<tr><td colspan="4"></td><td></td></tr>
<tr><td>3.1</td><td>Ecological amplitude</td><td>A</td><td>Other published material</td><td rowspan="2">“Distribution”
Section 3 Score:
A</td></tr>
<tr><td>3.2</td><td>Distribution</td><td>A</td><td>Observational</td></tr>
</table>

Red Flag Annotation

Melilotus spp. is invasive in a number of ecosystems/plant communities in Arizona. *Melilotus* spp. also may be used, however, in semiarid habitats in northern Arizona for reclamation purposes where it has been difficult to reestablish native species after disturbances such as fire. Once suitable native alternatives can be identified and successfully restored in these areas, use of *Melilotus* spp. for reclamation purposes should be discontinued.

Table 3. Documentation

Note: *Melilotus alba* and *M. officinalis* are being evaluated collectively because they are similar in the areas they invade, their impacts, reproductive biology, and physiology. They are indistinguishable except for their flower color. When the literatures refers to a specific species and not both collectively, it is noted in the Rationale section. If there are distinctions between these two species, these will be noted. Although much of the information was from Turkington et al. (1978), because this journal article is a summary article its documentation level will be considered as "Other published material."

Question 1.1 Impact on abiotic ecosystem processes *Score:* **C** *Doc'n Level:* **Other pub.**
Identify ecosystem processes impacted: Change in soil nutrients (nitrogen fixation) and potential to alter fire regime by adding fine fuels. Affect soil stabilization.
Rationale: *Melilotus albus* and *M. officinalis* both have root nodules, have a symbiotic relationship with *Rhizobium* bacteria (Turkington et al. 1978), and enrich soil nutrient levels of nitrogen (Sauer 1988). The plants have their highest nitrogen content in the fall while vegetative (Dunham 1933 in Turkington et al. 1978). Nitrogen enrichment, while important, is probably only a moderate factor and would be dependent upon the plant community it invades. In humid regions of western Canada, sweet clover has improved soil fertility and soil structure (Greenshields 1957 in Turkington et al. 1978). In addition to increasing available soil nitrogen, *M. officinalis* improves drainage, aerates the soil, and increases water absorption in heavy clay soils (Smith and Gorz 1965 in Sullivan 1992). Sweetclover is used for soil stabilization and erosion control on mine sites, road cuts, overgrazed rangeland, and following fires (see numerous authors in Sullivan 1992, Uchytil 1992). Because the species is annual or biennial, the accumulation of above ground biomass and fine fuel could alter fire regimes in some habitats (inference). Numerous studies on *M. alba* documented that fire stimulates germination (see Glenn-Lewin et al. 1990, Heitlinger 1975, and Kline 1986 all in Uchytil 1992). The season of burning plays a role in the mortality of both sweet clovers (see examples in Sullivan 1992, Uchytil 1992).
Sources of information: See cited literature. Also applied inference.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **C** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Changes composition, perhaps only on a short-term basis, and competes with native species for resources.
Rationale: Sweetclovers appear to have a negative impact on grain crops (primarily economical) and in prairies. It has been suggested that they may be more of an aesthetic problem than an ecological problem on prairie preserves in Minnesota (R. Johnson, Director of Stewardship, The Nature Conservancy, Minnesota Field Office, personal communication, 1987 in Eckhart 1987). Sweetclovers potentially displace native nitrogen fixers, in particular, plants like scurf pea (*Psoralia* spp.) and annual lupin (*Lupinus pusillus*) (W. Litzinger, personal observations, 2004). From Turkington et al. (1978): Sweetclovers are considered noxious in several states because they sometimes occurs as "an adulteration in other crops" (cited from York and Pammel 1919). Sweetclovers attract pollinators and may compete with native plants for pollinators. Competition for pollinators could potentially reduce the reproductive potential of native plants (inference). Sweetclovers do not persist in shaded sites. Isolated plants growing in partial shade are less vigorous than those in open areas and produce few seeds. This suggests that sweetclover populations require an open habitat and do not compete well as other species invade (inference). Sweetclovers can form dense stands along streambanks after disturbance (flooding), but sweet clovers are early successional and do not persist (discussion by Working Group, July 2004).

Sources of information: See cited literature. Also considered unpublished field observations by W. Litzinger (Professor, Prescott College, Prescott, Arizona, 2004), discussions by the Working Group, and inference.

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Minor alteration to higher trophic levels. Provides cover for small mammals.
Rationale: Sweetclovers are an important honey bee forage plant and cultivated forms are planted for honey production. *Melilotus officinalis* is also attractive to other bee species and halictids and *M. alba* is attractive to a wider array of insects, including wasps and flies (Coe and Martin 1920 In Turkingtson et al. 1978). In several western states (Utah, Colorado, Wyoming, Montana, and North Dakato), *M. officinalis* and/or *M. alba* are good for cover for small mammals, birds, waterfowl, and ungulates such as deer and pronghorn (see numerous authors in Sullivan 1992 and Uchytil 1992). In South Dakota, bison tend to avoid it while cattle consume it quite readily (M. Heitlinger, Director of Stewardship, The Nature Conservancy, Midwest Region, personal communication, 1987 in Eckardt 1987). Cattle, however, can develop a condition known as sweetclover disease (Greenshields 1957) from feeding on spoiled sweetclover hay (Turkington et al. 1978). Ridley (1930 in Guertin and Halvorson 2003) reports that *Melilotus* seeds have been recorded to be eaten by horses and birds and are found in dung and bird's coups. *Melilotus* appears to have primarily positive impacts, though these impacts are not well-documented. As a result, the resultant score is negligible impact.
Sources of information: See cited literature. Score based on inference.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: No known hybridization.
Rationale: Natural interspecific hybrids in *Melilotus* are rare and most reports of natural hybrids are subject to doubt (Stevenson 1969 in Turkington et al. 1978). Sweetclovers in cultivation are varieties and not hybrids (Turkington et al. 1978). No native congeners in Arizona (Kearney and Peebles 1960).
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Sweetclovers invade human and natural disturbed habitats (particularly flooding). They quickly colonize open areas and require full sun (Turkington et al. 1978).
Rationale: *Melilotus alba* is an early colonizer of disturbed sites and will usually be eliminated in an area when perennial species come in (Turkington et al. 1978). Other researchers have detailed its persistence in many native and established tallgrass prairies; however, its abundance in these communities was probably due to periodic disturbance (fire) (Heitlinger 1975 and Kline 1986 both in Uchytil 1992).
Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**
Describe rate of spread: As noted elsewhere, unless the habitat is maintained in an open condition, sweetclovers do not maintain populations because they require full sun (Turkington et al. 1978).
Rationale: Given the overall increase in disturbance in Arizona wildlands, it seems reasonable to infer that local populations of sweetclover are increasing, but probably not doubling in <10 years.
Sources of information: Based on Working Group discussion/observations.

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n Level:* **Obs.**

Describe trend: Stable

Rationale: Sweetclovers do not seem to be expanding into new niches with the state. In recent times their distribution appears stable.

Sources of information: Based on Working Group discussion/observations.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Other pub.**

Describe key reproductive characteristics: From Turkington et al. (1978): Sweetclovers can be an annual or biennial, thus they reach reproductive maturity in less than two years. They can produce between 14,000 to 350,000 seeds per plant. Various studies showed seeds can remain viable for approximately 40 years.

Melilotus alba is both self- and cross-pollinated (Barcikowska 1966, Gorz and Haskins 1971). It can flower any month of the year. *Melilotus alba* growing in the open with little competition produced 200,000 to 350,000 seeds and *M. officinalis* seldom produced more than 100,000 seeds (in Ontario; Coe 1917 cited in Heitlinger 1975).

Rationale: See Worksheet A.

Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **B** *Doc'n Level:* **Other pub.**

Identify dispersal mechanisms: Moderate level; hay and seed contaminant; roadways; railways; hikers; waste areas.

Rationale: From Turkington et al. (1978): Sweetclovers have been cultivated as a forage crop [early-mid 1900s] yet their use as a hay crop is restricted due to the coarseness of their stems (Stevenson 1937). Dispersed as a crop seed contaminant and in hay. In recent years, the overall use of sweetclover in North America has declined. Used for commercial seed production (Smith and Gorz 1965). Cultivated by beekeepers; sweetclover dispersion has probably been hastened by beekeepers (Heitlinger 1975).

Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Obs.**

Identify dispersal mechanisms: Frequent long-distance dispersal. Dispersed by wind, water, (Turkington et al. 1978) and animals (study at Hassayampa Preserve; Drezner et al. 2001).

Rationale: From Turkington et al. (1978): Seeds can be blown over short distances (a few meters) by strong winds but rain wash and stream flow are probably much more important for dispersal. Seeds float. *Melilotus* can frequently move long distances by water along riparian systems (Working Group discussion).

Sources of information: See cited literature. Also considered Working Group discussion and use of inference.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Other pub.**

Identify other regions: No other ecological types besides those invaded in Arizona (based on information in Sullivan 1992 and Uchytil 1992).

Rationale: Originating in Europe and Asia, sweetclovers are now cosmopolitan weeds throughout the temperate regions of the world (Sauer 1988).

From Guertin and Halvorson (2003): *Melilotus albus* is native to Africa (northern Egypt, northern Libya), temperate Asia (Middle East to western Siberia and China), tropical Asia (India, Pakistan, Bhutan, Myanmar), and Europe (GRIN 2000). *Melilotus officinalis* is native to temperate Asia (Middle East to eastern Siberia and western China), tropical Asia (northern India, northern Pakistan), and Europe (GRIN 2000).

Melilotus albus was entered into the 1739 'Flora Virginica' by Gronovius (Stevenson 1969 in Turkington et al. 1978). *Melilotus officinalis* was introduced into North America in the 18th century as a forage crop (Sullivan 1992).

Sources of information: See cited literature.

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Other pub.**

Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: First collection record in Arizona based on records in SEINet (2004):

Melilotus alba: Coconino County, Camp Junipine, Oak Creek Canyon. July 1935. Although there is a record from 1910 in Flagstaff, there is no other info.

Melilotus officinalis: Coconino County, SW Forest Experimental Station near Flagstaff October 1929 and in a natural area [L.N. Goodding] Coconino County, Jacob Reservoir, Kaibab Plateau, August 1948.

From Turkington et al. (1978): Both *M. alba* and *M. officinalis* are adapted to a wide range of climatic conditions. They have long taproots and are drought tolerant and winter hardy, but cannot withstand prolonged flooding. *Melilotus alba* is somewhat more tolerant to standing water than *M. officinalis* and is occasionally found on gravelly, open river banks subject to periodic flooding. Sweetclovers are found on a wide range of soil types and textures from clay and loam to dune sand and river gravel. *Melilotus alba* is found most commonly on calcareous soils (Dunham 1933). Both *M. alba* (Shestakov and Vladimirov 1973) and *M. officinalis* (Lavado and Nella 1972) are apparently salt tolerant. They can also grow on soils of moderately low fertility (Smith and Gorz 1965).

Rationale: Sweetclovers appear to have broad ecological amplitudes and occur within a number of ecological types in Arizona. Known locations in Grand Canyon National Park (from Makarick 1999):

Melilotus alba:
South Rim – Common and abundant along roadsides and in waste places.
North Rim – Cape Royal.

Melilotus officinalis:
South Rim – Common along the roadsides and in disturbed areas.
North Rim – Greenland Lake
Inner Canyon – Roaring Springs, Havasu Canyon
Inner Gorge – Common along the river from Lees Ferry to Vaseys Paradise (RM 32).
Inner Canyon – Scattered locations

SEINet (2004) included only records within the last 9 years. Did not include any records that specifically stated roadside. These records are:

Melilotus alba: floodplain of Upper San Pedro (SPRNCA; Cochise Co.); Lower San Pedro River near Cooks Lake (Pinal Co.); near Springs in Tonto National Forest (Maricopa Co); long Verde River on the Verde Ranch (Yavapai Co.); Whiskey Creek (Apache Co.); West Fork of Oak Creek Canyon within wilderness area of Red Rock/Secret Mt. (Coconino NF).

Melilotus officinalis: few records for *M. officinalis* were collected within the last 9 years. Those that were collected within that time period are primarily the same as the collections for *M. alba* and include Seven Springs Wash in Tonto National Forest, West Fork of Oak Creek Canyon including within the wilderness area, in Ramsey Canyon of the Huachuca Mountains. Some records prior to 1995 applicable to either of the two species include: Sierra Wilderness Area (near Hunt Spring, Tonto NF); Weaver Creek; Silver Spur Meadow at mouth of Bonita Canyon in Chiracahua NM; top of Signal Peak; Turkey Flat in Pinaleno Mountains; Sycamore Canyon Wilderness; Roaring Springs Canyon, Grand Canyon NP; Audubon Research Ranch; Southwest Research Station in Cave Creek, Ciricauhua Mtns; and Moonshine Springs in Sheridan Mountains, Prescott.
Sources of information: See cited literature. Also considered personal observations by W. Litzinger (Professor, Prescott College, Prescott, Arizona, 2004) and SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed July 14, 2004).

Question 3.2 Distribution	*Score:* **A** *Doc'n Level:* **Obs.**
Describe distribution: Sweetclovers appear to be widespread and common throughout the ecological types where they occur in Arizona.	
Rationale: No specific information is available, but observations of occurrences, at least in the northern Arizona region, indicate that at the minimum sweetclovers are commonly found throughout the ecological types in the region.	
Sources of information: Personal observations by W. Litzinger (Professor, Prescott College, Prescott, Arizona, 2004).	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 9	**Total unknowns: 0**	
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	**C**
	southwestern interior chaparral scrub	**C**
Desertlands	Great Basin desertscrub	**C**
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	**C**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	**A**
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**A**
	southwestern interior riparian	**A**
	montane riparian	**B**
Woodlands	Great Basin conifer woodland	**B**
	Madrean evergreen woodland	**C**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	**D**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Barcikowska, B. 1966. Self-fertility and inbreeding depression in white and yellow sweet clover (*Melilotus albus* Desr. and *Melilotus officinalis* (L.) Desr.). Genetica Polonica 7:1–11.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Coe, H.S. 1917. Sweetclover: growing the crop. Farmer's Bulletin 797. U.S. Department of Agriculture.

Coe, H.S., and J.N. Martin. 1920. Sweet-clover seed. Bulletin 844. Part 2. U.S. Department of Agriculture.

Drezner, T.D., P.L. Fall, and J.C. Stromberg. 2001. Plant distribution and dispersal mechanisms at the Hassayampa River Preserve, Arizona, USA. Global Ecology and Biogeograpghy 10:205–217.

Dunham, R.S. 1933. Effect of method of sowing on the yield and root and top development of sweetclover in the Red River Valley. Journal of Agricultural Research 47:979–995.

Eckardt, N. 1987. *Melilotus alba* (white sweetclover) and *Melilotus officinalis* (yellow sweetclover). Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documnts/melialb.html; accessed July 2004.

Gorz, H.J., and F.A. Haskins. 1971. Cross-fertilization in *Melilotus alba*. Crop Science 11:767–768.

Greenshields, J.E. 1957. Sweet clover in western Canada. Publication 998. Canadian Department of Agriculture, Ottawa, Ontario. 14 p.

[GRIN] Germplasm Resources Information Network (online database). 2000. United States Department of Agriculture, Agricultural Research Service, National Genetic Resources Program, National Germplasm Resources Laboratory, Beltsville, Maryland. Available online at: http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Glenn-Lewin, D.C., L.A. Johnson, T.W. Jurik [and others]. 1990. Fire in central North American grasslands: vegetative reproduction, seed germination, and seedling establishment. Pages 28–45 in S.L. Collins and L.L.Wallace (eds.), Fire in North American Tallgrass Prairies. University of Oklahoma Press, Norman.

Heitlinger, M.E. 1975. Burning a protected tallgrass prairie to suppress sweetclover, *Melilotus alba* Desr. Pages 123–132 in M.K. Wali (ed.), Prairie: A Multiple View. University of North Dakota Press, Grand Forks.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Kline, V.M. 1986. Response of sweet clover (*Melilotus alba* Desr.) and associated prairie vegetation to seven experimental burning and mowing treatments. Pages 149–152 in G.K. Clambey and R.H. Pemble (eds.), The Prairie: Past, Present and Future: Proceedings, 9th North American Prairie Conference.July 29 to August 1, 1984, Moorhead, Minnesota. Tri-College University Center for Environmental Studies, Fargo, North Dakota.

Lavado, R.S., and J.C. Nella. 1972. Modifications to a saline-alkaline soil after 2 years of cropping with forage species. Idia 291:77–80.

Makarick, L.J. 1999 Draft Exotic Plant Plan for Grand Canyon National Park. National Park Service, Grand Canyon National Park, Arizona.

Ridley, H.N. 1930. The Dispersal of Plants Throughout the World. L. Reeve and Co., Ltd., Ashford, Kent. 744 p.

Sauer, J.1988. Plant Migration: The Dynamics of Geographic Patterning in Seed Plant Species. University of California Press, Berkeley.

Shestakov, I.L., and P.M. Vladimirov. 1973. Salt tolerance of cultivated plants and kinetics of uptake of ash elements during the reclamation of saline soils in Moldavia. Pages 279–284 in Voprosy soleustoĭchivosti rasteniĭ. Tashkent, Uzbek, SSR, 'Fan'.

Smith, W. K., and H.J. Gorz. 1965. Sweetclover improvement. Advances in Agronomy 17:163–231.

Stevenson, G.A. 1969. An agronomic and taxonomic review of the genus *Melilotus* Mill. Canadian Journal of Plant Science 49:1–20.

Stevenson, T.M. 1937 Sweet clover studies on habit of growth, seed pigmentation and permeability of the seed coat. Sci. Agric. 17:627–654.

Sullivan, J. 1992. *Melilotus officinalis*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Intermountain Fire Science Laboratory Missoula, Montana (producer). Available online at http://www.fs.fed.us/database/feis/plants/forb/meloff/all.html; accessed June 2004.

Turkington, R. A., P.B. Cavers, and E.A. Rempel. 1978. The Biology of Canadian weeds. 29. *Melilotus albus* Desr. And *Melilotus officinalis* (L.) Lam. Canadian Journal of Plant Sciences 58:523–537.

Uchytil, R. 1992. *Melilotus alba*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Intermountain Fire Science Laboratory Missoula, Montana (producer). Available online at http://www.fs.fed.us/database/feis/plants/forb/meloff/all.html; accessed June 2004.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

York, G.W., and L.H. Pammel. 1919. Sweet clover a weed. Amer. Bee J. 59:412–413.

Other References of Interest Not Cited in the Text

McDougell, W.B. 1973. Seed Plants of Northern Arizona. Northern Arizona Society for Science and Art, Flagstaff, Arizona.

Olson, W.W. 1975. Effects of controlled burning on grassland within the Tewaukon National Wildlife Refuge. Master’s thesis. North Dakota University of Agriculture and Applied Science, Fargo. 137 p.

Stevens, O.A. 1932. The number and weight of seeds produced by weeds. American Journal of Botany 19:784–794.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Melilotus alba* Medikus; *Melilotus officinalis* (L.) Lam. (USDA 2005)
Synonyms:	*Melilotus alba*: none identified in USDA (2005); *Melilotus officinalis*: *Melilotus albus* Medik., *Melilotus albus* Medik. var. *annuus* Coe (USDA 2005)
Common names:	*Melilotus alba*: white sweetclover; *Melilotus officinalis*: yellow sweetclover
Evaluation date (mm/dd/yy)**:**	06/15/2004
Evaluator #1 Name/Title:	William J. Litzinger
Affiliation:	Prescott College
Phone numbers:	(928) 778–2090, extension 2233
Email address:	wlitzinge@prescott.edu
Address:	220 Grove Ave., Prescott, Arizona 86301
Evaluator #2 Name/Title:	Dana Backer, Conservation Ecologist
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85719

List committee members:	D. Backer, G. Ferguson, J. Hall, C. Laws, M. Van Glider, P. Warren
Committee review date:	07/16/04
List date:	07/16/04
Re-evaluation date(s):	

Taxonomic Comment

Different authorities address the taxonomy of *Melilotus alba* and *M. officinalis* differently. The taxonomy followed here is that of USDA (2005), which identifies these two taxa as separate species.

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**C**	Other published material	**“Impact”** **Section 1 Score:** **C**	**“Plant Score”** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**C**	Other published material		
1.3	Impact on higher trophic levels	**D**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**“Invasiveness”** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **14 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**A**	Other published material		
2.5	Potential for human-caused dispersal	**B**	Other published material		
2.6	Potential for natural long-distance dispersal	**A**	Observational		
2.7	Other regions invaded	**C**	Other published material		 Something you should know.
3.1	Ecological amplitude	**A**	Other published material	**“Distribution”** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Red Flag Annotation

Melilotus spp. is invasive in a number of ecosystems/plant communities in Arizona. *Melilotus* spp. also may be used, however, in semiarid habitats in northern Arizona for reclamation purposes where it has been difficult to reestablish native species after disturbances such as fire. Once suitable native alternatives can be identified and successfully restored in these areas, use of *Melilotus* spp. for reclamation purposes should be discontinued.

Table 3. Documentation

Note: *Melilotus alba* and *M. officinalis* are being evaluated collectively because they are similar in the areas they invade, their impacts, reproductive biology, and physiology. They are indistinguishable except for their flower color. When the literatures refers to a specific species and not both collectively, it is noted in the Rationale section. If there are distinctions between these two species, these will be noted. Although much of the information was from Turkington et al. (1978), because this journal article is a summary article its documentation level will be considered as "Other published material."

Question 1.1 Impact on abiotic ecosystem processes *Score:* **C** *Doc'n Level:* **Other pub.**
Identify ecosystem processes impacted: Change in soil nutrients (nitrogen fixation) and potential to alter fire regime by adding fine fuels. Affect soil stabilization.
Rationale: *Melilotus albus* and *M. officinalis* both have root nodules, have a symbiotic relationship with *Rhizobium* bacteria (Turkington et al. 1978), and enrich soil nutrient levels of nitrogen (Sauer 1988). The plants have their highest nitrogen content in the fall while vegetative (Dunham 1933 in Turkington et al. 1978). Nitrogen enrichment, while important, is probably only a moderate factor and would be dependent upon the plant community it invades. In humid regions of western Canada, sweet clover has improved soil fertility and soil structure (Greenshields 1957 in Turkington et al. 1978). In addition to increasing available soil nitrogen, *M. officinalis* improves drainage, aerates the soil, and increases water absorption in heavy clay soils (Smith and Gorz 1965 in Sullivan 1992). Sweetclover is used for soil stabilization and erosion control on mine sites, road cuts, overgrazed rangeland, and following fires (see numerous authors in Sullivan 1992, Uchytil 1992). Because the species is annual or biennial, the accumulation of above ground biomass and fine fuel could alter fire regimes in some habitats (inference). Numerous studies on *M. alba* documented that fire stimulates germination (see Glenn-Lewin et al. 1990, Heitlinger 1975, and Kline 1986 all in Uchytil 1992). The season of burning plays a role in the mortality of both sweet clovers (see examples in Sullivan 1992, Uchytil 1992).
Sources of information: See cited literature. Also applied inference.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **C** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Changes composition, perhaps only on a short-term basis, and competes with native species for resources.
Rationale: Sweetclovers appear to have a negative impact on grain crops (primarily economical) and in prairies. It has been suggested that they may be more of an aesthetic problem than an ecological problem on prairie preserves in Minnesota (R. Johnson, Director of Stewardship, The Nature Conservancy, Minnesota Field Office, personal communication, 1987 in Eckhart 1987). Sweetclovers potentially displace native nitrogen fixers, in particular, plants like scurf pea (*Psoralia* spp.) and annual lupin (*Lupinus pusillus*) (W. Litzinger, personal observations, 2004). From Turkington et al. (1978): Sweetclovers are considered noxious in several states because they sometimes occurs as "an adulteration in other crops" (cited from York and Pammel 1919). Sweetclovers attract pollinators and may compete with native plants for pollinators. Competition for pollinators could potentially reduce the reproductive potential of native plants (inference). Sweetclovers do not persist in shaded sites. Isolated plants growing in partial shade are less vigorous than those in open areas and produce few seeds. This suggests that sweetclover populations require an open habitat and do not compete well as other species invade (inference). Sweetclovers can form dense stands along streambanks after disturbance (flooding), but sweet clovers are early successional and do not persist (discussion by Working Group, July 2004).

Sources of information: See cited literature. Also considered unpublished field observations by W. Litzinger (Professor, Prescott College, Prescott, Arizona, 2004), discussions by the Working Group, and inference.	

Question 1.3 Impact on higher trophic levels	*Score:* **D** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Minor alteration to higher trophic levels. Provides cover for small mammals.	
Rationale: Sweetclovers are an important honey bee forage plant and cultivated forms are planted for honey production. *Melilotus officinalis* is also attractive to other bee species and halictids and *M. alba* is attractive to a wider array of insects, including wasps and flies (Coe and Martin 1920 In Turkingtson et al. 1978). In several western states (Utah, Colorado, Wyoming, Montana, and North Dakato), *M. officinalis* and/or *M. alba* are good for cover for small mammals, birds, waterfowl, and ungulates such as deer and pronghorn (see numerous authors in Sullivan 1992 and Uchytil 1992). In South Dakota, bison tend to avoid it while cattle consume it quite readily (M. Heitlinger, Director of Stewardship, The Nature Conservancy, Midwest Region, personal communication, 1987 in Eckardt 1987). Cattle, however, can develop a condition known as sweetclover disease (Greenshields 1957) from feeding on spoiled sweetclover hay (Turkington et al. 1978). Ridley (1930 in Guertin and Halvorson 2003) reports that *Melilotus* seeds have been recorded to be eaten by horses and birds and are found in dung and bird's coups. *Melilotus* appears to have primarily positive impacts, though these impacts are not well-documented. As a result, the resultant score is negligible impact.	
Sources of information: See cited literature. Score based on inference.	

Question 1.4 Impact on genetic integrity	*Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: No known hybridization.	
Rationale: Natural interspecific hybrids in *Melilotus* are rare and most reports of natural hybrids are subject to doubt (Stevenson 1969 in Turkington et al. 1978). Sweetclovers in cultivation are varieties and not hybrids (Turkington et al. 1978). No native congeners in Arizona (Kearney and Peebles 1960).	
Sources of information: See cited literature.	

Question 2.1 Role of anthropogenic and natural disturbance in establishment	*Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Sweetclovers invade human and natural disturbed habitats (particularly flooding). They quickly colonize open areas and require full sun (Turkington et al. 1978).	
Rationale: *Melilotus alba* is an early colonizer of disturbed sites and will usually be eliminated in an area when perennial species come in (Turkington et al. 1978). Other researchers have detailed its persistence in many native and established tallgrass prairies; however, its abundance in these communities was probably due to periodic disturbance (fire) (Heitlinger 1975 and Kline 1986 both in Uchytil 1992).	
Sources of information: See cited literature.	

Question 2.2 Local rate of spread with no management	*Score:* **B** *Doc'n Level:* **Obs.**
Describe rate of spread: As noted elsewhere, unless the habitat is maintained in an open condition, sweetclovers do not maintain populations because they require full sun (Turkington et al. 1978).	
Rationale: Given the overall increase in disturbance in Arizona wildlands, it seems reasonable to infer that local populations of sweetclover are increasing, but probably not doubling in <10 years.	
Sources of information: Based on Working Group discussion/observations.	

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n Level:* **Obs.**

Describe trend: Stable

Rationale: Sweetclovers do not seem to be expanding into new niches with the state. In recent times their distribution appears stable.

Sources of information: Based on Working Group discussion/observations.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Other pub.**

Describe key reproductive characteristics: From Turkington et al. (1978): Sweetclovers can be an annual or biennial, thus they reach reproductive maturity in less than two years. They can produce between 14,000 to 350,000 seeds per plant. Various studies showed seeds can remain viable for approximately 40 years.

Melilotus alba is both self- and cross-pollinated (Barcikowska 1966, Gorz and Haskins 1971). It can flower any month of the year. *Melilotus alba* growing in the open with little competition produced 200,000 to 350,000 seeds and *M. officinalis* seldom produced more than 100,000 seeds (in Ontario; Coe 1917 cited in Heitlinger 1975).

Rationale: See Worksheet A.

Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **B** *Doc'n Level:* **Other pub.**

Identify dispersal mechanisms: Moderate level; hay and seed contaminant; roadways; railways; hikers; waste areas.

Rationale: From Turkington et al. (1978): Sweetclovers have been cultivated as a forage crop [early-mid 1900s] yet their use as a hay crop is restricted due to the coarseness of their stems (Stevenson 1937). Dispersed as a crop seed contaminant and in hay. In recent years, the overall use of sweetclover in North America has declined. Used for commercial seed production (Smith and Gorz 1965). Cultivated by beekeepers; sweetclover dispersion has probably been hastened by beekeepers (Heitlinger 1975).

Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Obs.**

Identify dispersal mechanisms: Frequent long-distance dispersal. Dispersed by wind, water, (Turkington et al. 1978) and animals (study at Hassayampa Preserve; Drezner et al. 2001).

Rationale: From Turkington et al. (1978): Seeds can be blown over short distances (a few meters) by strong winds but rain wash and stream flow are probably much more important for dispersal. Seeds float. *Melilotus* can frequently move long distances by water along riparian systems (Working Group discussion).

Sources of information: See cited literature. Also considered Working Group discussion and use of inference.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Other pub.**

Identify other regions: No other ecological types besides those invaded in Arizona (based on information in Sullivan 1992 and Uchytil 1992).

Rationale: Originating in Europe and Asia, sweetclovers are now cosmopolitan weeds throughout the temperate regions of the world (Sauer 1988).

From Guertin and Halvorson (2003): *Melilotus albus* is native to Africa (northern Egypt, northern Libya), temperate Asia (Middle East to western Siberia and China), tropical Asia (India, Pakistan, Bhutan, Myanmar), and Europe (GRIN 2000). *Melilotus officinalis* is native to temperate Asia (Middle East to eastern Siberia and western China), tropical Asia (northern India, northern Pakistan), and Europe (GRIN 2000).

Melilotus albus was entered into the 1739 'Flora Virginica' by Gronovius (Stevenson 1969 in Turkington et al. 1978). *Melilotus officinalis* was introduced into North America in the 18th century as a forage crop (Sullivan 1992).

Sources of information: See cited literature.

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Other pub.**

Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: First collection record in Arizona based on records in SEINet (2004):

Melilotus alba: Coconino County, Camp Junipine, Oak Creek Canyon. July 1935. Although there is a record from 1910 in Flagstaff, there is no other info.

Melilotus officinalis: Coconino County, SW Forest Experimental Station near Flagstaff October 1929 and in a natural area [L.N. Goodding] Coconino County, Jacob Reservoir, Kaibab Plateau, August 1948.

From Turkington et al. (1978): Both *M. alba* and *M. officinalis* are adapted to a wide range of climatic conditions. They have long taproots and are drought tolerant and winter hardy, but cannot withstand prolonged flooding. *Melilotus alba* is somewhat more tolerant to standing water than *M. officinalis* and is occasionally found on gravelly, open river banks subject to periodic flooding. Sweetclovers are found on a wide range of soil types and textures from clay and loam to dune sand and river gravel. *Melilotus alba* is found most commonly on calcareous soils (Dunham 1933). Both *M. alba* (Shestakov and Vladimirov 1973) and *M. officinalis* (Lavado and Nella 1972) are apparently salt tolerant. They can also grow on soils of moderately low fertility (Smith and Gorz 1965).

Rationale: Sweetclovers appear to have broad ecological amplitudes and occur within a number of ecological types in Arizona. Known locations in Grand Canyon National Park (from Makarick 1999):

Melilotus alba:
South Rim – Common and abundant along roadsides and in waste places.
North Rim – Cape Royal.

Melilotus officinalis:
South Rim – Common along the roadsides and in disturbed areas.
North Rim – Greenland Lake
Inner Canyon – Roaring Springs, Havasu Canyon
Inner Gorge – Common along the river from Lees Ferry to Vaseys Paradise (RM 32).
Inner Canyon – Scattered locations

SEINet (2004) included only records within the last 9 years. Did not include any records that specifically stated roadside. These records are:

Melilotus alba: floodplain of Upper San Pedro (SPRNCA; Cochise Co.); Lower San Pedro River near Cooks Lake (Pinal Co.); near Springs in Tonto National Forest (Maricopa Co); long Verde River on the Verde Ranch (Yavapai Co.); Whiskey Creek (Apache Co.); West Fork of Oak Creek Canyon within wilderness area of Red Rock/Secret Mt. (Coconino NF).

Melilotus officinalis: few records for *M. officinalis* were collected within the last 9 years. Those that were collected within that time period are primarily the same as the collections for *M. alba* and include Seven Springs Wash in Tonto National Forest, West Fork of Oak Creek Canyon including within the wilderness area, in Ramsey Canyon of the Huachuca Mountains. Some records prior to 1995 applicable to either of the two species include: Sierra Wilderness Area (near Hunt Spring, Tonto NF); Weaver Creek; Silver Spur Meadow at mouth of Bonita Canyon in Chiracahua NM; top of Signal Peak; Turkey Flat in Pinaleno Mountains; Sycamore Canyon Wilderness; Roaring Springs Canyon, Grand Canyon NP; Audubon Research Ranch; Southwest Research Station in Cave Creek, Ciricauhua Mtns; and Moonshine Springs in Sheridan Mountains, Prescott.
Sources of information: See cited literature. Also considered personal observations by W. Litzinger (Professor, Prescott College, Prescott, Arizona, 2004) and SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed July 14, 2004).

Question 3.2 Distribution *Score:* **A** *Doc'n Level:* **Obs.**
Describe distribution: Sweetclovers appear to be widespread and common throughout the ecological types where they occur in Arizona.
Rationale: No specific information is available, but observations of occurrences, at least in the northern Arizona region, indicate that at the minimum sweetclovers are commonly found throughout the ecological types in the region.
Sources of information: Personal observations by W. Litzinger (Professor, Prescott College, Prescott, Arizona, 2004).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 9	**Total unknowns: 0**	
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	**C**
	southwestern interior chaparral scrub	**C**
Desertlands	Great Basin desertscrub	**C**
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	**C**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	**A**
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**A**
	southwestern interior riparian	**A**
	montane riparian	**B**
Woodlands	Great Basin conifer woodland	**B**
	Madrean evergreen woodland	**C**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	**D**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Barcikowska, B. 1966. Self-fertility and inbreeding depression in white and yellow sweet clover (*Melilotus albus* Desr. and *Melilotus officinalis* (L.) Desr.). Genetica Polonica 7:1−11.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Coe, H.S. 1917. Sweetclover: growing the crop. Farmer's Bulletin 797. U.S. Department of Agriculture.

Coe, H.S., and J.N. Martin. 1920. Sweet-clover seed. Bulletin 844. Part 2. U.S. Department of Agriculture.

Drezner, T.D., P.L. Fall, and J.C. Stromberg. 2001. Plant distribution and dispersal mechanisms at the Hassayampa River Preserve, Arizona, USA. Global Ecology and Biogeograpghy 10:205−217.

Dunham, R.S. 1933. Effect of method of sowing on the yield and root and top development of sweetclover in the Red River Valley. Journal of Agricultural Research 47:979−995.

Eckardt, N. 1987. *Melilotus alba* (white sweetclover) and *Melilotus officinalis* (yellow sweetclover). Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documnts/melialb.html; accessed July 2004.

Gorz, H.J., and F.A. Haskins. 1971. Cross-fertilization in *Melilotus alba*. Crop Science 11:767−768.

Greenshields, J.E. 1957. Sweet clover in western Canada. Publication 998. Canadian Department of Agriculture, Ottawa, Ontario. 14 p.

[GRIN] Germplasm Resources Information Network (online database). 2000. United States Department of Agriculture, Agricultural Research Service, National Genetic Resources Program, National Germplasm Resources Laboratory, Beltsville, Maryland. Available online at: http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Glenn-Lewin, D.C., L.A. Johnson, T.W. Jurik [and others]. 1990. Fire in central North American grasslands: vegetative reproduction, seed germination, and seedling establishment. Pages 28−45 in S.L. Collins and L.L.Wallace (eds.), Fire in North American Tallgrass Prairies. University of Oklahoma Press, Norman.

Heitlinger, M.E. 1975. Burning a protected tallgrass prairie to suppress sweetclover, *Melilotus alba* Desr. Pages 123−132 in M.K. Wali (ed.), Prairie: A Multiple View. University of North Dakota Press, Grand Forks.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Kline, V.M. 1986. Response of sweet clover (*Melilotus alba* Desr.) and associated prairie vegetation to seven experimental burning and mowing treatments. Pages 149–152 in G.K. Clambey and R.H. Pemble (eds.), The Prairie: Past, Present and Future: Proceedings, 9th North American Prairie Conference.July 29 to August 1, 1984, Moorhead, Minnesota. Tri-College University Center for Environmental Studies, Fargo, North Dakota.

Lavado, R.S., and J.C. Nella. 1972. Modifications to a saline-alkaline soil after 2 years of cropping with forage species. Idia 291:77–80.

Makarick, L.J. 1999 Draft Exotic Plant Plan for Grand Canyon National Park. National Park Service, Grand Canyon National Park, Arizona.

Ridley, H.N. 1930. The Dispersal of Plants Throughout the World. L. Reeve and Co., Ltd., Ashford, Kent. 744 p.

Sauer, J.1988. Plant Migration: The Dynamics of Geographic Patterning in Seed Plant Species. University of California Press, Berkeley.

Shestakov, I.L., and P.M. Vladimirov. 1973. Salt tolerance of cultivated plants and kinetics of uptake of ash elements during the reclamation of saline soils in Moldavia. Pages 279–284 in Voprosy soleustoǐchivosti rasteniǐ. Tashkent, Uzbek, SSR, 'Fan'.

Smith, W. K., and H.J. Gorz. 1965. Sweetclover improvement. Advances in Agronomy 17:163–231.

Stevenson, G.A. 1969. An agronomic and taxonomic review of the genus *Melilotus* Mill. Canadian Journal of Plant Science 49:1–20.

Stevenson, T.M. 1937 Sweet clover studies on habit of growth, seed pigmentation and permeability of the seed coat. Sci. Agric. 17:627–654.

Sullivan, J. 1992. *Melilotus officinalis*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Intermountain Fire Science Laboratory Missoula, Montana (producer). Available online at http://www.fs.fed.us/database/feis/plants/forb/meloff/all.html; accessed June 2004.

Turkington, R. A., P.B. Cavers, and E.A. Rempel. 1978. The Biology of Canadian weeds. 29. *Melilotus albus* Desr. And *Melilotus officinalis* (L.) Lam. Canadian Journal of Plant Sciences 58:523–537.

Uchytil, R. 1992. *Melilotus alba*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Intermountain Fire Science Laboratory Missoula, Montana (producer). Available online at http://www.fs.fed.us/database/feis/plants/forb/meloff/all.html; accessed June 2004.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

York, G.W., and L.H. Pammel. 1919. Sweet clover a weed. Amer. Bee J. 59:412–413.

Other References of Interest Not Cited in the Text

McDougell, W.B. 1973. Seed Plants of Northern Arizona. Northern Arizona Society for Science and Art, Flagstaff, Arizona.

Olson, W.W. 1975. Effects of controlled burning on grassland within the Tewaukon National Wildlife Refuge. Master's thesis. North Dakota University of Agriculture and Applied Science, Fargo. 137 p.

Stevens, O.A. 1932. The number and weight of seeds produced by weeds. American Journal of Botany 19:784–794.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Mesembryanthemum crystallinum* L. (USDA 2005)
Synonyms:	*Gasoul crystallinum* (L.) Rothm. (USDA 2005)
Common names:	Common iceplant
Evaluation date (mm/dd/yy)**:**	05/14/03
Evaluator #1 Name/Title:	Sue Rutman/Plant Ecologist
Affiliation:	Organ Pipe Cactus National Monument
Phone numbers:	(520) 387–7661 ext. 7115
Email address:	sue_rutman@nps.gov
Address:	10 Organ Pipe Drive, Ajo, Arizona 85321–9626
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	05/20/03: D. Backer, D. Casper, P. Guertin, J. Hall, R. Paredes, S. Rutman, J. Ward 03/01/05: D. Backer, D. Casper,J. Filar, E. Geiger, J. Hall, H. Messing, B. Munda, F. Northam
Committee review date:	05/20/03 and 03/01/05
List date:	05/20/03; revised 03/01/05
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**C**	Reviewed scientific publication	**"Impact"** **Section 1 Score:** **C**	**"Plant Score"** **Overall Score:** **Low** **Alert Status:** **None**
1.2	Impact on plant community	**C**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**D**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**A**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **11 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**U**	No information		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**C**	Other published material		
2.5	Potential for human-caused dispersal	**A**	Observational		
2.6	Potential for natural long-distance dispersal	**C**	Observational		
2.7	Other regions invaded	**B**	Other published material		
3.1	Ecological amplitude	**D**	Other published material	**"Distribution"** **Section 3 Score:** **D**	 Something you should know.
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **C** *Doc'n Level:* **Rev. sci. pub.**
Identify ecosystem processes impacted: Alters chemical and physical soil properties.
Rationale: *Mesembryanthemum crystallinum* in California takes up salt from soils and deposits it on the surface (Vivrette and Muller 1977). By this mechanism, *M. crystallinum* in Australia formed a monotypic stand after replacing another non-native species (Kloot 1983).
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **C** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: This species is known to form near-monotypic stands to the near-exclusion of native annuals.
Rationale: The species' ability to form and maintain monotypic stands has been documented in California (Vivrette and Muller 1977) and Australia (Kloot 1983). The species is still rare and localized in Arizona, however. Low winter rainfall during some years results in low *Mesembryanthemum* (both *M. crystallinum* and *M. nodiflorum*) numbers; otherwise plant community alteration would be more significant.
Sources of information: See cited literature. Also considered personal observations on Organ Pipe Cactus National Monument by S. Rutman (Plant Ecologist, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 1995–2003).

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: None known
Rationale: Too rare to have any effects yet. If populations expand, animals that depend on herbaceous forage will be depleted locally. No herbivory has been noted on the Organ Pipe Cactus National Monument populations, perhaps because the high concentration of salts in the epidermal bladder cells make the plant unpalatable.
Sources of information: Personal observations by S. Rutman on Organ Pipe Cactus National Monument (Plant Ecologist, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 1995–2003).

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: None.
Rationale: No native *Mesembryanthemum* or any other spring-blooming member of the Aizoaceae in the state.
Sources of information: See Kearney and Peebles (1960). Also considered information from the unpublished Organ Pipe Cactus National Monument plant checklist (2003).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **A** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Populations can tolerate and benefit from disturbance, but disturbance is not needed for persistence or expansion.
Rationale: *Mesembryanthemum crystallinum* is found on disturbed and undisturbed sites. Unlike native perennials, *M. crystallinum* quickly establishes on freshly graded roads and road shoulders on Organ Pipe Cactus National Monument (S. Rutman, personal observations, 2003). Observers in California and Sonora, Mexico, noted that it can grow on disturbed areas (Felger 2000, Randall 2000, De Ruff 2003). Early monopolization of disturbed sites and soil modification might be the mechanisms whereby *M. crystallinum* monopolizes a site.

Sources of information: See cited literature. Also considered personal observations by S. Rutman on the La Abra Plain at the International Boundary, Organ Pipe Cactus National Monument (Plant Ecologist, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 1995–2003).	

Question 2.2 Local rate of spread with no management	*Score:* **U** *Doc'n Level:* **No info.**
Describe rate of spread: Unknown	
Rationale: Population size fluctuates with the amount of winter rains. Germination and establishment occur only during favorable rainfall years; this trait would mediate the intrinsic rate of increase.	
Sources of information: None.	

Question 2.3 Recent trend in total area infested within state	*Score:* **C** *Doc'n Level:* **Obs.**
Describe trend: No information on whether other populations of *M. crystallinum* currently exit in Arizona besides the Organ Pipe Cactus National Monument population (however, see question 2.7). The size of the population on the monument fluctuates with the amount of winter rains.	
Rationale: In 1995 a large population of *M. crystallinum* in Sonoran, Mexico, extended onto about 0.1 acre on Organ Pipe Cactus National Monument (Rutman, unpublished data, 1995). The population consisted of fewer than 500 plants. The same area was occupied in 2003, but the population was sparse and probably consisted of fewer than 50 plants (Rutman, unpublished data, 2003). No plants were seen in formerly occupied habitat during some years. No other information about the presence or size of populations elsewhere in Arizona is available.	
Sources of information: Unpublished data of S. Rutman: (1) Memo to the files, May 12, 1995. Subject: Discovery of two previously unrecorded non-native species in Organ Pipe Cactus National Monument. Organ Pipe Cactus National Monument, Ajo, Arizona. 3 p. (2) 2003. Map of exotic plants on Organ Pipe Cactus National Monument.	

Question 2.4 Innate reproductive potential	*Score:* **C** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: An annual species capable of producing about 15,000 seeds per plant when grown under laboratory conditions (Bohnert Laboratories 2003).	
Rationale: *Mesembryanthemum crystallinum* has the potential for rapidly expanding its population.	
Sources of information: See cited literature.	

Question 2.5 Potential for human-caused dispersal	*Score:* **A** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Spread along transportation corridors and by off-road vehicles; potential for spread by agricultural activities; transported by undocumented migrants.	
Rationale: Seeds are tiny and can easily attach to shoes, clothing and tires. Vehicle traffic along Mexico Highway 2 probably spread the species from California to Arizona. Seeds could be transported by vehicles driving along the South Puerto Blanco Drive, which bisects the population.	
Sources of information: Personal observations by S. Rutman on Organ Pipe Cactus National Monument (Plant Ecologist, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 1995–2003).	

Question 2.6 Potential for natural long-distance dispersal	*Score:* **C** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Wind.	
Rationale: Strong winds that accompany summer thunderstorms and 'dust devils' could move seeds long distances.	
Sources of information: Personal observations by S. Rutman on Organ Pipe Cactus National Monument (Plant Ecologist, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 1995–2003).	

Question 2.7 Other regions invaded	*Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: In North America this species occurs in Arizona (Pima and Yuma Counties), California (coastal strands, marshes, coastal sagescrub; four counties), Missouri, and Pennsylvania, USA and Baja California and Sonora, Mexico (Vivrette 1993, MBG 2003, USDA 2005). Elsewhere in the world it is reported from Peru, Chile, Ecuador, China, and Australia (MBG 2003).	
Rationale: Although *M. crystallinum*'s current occupied habitat is small, its potential range seems large. Its presence in Missouri and Pennsylvania indicates that it can establish in temperate climates. Potential for occurring at least in areas with saline soils in Mediterranean-type climates and as well as cold and warm deserts. Potential for occurring in playas. It appears to be shade-intolerant, however, and would not grow where plant cover is high.	
Sources of information: See cited literature.	

Question 3.1 Ecological amplitude	*Score:* **D** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Currently documented from the Sonoran desertscrub, *Atriplex polycarpa-Atriplex linearis-Larrea divaricata* ssp. *tridentata* Association. Specimens at the University of Arizona indicate the species was found in Reddington (near Tucson) in 1905 (ARIZ 45200) and Yuma in 1986 (ARIZ 262652). Seeds were commercially available in U.S. trade by 1807 (Mack 1991).	
Rationale: The species probably has not reached its full potential in Arizona. High salinity is the only unifying theme among the habitat types where it occurs. In Arizona it might establish in the Great Basin Desert, Mohave Desert, semi-desert grassland, canals, floodplains and playas, and especially in agricultural areas.	
Sources of information: See cited literature. Current herbarium records can be accessed through SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections).	

Question 3.2 Distribution	*Score:* **D** *Doc'n Level:* **Other pub.**
Describe distribution: Only known extant population in Arizona is on hypersaline soils on Organ Pipe Cactus National Monument, Pima County (Rutman, unpublished data, 1995, 2003). Surveys in Arizona should occur in and around agricultural fields, irrigation canals, river floodplains (including saltbush uplands).	
Rationale: Known distribution is a fraction of 1% of Sonoran desertscrub.	
Sources of information: Unpublished data of S. Rutman: (1) Memo to the files, May 12, 1995. Subject: Discovery of two previously unrecorded non-native species in Organ Pipe Cactus National Monument. Organ Pipe Cactus National Monument, Ajo, Arizona. 3 p. (2) 2003. Map of exotic plants on Organ Pipe Cactus National Monument.	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	[Yes] No 1 pt.
Dense infestations produce >1,000 viable seed per square meter	[Yes] No 2 pt.
Populations of this species produce seeds every year.	Yes [No] 1 pt.
Seed production sustained for 3 or more months within a population annually	Yes [No] 1 pt.
Seeds remain viable in soil for three or more years	Yes No 2 pt.
Viable seed produced with *both* self-pollination and cross-pollination	Yes No 1 pt.
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	Yes [No] 1 pt.
Fragments easily and fragments can become established elsewhere	Yes [No] 2 pt.
Resprouts readily when cut, grazed, or burned	Yes [No] 1 pt.
	Total pts: 3 Total unknowns: 2
	Score : C
Note any related traits:	

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	**D**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Bohnert Laboratories. 2003. *Mesembryanthemum*. Bohnert Laboratories, University of Illinois, Plant Biology/Crop Sciences Departments, Urbana-Champaign. Available online at: http://www.life.uiuc.edu/bohnert/projects/mesem.html; accessed May 14, 2003.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

De Ruff, R. 2003. Plants of Upper Newport Bay, Orange County, California. Available online at: http://mamba.bio.uci.edu/~pjbryant/biodiv/plants; accessed May 14, 2003.

Felger, R.S. 2000. Flora of the Gran Desierto and Rio Colorado of Northwestern Mexico. University of Arizona Press, Tucson.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Kloot, P.M. 1983. The role of common iceplant (*Mesembryanthemum crystallinum*) in the deterioration of medic pastures. Austral. J. Ecol. 8:301–306.

Mack, R.N. 1991. The commercial seed trade: an early disperser of weeds in the United States. Econ. Bot. 45:257–273.

[MBG] Missouri Botanical Garden. 2003. W3TROPICOS Nomenclatural data base. Available online at: http://mobot.mobot.org/cgi-bin/; accessed May 14, 2003.

Randall, J.M. 2000. *Mesembryanthemum crystallinum* L. Pages 244–246 in C.C Bossard, J.M. Randall, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Vivrette, N.J. 1993. *Mesembryanthemum*. Page 129 in J.C.Hickman. (ed.), The Jepson Manual: Higher Plants of California. University of California Press, Berkeley.

Vivrette, N.J., and C.H. Muller. 1977. Mechanism of invasion and dominance of coastal grassland by *Mesembryanthemum crystallinum*. Ecol. Monogr. 47:301–318.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Mesembryanthemum nodiflorum* L. (USDA 2005)
Synonyms:	*Gasoul nodiflorum* (L.) Rothm. (USDA 2005)
Common names:	Slenderleaf iceplant, crystal iceplant
Evaluation date (mm/dd/yy)**:**	05/14/03
Evaluator #1 Name/Title:	Sue Rutman/Plant Ecologist
Affiliation:	Organ Pipe Cactus National Monument
Phone numbers:	(520) 387−7661 ext 7115
Email address:	Sue_rutman@nps.gov
Address:	10 Organ Pipe Drive, Ajo, Arizona 85321−9626
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	05/20/03: D. Backer, D. Casper, P. Guertin, J. Hall, R. Paredes, S. Rutman, J. Ward 03/01/05: D. Backer, D. Casper,J. Filar, E. Geiger, J. Hall, H. Messing, B. Munda, F. Northam
Committee review date:	05/20/03 and 03/01/05
List date:	05/20/03; revised 03/01/05
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Observational	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **Alert**
1.2	Impact on plant community	**B**	Observational		
1.3	Impact on higher trophic levels	**B**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**A**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **11 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**U**	Observational		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**C**	Other published material		
2.5	Potential for human-caused dispersal	**B**	Observational		
2.6	Potential for natural long-distance dispersal	**B**	Observational		
2.7	Other regions invaded	**B**	Other published material		 Information you should know.
3.1	Ecological amplitude	**B**	Other published material	**"Distribution"** **Section 3 Score:** **C**	
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Obs.**
Identify ecosystem processes impacted: *Mesembryanthemum crystallinum* in California takes up salt from soils and deposits it on the surface (Vivrette & Muller 1977). By this mechanism, *M. crystallinum* in Australia formed a monotypic stand after replacing another non-native species (Kloot 1983).
Rationale: Although there is no published literature documenting that *M. nodiflorum* changes soil properties, a study in California showed that a related and conspecific species, *M. crystallinum,* takes up salt from soils and deposits it on the surface (Vivrette and Muller 1977). Concentrated salts decrease establishment, growth and survival rates of some annual and perennial species native to the Sonoran Desert. Surface deposition of salt is the mechanism whereby *M. crystallinum* formed a monotypic stand in Australia after replacing another non-native species (Kloot 1983).
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **B** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Moderate alteration of plant community composition. Impact would be severe if *Mesembryanthemum* populations were dense every year.
Rationale: The ability to form and maintain monotypic stands has been documented for a related species, *M. crystallinum*, in California (Vivrette and Muller 1977) and Australia (Kloot 1983). Low winter rainfall during some years causes low number of *Mesembryanthemum* plants; otherwise plant community alteration would be severe. Although monotypic stands have not been witnessed in Arizona, this species dominates the annual spring flora on a five-acre area of Organ Pipe Cactus National Monument to the near-exclusion of native annuals. On other areas of the monument, the species is a common member of the spring annual community. In some areas of Maricopa County, the species is the numerical dominant across thousands of acres. It is possible that the increase in soil surface salinity caused by the occupation of *M. nodiflorum* has interfered with the re-establishment of native perennials on some sites.
Sources of information: See cited literature. Also considered unpublished data of Rutman: Memo to the files, May 12, 1995. Subject: Discovery of two previously unrecorded non-native species in Organ Pipe Cactus National Monument. Organ Pipe Cactus National Monument, Ajo, Arizona. 3 p.

Question 1.3 Impact on higher trophic levels *Score:* **B** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Decline or exclusion of animals that are dependent on herbaceous forage or large-seeded plants.
Rationale: Epidermal bladder cells contain concentrated salt solutions (Bohnert Laboratories 2003), which undoubtedly make the plants unpalatable to native animals. No herbivory has been noted on the Organ Pipe Cactus National Monument populations, despite the plants' succulence. High-density populations of *M. nodiflorum* are expected to cause the local depletion of animals that depend on herbaceous forage. Low densities during years of low winter rainfall might mitigate the adverse effects on animal populations.
Sources of information: Personal observations by S. Rutman on Organ Pipe Cactus National Monument (Plant Ecologist, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 1995–2003).

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: None.
Rationale: No native *Mesembryanthemum* or any other spring-blooming member of the Aizoaceae in the state.

Sources of information: See Kearney and Peebles (1960). Also considered information from the unpublished Organ Pipe Cactus National Monument plant checklist (2003).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **A** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Populations can tolerate and benefit from disturbance, but disturbance is not needed for persistence or expansion.
Rationale: *Mesembryanthemum nodiflorum* grew on freshly graded roads and road shoulders on Organ Pipe Cactus National Monument (S. Rutman, personal observations, 2003). Felger (2000) noted that it grows on disturbed areas Sonora, Mexico. *Mesembryanthemum nodiflorum* occurs on a five-acre site south of Pozo Salado and another site west of Hocker Well on Organ Pipe Cactus National Monument that has had no anthropogenic disturbance during the last 25 years (S. Rutman, personal observations, 2003).
Sources of information: See cited literature. Also considered personal observations by S. Rutman (Plant Ecologist, National Park Service, Organ Pipe Cactus National Monument, observations of *M. nodiflorum* and map of population near Pozo Salado produced with a Global Positioning System, International Boundary, Organ Pipe Cactus National Monument, 2003).

Question 2.2 Local rate of spread with no management *Score:* **U** *Doc'n Level:* **Obs.**
Describe rate of spread: Unknown. Population sizes fluctuate with the amount of winter rains. Germination and establishment occur only during favorable rainfall years; this trait would mediate the intrinsic rate of increase.
Rationale: Population on Organ Pipe Cactus National Monument has not been documented long enough to assess the species' potential for spread.
Sources of information: None

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n Level:* **Obs.**
Describe trend: No information is available about the location or size of most populations.
Rationale: In 1995 a large population of *M. nodiflorum* in Sonora, Mexico, extended onto dozens of acres in three or four locations on Organ Pipe Cactus National Monument (Rutman, unpublished data, 1995). At the international boundary near Pozo Salado in 1995, the *M. nodiflorum* population on Organ Pipe occupied about five acres and consisted of more than 20,000 plants. In 2003 the population occupied the same area but consisted of a few thousand plants (Rutman, unpublished data, 2003). No plants were seen during some intervening years. Trend in total area infested within Arizona is unknown but the amount of unoccupied habitat is substantial.
Sources of information: Unpublished data of S. Rutman: (1) Memo to the files, May 12, 1995. Subject: Discovery of two previously unrecorded non-native species in Organ Pipe Cactus National Monument. Organ Pipe Cactus National Monument, Ajo, Arizona. 3 p. (2) 2003. Map of exotic plants on Organ Pipe Cactus National Monument.

Question 2.4 Innate reproductive potential *Score:* **C** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: *Mesembryanthemum nodiflorum* is an annual that can produce thousands of seeds per year. A related species, *M. crystallinum*, is capable of producing about 15,000 seeds per plant when grown under laboratory conditions (Bohnert Laboratories 2003).
Rationale: *Mesembryanthemum nodiflorum* has the potential for rapidly expanding its population. Using the scoring form, this species would score as having 'low reproductive potential' (3 points), but additional research on the reproductive potential of this species could justify a higher score.
Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **B** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Spread along transportation corridors and by off-road vehicles; potential for spread by agricultural activities; transported by undocumented migrants.
Rationale: Seeds are tiny and can easily attach to shoes, clothing and tires. Vehicle traffic along Mexico Highway 2 probably spread the species from California to Arizona. Vehicle driving along the South Puerto Blanco Drive, which bisects the population, could transport seeds. Hikers—including undocumented migrants and smugglers—probably transport seeds on shoes and clothing. Vehicle traffic along illegal roads created by smugglers and illegal migrants could transport seeds almost anywhere.
Sources of information: Personal observations by S. Rutman on Organ Pipe Cactus National Monument (Plant Ecologist, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 1995–2003).

Question 2.6 Potential for natural long-distance dispersal *Score:* **B** *Doc'n Level:* **Obs**.
Identify dispersal mechanisms: Wind.
Rationale: Strong winds that accompany summer thunderstorms and 'dust devils' could move seeds long distances.
Sources of information: Personal observations by S. Rutman on Organ Pipe Cactus National Monument (Plant Ecologist, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 1995–2003).

Question 2.7 Other regions invaded *Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: In North America this species occurs in Arizona (Pima and Maricopa Counties), California (coastal bluffs, margins of saline wetlands; four counties), and Oregon, USA and Baja California and Sonora, Mexico (Vivrette 1993, MBG 2003, USDA 2005). Elsewhere in the world it is reported from Chile and Australia (MBG 2004).
Rationale: The amount of unoccupied habitat is difficult to assess given the existing published information. Potential for occurring at least in areas with saline soils in Mediterranean-type climates and as well as warm deserts. It could invade inter-dunal sloughs, playas, agricultural areas, desert saltbush associations, and the perimeter of cienegas and other waters. It appears to be shade-intolerant, however, and would not grow where plant cover is high.
Sources of information: See cited literature.

Question 3.1 Ecological amplitude *Score:* **B** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Currently documented from the Sonoran desertscrub, *Atriplex polycarpa-Atriplex linearis-Larrea divaricata* ssp. *tridentata* Association. Earliest specimens at the University of Arizona were collected in 1983, indicating the species is a recent arrival to the state. In contrast, the species was collected as early as 1935 in California (Shreve 7427, no ARIZ accession number). Hamilton's 1983 collection (ARIZ 241065) is the first documentation of a population in Maricopa County that covered many square miles in 1995 (Rutman, unpublished data, 1995).
Rationale: The species probably has not reached its full potential in Arizona. In Arizona it might establish on saline soils in the Great Basin Desert, Mohave Desert, semi-desert grassland, canals, riverbanks, floodplains and playas, and especially in agricultural areas.
Sources of information: See unpublished data of Rutman. 1995. Summary of label information on herbarium specimens at the University of Arizona (ARIZ), July 1995, and related notes. Also see Mack (1991). Current herbarium records can be accessed through SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections).

Question 3.2 Distribution	*Score:* **D** *Doc'n Level:* **Obs.**
Describe distribution: Distribution is poorly known. Three extant 'populations' are known in Arizona: (1) Organ Pipe Cactus National Monument, Pima County (Rutman, unpublished data, 1995, 2003), (2) several square miles in each direction from the intersection of Interstate 10 and Maricopa Road south of Phoenix, and (3) along irrigation ditches serving an alfalfa field to the north of the Gila River and west of State Route 85. Surveys in Arizona should occur in and around agricultural fields and irrigation canals as well as river floodplains, saltbush uplands, playas and Pleistocene surfaces.	
Rationale: Known distribution is less than <5% of Sonoran desertscrub.	
Sources of information: Unpublished data of S. Rutman: (1) Memo to the files, May 12, 1995. Subject: Discovery of two previously unrecorded non-native species in Organ Pipe Cactus National Monument. Organ Pipe Cactus National Monument, Ajo, Arizona. 3 p. (2) 2003. Map of exotic plants on Organ Pipe Cactus National Monument.	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**Yes**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**Yes**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**No**	**1 pt.**
	Total pts: 3 Total unknowns: 2		
	Score : C		
Note any related traits:			

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	**D**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	**D**
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Bohnert Laboratories. 2003. *Mesembryanthemum*. Bohnert Laboratories, University of Illinois, Plant Biology/Crop Sciences Departments, Urbana-Champaign. Available online at: http://www.life.uiuc.edu/bohnert/projects/mesem.html; accessed May 14, 2003.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Felger, R.S. 2000. Flora of the Gran Desierto and Rio Colorado of Northwestern Mexico. University of Arizona Press, Tucson.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Kloot, P.M. 1983. The role of common iceplant (*Mesembryanthemum crystallinum*) in the deterioration of medic pastures. Austral. J. Ecol. 8:301−306.

Mack, R.N. 1991. The commercial seed trade: an early disperser of weeds in the United States. Econ. Bot. 45:257–273.

[MBG] Missouri Botanical Garden. 2003. W3TROPICOS Nomenclatural data base. Available online at: http://mobot.mobot.org/cgi-bin/; accessed May 14, 2004.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Vivrette, N.J. 1993. *Mesembryanthemum*. Page 129 in Hickman, J.C. (ed.), The Jepson Manual: Higher Plants of California. Univiversity of California Press, Berkeley.

Vivrette, N.J., and C.H. Muller. 1977. Mechanism of invasion and dominance of coastal grassland by *Mesembryanthemum crystallinum*. Ecol. Monogr. 47:301−318.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Myriophyllum aquaticum* (Vell.) Verdc. (USDA 2005)
Synonyms:	*Enydria aquatica* Vell., *Myriophyllum brasiliense* Camb., *Myriophyllum proserpinacoides* Gillies ex Hook. & Arn. (USDA 2005)
Common names:	Parrot's feather, parrot feather watermilfoil, Brazilian water milfoil
Evaluation date (mm/dd/yy)**:**	02/15/05
Evaluator #1 Name/Title:	Theresa Olson / Wildlife Biologist
Affiliation:	U.S. Bureau of Reclamation
Phone numbers:	(702) 293–8127
Email address:	tolson@lc.usbr.gov
Address:	P.O. Box 61470, Boulder City, Nevada 89006
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	W. Albrecht, S. Harger, L. Moser, F. Northam, T. Olson
Committee review date:	03/2/05
List date:	03/2/05
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

Question		Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**A**	Reviewed scientific publication	**"Impact"** **Section 1 Score:** **A**	**"Plant Score"** **Overall Score:** **High** **Alert Status:** **Alert**
1.2	Impact on plant community	**A**	Other published material		
1.3	Impact on higher trophic levels	**A**	Other published material		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **15 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**A**	Other published material		
2.3	Recent trend in total area infested within state	**B**	Other published material		
2.4	Innate reproductive potential	**B**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Other published material		
2.6	Potential for natural long-distance dispersal	**B**	Other published material		
2.7	Other regions invaded	**C**	Other published material		 Something you should know.
3.1	Ecological amplitude	**C**	Other published material	**"Distribution"** **Section 3 Score:** **C**	
3.2	Distribution	**D**	Other published material		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Identify ecosystem processes impacted: Uncontrolled growth of parrot's feather impacts abiotic ecosystems by: (1) restricting flow in streams, 2) increasing sediment and organic matter deposition, (3) depleting oxygen under dense mats, and 4) altering water quality and flooding regime.

Rationale: Parrot's feather, a rhizomatous South American aquatic perennial in the water-milfoil family, colonizes in slow moving or still water, forming dense mats. This plant roots in the sediment and stems grow throughout the water column until they reach the water surface (Orchard 1981). These stands lower dissolved oxygen and increase acidity in aquatic systems (Evans et al. 2003), significantly altering both the physical and chemical characteristics of lakes and streams (WDOE 2003). Dense stands reduce stream flow, block water ways, and create water loss (evapotranspiration doubles when water surface is covered with parrot's feather; Cilliers 1999). In Washington dense infestations have caused flooding and drainage problems in shallow rivers and streams (WDOE 2003).

Sources of information: See cited literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Other pub.**

Identify type of impact or alteration: Uncontrolled growth of parrot's feather impacts plant communities by: (1) altering and possibly eliminating native plant communities, (2) decreasing algal growth, and (3) forming large monoculture mats.

Rationale: Parrot feather forms dense mats which shade native vegetation, and deplete nutrients from water. Observations of the Palo Verde Westside Drain near Blythe, California (just across the Colorado River from Ehrenberg, Arizona), indicate plants cover 75% to 100% of water surface in 2002–2004 (T. Olson, personal observations, 2002–2004). Infestations can alter aquatic ecosystems by shading out algae in the water column (WDOE 2003). Large mats prevent the growth of native vegetation, competing with native aquatic plants, eliminating them or reducing their numbers in infested sites (Cal-IPC website). Parrot's feather infested irrigation water used for raising tobacco and caused discoloring of the tobacco (Cilliers 1999).

Sources of information: See cited literature. Also considered personal observations of T. Olson (Wildlife Biologist, Bureau of Reclamation, Lower Colorado Regional Office, 2002–2004, observations at the Palo Verde Westside and Outfall Drains, Blythe, California and all along the Lower Colorado River from Blythe, California south to the international border) and information from the California Invasive Plant Council (Cal-IPC) website for *Myriophyllum aquaticum* (available online at: http://ucce.ucdavis.edu/datastore/detailreport.cfm?usernumber=64&surveynumber=182).

Question 1.3 Impact on higher trophic levels *Score:* **A** *Doc'n Level:* **Other pub.**

Identify type of impact or alteration: (1) Increases mosquito habitat. (2) Dense mats detrimental to fish. (3) Shades out algae, a food source for other animals.

Rationale: Parrot's feather: provides choice mosquito larvae habitat (WDOE 2003); reduces dissolved oxygen and increases acidity, which may be detrimental to fish (Evans et al. 2003); and shades out algae changing the food chain for several higher organisms including waterfowl (Cal-IPC website). A bio-control agent has been located for this species. *Lysathia* n. sp. (Coleoptera: Chrysomelidae), a leaf beetle has been studies in South Africa and found to be effective there, but is not available in the U.S. Parrot's feather has a high tannin content to most grazers, including grass carp find it unpalatable. Although *M. aquaticum* may provide cover for some aquatic organisms, large infestations can alter aquatic ecosystems by shading out the algae in the water column that serve as the basis of the aquatic food web (WDOE 2003). According to the Environmental Media Services website, parrot's feather has colonized sloughs and backwaters of the Chehalis River in Washington. These areas are known to be important

for salmon habitat. Because this plant alters water chemistry, these sloughs are becoming lost as rearing areas for juvenile salmon.
Sources of information: See cited literature. Also considered information from the California Invasive Plant Council (Cal-IPC) website for *Myriophyllum aquaticum* (available online at: http://ucce.ucdavis.edu/datastore/detailreport.cfm?usernumber=64&surveynumber=182) and the Environmental Media Services website (available online at: http://www.ems.org/cgi-bin/GPrint2002.pl?file=salmon/threats.rx).

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: None. Parrot's feather reproduces by fragmentation in the United States.
Rationale: Reproduction of parrot's feather in the U.S. is believed to be entirely by vegetative means, resulting from stem fragmentation and/or regrowth from rhizomes. Even in South America, virtually all plants are female. Male plants are unknown outside South America so no seeds are produced in the U.S. Parrot's feather also lacks tubers or other specialized reproductive over-wintering structures like turions; as a result, it spreads exclusively by plant fragments outside of its native range. Only one native plant is closely to this species: *Myriophyllum sibiricum* Komarov (= *M. exalbescens* Fern.). This species exists in Arizona in Apache, Navajo, and Coconino Counties, but because this plant does not produce seed in the U.S. hybridization is unknown (Kearney and Peebles 1960).
Sources of information: See cited literature. Also see USDA (2005).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Fragmentation and/or rhizomes needed for spread.
Rationale: Spread of parrot's feather is mainly by fragmentation through either natural stream flow or disturbance such as flooding, by animals such as waterfowl, and by human cultivation and/or disturbance through recreation and boating. Parrot's feather can also spread locally by rhizomes rooted in sediment. It tends to colonize slowly moving or still water rather than in areas with higher flow rates. While it grows best when rooted in shallow water, it has been known to occur as a floating plant in the deep water of nutrient-enriched lakes. The emergent stems can survive on wet banks of rivers and lake shores, so it is well adapted to moderate water level fluctuations.
Sources of information: See WDOE (2003). Also considered information from the California Invasive Plant Council (Cal-IPC) website for *Myriophyllum aquaticum* (available online at: http://ucce.ucdavis.edu/datastore/detailreport.cfm?usernumber=64&surveynumber=182) and the Washington State Noxious Weed Control Board website for *Myriophyllum aquaticum* (available online at: http://www.nwcb.wa.gov/weed_info/Written_findings/Myriophyllum_aquaticum.html).

Question 2.2 Local rate of spread with no management *Score:* **A** *Doc'n Level:* **Other pub.**
Describe rate of spread: Increasing rapidly (doubling in <10 years).
Rationale: In the lower Colorado River, south of Ehrenberg, Arizona and Blythe, California, parrot's feather has rapidly taken over small backwaters and canal systems. The area of spread has more than doubled in five years. Infestation was first found in the Palo Verde Irrigation Drain in 1999 along with *Salvinia molesta.* Since 1999 infestations of parrot's feather have now been found up to the Imperial Dam, just north of Yuma, Arizona, an approximate distance of 75 river miles (T. Olson, personal observations, 2002–2004).
Sources of information: Personal observations of T. Olson (Wildlife Biologist, Bureau of Reclamation, Lower Colorado Regional Office, 2002–2004, observations at the Palo Verde Westside and Outfall Drains, Blythe, California and all along the Lower Colorado River from Blythe, California south to the international border).

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Other pub.**
Describe trend: Increasing, but less rapidly than doubling in area in <10 years.
Rationale: Since 1999 infestations of parrot's feather have now been found (2004) south to the Imperial Dam, just north of Yuma, Arizona, an approximate distance of 75 river miles (T. Olson, personal observations, 2002–2004). This is a localized rapid spread and is part of the same river system, and populations to date have not spread outside this watershed. Other areas infested in the state include Kiper Springs (1979), Pond in McClellan Wash, Gila Indian Reservation (1934), Artificial pond eight miles northwest of Benson (1955), and Kinsley's Ranch south of Tucson (1958) (Global Biodiversity Information Facility website). It is unknown at this time what the spread is of those populations.
Sources of information: See cited literature. Also considered personal observations of T. Olson (Wildlife Biologist, Bureau of Reclamation, Lower Colorado Regional Office, 2002–2004, observations at the Palo Verde Westside and Outfall Drains, Blythe, California and all along the Lower Colorado River from Blythe, California south to the international border) and information from the Global Biodiversity Information Facility website (available online at: www.gbif.net/portal or http://www.gbif.net/portal/ecat_browser.jsp?taxonKey=291331&nextTask=digit_viewer.jsp).

Question 2.4 Innate reproductive potential *Score:* **B** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: Reproduces in the U.S. only by fragmentation and rhizomes.
Rationale: Reproduction in the U.S. is believed to be entirely by vegetative means, resulting from stem fragmentation and/or regrowth from sections of rhizomes. Even in South America, most plants are female. Male plants are unknown outside of South America, so no seeds are produced in North American populations (Cilliers 1999, WDOE 2003) Parrot's feather also lacks tubers or other specialized reproductive over-wintering structures like turions. It spreads exclusively by plant fragmentation outside of its native range (Evans 2003). Unlike *Myriophyllum spicatum*, this plant does not form auto-fragments. However, fragments can be formed mechanically and through disturbance, and will readily root. With its tough rhizomes, parrot's feather can be transported long distances on boat trailers. Rhizomes stored under moist conditions can survive for over a year. Female plants do flower, but no male plants exist to pollinate. Plants flower in the spring, but some may flower in the fall. The inconspicuous flowers form where emergent leaves attach to the stem.
Sources of information: See cited literature. Also considered information from the California Invasive Plant Council (Cal-IPC) website for *Myriophyllum aquaticum* (available online at: http://ucce.ucdavis.edu/datastore/detailreport.cfm?usernumber=64&surveynumber=182)

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: (1) Available for commercial sale, (2) spread along riverways that act as transportation corridors, and (3) transported on boats or by boat trailers.
Rationale: Because of its attractiveness and ease of cultivation, parrot's feather has been introduced worldwide for use in indoor and outdoor aquaria. It is also a popular aquatic garden plant. It has escaped cultivation, however, and spread via plant fragments and intentional plantings. This plant is readily available for commercial sale on several internet sites and at nurseries. This plant has been used in several scientific studies for uptake of contaminants in the environment (Wilson et al. 2001), including phyto-remediation of explosive wastes in Tennessee (USAEC 1996, USEPA 1998, Project Oceanography 2000). This plant is readily transported by boat and boat trailers through fragments and its tough rhizomes. Parrot's feather is a great threat to irrigation canal and drainage systems, and its distribution through these systems is an inoculation source to wildlands.
Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **B** *Doc'n Level:* **Other pub**.
Identify dispersal mechanisms: Species can fragment and float long distances downstream of rivers. May be carried by waterfowl or other avian/animal species.
Rationale: Parrot's feather easily fragments and may float and travel long distances in river systems where there is flowing water (Evans et al. 2003). For example, one infestation was first found in the Palo Verde Irrigation Drain in 1999 along with *Salvinia molesta.* Since 1999 infestations of parrot's feather have now been found (2004) up to the Imperial Dam, just north of Yuma, Arizona, an approximate distance of 75 river miles (T. Olson, personal observations, 2002–2004) This plant also spreads by floods and animals (Henderson and Cilliers 2002).
Sources of information: See cited literature. Also considered personal observations of T. Olson (Wildlife Biologist, Bureau of Reclamation, Lower Colorado Regional Office, 2002–2004, observations at the Palo Verde Westside and Outfall Drains, Blythe, California and all along the Lower Colorado River from Blythe, California south to the international border).

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Other pub**.
Identify other regions: This plant has a distribution in several wetland and river systems worldwide including: Africa**,** Australia**,** Indonesia**,** New Zealand**,** South Africa**,** and the United States (including California and Washington).
Rationale: This plant was first collected in the U.S. near Washington, DC in 1890. It was reported from South Africa in 1918 or 1919, Japan in 1920, New Zealand in 1929, Australia in the 1960s, and England in the 1970s. A population was reported in western Washington in 1944 (WDOE 2003) and now is in several lakes and coastal streams. In California this species is in several streams, coastal wetlands, irrigation, and drainage canals. A 1985 survey of irrigation, mosquito abatement, flood control, and reclamation agencies in California indicated that parrot feather infested nearly 600 miles of waterways and over 500 surface acres (WDOE 2003). Parrot's feather is a great threat to irrigation canal and drainage systems, and distribution through these systems is an inoculation source to wildlands. Currently in Arizona it has been located in the Lower Colorado River below Ehrenberg, Arizona and Blythe California, and has been in several small localized ponds. Although it has invaded other Non-Riparian Wetlands in other states in the U.S. (e.g., California and Washington), the potential to invade this ecological type in Arizona is slim because non-riparian wetland in Arizona tend to be ephemeral and intermittent in nature and also tend to be saline.
Sources of information: See cited literature.

Question 3.1 Ecological amplitude *Score:* **C** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: This plant is currently know from freshwater systems in Arizona.
Rationale: Since 1999 infestations of parrot's feather have now been found south to the Imperial Dam, just north of Yuma, Arizona, an approximate distance of 75 river miles (Lower Colorado River giant salvinia website; T. Olson, personal communication, 2002–2004). This is a localized rapid spread and is part of the same river system. Other areas infested in the state include Kiper Springs (1979), pond in McClellan Wash, Gila Indian Reservation (1934), artificial pond eight miles northwest of Benson (1955), and Kinsley's Ranch south of Tucson (1958) (Global Biodiversity Information Facility website). It is unknown at this time whether these populations have spread.
Sources of information: Personal observations of T. Olson (Wildlife Biologist, Bureau of Reclamation, Lower Colorado Regional Office, 2002–2004, observations at the Palo Verde Westside and Outfall Drains, Blythe, California and all along the Lower Colorado River from Blythe, California south to the international border). Also considered information from the Lower Colorado River giant salvinia website (available online at: www.lcrsalvinia.org) and the Global Biodiversity Information

Facility website (available online at: www.gbif.net/portal or http://www.gbif.net/portal/ecat_browser.jsp?taxonKey=291331&nextTask=digit_viewer.jsp).

Question 3.2 Distribution *Score:* **D** *Doc'n Level:* **Other pub.**
Describe distribution: Only known in one river system (Lower Colorado River) and four small freshwater or man-made ponds.
Rationale: Since 1999 infestations of parrot's feather have now been found south to the Imperial Dam, just north of Yuma, Arizona, an approximate distance of 75 river miles (Lower Colorado River giant salvinia website; T. Olson, personal communication, 2002–2004). This is a localized rapid spread and is part of the same river system. Other areas infested in the state include Kiper Springs (1979), pond in McClellan Wash, Gila Indian Reservation (1934), artificial pond eight miles northwest of Benson (1955), and Kinsley's Ranch south of Tucson (1958) (Global Biodiversity Information Facility website). It is unknown at this time whether these populations have spread.
Sources of information: Personal observations of T. Olson (Wildlife Biologist, Bureau of Reclamation, Lower Colorado Regional Office, 2002–2004, observations at the Palo Verde Westside and Outfall Drains, Blythe, California and all along the Lower Colorado River from Blythe, California south to the international border). Also considered information from the Lower Colorado River giant salvinia website (available online at: www.lcrsalvinia.org) and the Global Biodiversity Information Facility website (available online at: www.gbif.net/portal or http://www.gbif.net/portal/ecat_browser.jsp?taxonKey=291331&nextTask=digit_viewer.jsp).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**[No]**	**2 pt.**
Populations of this species produce seeds every year.	**Yes**	**[No]**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**[No]**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**[No]**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**[Yes]**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 5 Total unknowns: 0		
	Score : B		
Note any related traits:			

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	Dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	**D**
	rivers, streams	**D**
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	Playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Cilliers, C.J. 1999. *Lysanthia* n.sp. (Coleoptera: Chrisomelidae), a host-specific beetle for the control of the aquatic weed Myriophyllum aquaticum (Haloragaceae) in South Africa. Hydrobiologia 415:271–276.

Evans, J.R., J.J. Nugent, and J.K. Meisel. 2003. Parrotfeather: *Myriophyllum aquaticum*. Pages 141–142 in Invasive Plant Species Inventory and Management Plan for the Hanford Reach National Monument.

Henderson, L., and C.J. Cilliers. 2002. Invasive Aquatic Plants. Paarl Printers, Cape Town.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Orchard, A. 1981. A revision of South American *Myriophyllum* (Haloragaceae) and its repercussions on some Australian and North American species. Brunonia 4:27–65.

Project Oceanography. 2000. Neighborhood Water Quality, Lesson 3. Solutions to Pollution. Available online at: http://aquat1.ifas.ufl.edu.

[USACE] United States Army Environmental Center. 1996. Research Demonstrates Potential of Plants to Break Down Some Types of Explosives. Available online at: http://aec.army.mil/usaec/publicaffairs/update/jan96/plants.htm.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

[USEPA] United States Environmental Protection Agency. 1998. A Citizen's Guide to Phytoremediation. EPA 542-F-98-001.Office of Solid Waste and Emergency Response (5102G). August.

[WDOE] Washington State Department of Ecology. 2003. Technical Information about Parrotfeather (*Myriophyllum aquaticum*). Available online at: www.ecy.wa.gov/programs/wq/plants/weeds/aqua003.html.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Wilson, P.C., T. Whitwell, and S.J. Klane. 2001. Simazine toxicity and uptake by parrotfeather. Journal of Aquatic Plant Management 39:112–117.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Myriophyllum spicatum* L. (USDA 2005)
Synonyms:	None identified in USDA (2005).
Common names:	Eurasian watermilfoil, spike watermilfoil, spiked water milfoil, myriophylle en epi
Evaluation date (mm/dd/yy)**:**	04/12/04
Evaluator #1 Name/Title:	Dr. Francis E. Northam
Affiliation:	freelance weed biologist
Phone numbers:	(480) 947–3882
Email address:	fnortham@msn.com
Address:	216 E. Taylor St., Tempe, Arizona 85281
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	04/16/04: W. Albrecht, D. Backer, J. Crawford, H. Folger, J. Hall, R. Hiebert, F. Northam, T. Olson, K. Watters 06/23/04: W. Albrecht, D. Backer, J. Brock, J. Busco, J. Hall, C. Laws, B. Phillips, K. Watters
Committee review date:	04/16/04 and 06/23/04
List date:	06/23/04
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**A**	Reviewed scientific publication	**"Impact"** **Section 1 Score:** **A**	**"Plant Score"** **Overall Score:** **High** **Alert Status:** **Alert**
1.2	Impact on plant community	**A**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**A**	Reviewed scientific publication		
1.4	Impact on genetic integrity	**U**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**A**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **14 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**C**	Observational		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Reviewed scientific publication		
2.6	Potential for natural long-distance dispersal	**B**	Other published material		
2.7	Other regions invaded	**C**	Other published material		RED FLAG **NO** Something you should know.
3.1	Ecological amplitude	**C**	Observational	**"Distribution"** **Section 3 Score:** **C**	
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify ecosystem processes impacted: Uncontrolled growth of *Myriophyllum spicatum* is detrimental to abiotic processes in natural waters for the following reasons: (1) restricts (slows) water flow in streams, (2) increases sediment and organic matter deposition, (3) reduces availability of light to submerged plants and animals, and (4) alters water quality.
Rationale: No impacts on Arizona's natural waters have been reported for Eurasian watermilfoil; however, observations in other states have documented definite impacts. Because of *M. spicatum* and hydrilla's (*Hydrilla verticillata*) growth and colony similarities, these two submerged aquatic species have similar impacts (Bossard 2000, Florida Department of Environmental Protection Undated). Both species fill water columns with numerous stems (300/m^2 for *M. spicatum*; Aiken et.al.1979). These stems grow toward the water surface and produce dense, tangled mats which physically impede (slow) water flow and increase sedimentation. Furthermore, flood damage increases in streams with extensive infestations of these species (Bossard 2000, Rhoads and Block 2000). As vertical *M. spicatum* stems grow from mud/sediment toward water surface, shoots branch laterally. A dense vegetative mat forms which severely reduces sunlight penetration (Jacono and Richardson 2003). Because *M. spicatum*'s photosynthetic system can function at low light intensities (<1% of sunlight), this species can colonize deeper areas of water bodies (9 to 15 meters) than most aquatic macrophytes (Batcher 2000). As a result, this species can occupy portions of aquatic habitats that have no native submerged plant life; however, *M. spicatum* typically infests waters <5 meters deep (Johnson and Blossey 2002). In situations where *M. spicatum* is the predominate macrophyte biomass, pH is raised, dissolved oxygen concentrations decrease and water temperature increases (Honnell et al. 1992, Jacono and Richardson 2003).
Sources of information: See cited literature. Also considered information from the Florida Department of Environmental Protection. Undated. Weed Alert: Hydrilla. Available online at: http://www.dep.state.fl.us/lands/invaspec/2ndlevpags/wedalrt.htm; accessed 2004.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: Seventeen *M. spicatum* sites have been confirmed with botanical specimens since 1957 in Arizona. *Myriophyllum spicatum* displaces native species and biomass production by *M. spicatum* excludes light from reaching native plants. This latter factor is probably part of the reason native plant densities decrease in the presence of *M. spicatum*.
Rationale: Seventeen *M. spicatum* sites have been confirmed with botanical specimens since 1966 in Arizona (SEINet 2004), but no detrimental impacts have been verified in Arizona. Impacts documented in other North American natural areas, however, indicate the species poses a direct threat to Arizona lakes and stream biota. *Myriophyllum spicatum* has been shown to have the capability to replace native species of eelgrass (*Vallisneria*) and niaid (*Najas*) in Alabama (Jacono and Richardson 2003). Colonies of *M. spicatum* have been shown to reduce native species density from 5.5 to 2.2 species per m^2 in two years at Lake George, New York (Madsen et al. 1991)**.** *Myriophyllum spicatum*'s mat-forming ability at water surfaces intercept (block) light to other submerged plants (Madsen 1994, Jacono and Richardson 2003).
Sources of information: See cited literature. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed April 2004).

Question 1.3 Impact on higher trophic levels *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: *Myriophyllum spicatum* increases mosquito habitat, which increases the potential for mosquito-borne diseases. Dense infestations are detrimental to fish habitat. *Myriophyllum spicatum* provides non-native forage for water fowl.
Rationale: Tennessee Valley streams clogged with dense Eurasian watermilfoil populations stagnate to the point that mosquito larvae survive in previously unsuitable habitat (Bates et al. 1985). This situation is assumed to be possible in Arizona streams; however it has not yet been documented in Arizona. As *M. spicatum* growth produces dense colonies, mosquito habitat increases which becomes potential breeding sites for vectors of arthropod borne diseases such as West Nile virus, malaria and encephalitis (Bates et al. 1985, NWHC 2001, Center for Disease Control). At high densities of *M. spicatum,* abundance and diversity of invertebrates (fish food) was less than in native plant communities (Keast 1984). Wildlife biologists have detected waterfowl utilizing *M. spicatum* as forage plant in Alabama (McNight and Hepp 1998, Benedict and Hepp 2000).
Sources of information: See cited literature. Also considered information from the Center for Disease Control, Division of Vector-Borne Infectious Diseases, Arboviral Encephalitides. Undated. Available online at: http://www.cdc.gov/ncidod/dvbid/arbor/indes.htm; accessed 2004.

Question 1.4 Impact on genetic integrity *Score:* **U** *Doc'n Level:* **Other pub.**
Identify impacts: Hybridization is unknown, but potentially could occur.
Rationale: A closely related native species, *M. sibiricum* Komarov (= M. exalbescens Fern.) or shortspike watermilfoil, is present in Arizona waters (Kearney and Peebles 1960, USDA 2005). Forty-six collections from 25 sites are recorded in Arizona herbaria for *M. sibiricum* (SEINet 2004). Both *M. spicatum* and *M. sibiricum* are present in Cochise, Coconino, Graham, Navajo and Yavapai Counties. *Myriophyllum sibiricum* has been considered a variety or subspecies of *M. spicatum* in the past (Kearney and Peebles 1960, USDA 2005). No reports exist of *M. spicatum* hybridization with the native *Myriophyllum*, but the close taxonomic relationship between these to taxa does not enable ruling out the potential for hybridization.
Sources of information: See cited literature. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed April 2004).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **A** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Habitat disturbance is not necessary for establishment of this species.
Rationale *Myriophyllum spicatum* grows in a wide range of water quality conditions, including oligotrophic near-pristine habitats (Bossard 2000). Water quality is rarely a limiting factor for establishment, but *M. spicatum* is most common in nutrient rich lakes and waterways in Canada (Aiken et al. 1979). Initial establishment of pioneer colonies in an ecosystem requires direct human intervention or animal (usually waterfowl) transport from another ecosystem.
Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **C** *Doc'n Level:* **Obs.**
Describe rate of spread: Stable.
Rationale: No known reports of spread found for Arizona waters (F. Northam, personal observation, 2004).
Sources of information: Personal observations by F. Northam (Weed Biologist, Tempe, Arizona, 2004).

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n Level:* **Obs.**
Describe trend: Stable.
Rationale: No reports exist of recent increases or decreases of total area infested in Arizona (F. Northam, personal observation, 2004). Collections of *M. spicatum* deposited in Arizona herbaria started in 1957 and the latest record was for 1997 (SEINet 2004). Of seventeen sites reported, only two were collected after 1990 (1991 and 1997).
Sources of information: Personal observations by F. Northam (Weed Biologist, Tempe, Arizona, 2004) and information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed April 2004).

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: New infestations are easily started by small fragments of stem. Seed production is possible, but seeds have a minor impact on dispersal of new infestations.
Rationale: Vegetative reproduction by fragment transport is credited as the predominant dispersal method (Johnson and Blossey 2002). Seed production is common through out its range, but seedlings are rarely seen (Bossard 2000). See Worksheet A.
Sources of information: See cited literature; also see Aiken et al. 1979.

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify dispersal mechanisms: Vegetative fragment transport via watercraft and trailers; ornamental plant used by aquarium and backyard pond hobbyists; contaminate of other commercially traded aquatic ornamental species, including aquarium plants.
Rationale: All authors cited in previous questions acknowledge the threat of new infestations being established by moving *M. spicatum* fragments on boats, boat trailers, bait buckets/boxes, fishing gear, anchors, swamp buggies, etc. They also affirm these human activities are the primary source of extant infestations in the U.S.
Sources of information: See cited literature in previous questions; in particular, see Aiken et al. (1979), Bossard (2000), and Johnson and Blossey (2002).

Question 2.6 Potential for natural long-distance dispersal *Score:* **B** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Downstream movement of stem fragments or seed; wildlife transport of stem fragments.
Rationale: Once initial human-induced *M. spicatum* populations are established in non-infested regions, natural transport mechanisms are effective dispersers because of the ease with which stem fragments produce roots (Johnson and Blossey 2002).
Sources of information: See cited literature; also see Haber (1997) and Bossard (2000).

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Other pub.**
Identify other regions: Wide amplitude of aquatic conditions are infested in North America; only invades areas within same ecological type as in Arizona.
Rationale: *Myriophyllum spicatum* can infest any freshwater aquatic system in California from desert waters to upper estuaries to mountain lakes (Bossard 2000). The cool northern waters of Washington, North Dakota, Minnesota, Michigan, Ohio, New York, and the New England states are heavily infested (Jacono and Richerson 2003). Warm temperate and humid subtropical areas of the southeastern U.S. have documented populations (USDA 2005). Introduction date in North America is uncertain (from late 1800s to 1942; Johnson and Blossey 2002); however, since first confirmed in Washington DC in 1942, *M. spicatum* has spread from the northeastern U.S. through the southern and Midwestern U.S. and down the west coast states to where it now infests 44 states.

Sources of information: See cited literature.

Question 3.1 Ecological amplitude *Score:* **C** *Doc'n Level:* **Obs.**

Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Limited to permanent freshwater habitats; see question 2.7 rationale.

Rationale: Based on *M. spicatum*'s distribution in temperate regions of North America (see question 2.7 rationale and sources of information), this species seems capable of colonizing any Arizona aquatic sites, below alpine ecological types, which have permanent sources of water. Distribution records, which start in Phoenix during early 1960s, are in the elevation range of 200 to 6500 feet.

Sources of information: SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed April 2004).

Question 3.2 Distribution *Score:* **D** *Doc'n Level:* **Obs.**

Describe distribution: Ponds, reservoirs, and streams from Rocky Mountain forests above 5000 feet to the lower Colorado River below 500 feet.

Rationale: This species infests both types of freshwater ecological types in Arizona, but has a limited distribution in each. See Worksheet B.

Sources of information: SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed April 2004).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**Yes**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**Yes**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**No**	**1 pt.**
	Yes	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**No**	**1 pt.**

Total pts: 6 Total unknowns: 3

Score : A

Note any related traits: Seed production is not considered an important part of Eurasian watermilfoil reproduction.

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	**D**
	rivers, streams	**D**
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Aiken, S.G.., P.R. Newroth, and I Wile. 1979. The biology of Canadian weeds. 34 *Myriophyllum spicatum* L. Canadian J. of Plant Science 59:201−215.

Batcher, M.S. Undated. *Hydrilla verticillata* (L.F.) Royle. Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documnts/hydrver.rtf; accessed March 2004.

Bates, A.L., E.R. Burns, and D.H. Webb. 1985. Eurasian watermilfoil (*Myriophyllum spicatum L.*) in the Tennessee Valley: an update on biology and control. Pages 104−115 in L.W.J. Anderson (ed.), Proceedings of the First International Symposium on Watermilfoil (*Myriophyllum spicatum*) and Related Haloragaceae Species. July 23−24, 1985, Vancouver, British Columbia. The Aquatic Plant Management Society, Inc., Vicksburg, Mississippi.

Benedict, R.J. and G.R. Hepp. 2000. Wintering waterbird use of two aquatic plant habitats in a southern reservoir. Journal of Wildlife Management 64:269−278.

Bossard, C. 2000. *Myriophyllum spicatum* L. Pages 254−258 in C.C. Bossard, J.M. Randall, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Haber, E. 1997. Eurasian Watermilfoil. Invasive Exotic Plants of Canada. Fact Sheet No. 10. National Botanical Services, Ottawa, Ontario. Available online at: http://24.43.80.213/nbs/IPCAN/factfoil.html.

Honnell, D., J.D. Madsen, and R.M. Smart. 1992. Effects of aquatic plants on water quality in pond ecosystems. 26^{th} Annual Meeting, Aquatic Plant Control Research Program. Report A-92-2. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Jacono, C.C., and M.M. Richerson. 2003. *Myriophyllum spicatum* L. Nonindigenous Aquatic Species. U.S. Department of the Interior, U.S. Geological Survey. Available online at: http://nas.er.usgs.gov/taxgroup/plants/docs/my_spica.html; accessed March 2004.

Johnson, R.L., and B. Blossey. 2002. Eurasian Watermilfoil. In R. Van Driesche, S. Lyon, B. Blossey, M. Hoddle, and R. Reardon (tech. coords.), Biological Control of Invasive Plants in the Eastern United States. Publication FHTET-2002-04. U.S. Department of Agriculture, Forest Service. Available online at: http://www.invasive.org/eastern/biocontrol/6EurasianMilfoil.html.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2^{nd} edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Keast, A. 1984. The introduced aquatic macrophyte, *Myriophyllum spicatum*, as habitat for fish and their invertebrate prey. Canadian Journal of Zoology 62:1289−1303.

Madsen, J.D. 1994. Invasions and declines of submerged macrophytes in Lake George and other Adirondack lakes. Lake and Reservoir Management 10:19–23.

Madsen, J.D., J.W. Sutherland, J.A. Bloomfield, L.W. Eichler, and C.W. Boylen. 1991. The decline of native vegetation under dense Eurasian watermilfoil canopies. Journal of Aquatic Plant Management 29:94–99.

McKnight, S.K., and G.R. Hepp. 1998. Diet selectivity of gadwalls wintering in Alabama. Journal of Wildlife Management 62:1533–1543.

[NWHC] National Wildlife Health Center. 2001. Wild Birds Implicated in Rapid Spread of West Nile Virus. Wildlife Alert #01–02. U.S. Department of the Interior, U.S. Geological Survey, National Wildlife Health Center. Available online at: http://www.nwhc.usgs.gov/whats_new/wha/wha0102.html; accessed April 2004.

Rhoads, A.F., and T.A. Block. 2000. Eurasian Water-milfoil, *Myriophyllum spicatum* L., Water-milfoil Family (Haloragaceae). Invasive species fact sheet. University of Pennsylvania, Morris Arboretum. Available online at: http://www.paflora.org/Myriophyllum%20spicatum.pdf; accessed March 2004.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial):	*Onopordum acanthium* L. (USDA 2005)
Synonyms:	None identified in USDA (2005).
Common names:	Scotch thistle, Scotch cotton thistle, Scots cottonthistle, cotton thistle, wooly thistle, downy thistle, silver thistle, winged thistle, Queen Mary's thistle, heraldic thistle, asses' thistle
Evaluation date (mm/dd/yy):	03/15/05
Evaluator #1 Name/Title:	Debra Crisp, Botanist
Affiliation:	USDA Forest Service, Coconino National Forest
Phone numbers:	(928) 527–3424
Email address:	dcrisp@fs.fed.us
Address:	1824 S. Thompson St., Flagstaff, Arizona 86001
Evaluator #2 Name/Title:	Dr. Francis E. Northam
Affiliation:	Weed Biology consultant
Phone numbers:	480/947-3882
Email address:	fnortham@msn.com
Address:	216 E. Taylor St., Tempe, Arizona 85281

List committee members:	P. Fenner, J. Hall, L. Making, F. Northam, T. Olson, G. Russell
Committee review date:	04/22/05
List date:	04/22/05
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	C	Observational	**"Impact"** **Section 1 Score:** **C**	**"Plant Score"** **Overall Score:** **Low** **Alert Status:** **None**
1.2	Impact on plant community	C	Other published material		
1.3	Impact on higher trophic levels	C	Other published material		
1.4	Impact on genetic integrity	D	Other published material		
2.1	Role of anthropogenic and natural disturbance	B	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **14 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	B	Observational		
2.3	Recent trend in total area infested within state	B	Observational		
2.4	Innate reproductive potential	B	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	A	Other published material		
2.6	Potential for natural long-distance dispersal	C	Observational		
2.7	Other regions invaded	B	Other published material		 Something you should know.
3.1	Ecological amplitude	A	Observational	**"Distribution"** **Section 3 Score:** **B**	
3.2	Distribution	C	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **C** *Doc'n Level:* **Obs.**
Identify ecosystem processes impacted: No documentation of impacts found in published literature. However numerous authors noted that this species establishes in areas subjected to extensive disturbance of soil surfaces such as cultivated pastures (Parsons 1973), rights-of-way, disturbed areas (Stubbendieck et al. 1994) and is especially abundant in disturbed habitats with high soil moisture (Beck 1999).
Rationale: Based on inferences from the above citations, wildland sites where soil surfaces have been cleared of native vegetation by activities such as timber harvest, wildfires, fire-suppression operations with bulldozers, livestock trampling, pipeline construction or hiking/camping activities can be impacted by *Onopordum acanthium* removal of soil moisture and nutrients or through sunlight interception by dense foliage. This indicates Scotch thistle impacts will be restricted to recovery and restoration following intense disturbance to wildland soils.
Sources of information: See cited literature. Score based on inference drawn from the literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **C** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Invades disturbed areas. Population numbers and density increase after disturbance. Occupies habitat otherwise used by native species. Competes with native plants for resources.
Rationale: Scotch thistle can alter the composition, structure and function of the invaded plant community. Scotch thistle favors disturbed sites especially in areas of high soil moisture; however, dry sites also may be invaded. Scotch thistle is often associated with areas invaded by non-native annual grasses, such as cheatgrass (*Bromus tectorum*), in areas where annual grasses have displaced native sod-forming species (Beck 1999). Invading plants can compete with native species for water, light, nutrients, pollinators and space (Staphanian et al. 1998).
Sources of information: See cited literature.

Question 1.3 Impact on higher trophic levels *Score:* **C** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Mature plants are avoided by grazing animals, and compete with native forage plants.
Rationale: Infestations of Scotch thistle may prevent or discourage access to suitable areas for grazing because of its spiny nature (Stubbendieck et al. 1994, Beck 1999). Dense colonies of Scotch thistle can reduce or eliminate desirable forage species (Julian and Rife Undated). Invading plants can compete with native species for water, light, nutrients, pollinators and space (Staphanian et al. 1998).
Sources of information: See cited literature. Also considered information from J. Julian and J. Rife. Undated. Integrated weed management of Scotch Thistle. Douglas County Cooperative Extension, Castle Rock, Colorado. Available online at: http://www.douglas.co.us/DC/PublicWorks/Weeds/scotch_thistle.htm; accessed March 16, 2005.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: No known hybridization.
Rationale: No native plants in the genus *Onopordum* are known to exist in Arizona (Kearny and Peebles 1960). Although three species of the genus *Onopordum* (*O. acanthium* L., *O. illyricum* L., and *O. tauricum* Willd.) are known to occur in the U.S., all of these are introduced (USDA 2005). The absence of closely related native relatives reduces the chance of hybridization or introgression between non-native and native plants. No data were found to indicate that the three known introduced species hybridize.
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Disturbance is necessary for Scotch thistle to establish. This can be either natural or anthropogenic disturbance.
Rationale: Beck (1999) stated that disturbance favors the establishment of Scotch thistle. Biennial species including most thistles benefit from disturbance which provides "safe sites" for establishment (van der Meijden et al. 1992). Also see question 1.1. Numerous stream environments where human or natural flood activity has disturbed riparian soil are colonized in Arizona at elevations above 4000 feet (F. Northam, personal observation, 2005).
Sources of information: See cited literature. Also considered personal observations of F. Northam while serving as the Arizona Department of Agriculture, Noxious Weed Program Coordinator during 2000−2003 (Weed Biologist, Tempe, Arizona, 2005).

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**
Describe rate of spread: Moderate depending on disturbance frequency.
Rationale: No published rates of spread were found; however, observational information provided for the Prineville District, Bureau of Land Management (Julian and Rife Undated) indicates the potential to spread is high. Local spread in northern Arizona in the recent past has been clearly observable (D. Crisp, personal observation, 2004). Intense flooding as occurred during the winter of 2004−2005, or activities such as constructing stream crossings, mining sand/gravel, trampling riparian vegetation by livestock grazing or recreational vehicle traffic can create sites where *O. acanthium* will readily colonize (F. Northam, personal observation, 2005).
Sources of information: See cited literature. Also considered personal observations of F. Northam while serving as the Arizona Department of Agriculture, Noxious Weed Program Coordinator during 2000−2003 (Weed Biologist, Tempe, Arizona, 2005) and D. Crisp (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2004) and information from J. Julian and J. Rife. Undated. Integrated weed management of Scotch Thistle. Douglas County Cooperative Extension, Castle Rock, Colorado. Available online at: http://www.douglas.co.us/DC/PublicWorks/Weeds/scotch_thistle.htm; accessed March 16, 2005.

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**
Describe trend: Numerous locations of Scotch thistle documented in the northern half of the state (CAIN 2005, SEINet 2005).
Rationale: Scotch thistle occupies many disturbed areas along roadways, vacant lots, and other disturbed areas in northern Arizona, but the statewide trend in wildlands has not been documented. Three specimens, however, included within Arizona herbaria records were collected from streamside sites between 1961 and 2000 (SEINet 2005). Also see observations reported in questions 2.1 and 2.2. Based on inference based on the assumed continuance of natural flood disturbances, plus continuance of human alteration of riparian areas at elevations of 4,000 to 8,000 feet, it is concluded that Scotch thistle populations are increasing. It cannot be assumed, however, that the rate is doubling each year; as a result, a rating of "increasing but less rapidly than doubling in total range in <10 years" is assigned.
Sources of information: [CAIN] California Information Node, CRISIS Maps accessed through Southwest Exotic Plant Information Clearinghouse (available online at: http://www.usgs.nau.edu/SWEPIC/swemp/maps.html; accessed 2005). Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2005). Score based on inference drawn from observations.

Question 2.4 Innate reproductive potential *Score:* **B** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: Reproduction is solely from seed and is a monocarpic biennial. Individual plants reproduce only once during a lifetime. No information was found that indicates this species reproduces vegetatively or by apomixis.
Rationale: Scotch thistle reproduces solely from seed (Beck 1999). Emergence of *Onopordum acanthium* from seeds is variable and complex and depends on factors including photoperiod, soil, genetics and depth of burial. The seeds have an impermeable seed coat that must be dissolved by water before germination can occur. The thickness of the seed coat is also thought to be genetically controlled (Qaderi et al. 2002). Seed longevity in the seed bank is affected by depth of burial; seeds buried at 3 cm or deeper can remain viable for several years (Qaderi et al. 2002). Young and Evans (1969) reported Scotch thistle produced 110 to 140 seeds per head and plants produced 70 to 310 heads/plant; however, similar levels seed production has not been documented in Arizona.
Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Water, wind, livestock and human activities disperse Scotch thistle seed (Beck 1999).
Rationale: Recreational vehicles, gravel trucks, livestock fur and hunting/fishing/hiking activities provide numerous opportunities for transporting scotch thistle seed. Local dispersal may be from seeds dispersed by vehicles, by contaminated seed or hay, or by water (D. Crisp, personal observation, 2004).
Sources of information: See cited literature. Also considered personal observations of D. Crisp (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2004).

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Long distance dispersal may occur via attachment to animal fur.
Rationale: Seeds are equipped with pappi, specialized attachments that provide occasional opportunity for dispersal in the fur of livestock (Parsons 1973). Based on this information it is inferred that Arizona wildlife can transport seed <1 km; however, no information was found indicating wildlife graze this plant. Furthermore, *O. acanthium* plants are so uncomfortable because of their spines that animals will not walk through dense populations (Stubbendieck et al. 1994). Even though the potential exists for long distance animal dispersal, it is most likely an infrequent occurrence.
Sources of information: See cited literature. Score based on inference drawn from the literature.

Question 2.7 Other regions invaded *Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: *Onopordum acanthium* populations have been detected in 39 of the 48 contiguous states of the U.S. (USDA 2005). In Utah, *O. acanthium* invades sagebrush (*Artemisia* spp.) ecological types that are similar to Great Basin desertscrub in Arizona. In addition, Utah has native plant communities invaded by *O. acanthium* at elevations of 3700 to 7000 feet that includes an ecological type similar to southwestern interior chaparral scrub in Arizona (Welsh et al. 1993). Both Great Basin desertscrub and southwestern interior chaparral scrub are not yet invaded by *O. acanthium* in Arizona. *Onopordum acanthium* occurs in the Australian states of Victoria, New South Wales, and Tasmania in regions with 20 to 35 inches of rainfall per year (Parsons 1973).
Rationale: Two major and two minor Arizona ecological types do not have *Onopordum acanthium* populations, but similar areas elsewhere in North America do have wildlands with established populations of Scotch thistle.
Sources of information: See cited literature.

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Five major ecological types and six minor types—plains and Great Basin shrub-grassland, montane wetlands, montane riparian, Great Basin conifer woodland, Madrean evergreen woodland, and montane conifer forest— are known to have *O. acanthium* populations in wildlands. Most of the herbarium specimens, however, are from roadside rights-of-way.
Rationale: The oldest Arizona herbarium record for *O. acanthium* was collected in 1961 and the second one was in 1976 (SEINet 2005). Nineteen additional specimens were deposited in Arizona herbaria between 1986 and 2000, but only three were from wildland sites. Additional evidence of ecological amplitude was obtained from field observations (D. Crisp, personal observation, 2004; F. Northam, personal observation, 2005).
Sources of information: SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2005). Also considered personal observations of F. Northam while serving as the Arizona Department of Agriculture, Noxious Weed Program Coordinator during 2000–2003 (Weed Biologist, Tempe, Arizona, 2005) and D. Crisp (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2004).

Question 3.2 Distribution *Score:* **C** *Doc'n Level:* **Obs.**
Describe distribution: Populations have been observed in six minor Arizona ecological types (see question 3.1 and Worksheet B). Within all ecological types infested, the degree of Scotch thistle occurrence frequency is in all cases less than 20%.
Rationale: Observed in disturbed areas in Ponderosa pine forests and pinyon-juniper woodlands, along the Rio de Flag drainage in Flagstaff (D. Crisp, personal observation, 2004), and around at least one spring in the Stoneman Lake area (Lutz 1997). Herbarium specimen locations from Granite Creek in Prescott and in plains and Great Basin shrub-grassland in northwest Mohave County (Arizona Strip) are available in SEINet (2005). Current distribution data indicate seed sources are available in disturbed areas through out Arizona ecological types above 4500 feet. New Scotch thistle populations are likely to encroach into future road construction sites, fire abatement trails, pipeline scars, landscaped camp grounds/recreational areas, military operations, etc in lands presently dominated with native plant vegetation. As a result, the currently limited distribution of Scotch thistle has the potential to increase.
Sources of information: SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2005). Also considered personal observations of D. Crisp (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2004) and information from D. Lutz. 1997. Noxious Weed Survey, Coconino National Forest. Unpublished document on file at Supervisor's Office, Coconino National Forest, Flagstaff, Arizona.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**[No]**	**1 pt.**
	Total pts: 4 Total unknowns: 2		
	Score : B		

Note any related traits: No data were found on pollination mechanisms for Scotch thistle. Heslop-Harrison (1978) stated that members of the family Asteraceae have a genetically controlled system that makes the plants self incompatible; however, self-pollination has been documented in bull thistle (*Cirsium vulgare*) (van Leeuwen 1981).

Populations are assumed to be cohorts so all plants in the population would produce seed within the same years, as opposed to continual reproduction as in a perennial plant**.**

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	**D**
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	**C**
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	**C**
Woodlands	Great Basin conifer woodland	**C**
	Madrean evergreen woodland	**D**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	**C**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Beck, K.G. 1999. Biennial thistles. Pages 145−161 in R.L. Sheley and J.K. Petroff (eds.), Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Heslop-Harrison, J. 1978. Cellular Recognition Systems in Plants: Studies in Biology No. 100. University of Baltimore Press. 60 p.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Parsons, W.T. 1973. Noxious Weeds of Victoria. Inkata Press, Melbourne, Australia.

Qaderi, M.M., P.B. Cavers, and M.A. Bernards. 2002. Seed bank dynamics of *Onopordum acanthium*: emergence patterns and chemical attributes. Journal of Ecology 90:672−683.

Staphanian, M.A., S.D. Sundberg, G.A. Baumgardner, and A. Liston. 1998. Alien plant species composition and associations with anthropogenic disturbance in North American forests. Plant Ecology 139:49−62.

Stubbendieck, J., G.Y. Friisoe, and M.R. Bolick. 1994. Weeds of Nebraska and the Great Plains. Nebraska Department of Agriculture, Lincoln.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

van der Meijden, E., P.G.L. Klinkhamer, T.J. de Jong, and C.A.M. Van Wijk. 1992. Meta-population dynamics of biennial plants: how to exploit temporary habitats. Acta Botanica Neerlandica 41:249−270.

van Leeuwen, B.H. 1981. The role of pollination in the population biology of the monocarpic species *Cirsium palustre* and Cirsium vulgare. Oecologia 51:28−32.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Welsh, S.L., N.D. Atwood, S. Goodrich, and L. Higgins. 1993. A Utah Flora. Brigham Young University, Provo, Utah. 242 p.

Young, J.A., and R.A. Evans. 1969. Control and ecological studies of Scotch thistle. Weed Science 17:60−63.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Panicum antidotale* Retz. (USDA 2005)
Synonyms:	None identified in USDA (2005).
Common names:	Blue panicum, blue panic grass, blue panic, Blue panicum, giant panic, perennial Sudan grass
Evaluation date (mm/dd/yy)**:**	05/21/04
Evaluator #1 Name/Title:	Patty Guertin / Research Specialist
Affiliation:	USGS / Sonoran Desert Field Station
Phone numbers:	(520) 670–6885; (520) 621–1174
Email address:	pguertin@nexus.srnr.arizona.edu
Address:	USGS / Sonoran Desert Field Station, University of Arizona, 125 Biological Sciences East, Tucson, Arizona 85721
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	05/21/04: D. Backer, K. Brown, D. Casper, G. Ferguson, D. Foster, P. Guertin, J. Hall, C. Laws, D. Madison, F. Northam, J. Ward 07/16/04: D. Backer, J. Hall, G. Ferguson, C. Laws, M. Van Glider, P. Warren
Committee review date:	05/21/04 and 07/16/04
List date:	07/16/04
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**C**	Observational	**"Impact"** **Section 1 Score:** **C**	**"Plant Score"** **Overall Score:** **Low** **Alert Status:** **None**
1.2	Impact on plant community	**C**	Observational		
1.3	Impact on higher trophic levels	**D**	Observational		
1.4	Impact on genetic integrity	**U**	No information		
2.1	Role of anthropogenic and natural disturbance	**C**	Reviewed scientific publication	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **10 pts** **Section 2 Score:** **C**	
2.2	Local rate of spread with no management	**D**	Observational		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**C**	Other published material		
2.6	Potential for natural long-distance dispersal	**C**	Other published material		
2.7	Other regions invaded	**B**	Other published material		Information you should know.
3.1	Ecological amplitude	**B**	Other published material	**"Distribution"** **Section 3 Score:** **C**	
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **C** *Doc'n Level:* **Obs.**

Identify ecosystem processes impacted: May impact soil water content, nutrient cycling, and light availability. At present in Arizona, abiotic impact is limited as this plant is no longer actively promoted and cannot seemingly survive unless acquiring supplemental water. It was historically promoted for wind erosion control.

Rationale: *Panicum antidotale* is a tall (5 to 7 feet tall), sometimes highly branched, sod-forming grass having both rhizomes and fibrous roots. The fibrous roots can reach depths of 18 inches (46 cm), potentially harvesting deep soil water (Skerman and Riveros 1990, Ruyle and Young 1997, CDFA 2002). *Panicum antidotale*'s ability to form dense stands with deep roots creates the potential depletion of resources on a site: light, water, nutrients. A potential exists for this plant to negatively impact the soil water table of a site, deplete nutrients from the soil, and/or shade an otherwise sunny and open site with its tall stature.

When it was used commercially in Arizona, *P. antidotale* was used primarily as a pasture grass. This mostly occurred during the 1950 to 1970s (B. Munda, personal communication, 2004). In parts of the United States is it planted to control wind erosion. At present it is no longer promoted in Arizona as a pasture grass and has only a scattered presence in Arizona (B. Munda, F. Northham, and D. Robinett, personal communications, 2004). Bruce Munda and Dan Robinett (personal communications, 2004) report that they have not observed this plant spreading from where it is planted other than a few isolated stands along river drainages. It can only seemingly be successful if the location gets supplemental water; they report that this is rare.

Although *P. antidotale* is reported to survive fire and send up new shoots, no information could be found about its potential for carrying fire. Given that *P. antidotale* is presently rare in this state, this does not seem to be a problem.

Sources of information: See cited literature. Also considered personal communications with B. Munda (Plant Resource Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Material Center, Tucson, Arizona, 2004), F. Northam (Weed Biologist [former Arizona Department of Agriculture Noxious Weed Coordinator], Tempe, Arizona, 2004), and D. Robinett (Rangeland Management Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Tucson, Arizona, 2004). Score based on inference drawn from the literature and observations.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **C** *Doc'n Level:* **Obs.**

Identify type of impact or alteration: *Panicum antidotale* has the ability to displace native plant species in some habitats in Arizona.

Rationale: Marshall et al. (2000) report that *P. antidotale* competes with and displaces native plant species (this information is anecdotal, based on expert opinion, for Arizona, with no studies to document this impact). As stated in question 1.1, *P. antidotale*'s ability to form dense stands with deep roots creates the potential depletion of resources on a site (light, water, nutrients) with the potential outcome the taking over habitat for native species and competition.

Panicum antidotale has the potential to change the innate structure of a plant community. In some of the places it occurs it is a larger plant than many of Arizona's native species and it is sod-forming, forming small to large patches (with its rhizomes and extensive roots). It has been observed to form small patches, to the exclusion of other species, in the depressions where water collects in desert scrub; these water-collecting microsites often support (in similar situations) hardier individuals of

species of the surrounding vegetation or a variety of species differing from the surrounding flora, increasing species diversity.
Sources of information: See cited literature. Score based on inference drawn from the literature and observations.

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Likely changes in food resources and habitat structure. Impact likely severe for desert specialists that are infrequent in grasslands (e.g., desert tortoises and some lizards), which will probably suffer the greatest impact due to a conversion from desert to grassland.
Rationale: *Panicum antidotale* was brought into the United States as a range species for cattle and is reportedly toxic at late flowering stage when it accumulates large amounts of oxalic acid (causing kidney disorders; FAO website). A report by the Tucson Plant Materials Center (Undated) indicates that *P. antidotale* is used by antelope and California jackrabbits. It is unknown if it is palatable to other wildlife or if its toxic properties impact wildlife. In addition, *P. antidotale*'s stature and sod-forming properties could potentially impact smaller fauna if the patches were sufficiently large. In Arizona, however, *P. antidotale* is seemingly present in small patches in limited localities. Tucson Plant Materials Center (Undated) also reports that the seeds of *P. antidotale* are used by upland game birds (doves), song birds (horned lark, pyrrhuloxia), and sparrows.
Sources of information: See cited literature. Also considered information from the Food and Agriculture Organization (FAO) of the United Nations, Animal Feed Resources Information System for *Panicum antidotale*. Available online at: http://www.fao.org/ag/aga/AGAP/FRG/afris/Data/119.htm. Score based on inference drawn from the literature and observations.

Question 1.4 Impact on genetic integrity *Score:* **U** *Doc'n Level:* **No info**.
Identify impacts: Unknown.
Rationale: Native species within the genus *Panicum* do occur in Arizona (Kearney and Peebles 1960). Although reports on research for cross-species pollination and potential hybridization occur, no literature was found that specifically addresses the potential for hybridization between *P. antidotale* and Arizona's native panicums.
Sources of information: See cited literature. No information regarding the potential for hybridization with native panicums.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **C** *Doc'n Level:* **Rev. sci. pub.**
Describe role of disturbance: *Panicum antidotale* seems to benefit from anthropomorphic disturbance in Arizona (it requires planting/seeding), though in limited situations it can establish minimally with natural disturbance. Available water seems to be an important and a major limiting factor under all situations.
Rationale: Dan Robinett and B. Munda (personal communications, 2004) have observed that once *P. antidotale* is planted, it seems to 'stay in place'; where it persists following planting for forage, it is observed to have little to no spread. Dan Robinett (personal communication, 2004) has observed that it seemingly spreads only when it can acquire additional water, albeit, minimally; he has observed this in the stormwater drains and washes within the Tucson city area. Winkel and Roundy (1991) report that during a three-year trial measuring emergence of seeded plots treated with varying types of disturbance on the east slopes of the Baboquivari mountains southwest of Tucson, *P. antidotale* (type A-130) had comparatively little emergence on undisturbed (though all

competitive plants were removed with chemicals or cutting) to lightly trampled plots, moderate emergence on root-plowed plots (seeded immediately after treatment), and high emergence on heavily trampled plots during the wet year of 1987. Although 1988 was drier and 1989 even drier still, emergence was lower but the general pattern was similar on disturbed versus undisturbed plots. Interestingly, in the drier years, *P. antidotale* consistently emerged on the undisturbed plots in approximately the same frequencies as the wet year. They also noted that the slightly longer period of soil water availability in the wet year accompanied by seed burial during disturbance may explain the higher seedling emergence during a wet year.
Sources of information: See cited literature. Also considered personal communications with B. Munda (Plant Resource Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Material Center, Tucson, Arizona, 2004) and D. Robinett (Rangeland Management Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Tucson, Arizona, 2004).

Question 2.2 Local rate of spread with no management *Score:* **D** *Doc'n Level:* **Obs.**
Describe rate of spread: *Panicum antidotale* seems to have a limited, low rate of spread with no management. Available water seems to be an important factor regulating this species' spread.
Rationale: Skerman and Riveros (1990) note that *P. antidotale* has a slow spread rate from fallen seed in natural situations. During the 1950s to the 1970s, *P. antidotale* was planted and promoted for cattle forage on rangelands in Arizona. Dan Robinett and B. Munda (personal communications, 2004) have observed that *P. antidotale* seems to 'stay in place' where it persists following planting for forage, with little to no spread. In addition, D. Robinett has observed that it seemingly spreads only when it can acquire additional water, albeit, minimally. He has observed this in the stormwater drains and washes within the Tucson city area (D. Robinett, personal communication, 2004). *Panicum antidotale* has been planted at a few localities in southern Arizona along floodplains and washes where it now persists in a few scattered stands. In many areas outside Tucson, D. Robinett (personal communication, 2004) has observed that *P. antidotale* has died out when no longer used for pasture and once the irrigation was removed. On the east slope of the Huachuca Mountains it was planted in the late 1970s during wet years on root-plowed mesquite areas, where it established and still persists, but hasn't spread "one inch" outside of the root-plowed strips (D. Robinett, personal communication, 2004).
Sources of information: See cited literature. Also considered personal communications with B. Munda (Plant Resource Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Material Center, Tucson, Arizona, 2004) and D. Robinett (Rangeland Management Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Tucson, Arizona, 2004).

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**
Describe trend: Minimally increasing.
Rationale See questions 2.1 and 2.2. Given that *P. antidotale* was planted during the 1950s to 1970s in Arizona, and has been observed to die out, generally, in those areas when additional water was removed, it seemingly is declining in total area. It must be noted, however, that it more recently has established a small presence in Organ Pipe Cactus National Monument in Sonoran desertscrub, in low areas that collect water along the international border (Guertin and Halvorson 2003; D. Casper, personal communication, 2004). *Panicum antidotale* tended to be planted in uplands and floodplains within the state, where it seems to have declined in total area.
Sources of information: See cited literature. The Guertin and Halvorson (2003) citation reflects P. Guertin's observation during a U.S. Geological Survey mapping project for non-native plants on the Pipe Cactus National Monument. Also considered a personal communication with D. Casper (Biological Technician, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 2004).

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: *Panicum antidotale* has seeds possessing dormancy characteristics and long-term viability. It also has rhizomes, with the potential to reproduce vegetatively.
Rationale: *Panicum antidotale* reproduces both by seeds produced sexually and vegetatively by its rhizomes (Skerman and Riveros 1990, CDFA 2002). Up to two years following *P. antidotale* seed maturation, maximum germination can occur. At 5 to 8 years, 80% germination can be reached, at 11 years 25% germination can be reached, and at 13 years 3% germination can be reached (Myers 1940 cited in the FAO website, Skerman and Riveros 1990). When kept under dry storage *P. antidotale* seed had germination percentages of 82.33±6.24 and 83.33±4.26 at one and two years, respectively, 69.33±3l.2% at three years, 37.33±2.94% at four years, and 19±2.74% at six years (Parihar and Rai 1985). Barrow and Havstad (1995 in Simonin 2000) note that in a seeding trial in the northern Chihuahuan Desert, *P. antidotale* seed survived cattle grazing, passing through cattle guts and subsequently germinating successfully.
Sources of information: See cited literature. Also considered information from the Food and Agriculture Organization (FAO) of the United Nations website for *Panicum antidotale* Retz. Available online at: http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPC/doc/GBASE/Data/pf000275.htm.

Question 2.5 Potential for human-caused dispersal *Score:* **C** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Because *P. antidotale* is occasionally used for livestock feed and soil stabilization but has declined notably in use in Arizona, it is limited in potential for dispersal in this state.
Rationale: *Panicum antidotale* can be dispersed with human activities, as a contaminant in seed or hay (GRIN 2000, CDFA 2002). It was brought into Arizona as an experimental feed. Seed can also survive and successfully germinate following ingestion and excretion by cattle (Barrow and Havstad 1995 in Simonin 2000). In research in New Mexico, it has experimentally been placed in gelatin capsules for spread by cattle through ingestion and subsequent dispersion for germination and establishment. Yet as noted previously, *P. antidotale* has been decreasing primarily because its use for cattle forage has not been promoted since the 1970s (B. Munda, personal communication, 2004)
Sources of information: See cited literature. Also considered personal communications with B. Munda (Plant Resource Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center, Tucson, Arizona, 2004).

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Other pub**.
Identify dispersal mechanisms: *Panicum antidotale* can be dispersed long distances by soil movement, water, animals, or wind.
Rationale: *Panicum antidotale* can supposedly be dispersed at great distances by soil movement, water, animals, or wind, yet no specific distance estimations were stated in the literature (GRIN 2000, CDFA 2002). As stated in question 1.3, Tucson Plant Materials Center (Undated) reports that *P. antidotale* is used by antelope and California jackrabbits, upland game birds (doves), song birds (horned lark, pyrrhuloxia), and sparrows. Barrow and Havstad (1995 in Simonin 2000) have noted that *P. antidotale* seeds survived cattle ingestion, with little subsequent loss in germination. Although no information was found, this may also apply to other faunal species.
Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: Mojave desert (Mojave desertscrub and in stabilized dunes) vegetation types in Utah and California; exists in Texas in unidentified vegetation types.

Rationale: *Panicum antidotale*'s native habitat is the sand dunes and dry river beds of northwest Pakistan, Afghanistan, and Iran; it is also a native of India and Yemen (Skerman and Riveros 1990, GRIN 2000).

In Utah it has been noted in a creosotebush-blackbrush community (Mojave desertscrub) and in the stabilized dunes south of Ivins (Welsh et al. 1993). Hickman (1993) has noted *P. antidotale* in the southern Mojave Desert, but no specific vegetation type was mentioned (e.g., desert riparian versus desertscrub). Hatch and Pluhar (1980) identify *P. antidotale* as occurring in Texas in the coastal bend, south Texas, south and west Central Texas, and north to the Panhandle border (no specific vegetation types noted). Roalson and Allred (1995) note the occurrence *P. antidotale* in New Mexico, but no associated vegetation type was identified.

Sources of information: See cited literature. See additional flora checklist table following Worksheet B.

Question 3.1 Ecological amplitude *Score:* **B** *Doc'n Level:* **Other pub.**

Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: *Panicum antidotale* was introduced into the United States from India, via Australia (Ruyle and Young 1997, CDFA 2002) in 1912 (Magness et al. 1971 in NewCROP 1999, Tucson Plant Materials Center Undated). Several accessions and selections have been released: A-130 from Australia, P-15630 from Afghanistan, and a Seedling Drought Tolerant (SDT; selected from type A-130) type (Wright and Dobrenz 1970 in Frasier et al. 1985, Tucson Plant Materials Center Undated, FAO website). A-130 was tested and released in 1950 by the Tucson Plant Materials Center (Undated).

Panicum antidotale is tolerant of salinity (Ryan et al. 1975 cited in the FAO website). Trew (1954 cited in FAO website) reports that *P. antidotale* grows best on fertile soils and well-drained soils. *Panicum antidotale* prefers heavy loams or dark clay soils high in lime (Trew 1954 cited in the FAO website). Field studies showed that *P. antidotale* seed emerged best from depths less than 0.47 inches (1.2 cm) (Winkel et al. 1991 in Roundy et al. 1993). *Panicum antidotale* emergence is seemingly more successful on the more disturbed sites, though available moisture also plays a part (Winkel and Roundy 1991). *Panicum antidotale* is well suited as a warm-season pasture grass in Arizona (Tucson Plant Materials Center Undated). It is best adapted to areas having summer rainfall and areas having annual precipitation totals between 19.7 to 29.5 inches (50 to 75 cm) or lands that are irrigated (FAO website). *Panicum antidotale* is not winter-hardy in northern locations (Magness et al. 1971 in NewCROP 1999) and does not tolerate extended periods of freezing temperatures elsewhere (CDFA 2002). *Panicum antidotale* prefers full sunlit sites and does not tolerate shade well (CDFA 2002, FAO website).

Rationale: See above and Worksheet B.

Sources of information: See cited literature citations. Also considered information from the Food and Agriculture Organization (FAO) of the United Nations website for *Panicum antidotale* Retz. Available online at: http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPC/doc/GBASE/Data/pf000275.htm. Score based on Working Group discussion and known distribution and extent.

Question 3.2 Distribution *Score:* **D** *Doc'n Level:* **Obs.**

Describe distribution: See question 3.1 and Worksheet B.

Rationale: In Arizona it seems to occur along our larger rivers in the southern part of the state, but needs additional water to persist; it has not been observed in sand dunes in the western part of our state, as in its native area. It was mostly planted in floodplains and uplands of Arizona (Sonoran desertscrub and semi-desert grassland), yet persists seemingly only on the floodplains in scattered patches except for one noted population on the east slope of the Huachuca Mountains (S. McLaughlin, B. Munda, and

D. Robinett, personal communications, 2004). Steve McLaughlin (personal communication, 2004) stated he observed *P. antidotale* in a rather large patch in the floodplain bordering the Santa Cruz River at the Canoa Ranch site. At this locale, the vegetation type has changed over the last 100 years because of disturbance on the landscape. The following represents information from various Natural Resources Conservation Service field offices as accessed by B. Munda (personal communication, 2004): San Carlos: small planting north of the town of San Carlos appears approximately 5 acres +/- was planted in the past. A few remnant plants remain from this old planting with the current stand still in rows and appears to be less than one acre now. Near Globe, by the drive-in theatre in a drainage way: +/- 2 acres. Safford: District Conservationist is not aware of any plantings. Douglas: small planting on Nimon Hopkins ranch east of Douglas. Site was started from one sprig and is in a dry sandy wash that receives flood waters. Planting probably done in the 60s or early 70s. The total area is small 0.05 acre or less. The available information seems to indicate that it has increased but not much. Elevation is 4000 feet. The area was grazed (may still be) and the grazing kept the plant(s) grazed down.
Sources of information: Personal communications with S. McLaughlin (Professor, Arid Lands Department, University of Arizona, Tucson, 2004), B. Munda (Plant Resource Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Material Center, Tucson, Arizona, 2004), and D. Robinett (Rangeland Management Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Tucson, Arizona, 2004). Score based on Working Group discussion and known distribution and extent.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**Yes** No 1 pt.
Dense infestations produce >1,000 viable seed per square meter	**Yes** No 2 pt.
Populations of this species produce seeds every year.	**Yes** No 1 pt.
Seed production sustained for 3 or more months within a population annually	Yes **No** 1 pt.
Seeds remain viable in soil for three or more years	**Yes** No 2 pt.
Viable seed produced with *both* self-pollination and cross-pollination	**Yes** No 1 pt.
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes** No 1 pt.
Fragments easily and fragments can become established elsewhere	Yes No 2 pt.
Resprouts readily when cut, grazed, or burned	**Yes** No 1 pt.
	Total pts: 9 Total unknowns: 1
	Score : A
Note any related traits:	

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	**D**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	**D** (planted)
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**D**
	southwestern interior riparian	**D**
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Table 1. Floral Checklist for *Panicum antidotale* Based on Surveys by Location

Location	Occurrence	Major Ecological Type	Minor Ecological Type
Gila River, just north of Navajo Point (Graham County) with riparian species, 2570 feet, Specimen 8489 collected by M. Baker (Arizona State University Herbarium catalogue record #182581).	Present	Non-Riparian Wetlands	Southwestern interior wetlands, surrounded by semi-desert grassland
Flora for the Santa Teresa Mountains (Graham County) (Buegge 1998).	Present	No information	No information
Bordering Santa Cruz at Canoa Ranch site (S. McLaughlin, Professor, Arid Lands Department, University of Arizona, Tucson, personal communication, 2004).	Present	No information	No information
Flora for the San Pedro National Conservation Area, Cochise County; (Flora of the San Pedro Riparian National Conservation Area: Cochise County, Arizona. Undated. Available online at: http://ls.la.asu.edu/herbarium/uppersanpedro/index.html).	Present	No information	No information
Found in Yavapai County at about 4000 feet (McDougal 1973).	Present	No information	No information
Plants of the West Branch of the Santa Cruz; scattered along the margin of the West Branch channel Mauz 2001).	Present	Riparian	Sonoran riparian, surrounded by semi-desert grassland
The following is developed from information available at http://seinet.asu.edu/bioExplorer/ChecklistChoices.jsp. The ecological types were described either within the context of the link or from other known information about specific locations.			
Buckeye Hills Recreational Area, Arizona	Not present	Desertlands	Sonoran desertscrub
Camp Creek, Arizona; Sonoran desert-chaparral transition	Not present	No information	No information
Canyon de Chelly, Arizona	Not present	Desertlands	Great Basin desertscrub
Castle Dome Mountains, Arizona	Not present	Desertlands	Sonoran desertscrub
Chiricahua National Monument	Not present	Forests/ Woodlands/ Grasslands	Montane conifer forest/ Madrean evergreen woodland/ Semi-desert grassland
Hassayampa River Preserve	Present	Riparian	Sonoran riparian
Lake Pleasant Regional Park, Arizona	Not present	Desertlands/ Freshwater Systems	Sonoran desertscrub/ lakes, ponds, reservoirs
McDowell Mountains Regional Park, Arizona	Not present	Desertlands	Sonoran desertscrub
Organ Pipe Cactus National Monument	Present	Desertlands	Sonoran desertscrub
Papago Park, Arizona	Not present	No information	No information
Phoenix Flora (wild plants)	Present	No information	No information

Table 1. Floral Checklist for *Panicum antidotale* Based on Surveys by Location—continued

Location	Occurrence	Major Ecological Type	Minor Ecological Type
Pinal Mountains	Not present	Woodlands/ Scrublands/ Forest	Great Basin conifer woodland and Madrean evergreen woodland/ southwestern interior chaparral scrub/ Montane Conifer Forest
San Tan Semi-Regional Park	Not present	Desertlands	Sonoran desertscrub
Seven Springs, Arizona	Not present	Desertlands/ Scrublands/ Grasslands/ Riparian	Sonoran desertscrub/ southwestern interior chaparral scrub/ semi-desert grassland/ Sonoran riparian
Sierra Ancha Wilderness Area, Arizona (Globe to Young)	Not present	No information	No information
Sierra Estrella Mountains Regional Park, Arizona	Not present	Desertlands	Sonoran desertscrub
South Mountain (south of Phoenix)	Not present	Desertlands	Sonoran desertscrub
Superstition Mountains Wilderness	Not present	Desertlands/ Scrublands/ Grasslands	Sonoran desertscrub/ southwestern interior chaparral scrub/ semi-desert grassland
Thunderbird Semi-Regional Park	Not present	No information	No information
Tonto National Forest; combined Camp Creek area (actually Rackensack Canyon), Pinal Mountains, Seven Springs Area, Sierra Ancha Wilderness Area, Superstition Wilderness Area, and Usery Mountain Park	Not present	No information	No information
Upper San Pedro River; St. David to Mexican border	Present	Riparian/ Grasslands	Southwestern interior riparian/ Semi-desert grassland
Usery Mountain Semi-Regional Park	Not present	No information	No information
West Fork of Oak Creek; northern section of the Red Rock / Secret Mt. Wilderness	Not present	Riparian/ Woodlands/ Forests	Southwestern interior riparian/ Great Basin conifer woodland and Madrean evergreen woodland/ Montane conifer forest
White Tank Mountains Regional Park	Not present	Desertlands	Sonoran desertscrub
Has been seeded in Pima, Pinal, Cochise, and Santa Cruz Counties (D. Robinett, Rangeland Management Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Tucson, Arizona, 2004, personal communication concerning *Panicum antidotale* and its presence in Arizona.	Present in Pima County and Cochise County	Desertlands (possibly Riparian)/ Grasslands	Sonoran Desert floodplains and drainages in Tucson (in the Altar Valley and Santa Cruz wash floodplains) and the Tohono O'odham Nation (Vamori, San Simon, and Santa Rosa wash floodplains): persists as scattered stands (this is either Sonoran desertscrub or Sonoran riparian or both). Grassland and mesquite on east slope of Fort Huachuca,

Table 1. Floral Checklist for *Panicum antidotale* Based on Surveys by Location—continued

Location	Occurrence	Major Ecological Type	Minor Ecological Type
It has not survived plantings in which irrigation was taken away in floodplains in Mammoth, Redington, Guevavi, and Tubac (2000 to 3500 feet).			approximately 4500 feet with mean annual precipitation of 15 inches on loamy and clayloam soils (semi-desert grassland). Urban: stormwater drains in Tucson.
Seeded in the Verde Valley in the 1970s (B. Munda, Plant Resource Specialist, U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center, Tucson, Arizona, 2004, personal communication concerning *Panicum antidotale* and its presence in Arizona).	Present	No information	No information
California (Hickman 1993)	Present	Desertlands	Mojave desertscrub and Sonoran desertscrub
New Mexico (Roalson and Allred. 1995)	Present	No information	No information
Texas (coastal bend, south Texas, south- and west-central Texas, north to Panhandle border; Hatch and 1980)	Present	No information	No information
Utah (Welsh et al. 1993)	Present	Desertlands/ Dunes	Creosotebush-blackbrush community (Mojave desertscrub) at 885 to 950 m (Washington County). Stabilized dunes, south of Ivins.

Literature Cited

Barrow, J.R., and K.M. Havstad. 1995. Natural methods of establishing native plants on arid rangelands. Pages 44−45 in B.A. Roundy, E.D. McArthur, J.S. Halley, and D.K. Mann (compilers), Proceedings: Wildland Shrub and Arid Land Restoration Symposium. October 19−21, 1993, Las Vegas, Nevada. General Technical Report INT-GTR-315. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah.

Buegge, J.J. 1998. Flora for the Santa Teresa Mountains in Graham County, Arizona. Journal of the Arizona -Nevada Academy of Science 33:132−149.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

[CDFA] California Department of Food and Agriculture. 2002. *Panicum* in E.A. Healy, S. Enloe, J.M. DiTomaso, B. Roberson, N. Dechoretz, S. Schoenig, P. Akers, L. Butler, and J. Garvin (eds.), EncycloWeedia. University of California, Non-Cropland Weed Group, University of California Extension Service, Weed Science Program, Department of Vegetable Crops, Davis. Available online at: http://pi.cdfa.ca.gov/weedinfo/panicum.htm.

Frasier, G.W., J.R. Cox, and D.A. Woolhiser. 1985. Emergence and survival response of seven grasses for six wet-dry sequences. Journal of Range Management 38:372−377.

[GRIN] Germplasm Resources Information Network. 2000. Grin Taxonomy. United States Department of Agriculture, Agricultural Research Service, Germplasm Resources Information Network (GRIN). Available online at: http://www.ars-grin.gov/npgs/tax/index.html; then click on 'simple queries of species data' and search for plant species.

Guertin, P. and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Hatch, S.L., and J. Pluhar. 1980. Texas Range Plants. Texas A&M University Press, College Station. 326 p.

Hickman, J.C. (ed.). 1993. The Jepson Manual: Higher Plants of California. University of California Press, Berkeley. 1400 p.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Magness, J.R., G.M. Markle, and C.C. Compton. 1971. Food and Feed Crops of the United States. Interregional Research Project IR-4, IR Bul. 1 (Bul. 828 New Jersey Agr. Expt. Sta.).

Marshall, R.M., S. Anderson, M. Batcher, P. Comer, S. Cornelius, R. Cox, A. Gondor, D. Gori, J. Humke, R. Paredes Aquilar, I.E. Parra, and S. Schwartz. 2000. An Ecological Analysis of Conservation Priorities in the Sonoran Desert Ecoregion. Prepared by The Nature Conservancy Arizona Chapter, Sonoran Institute, and Instituto del Medio Ambiente y el Desarrollo Sustentable del Estado de Sonora with support from the Department of Defense Legacy Program, agency, and Institutional partners. 146 p.

Mauz, K. 2001. Plants of the West Branch of the Santa Cruz. University of Arizona, Arid Lands Resource Sciences, Tucson, Arizona. Available online at: http://www.co.pima.az.us/cmo/sdcp/sdcp2/reports/WB/pflora.htm.

McDougall, W.B. 1973. Seed Plants of Northern Arizona. Museum of Northern Arizona, Flagstaff.

Myers, A. 1940. Longevity of seeds of native grasses. Agricultural Gazette NSW 51:405.

NewCROP. 1999. Introduced panicgrasses. Purdue University, Center for New Crops and Plants Products. Available online at: http://www.hort.purdue.edu/newcrop/Crops/Introduced_Panicgrasses.html.

Parihar, S.S., and P. Rai. 1985. Longevity and seed germination in range grasses. Indian Journal of Ecology 12:168−170.

Roalson, E.H., and K.W. Allred. 1995. A Working Index of New Mexico Vascular Plant Names. New Mexico Agr. Exp. Sta. Res. Rep. 702.

Roundy, B.A., V.K. Winkel, J.R. Cox, A.K. Dobrenz, and H. Tewolde. 1993. Sowing depth and soil water effects on seedling emergence and root morphology of three warm-season grasses. Agronomy Journal 85:975−982.

Ruyle, G.B., and D.J. Young (eds.). 1997. Arizona Range Grasses. Cooperative Extension Publication AZ97105. University of Arizona, College of Agriculture, Tucson. Available online at: http://ag.arizona.edu/pubs/natresources/az97105/.

Ryan, J., S. Miyamoto, and J.L. Stroehlein. 1975. Salt and specific ion effects on germination of four grasses. Journal of Range Management 28:61−64.

Simonin, K.A. 2000. *Bouteloua eriopoda*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/plants/graminoid/boueri/all.htm.

Skerman, P.J., and F. Riveros. 1990. Tropical grasses. Food and Agriculture Organization of the United Nations. Rome, Italy. 832 p.

Trew, E.M. 1954. Blue Panic Grass. Texas Agricultural Experiment Station Bulletin B-245.

Tucson Plant Materials Center. Undated. Management and uses of blue panicum, *Panicum antidotale*. U.S. Department of Agriculture, Natural Resources Conservation Service, Tucson Plant Materials Center, Tucson, Arizona. Publication ID# 3105.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native

Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Welsh, S.L., N.D. Atwood, S. Goodrich, and L.C. Higgins (eds.). 1993. A Utah Flora; 2nd edition. Brigham Young University, Provo, Utah. 891 p.

Winkel, V.K., and B.A. Roundy. 1991. Effect of cattle trampling and mechanical seedbed preparation on grass seedling emergence. Journal of Range Management 44:176−180.

Winkel, V.K., B.A. Roundy, and D.K. Blough. 1991. Effects of seedbed preparation and cattle trampling on burial of grass seeds. Journal of Range Management 44:171−175.

Wright, L.N., and A.K. Dobrenz. 1970. Water use in relation to management of blue panicgrass (*Panicum antidotale* Retz.). Journal of Range Management 23:193−196.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Pennisetum ciliare* (L.) Link (USDA 2005)
Synonyms:	*Cenchrus ciliaris* L. (USDA 2005)
Common names:	Buffelgrass
Evaluation date (mm/dd/yy)**:**	04/02/03
Evaluator #1 Name/Title:	Judy Ward
Affiliation:	USDA-ARS, Jornada Experimental Range
Phone numbers:	(505) 644–8363
Email address:	jward@nmsu.edu
Address:	MSC 3JER, NMSU Box 30003 Las Cruces, New Mexico 88003–8003
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	05/20/03: D. Backer, J. Brock, D. Casper, P. Guertin, J. Hall, R. Parades, S. Rutman, J. Ward 05/21/04: D. Backer, K. Brown, D. Casper, G. Ferguson, D. Foster, P. Guertin, J. Hall, C. Laws, D. Madison, F. Northam, J. Ward
Committee review date:	05/20/03 and 05/21/04
List date:	05/20/03; revised 05/21/04
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**A**	Reviewed scientific publication	**"Impact"** **Section 1 Score:** **A**	**"Plant Score"** **Overall Score:** **High** **Alert Status:** **None**
1.2	Impact on plant community	**A**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**A**	Observational		
1.4	Impact on genetic integrity	**D**	Reviewed scientific publication		
2.1	Role of anthropogenic and natural disturbance	**A**	Reviewed scientific publication	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **18 pts** **Section 2 Score:** **A**	
2.2	Local rate of spread with no management	**A**	Other published material		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Reviewed scientific publication		
2.6	Potential for natural long-distance dispersal	**B**	Other published material		
2.7	Other regions invaded	**B**	Observational		 Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Red Flag Annotation

At present *Pennisetum ciliare* is only occasionally observed in semi-desert grasslands and Chihuahuan desertscrub and has not been observed in southwestern interior chaparral scrub and Madrean evergreen woodland. Invasion into these "cooler" ecological types could increase or begin if the new cold-tolerant cultivar "Frio" is released into Arizona. Continued development of cold tolerance or drought tolerance in *P. ciliare* cultivars poses a significant ecological threat if such cultivars are released into Arizona wildlands.

Table 3. Documentation

Note: Levels of documentation were updated on September 5, 2003 by D. Backer and J. Ward after more explicit definitions of the levels of documentation were agreed upon by the Working Group. The assessment was revisited on May 21, 2004 to discuss addition of a Red Flag Annotation to reflect potential expansion of *Pennisetum ciliare*'s ecological amplitude in response to release of a cold-tolerant cultivar (Hussey and Burson 2005).

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify ecosystem processes impacted: Potentially dramatic changes in the fire regime by initiation of a positive feedback grass/fire cycle in ecotype without large frequent fires.
Rationale: Numerous authors (Felger 1990, Van Devender et al. 1997, Esque and Schwalbe 2000, Williams and Baruch 2000, Búrquez-Montijo et al. 2002) have concluded that continued buffelgrass expansion is likely to initiate a positive feedback grass/fire cycle (D'Antonio and Vitousek 1992) in the Arizona-upland subdivision of the Sonoran Desert, which will severely alter ecosystem function. Their conclusion is based on: (1) observations of a large increase in the amount and continuity of dead standing biomass in areas where buffelgrass has invaded (J. Ward, personal observations, 2001) in an ecosystem with naturally distinct vegetation patches and infrequent large fires (Schmid and Rogers 1988), (2) clear evidence that buffelgrass supports and benefits from fire (t' Mannetje et al. 1983, Lazarides et al. 1997) but the natives do not (McLaughlin and Bowers 1982), (3) general evidence that introduced African grasses increase the frequency and intensity of fires in the Americas (D'Antonio and Vitousek 1992) and specific evidence for buffelgrass in Sonora, Mexico (Búrquez-Montijo et al. 2002). However, although various lines of evidence support the likelihood of initiation of a buffelgrass/fire cycle in Arizona, it is yet to be clearly realized and documented without the confounding effects of human-caused initiations.
Sources of information: See cited literature. Also considered personal observations of J. Ward (U.S. Department of Agriculture, Agricultural Research Service, Jornada Experimental Range, observations of buffelgrass stands in Saguaro National Park, Arizona during field surveys from June to November 2001).

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: Development of a semi-continuous structural layer not previously present. Apparent reduction of native plant recruitment and displacement of shorter-lived perennials in dense stands.
Rationale: Buffelgrass establishes and forms dense stands in an ecotype that does not naturally support dense grass cover (Búrquez-Montijo et al. 2002). Casual observation indicates a lack of new recruits of long-lived species including Saguaros in dense buffelgrass patches in Saguaro National Park (J. Ward, personal observations, 2001). On rocky slopes of Tumamoc Hill, competes with brittlebush (*Encelia farinosa*) for shallow soil moisture; in stands of buffelgrass, brittlebush has not reestablished following a decline attributed to freezing (Burgess et al. 1991). In research on Tumamoc Hill near Tucson, A. Elits (personal communication, 2004) has found that buffelgrass is competing with palo verde trees. There is a negative impact on the palo verde trees but the factor is not known. "…not aware of any studies that specifically show that buffelgrass is displacing or outcompeting native plant without some type of disturbance [factor]."

Sources of information: See cited literature. Also considered personal observations of J. Ward (U.S. Department of Agriculture, Agricultural Research Service, Jornada Experimental Range, observations of buffelgrass stands in Saguaro National Park, Arizona during field surveys from June to November 2001) and personal communication with A. Elits (Graduate Student, Ecology and Evolutionary Biology, University of Arizona, Tucson, 2004).

Question 1.3 Impact on higher trophic levels *Score:* **A** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Likely changes in food resources and habitat structure. Impact likely severe for desert specialists that are infrequent in grasslands (e.g., desert tortoises and some lizards), which will probably suffer the greatest impact due to a conversion from desert to grassland.
Rationale: Changes in structure/cover alter predator/prey relationships as observed with desert iguana in Altar Valley following an increase in another introduced grass (*Bromus rubens* [red brome]) and increases in fire result in direct mortality above natural level as observed with desert tortoises in Saguaro National Park. Inferences based on observation.
Sources of information: Personal communication with C. Schwalbe (Research Scientist, U.S. Geological Survey and University of Arizona, Tucson, observations in Pima County, Arizona from 1978 to 2003).

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Rev. sci. pub.**
Identify impacts: None identified.
Rationale: Buffelgrass is apomictic and only rarely undergoes genetic recombination (Bashaw 1962). There are no closely allied native species in Arizona (Kearney and Peebles 1960).
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe role of disturbance: Buffelgrass is able to establish and spread in areas without known disturbance.
Rationale: Formal studies have not been conducted, but buffelgrass occurs in areas without apparent natural or human-caused disturbance in Sonora (Búrquez-Montijo et al. 2002, on Tumamoc Hill (Burgess et al. 1991), in Organ Pipe National Monument (Rutman and Dickson 2002) and in Saguaro National Park (unpublished non-native plant inventory data, 1997 to 2003).
Sources of information: See cited literature. Also considered unpublished inventory data from Saguaro National Park.

Question 2.2 Local rate of spread with no management *Score:* **A** *Doc'n Level:* **Other pub.**
Describe rate of spread: Increases rapidly, doubling in <10 years.
Rationale: Survey transects of Ironwood Forest National Monument northwest of Tucson indicate that buffelgrass expanded locally between 2001 and 2002 during a period of record low rainfall (Dimmitt 2003). Transects on Tumamoc Hill in 1983 reported buffelgrass presence (Burgess et al. 1991); these transects have not been reread (J. Bowers, personal communication, 2003). Arizona Department of Transportation records buffelgrass occurrences along roadsides (ADOT 2003); data or report not assessed by the evaluator. Numerous anecdotal reports of large rapid increases along roadsides. No experimental information on rate of spread was available.
Sources of information: See cited literature. Also considered presentation information by M. Dimmitt (Impact of recent weed invasions on desert ecosystems. Presentation at Arid Southwest Lands Habitat Restoration Conference, California Desert Managers Group, March 3–7, 2003. Proceedings accessible online at: http://www.dmg.gov/resto-pres/wed-15-dimmitt.pdf; accessed May 2003), personal communication with J. Bowers (U.S. Geological Survey, Desert Laboratory, Tucson, Arizona, 2003),

and information from the Arizona Department of Transportation (ADOT), Natural Resources, Noxious Weeds website (available online www.dot.state.az.us; accessed November 4, 2003).

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**
Describe trend: Increasing, but less rapidly than doubling in total area infested in <10 years.
Rationale Observations of large increases in the number and size of patches, particularly at the northern extent of their range. Arizona Department of Transportation survey information (see question 2.2) could potentially be used to begin to understand patterns relative to road corridors.
Sources of information: Arizona Department of Transportation (ADOT), Natural Resources, Noxious Weeds website (available online www.dot.state.az.us; accessed November 4, 2003) and personal communication with S. Rutman (Botanist, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 2003).

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: Apomictic perennial grass. Frequent and high seed production with high innate germination rate and short dormancy period.
Rationale: Buffelgrass is apomictic (Bashaw 1962, Highnight et al. 1991) and can produce seeds in first year and in response to both summer and winter precipitation in both urban and wildland areas in Pima County (J. Ward, personal observations, 2001). Common buffelgrass, the cultivar in southeastern Arizona, averaged 89 seeds per inflorescence and 357 inflorescences per plant in irrigated pastures in south Texas (Evers et al. 1969). Field studies have not been conducted, however, inflorescence production in Arizona appears to be much lower, perhaps 5 to 10% of this value (J. Ward, personal observations, 2001). When given optimal temperature and moisture, seeds collected from natural areas and stored in field conditions in Tucson displayed a germination rate of 20% after 2 months and from 35 to 85% after 11 months depending on location in the field (J. Ward, unpublished data, 2003).
Sources of information: See cited literature. Also considered personal observations of J. Ward (U.S. Department of Agriculture, Agricultural Research Service, Jornada Experimental Range, observations of buffelgrass stands in Saguaro National Park, Arizona during field surveys from June to November 2001) and unpublished data of J. Ward (ongoing work in Tucson, Arizona, 2003).

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Rev. sci pub.**
Identify dispersal mechanisms: Widely used for pasture development in Texas and Sonora, Mexico and used to stabilize mine tailings in southeastern Arizona. Dispersed along road corridors and foot trails via human traffic.
Rationale: Conservative estimates indicate that by 1988, 600,000 ha had been converted to buffelgrass pasture in Sonora and 700,000 ha in Texas (Hanselka 1988). In southeastern Arizona, buffelgrass is seeded to stabilize mine tailings. It is common along roadsides through desert regions of Arizona and locations of roadside patches are recorded by the Natural Resources division of Arizona Department of Transportation as part of their inventory for noxious weeds (ADOT 2003). Buffelgrass is common along migrant corridors from Mexico in Organ Pipe National Monument (Rutman and Dickson 2002).
Sources of information: See cited literature; also see Cox et al. 1988. Also considered information from the Arizona Department of Transportation (ADOT), Natural Resources, Noxious Weeds website (available online www.dot.state.az.us; accessed November 4, 2003).

Question 2.6 Potential for natural long-distance dispersal *Score:* **B** *Doc'n Level:* **Other pub**.
Identify dispersal mechanisms: Dispersed by wind and wildlife.
Rationale: Isolated patches of buffelgrass occur on relatively remote ridges away from human traffic in Saguaro National Park (unpublished non-native plant inventory data, 1997 to 2003). "The seeds' relatively high wing load encourages wind dispersal, and the barbed bristles loosely hook on skin, fur,

and moving vehicles" (Búrquez-Montijo et al. 2002:133). Evidence that buffelgrass travels long distances: buffelgrass found in San Manuel, along the San Pedro River and the closest population is in the Catalina Mountains north of Tucson (T. Van Devender, 2004, personal communication).
Sources of information: See cited literature. Also considered personal communication with T. Van Devender (Scientist, Arizona-Sonora Desert Museum, Tucson, Arizona, 2004) and unpublished inventory data from Saguaro National Park.

Question 2.7 Other regions invaded *Score:* **B** *Doc'n Level:* **Obs.**.
Identify other regions: Invades regions of the Chihuahuan Desert in Big Bend National Park (P. Guertin, personal communication, 2004). Observations of buffelgrass in the oak woodlands in Sonora (R. Paredes, personal communication, 2003).
Rationale: Buffelgrass has not been found in the Chihuahuan Desert nor the oak woodland of Arizona. This discrepancy is potentially due to cold intolerance (Cox et al. 1988) as the Chihuahuan Desert in Big Bend and the oak woodland in Sonora are warmer than in Arizona.
Sources of information: See cited literature. Also considered personal communications with P. Guertin (U.S. Geological Survey, Sonoran Desert Field Station, Tucson, Arizona, 2004) and R. Parades (Instituto del Medio Ambiente y el Desarrollo Sustentable del Estado de Sonora [IMADES], 2003).

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Buffelgrass observed in the semi-desert grassland, Sonoran riparian, and Sonoran desertscrub.
Rationale: Observations of buffelgrass have been made in the semi-desert grassland of the Catalina Mountains (D. Casper, personal communication, 2004) and the Sonoran riparian ecological type at Chimenea and Rincon Creek of Saguaro National Park (D. Foster, personal communication, 2004). However, it appears as if in Arizona, buffelgrass is only extensively invasive in the Sonoran Desert. Buffelgrass is not common above 1250 m in Saguaro National Park (unpublished non-native plant inventory data, 1997 to 2003). Higher altitude biomes appear to be too cold for buffelgrass. This status may potentially change due to release of new cold-tolerant varieties (Hussey and Burson 2005). Earliest record encountered for buffelgrass field trials in southeastern Arizona was 1941 (USDA, SCS unpublished data).
Sources of information: Personal communications with D. Casper (Biological Technician, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 2004) and D. Foster (Botanist, National Park Service, Saguaro National Park, 2004). Also considered unpublished inventory data from Saguaro National Park and unpublished establishment trial records of the United States Department of Agriculture, Soil Conservation Service (USDA, SCS), Tucson Plant Materials Center, Tucson, Arizona. The latter were accessed and reviewed by J. Ward in March 2001

Question 3.2 Distribution *Score:* **A** *Doc'n Level:* **Obs.**
Describe distribution: >50% of Sonoran Desert occurrences have buffelgrass.
Rationale: Observations of buffelgrass collectively reported by the committee members in most of the major Sonoran desert ranges. Found in Chihuahuan desertscrub and desert grasslands at 1127 to 1345 meters (T. Van Devender, personal communication, 2004)
Sources of information: Personal communication with T. Van Devender (Scientist, Arizona-Sonora Desert Museum, Tucson, Arizona, 2004) and the collective observations of Working Group members.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 7	**Total unknowns: 1**	
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	**D**
	Sonoran desertscrub	**A**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	**D**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**D**
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Bashaw, E.C. 1962. Apomixis and sexuality in buffelgrass. Crop Science 2:412–415.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burgess, T.L., J.E. Bowers, and R.M. Turner. 1991. Exotic plants at the Desert Laboratory, Tucson, Arizona. Madroño 38:96–114.

Búrquez-Montijo, A., M.E. Miller, and A. Martínez-Yrízar. 2002. Mexican grasslands, thornscrub, and the transformation of the Sonoran Desert by invasive exotic buffelgrass (*Pennisetum ciliare*). Pages 126–146 in B. Tellman (ed.), Invasive Exotic Species in the Sonoran Region. The University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson.

Cox, J.R., M.H. Martin, F.A. Ibarra, J.H. Fourie, N.F.G. Rethman, and D.G. Wilcox. 1988. The influence of climate and soils on the distribution of four African grasses. Journal of Range Management 41:127–139.

D'Antonio, C.M., and P.M Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle and global change. Annual Review of Ecology and Systematics 23:63–87.

Esque, T.C., and C. Schwalbe. 2000. Non-native grasses and fire create double jeopardy. People, Land, and Water. Department of the Interior. Available online at: http://www.usgs.gov/invasive_species/plw/grassfire.html.

Evers, G.W., E.C. Holt, and E.C. Bashaw. 1969. Seed production characteristics and photoperiodic responses in buffelgrass, *Cenchrus ciliaris* L. Crop Science 9:309–310.

Felger, R.S. 1990. Non-Native plants of Organ Pipe Cactus National Monument, Arizona. Technical Report No. 31. U.S. Geological Survey, Cooperative Park Studies Unit, The University of Arizona and National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona. 93 p.

Hanselka, C.W. 1988. Buffelgrass—South Texas wonder grass. Rangelands 10:279–281.

Highnight, K.W., E.C. Bashaw, and M.A. Hussey. 1991. Cytological and morphological diversity of native apomictic buffelgrass, *Pennisetum ciliare* (L.) Link. Botanical Gazette 152:214–218.

Hussey, M.A., and B.L. Burson. 2005. Registration of 'Frio' buffelgrass. Crop. Sci. 45:411–412.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Lazarides, M., K. Cowley, and P. Hohnen. 1997. CSIRO Handbook of Australian Weeds. CSIRO, Australia.

McLaughlin, S.P., and J.E. Bowers. 1982. Effects of wildfire on a Sonoran Desert plant community. Ecology 63:246−248.

Rutman, S., and L. Dickson. 2002. Management of buffelgrass on Organ Pipe Cactus National Monument, Arizona. Pages 311−318 in B. Tellman (ed.), Invasive Exotic Species in the Sonoran Region. The University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson.

Schmid, M.K. and G.F. Rogers. 1988. Trends in Fire Occurrence in the Arizona Upland subdivision to the Sonoran Desert, 1955, to 1982. Southwestern Naturalist 33:437−444.

t' Mannetje, L., S.J. Cook, and J.H. Wildin. 1983. The effects of fire on a buffelgrass and Siratro pasture. Tropical Grasslands. 17:30−39.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Van Devender, T.R., R.S. Felger, and A. Burquez-M. 1997. Exotic plants in the Sonoran Desert region, Arizona and Sonora. 1997 Symposium Proceedings, California Exotic Pest Plant Council. Available online at: http://endangered.fws.gov/r/fr94547.html; accessed April 2003.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Williams, D.G., and Z. Baruch. 2000. African grass invasion in the Americas: ecosystem consequences and the role of ecophysiology. Biological Invasions 2:123−140.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Pennisetum setaceum* (Forsk.) Chiov. (USDA 2005)
Synonyms:	*Pennisetum ruppelii* Steud., *Phalaris setacea* Forsk. (USDA 2005)
Common names:	Fountain grass
Evaluation date (mm/dd/yy)**:**	07/10/03
Evaluator #1 Name/Title:	Dennis J. Casper/Biological Technician
Affiliation:	National Park Service, Organ Pipe Cactus National Monument
Phone numbers:	(520) 387–7661 ext. 7118
Email address:	Dennis_Casper@nps.gov
Address:	10 Organ Pipe Drive, Ajo, Arizona 85321–9626
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	07/10/03: D. Backer, C. Barclay, D. Casper, R. Haughey, R. Parades, S. Rutman, H. Schussman, J. Ward, P. Warren 09/19/03: D. Backer, C. Barclay, K. Brown, D. Casper, P. Guertin, F. Northam, R. Paredes, W. Sommers, J. Ward, P. Warren
Committee review date:	07/10/03 and 09/19/03
List date:	09/19/03
Re-evaluation date(s):	

Taxonomic Comment

Working Group considered the misnamed *Pennisetum setaceum* "Rubrum" or *P. setaceum* purple-type as a distinct species, *P. advena*, based on Wipff and Veldkamp (1999). Only *P. setaceum* is evaluated here. See **Red Flag Annotation** for additional details.

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**A**	Other published material	**"Impact"** **Section 1 Score:** **A**	**"Plant Score"** **Overall Score:** **High** **Alert Status:** **None**
1.2	Impact on plant community	**A**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**B**	Other published material		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**A**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **16 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Other published material		
2.6	Potential for natural long-distance dispersal	**B**	Observational		
2.7	Other regions invaded	**C**	Other published material		 Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **B**	
3.2	Distribution	**C**	Observational		

Red Flag Annotation

Although *Pennisetum setaceum* is established in a number of ecosystems/plant communities, it is not yet present in many individual occurrences of these types. Large areas of suitable wildland habitat still remain for this species to colonize. The misnamed *Pennisetum setaceum* "Rubrum" (with dark purplish foliage and purplish crimson spikes) or *P. setaceum* purple-type is actually a distinct species, *P. advena*.

Pennisetum advena is sold commercially in Arizona as an ornamental but reportedly does not reproduce reliably from seed and, as a result, was not evaluated.

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n level:* **Other pub**.

Identify ecosystem processes impacted: Increase in fire occurrence, frequency, and intensity.

Rationale: Fountain grass raises fuel loads, which increase the intensity and spread of fire (Benton 1997). Fire facilitates its spread (Smith and Tunison 1992 in Lovich 2000). This can set up a positive feedback loop in which fountain grass facilitates fire and fire facilitates fountain grass to the detriment of native ecosystem processes. This process has yet to be documented to any large extent with this species in Arizona. Once in desert grasslands or chaparral, where fire is part of the ecology, the presence of fountain grass is not as serious an ecological threat (T. Van Devender, personal communication, 2004).

Sources of information: See cited literature. Also considered personal communication with T. Van Devender (Botanist, Arizona-Sonora Desert Museum, Tucson, Arizona, 2004).

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n level:* **Rev. sci. pub**.

Identify type of impact or alteration: Formation of more or less monotypic stands; change in structure due to increase in fire frequency, occurrence, and intensity

Rationale: Potentially, it can form monospecific stands (Tunison 1992). *Pennisetum setaceum* is a highly aggressive colonizing plant that is fire-adapted and readily outcompetes its native plant neighbors (Benton 1997).

In Hawaii *P. setaceum* dominates areas that formerly supported native *Heteropogon contortus* grasslands (Williams and Black 1994). Fires that follow invasions by non-native grasses have the ability to change the structure of deserts (Esque and Schwalbe 2000).

Sources of information: See cited literature.

Question 1.3 Impact on higher trophic levels *Score:* **B** *Doc'n level:* **Other pub**.

Identify type of impact or alteration: Fire has a negative impact on ground nesting birds and terrestrial animals; also community change can occur over time displacing wildlife that depend on intact native community structure.

Rationale: Fires fueled by fountain grass impact ground-nesting birds and terrestrial animals (Lovich 2000). Losses of cactus, woody shrubs, and trees may eliminate both nesting substrate and protective cover (Esque and Schwalbe 2002). The results (of fires carried by non-native grasses) can be devastating and cause lasting changes in desert communities (Esque and Schwalbe 2000). Current impact on higher trophic levels due to *P. setaceum* in Arizona is moderate in most infested areas.

Few reviewed scientific publications exist on this subject. The impact to higher trophic levels without the disturbance of fire is not entirely clear, so the Working Group also considered inference. *Pennisetum setaceum* is not considered a palatable grass.

Sources of information: See cited literature. Working Group also considered inference in assigning a score.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n level:* **Other pub**.

Identify impacts: No known direct impact on native species genomes.

Rationale: There are no native congeners (Kearney and Peebles 1960). Simpson and Baker (1969) reported that a putative purple variety of *P. setaceum* could set seed as high as 18% following the

application of pollen from *P. ciliare* (buffelgrass). Viable seed was produced primarily from pseudogamous development of an aposporus purple *P. setaceum* egg; however some progenies were hybrids that resulted from a sexual cross (Simpson and Bashaw 1969). As discussed in the Taxonomic Comment following Table 1, Wipff and Veldkamp (1999) determined that the putative purple variety of *P. setaceum* is actually a distinct species, *P advena.* As a result, the above results have implications for the invasiveness of that species, but not for *P. setaceum*. The finding of Simpson and Baker (1969) that is of interest here is their conclusion "improvement" (that is, improved cold tolerance, uniformity, and fertility) of *P. setaceum* through a standard breeding program seemed unlikely.
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **A** *Doc'n level:* **Other pub**.
Describe role of disturbance: Anthropogenic and natural disturbance are important in the establishment of this species, but it can readily establish independent of any known disturbance.
Rationale: In the southwestern U.S.and northern Mexico, *P. setaceum* invades natural and disturbed environments (CDFA 2002). It is also found on disturbed sites, roadsides especially near urban areas, and in urban sites (Benton 1997). It often colonizes naturally disturbed riparian and xeroriparian corridors (D. Casper, personal observation, 2003). It has been observed colonizing remote areas without any known natural or human disturbance (S. Rutman, personal communication, 2003).
Sources of information: See cited literature. Also considered personal observations by D. Casper (Biological Technician, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 2003) and personal communication with S. Rutman (Botanist, National Park Service, Organ Pipe National Monument, Ajo, Arizona, 2003).

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n level:* **Obs**.
Describe rate of spread: Increases, but less rapidly than doubling in <10 years.
Rationale: *Pennisetum setaceum* is increasing in desert regions of the southwestern U.S. (CDFA 2002). *Pennisetum setaceum* is a highly aggressive colonizing plant that is fire-adapted and readily outcompetes its native plant neighbors (Benton 1997). Fountain grass has been found to have a higher photosynthetic rate, produce more total biomass, and to allocate more biomass to leaves compared to *Heteropogon contortus* and this may explain the success of *P. setaceum* as an invader of lowland arid areas on Hawaii (Williams and Black 1994).
Sources of information: See cited literature. Reviewed scientific publications on the local rate of spread of *P. setaceum* in Arizona were not available; as a result, the score was based on the consensus of the Working Group.

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n level:* **Obs**.
Describe trend: Increasing, but less rapidly than doubling in total area infested in <10 years.
Rationale: *Pennisetum setaceum* is increasing in desert regions of the southwestern U.S. (CDFA 2002). Fountain grass has colonized many disturbed habitats along roadways throughout the state (D. Casper, personal observations [Southern Arizona *Pennisetum* Survey], 2003). It is now invading many wildland areas throughout the southern half of the state.
Sources of information: See cited literature. Also considered personal observations by D. Casper (Biological Technician, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 2003) as part of the Southern Arizona *Pennisetum* Survey. As part of this survey, the observer is recording occurrences of the genus *Pennisetum* as he travels throughout southern Arizona. Digital images, herbarium specimens, and waypoints are collected, compiled, and incorporated into an ArcView project. Because no data currently are available on the trend in total area infested within the state, the score was based on the consensus of the Working Group.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n level:* **Rev. sci. pub**.
Describe key reproductive characteristics: High reproductive potential.
Rationale: Reaches maturity in first year, produces seed every year, seed production is sustained over three months per year (D. Casper, personal observation, 2003), seed remains viable in soil for more than six years (Benton 1997, CDFA 2002), viable seed is produced by selfing and crossing, seed production is primarily through apomixis (Simpson and Bashaw 1969), resprouts readily when burned (D'Antonio and Vitousek 1992, Smith and Tunison 1992 in Lovich 2000). See Worksheet A.
Sources of information: See cited literature. Also considered personal observations by D. Casper (Biological Technician, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 2003).

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n level:* **Other pub**.
Identify dispersal mechanisms: High potential for human-caused dispersal; fountain grass is planted as an ornamental, the seed is dispersed by vehicles, humans, and by livestock.
Rationale: Fountain grass has spread in large part because of its popularity as an ornamental plant (Neal and Seneac 1991 and Hammer 1996 in Lovitch 2000). Fountain grass is easily dispersed by vehicles, humans, and livestock (Cuddihy et al. 1988 in Lovitch 2000). Seed is sold commercially in Arizona (F. Northam, personal communication, 2003).
Sources of information: See cited literature. Also considered personal communication with F. Northam (Noxious Weed Coordinator, Arizona Department of Agriculture, 2003).

Question 2.6 Potential for natural long-distance dispersal *Score:* **B** *Doc'n level:* **Obs**.
Identify dispersal mechanisms: Natural dispersal agents include wind, water, and possibly birds. There is occasional long-distance dispersal.
Rationale: *Pennisetum setaceum* seeds are dispersed short distances by *wind* (Benton 1997, Jacobi and Warshauer 1992); (seeds are) dispersed by *wind*, *water*, and possibly *birds* (Tunison 1992). Dust devils and strong straight-line wind associated with thunderstorms have the potential to transport the light fluffy caryopsis a long distance (Working Group discussion).
Sources of information: See cited literature. Score based on inference from the literature and personal observations by Working Group members.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n level:* **Other pub**.
Identify other regions: Invades elsewhere but only in ecological types that it has already invaded in Arizona
Rationale: Regions invaded include southern half of coastal California, Sacramento-San Joaquin Delta, southern San Joaquin Valley-annual grassland, Mohave and Sonoran Desert Scrub in southern California and Nevada, southern New Mexico, and other communities in Texas, Hawaii, Louisiana, Florida, Tennessee, and Kentucky; also a pest species in Mexico, the Canary Islands, Fiji, and Australia (Lovich 2000, Medio Ambiente Canarias 1999). See Worksheet B.
Sources of information: See cited literature. Also considered information from Utah State University, developed as part of the *Manual of Grasses for North America* project. Available online at: http//www.herbarium.usu.edu/webmanual/info.asp?name=Pennisetum_setaceum&type=map.

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n level:* **Obs**.
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Occurs in Sonoran desertscrub, Sonoran riparian, and semi-desert grassland (D. Casper, personal observation, 2003), Mohave desertscrub (Longshore and Defalco 2001),

and Madrean evergreen woodland (D. Casper, personal observations [Southern Arizona *Pennisetum* Survey], 2003). Planted in Tucson in 1935 (Crider 1935).
Rationale: Occurs in four major ecological types and six minor ecological types (from Worksheet B). Upper elevation recorded is approximately 4800 feet on south facing slopes of Santa Catalina Mountains (specimen collected just below this elevation in Madrean evergreen woodland by R. Barr, No. 60-303, 1960 [SEINet 2003]). Serious threat in rocky canyons such as Sabino Canyon (Catalina Mountains) and King Canyon (Tucson Mountains) (T. Van Devender, personal communication, 2004).
Sources of information: See cited literature. Also considered personal observations by D. Casper (Biological Technician, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 2003) as part of the Southern Arizona *Pennisetum* Survey (see question 2.3 for additional details), personal communication with T. Van Devender (Botanist, Arizona-Sonora Desert Museum, Tucson, Arizona, 2004), SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2003), and observations throughout Arizona by Working Group members.

Question 3.2 Distribution *Score:* **C** *Doc'n level:* **Obs**.
Describe distribution: Although *P. setaceum* ranges widely within Sonoran desertscrub, it is most common in rocky xeroriparian areas; it also is fairly common in rocky Sonoran riparian areas (D. Casper, personal observations [Southern Arizona *Pennisetum* Survey], 2003; SEINet 2003). It is locally present in Mohave desertscrub (Longshore and Defalco 2001) and in semi-desert grassland and Madrean evergreen woodland (D. Casper, personal observations [Southern Arizona *Pennisetum* Survey], 2003; SEINet 2003). It is reported to be one of the most widely distributed invasive plants of the Sonoran Desert (Marler 2000). The species thrives along waterlines in reservoirs and along the Colorado River; it can occur as high as 1445 m along the Mount Lemmon Highway north of Tucson (SEINet 2003, T. Van Devender, personal communication, 2004).
Rationale: The highest percent infested score is **C** for Sonoran desertscrub and Sonoran riparian. Although *P. setaceum* is widespread throughout the Arizona Upland subdivision of the Sonoran Desert, it is only locally common, particularly in areas adjacent to development or near road corridors. Within Sonoran desertscrub it is also most commonly found in rocky xeroriparian communities. This species is less common in the Lower Colorado subdivision of the Sonoran Desert within Arizona. When taken as a whole the Working Group determined that >5% to 20% of type occurrences are invaded within both Sonoran desertscrub and Sonoran riparian. Although *P. setaceum* is established in a number of ecosystems/plant communities, it is not yet present in many individual occurrences of these types. The Working Group concluded that large areas of suitable wildland habitat still remain for this species to colonize.
Sources of information: See cited literature. Also considered personal observations by D. Casper (Biological Technician, National Park Service, Organ Pipe Cactus National Monument, Ajo, Arizona, 2003) as part of the Southern Arizona *Pennisetum* Survey (see question 2.3 for additional details), personal communication with T. Van Devender (Botanist, Arizona-Sonora Desert Museum, Tucson, Arizona, 2004), SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2003), and observations throughout Arizona by Working Group members.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**[No]**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 7	**Total unknowns: 0**	
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	**D**
	Chihuahuan desertscrub	
	Sonoran desertscrub	**C**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	**D**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**C**
	southwestern interior riparian	**D**
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	**D**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Benton, N. 1997. Fountain grass: *Pennisetum setaceum* (Forsk.) Chiov. Native Plant Conservation Initiative, Exotic Plant Working Group. Available online at: http://www.nature.nps.gov/npci/epwg/pese1.htm.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

[CDFA] California Department of Food and Agriculture. 2002. *Pennisetum*. In E.A. Healy, S. Enloe, J.M. DiTomaso, B. Roberson, N. Dechoretz, S. Schoenig, P. Akers, L. Butler, and J. Garvin (eds.), Encycloweedia. Non-Cropland Weed Group, University of California Extension Service, Weed Science Program, Department of Vegetable Crops The University of California, Davis. Available online at: http://pi.cdfa.ca.gov/weedinfo/PENNISET2.htm.

Crider, F.J. 1935. Annual Report of Southwestern Nurseries. U.S. Department of Agriculture, Soil Conservation Service, Tucson, Arizona (Identified as *Pennisetum orientale*).

Cuddihy, L.W., C.P. Stone, and J.T. Tunison. 1988. Alien plants and their management in Hawaii Volcanoes National Park . Transactions of the Western Section of the Wildlife Society. 24:42−46.

D'Antonio, C.M., and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63−87.

Esque, T., and C. Swalbe. 2000. Non-native Grasses and Fires Create Double Jeopardy. People, Land, and Water, July/August 2000. Available online at: http://www.usgs.gov/invasive_species/plw/grassfire.html.

Esque, T., and C. Swalbe. 2002. Alien Annual Grasses and Their Relationships to Fire and Biotic Change in Sonoran Desertscrub Pages 165−194 in B. Tellman (ed.), Invasive Exotic Species in the Sonoran Region. The University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson.

Hammer, R. 1996. Fountain grass: turn off the spigot! Newsletter of the Florida Exotic Pest Plant Council. 6:1.

Jacobi, J.D., and F.R. Warshauer. 1992. Distribution of six alien plant species in upland habitats on the island of Hawaii. Pages 155−188 in C.P. Stone, C.W. Smith, and J.T. Tunison (eds.), Alien Plant Invasions in Native Ecosystems of Hawaii: Management and Research. University of Hawaii Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Longshore, K., and L. DeFalco 2001. Invasive Potential of Fountaingrass (*Pennisetum setaceum*) in Lake Mead National Recreation Area, Nevada. Unpublished study plan. U.S. Geological Survey, Las Vegas Field Station.

Lovich, J.E. 2000. *Pennisetum setaceum* Forsskal. Pages 258–262 in C.C. Bossard, J.M. Randall, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Marler, M. 2000. A survey of exotic plants in federal wilderness areas. In D.N. Cole, S.F. McCool, W.T. Corrie, and J. O'Loughlin (compilers.), Wilderness Science in a Time of Change Conference, Volume 5: Wilderness, Ecosystems, Threats, and Management. May 23–27, 1999, Missoula, Montana. Proceedings RMRS-P-15-VOL-5. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Ogden, Utah.

Medio Ambiente Canarias. 1999. Eradication of *Pennisetum setaceum* on the Island of La Palma. Issue 15/1999. Available online at: http//www.gobiernodecanarias.org/medioambiente/eng/revista/1999/15/217/.

Neal, J.C., and A.F. Senesac. 1991. Preemergent herbicide safety in container-grown ornamental grasses. HortScience 26:157–159.

Simpson, C.E., and E.C. Bashaw. 1969. Cytology and reproductive characteristics in *Pennisetum setaceum*. American Journal of Botany 56:31–36.

Smith, C.W., and J.T. Tunison. 1992. Fire and alien plants in Hawai'i: research and management implication for native ecosystems. Pages 394–408 in C.P. Stone, C.W. Smith, and J.T. Tunison (eds.), Alien Plant Invasions in Native Ecosystems of Hawaii: Management and Research. University of Hawaii Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu.

Tunison, J.T. 1992. Fountain grass control in Hawaii Volcanoes National Park: management considerations and strategies. Pages 376–393 in C.P. Stone, C.W. Smith, and J.T. Tunison (eds.), Alien Plant Invasions in Native Ecosystems of Hawaii: Management and Research. University of Hawaii Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Williams, D.G., and R.A. Black. 1994. Drought response of a native and introduced Hawaiian grass. Oecologia 97:512–519.

Wipff, J.K., and J.F. Veldkamp. 1999. *Pennisetum advena* sp. nov. (Poaceae: Paniceae): a common ornamental grass throughout the southern United States. Sida 18:1031–1036.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Rhus lancea* L. f. (not listed in USDA 2005; authority from MBG 2005; also see Gibbs Russell et al. 1987)
Synonyms:	*Rhus viminalis* Aiton (MGB 2005)
Common names:	African sumac, bastard willow, common karee
Evaluation date (mm/dd/yy)**:**	11/21/03; revised 02/16/05
Evaluator #1 Name/Title:	John H. Brock, Professor, Applied Biological Sciences
Affiliation:	Arizona State University East
Phone numbers:	(480) 727–1240
Email address:	john.brock@asu.edu
Address:	7001 E. Williams Field Rd., Mesa, Arizona 85212
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	11/21/03: D. Backer, J. Brock, K. Brown, D. Casper, P. Guertin, M. Quinn, J. Ward, P. Warren 09/24/04: D. Backer, J. Brock, D. Casper, J. Cotton, R. de la Torre, J. Hall, K. Klementowski, H. Messing, B. Munda, F. Northam, J. Ward
Committee review date:	11/21/03 and 09/24/04
List date:	09/24/04; revised 02/16/05 in response to Consistency Review Panel comments
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**A**	Reviewed scientific publication	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **Alert**
1.2	Impact on plant community	**C**	Observational		
1.3	Impact on higher trophic levels	**C**	Observational		
1.4	Impact on genetic integrity	**U**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Observational	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **12 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**C**	Observational		
2.5	Potential for human-caused dispersal	**B**	Other published material		
2.6	Potential for natural long-distance dispersal	**A**	Observational		
2.7	Other regions invaded	**U**	No information		 Something you should know.
3.1	Ecological amplitude	**B**	Observational	**"Distribution"** **Section 3 Score:** **C**	
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify ecosystem processes impacted: Change in channel flow in streams, produces shade that inhibits growth of sun loving plants.
Rationale: Invades desert washes (Brock and Farkas 1997, Tellman 2002; P. Jenkins, personal communication, 2005) in which its physical presence could divert channel flows during times of peak storm flow (Stromberg 2001). Presence in channel may also enhance potentials for streambank erosion by directing water with more force into the bank.
Sources of information: See cited literature. Also considered personal communication with P. Jenkins (Senior Assistant Curator, Herbarium, University of Arizona, Tucson, Arizona, 2005).

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **C** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Through shading and physical presence, African sumac plants can restrict understory vegetation. Although African sumac could supply a canopy micro-site for annuals, some biologists believe the plant may produce allelopathic materials to neighboring plants (P. Jenkins, personal communication, 2005). Allelopathy is always difficult to substantiate and separate from direct competition. The result in any event would be lowered community diversity. May replace mesquite and paloverde in the desert landscape, but this would not change the physical structure of the plant community.
Rationale: Deep shade tends to crowd out natives. Competitive with native species (J. Brock, personal observations, 2004 and P. Jenkins, personal communication, 2005).
Sources of information: Personal observations by J. Brock (Professor, Applied Biological Science, Arizona State University, Phoenix, Arizona, Arizona, 2004), personal communication with P. Jenkins (Senior Assistant Curator, Herbarium, University of Arizona, Tucson, Arizona, 2005), and information from the Saguaro Juniper website (available online at: www.saguaro-juniper.com/i_and_i/invasive_spp/invasive_plants.html).

Question 1.3 Impact on higher trophic levels *Score:* **C** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: African sumac contributes little to higher tropic level life cycle needs except for an abundance of seeds that are used by birds for seed and perhaps javelina in wildland or urban fringe settings. Pollen of African sumac is highly allergenic to some individuals (Chambers and Hawkins 2002) and perhaps to other mammals.
Rationale: Where it establishes, it decreases the diversity of food web material for native species. African sumac produces pollen from late November into February when there is decreased activity by insect pollinators, hence providing little food materials to trophic levels utilized by insects (J. Brock, personal observations, 2004).
Sources of information: See cited literature. Also considered personal observations by J. Brock (Professor, Applied Biological Science, Arizona State University, Phoenix, Arizona, Arizona, 2004) and information from the Saguaro Juniper website (available online at: www.saguaro-juniper.com/i_and_i/invasive_spp/invasive_plants.html).

Question 1.4 Impact on genetic integrity *Score:* **U** *Doc'n Level:* **Other pub.**
Identify impacts: None known.
Rationale: There are native *Rhus* species in Arizona (Kearney and Peebles 1960). It is not known if non-native *Rhus* hybridizes with native *Rhus*.
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Obs.**

Describe role of disturbance: Humans began planting African sumac in Arizona in the late 1920s (see question 2.7). Humans have continued to spread this tree by direct planting. It is also spreading naturally through the action of birds, since seedlings are observed under nest or perching sites, and establishing without human action along stream channels (Tellman 2002; J. Brock, personal observations, 2004 and P. Jenkins, personal communication, 2005). For example, it has been found several miles from residential areas along Skunk Creek in Maricopa County and is observed to be moving along washes in Pima County.

Rationale: Humans are establishing African sumac by direct planting and now it is in the early stages of invading natural sites on its own.

Sources of information: See cited literature. Also considered personal observations by J. Brock (Professor, Applied Biological Science, Arizona State University, Phoenix, Arizona, Arizona, 2004) and personal communication with P. Jenkins (Senior Assistant Curator, Herbarium, University of Arizona, Tucson, Arizona, 2005).

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**

Describe rate of spread: Is spreading from urbanized/human settlements into desert habitats, especially along streams/washes and arroyos (Baker 1997). Spread is estimated to be 0.5 mile per year (J. Brock, personal observations, 2004). Phil Jenkins (personal communication, 2005) has observed that in 10 years this species has spread from the Tucson urban area into the Tucson Mountains and Saguaro National Park.

Rationale: Is being observed spreading in wildland settings adjacent to urban areas and downstream from Boyce Thompson Arboretum by Superior, Arizona.

Sources of information: See cited literature. Also considered personal observations by J. Brock (Professor, Applied Biological Science, Arizona State University, Phoenix, Arizona, Arizona, 2004) and personal communication with P. Jenkins (Senior Assistant Curator, Herbarium, University of Arizona, Tucson, Arizona, 2005).

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**

Describe trend: Invasion into wildlands is in its initial stages. Areas of urban desert lands (Baker 1997), plus several thousand acres in the urban fringes would describe its current extent of invasion.

Rationale: This plant seems to be emerging from its lag phase and has the potential to spread rapidly (consensus opinion by J. Brock, 2004 and P. Jenkins, 2005).

Sources of information: See cited literature. Also considered personal observations by J. Brock (Professor, Applied Biological Science, Arizona State University, Phoenix, Arizona, Arizona, 2004) and personal communication with P. Jenkins (Senior Assistant Curator, Herbarium, University of Arizona, Tucson, Arizona, 2005).

Question 2.4 Innate reproductive potential *Score:* **C** *Doc'n Level:* **Obs.**

Describe key reproductive characteristics: Relatively profilic seed producer and sprouts from basal stems and roots.

Rationale: African sumac was the second most invasive plant, after Bermudagrass (*Cynodon dactylon*), in a "plants-out-of-place" survey conducted as a field laboratory on the Arizona State University, Tempe Campus, by students in a landscape architecture course (PLA 240) in the fall of 2003 (J. Brock, personal observations, 2004). African sumac is now commonly seen growing with other horticultural plantings in urban areas indicating a high reproductive potential. See Worksheet A.

Sources of information: See cited literature. Also considered personal observations by J. Brock (Professor, Applied Biological Science, Arizona State University, Phoenix, Arizona, Arizona, 2004) and

information from the Saguaro Juniper website (available online at: www.saguaro-juniper.com/i_and_i/invasive_spp/invasive_plants.html).

Question 2.5 Potential for human-caused dispersal *Score:* **B** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Humans continue to plant this species in landscape/horticultural settings (Pima County Board of Supervisors 2002, Duffield and Jones 2003).
Rationale: Is highly related to sites with human activities. People continue to plant this species into new landscaping schemes, including plantings along urban freeways.
Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Flooding and wildlife, especially birds, can distribute seeds to natural sites.
Rationale: Birds relish the fruit of African sumac and excrete the seeds under roost trees or perching sites, as seedlings of this species often are found under established trees (J. Brock, personal observations, 2004). Seeds are dispersed primarily by birds and with flood flows in invaded channels. Fruit/seeds are a food source for birds and perhaps small mammals that subsequently can disperse the seeds to new locales (J. Brock, personal observations, 2004)
Sources of information: Personal observations by J. Brock (Professor, Applied Biological Science, Arizona State University, Phoenix, Arizona, Arizona, 2004) and information from the Saguaro Juniper website (available online at: www.saguaro-juniper.com/i_and_i/invasive_spp/invasive_plants.html).

Question 2.7 Other regions invaded *Score:* **U** *Doc'n Level:* **No info.**
Identify other regions: Not known if African sumac is invasive in these states, but it is present in California, Nevada, New Mexico, and Texas (Duffield and Jones 2003).
Rationale: No information is available from other regions to determine if *R. lancea* is invasive in other ecological types not already invaded in Arizona.
Sources of information: Duffeld and Jones (2003) identify the presence of *R. lancea* in other states but not whether in occurs in wildlands.

Question 3.1 Ecological amplitude *Score:* **B** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: In warm desert plantings, said to be hardy to 12°F. Occurs in Western Garden Zones 8–9 and 12–24, which includes most of the warm deserts of the southwestern U.S., except the Chihuahuan desert (Brexzel 2001). Introduced to Arizona in the 1920s. Seeds were collected in North Pretoria, South Africa in 1919, germinated in Chico, California, and seedlings first planted at the Boyce Thompson SW Arboretum near Superior, Arizona and then on the University of Arizona campus in 1928 (Campus Arboretum, University of Arizona website).
Rationale: Invades two major ecological types and four minor ecological types (see Worksheet B).
Sources of information: See cited literature. Also considered observations by Working Group members and information from the Campus Arboretum, University of Arizona website (available online at: http://arboretum.arizona.edu/heritage_trees.html).

Question 3.2 Distribution *Score:* **D** *Doc'n Level:* **Obs.**
Describe distribution: Is localized in distribution to areas of human habitation, especially the larger cities and towns in the Sonoran Desert and the Mohave Desert of Las Vegas, Nevada.

Rationale: Still largely planted as a landscape tree, but is spreading from the urban areas of the hot deserts into adjacent wildlands.	
Sources of information: Observations by Working Group members.	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**Yes**	**[No]**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**[No]**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 2	**Total unknowns: 2**	
	Score : C		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	**D**
	Chihuahuan desertscrub	**D**
	Sonoran desertscrub	**D**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**D**
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Baker, M.G. 1997. Relationships of avifauna in urban riparian habitats. Master's thesis. Arizona State University, Tempe.

Brexzel, K.N. (ed.). 2001. Western Garden Book. Sunset Publishing Co., Menlo Park, California.

Brock, J. H., and M.C. Farkas. 1997. Alien woody plants in a Sonoran Desert urban riparian cooridor: an early warning system about invasiveness? Pages 19−35 in Plant Invasions: Studies from North America and Europe. Backhuys Publishers, Leiden, The Netherlands.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Chambers, N., and T. Oshant Hawkins. 2002. Invasive Plants of the Sonoran Desert: A Field Guide. Sonoran Institute, Environmental Education Exchange, and National Fish and Wildlife Foundation.

Duffield, M.R. and W.D. Jones. 2003. Plants for Dry Climates: How to Select, Grow and Enjoy. Perseus Publishing.

Gibbs Russell, G.E., W. G. Welman, E. Reitief, K. L. Immelman, G. Germishuizen, B. J. Pienaar, M. van Wyk, and A. Nicholas. 1987. List of species of southern African plants. Memoirs of the Botanical Survey of South Africa 2(1−2):1−152 (Part 1) and 1−270 (Part 2).

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

[MBG] Missouri Botantical Garden. 2005. *Rhus lancea* L. f. in VAST (VAScular Tropicos) nomenclatural database and associated authority files. Version 1.5. Missouri Botanical Garden. Available online at: http://mobot.mobot.org/W3T/Search/vast.html.

Pima County Board of Supervisors. 2002. An Invasive Species Management Program: Sonoran Desert Conservation Plan. Board of Supervisors, Pima County, Arizona.

Stromberg, J.C. 2001. Restoration of riparian vegetation in the south-western United States: importance of flow regimes and fluvial dynamism. Journal of Arid Environments 49:17−34.

Tellman, B. (ed.). 2002. Invasive Exotic Species in the Sonoran Region. The University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson. 424 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native

Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Rubus armeniacus* Focke; *Rubus discolor* Weihe & Nees (USDA 2005)
Synonyms:	*Rubus armeniacus*: None listed in USDA (2005); *Rubus discolor: Rubus procerus* auct. non P.J. Muell. ex Genev (USDA 2005).
Common names:	Himalayan blackberry, Himilaya-berry (names apply to both species)
Evaluation date (mm/dd/yy)**:**	06/01/04
Evaluator #1 Name/Title:	Christopher S. Laws / Consv. Bio. Intern
Affiliation:	The University of Arizona
Phone numbers:	(520) 573–3994
Email address:	cslaws@email.arizona.edu
Address:	7881 W. Schoolhill Pl. Tucson, Arizona 85743
Evaluator #2 Name/Title:	Dana Backer
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85713

List committee members:	06/23/04: W. Albrecht, D. Backer, J. Brock, J. Hall, C. Laws, L. Moser, B. Phillips, K. Watters 12/17/04: W. Albrecht, D. Backer, J. Crawford, D. Crisp, S. Harger, F. Northam, T. Olson, B. Phillips, S. Masek-Lopez
Committee review date:	06/23/04 and 12/17/04
List date:	12/17/04
Re-evaluation date(s):	

Taxonomic Comment

Some authorities maintain that the species of *Rubus* introduced to the United States and referred to as Himalayan blackberry is actually *R. armeniacus* Focke (Ceska 1999 in Francis 2003). To accommodate this possibility, we treat *R. armeniacus* and *R. discolor* together, though the literature in general refers to *R. discolor*.

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Observational	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **Alert**
1.2	Impact on plant community	**A**	Other published material		
1.3	Impact on higher trophic levels	**C**	Other published material		
1.4	Impact on genetic integrity	**U**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **16 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**A**	Other published material		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**A**	Other published material		
2.5	Potential for human-caused dispersal	**C**	Observational		
2.6	Potential for natural long-distance dispersal	**A**	Other published material		
2.7	Other regions invaded	**A**	Observational		 Something you should know.
3.1	Ecological amplitude	**C**	Observational	**"Distribution"** **Section 3 Score:** **C**	
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Obs.**

Impact: Blocks sunlight, cools surface temperature, increase fuel load

Rationale: From Hoshovsky (1989): Himalayan blackberry creates thick impenetrable stands that create a substantial amount of litter and standing dead stems (Amor 1972). Hoshovsky (1989) inferred that these stands can become a fire hazard, but there was no mention of this in Tirmenstein (1989).

Himalayan blackberry thickets produce large quantities of hard and dry litter as well as standing dead canes which do not readily decompose (Crisp 2000). This decomposition process may differ from the natural process. Dead biomass will increase the fuel load (inference).

Dense thickets can compete with low-stature vegetation and can prevent the establishment of shade-intolerant trees (such as Douglas fir, ponderosa pine) (Soll 2004 and other authors). This implies that the thickets block sunlight from penetrating and the soil and microclimate may be cooler in temperature. Working Group members commented that these stands of blackberry are so thick that they block sunlight from penetrating and their massiveness consumes available moisture (personal observations by Working Group members).

Sources of information: See cited literature. Score based on Working Group member observations and inference from the literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Other pub.**

Identify type of impact or alteration: *Rubus discolor* impacts structure (forming thickets), composition (excluding shade-intolerant species), and interactions (competition for resources).

Rationale: Through rapid growth and reproduction, *R. discolor* forms dense thickets that compete with other plants for moisture, light and nutrients (Crisp 2000, various Working Group member observations).

From Hoshovsky (1989): Plant community composition is impacted because Himalayan blackberry is a scrambling, vining species that smothers local plant growth and replaces it with a dense monotypic thicket. Stems grow to 40 cm before arching over and trailing on the ground (Amor 1974, observed in Australia). Each stem tip that touches the ground then forms roots at the nodes, leading to rapid formation of dense stands that may inhibit native plant growth or competition. Although stems only survive for 2 to 3 years, they can reach a density of 525 canes per square meter. Re-entry of stems back into the central mass creates daughter plants that in turn produces an impenetrable conglomerate of dead stems and litter leading to thicket densities.A large quantity of litter and standing dead canes develops in old thickets (Amor 1972). Canes of *R. discolor* can grow to lengths of up to 7 m in a single season. At one site observed by Amor (1974), the mean horizontal projection of 50 first-year canes was 3.3 m. Ninety-six percent of these canes had daughter plants at their apices. In less than two years a cane cutting can produce a thicket 5 m in diameter (Amor 1973). Roots, while not deep maximum depth of 90 cm, can reach 10 m or more (Northcroft 1927).

In the Pacific Northwest (Soll 2004), "once *R. discolor* becomes well established, it out competes low stature native vegetation and can prevent establishment of shade intolerant trees (such as Douglas fir, ponderosa pine and Oregon white oak), leading to the formation of apparently permanent thickets with little other vegetation present.

In some places in Arizona (Oak Creek Canyon for example), it has >75% cover (B. Phillips, personal communication, 2004).

Sources of information: See cited literature. Also considered personal communication with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004).

Question 1.3 Impact on higher trophic levels *Score:* **C** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Minor alterations; positive alterations (provide forage and cover) and negative alterations (impenetrable).
Rationale: From Tirmenstein (1989): The Himalayan blackberry provides food and cover for many wildlife species. Fruits of blackberries are eaten by numerous birds, including the northern bobwhite, scaled quail, ruffed grouse, sharp-tailed grouse, California quail, ring-necked pheasant, blue grouse, gray (Hungarian) partridge, band-tailed pigeon, gray catbird, northern cardinal, American robin, yellow-breasted chat, pine grosbeak, summer tanager, orchard oriole, brown thrasher, thrushes, and towhees (Van Dersal 1938, Core 1974, Bernard and Brown 1977). Mammals such, as the coyote, common opossum, red squirrel, raccoon, gray fox, red fox, skunks, squirrels, chipmunks, and black bear, also feed on blackberries (Van Dersal 1938, Core 1974). Deer, rabbits, and mountain beaver consume the buds, stems, and leaves of blackberries (Van Dersal 1938, Core 1974). The Himalayan blackberry is considered a primary elk browse in parts of California, where it is used primarily during the winter months (Harper 1962). Porcupines and beaver feed on the cambium, buds, and stems of many species of blackberries (Van Dersal 1938). The dense thickets (Pacific Northwest) can limit movement of large animals from meadow to forest and vice versa, reducing the utility of small openings and meadows as foraging areas (Hoshovsky 1989, Soll 2004). These impenetrable thickets can physically block animals (Crisp 2000, Soll 2004). Thorny stems can cause injury to grazing animals (Crisp 2000).
Sources of information: See cited literature. Score reflects a net accounting between the positive and negative impacts and is also a reflection of the Working Group member observations and various unpublished plant profiles.

Question 1.4 Impact on genetic integrity *Score:* **U** *Doc'n Level:* **Other pub.**
Identify impacts: *Rubus discolor* hybridizes with *R. thyrsiger, R. calvatus,* and *R. schlechtendalii* (Tirmenstein 1989).
Rationale: There are native *Rubus* species in Arizona, but there are no known studies or documentation of hybridization between the native and the non-native *Rubus* species in Arizona.
Sources of information: See cited literature; also see Kearney and Peebles (1960) for identification of native *Rubus* species.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Occasionally establishes in undisturbed areas but readily establishes with disturbance.
Rationale: Himalayan blackberry prefers disturbed, open, and abandoned sites that are exposed to sunlight. The seeds are shade intolerant; in Australia Amor (1974) observed that seeds receiving less than 44% full sunlight died. From Tirmenstein (1989): "Rapid vegetative spread occurs even in the absence of disturbance. Open spaces that are degraded, fire-damaged, or recently abandon are susceptible to invasion for their lack of mature shrubs, trees, or grass, that would otherwise shade-out blackberry seeds. Flooded riparian areas become susceptible when stream and river soil becomes exposed to sunlight. Himalayan blackberry

responds favorably to fire due to on-site seed banks unaffected by fire, and its ability to reproduce and regenerate vegetatively by roots, rootstocks, and rhizomes (Dale 1986, Hitchcock and Cronquist 1973, Lyon and Stickney 1976)." Roadsides, degraded pastures, right-of-ways, creek gullies, fencelines, and abandoned lots become suitable germination areas for *Rubus discolor*.
Sources of information: See cited literature; also see Soll (2004) and Crisp (2000).

Question 2.2 Local rate of spread with no management *Score:* **A** *Doc'n Level:* **Other pub.**
Describe rate of spread: Doubles in < 10 years.
Rationale: A survey conducted in 1992 in the Garden Creek area of Grand Canyon National Park reported that Himalayan blackberry colonized ~four acres of riparian habitat and by 1996 it had spread to ~1.5 miles of riparian zone along Garden Creek (Makarick 2001). Rapid vegetative spread occurs even in the absence of disturbance (Tirmenstein 1989). Increasing spread has also been observed in Oak Creek (B. Phillips, personal communication, 2004). The plant itself can have trailing canes that spread 20 to 40 feet, frequently rooting at the tips (Soll 2004).
Sources of information: See cited literature. Also considered personal communication with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004).

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n Level:* **Obs.**
Describe trend: Stable. Restricted to riparian areas in northern Arizona (at this time).
Rationale: Himalayan blackberry is actively managed where it is found (L. Makarick, personal communication, 2004). Although Himalayan blackberry maybe increasing within its range, the Working Group does not think it is expanding its range.
Sources of information: Score based on personal communication with L. Makarick (Below the Rim Vegetation Program Manager, Grand Canyon National Park, Science Center, Flagstaff, Arizona, 2004), Working Group member observations, and inference.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: Reproduces vegetatively, sexually, and asexually; produces large numbers of seeds, fragments easily.
Rationale: *Rubus discolor* regenerates vegetatively, stems develop typically from the creeping stems and perennial rootstocks. *Rubus discolor* spreads aggressively by its trailing stems which root at the nodes. From Tirmenstein (1989): "The Himalayan blackberry is capable of extensive and vigorous vegetative regeneration (Willoughby and Davilla 1984). Sexual reproduction may also be important. Reproductive versatility is well represented in the *Rubus* genus, with sexual reproduction, parthenogenesis (development of the egg withoutfertilization), pseudogamy (a form of apomixis in which pollination is required), and parthenocarpy (production of fruit without fertilization), occurring widely (Crane 1940). The following types of reproduction have been documented in blackberries: (1) sexual reproduction, (2) nonreduction at meiosis on the female, male, or both sides, (3) apomixis (seeds contain embryos of maternal, rather than sexual origin) with segregation, (4) apomixis without segregation, and (5) haploid parthenogenesis (Crane 1940). These modes of asexual reproduction contribute significantly to the aggressive, vigorous spread of blackberries.Seeds of most blackberries can remain viable when stored in the soil for a period of at least several years (Bernard and Brown 1977). However, the specific length of viability has not been documented for the Himalayan blackberry."

Blackberries also readily propagate from root pieces and cane cuttings (Amor 1974). In Victoria, Australia stands of Himalayan blackberry were estimated to produce 7,000 to 13,000 seeds/m^2 / year (Amor 1974).
Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **C** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Historically, *R. discolor* was used for erosion control and cultivated for its berries.
Rationale: Historically this plant was planted at homesteads and used locally. Currently, the plants are localized in Arizona and are harvested on site (Working Group discussion). Blackberry was once used for erosion control on infertile, barren, and disturbed sites (Van Dersal 1938, Brinkman 1974 in Tirmenstein 1989) but is no longer recommended for such purpose. No specific cases of intentional plantings were found for this purpose in Arizona.
Sources of information: See cited literature. Score based on Working Group discussion.

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Consumption by a wide variety of animals and birds (see question 1.3). Berries are buoyant.
Rationale: Blackberry is an important food source for a wide range of animals (most mammals are known to eat the fruit, as are many birds) (Barber 1976 and Van Dersal 1938 in Tiermenstein 1989).
Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **A** *Doc'n Level:* **Obs.**
Identify other regions: Ecological types invaded in California but not in Arizona include meadows, marshes, riparian scrub (desert washes), lower montane coniferous forests.
Rationale: According to the draft California plant assessment for *Rubus armeniacus and R. discolor* by P. Warner (reviewed by the California list committee on August 27, 2004), Himalayan blackberry invades the above mentioned ecological types in California, as well as many other ecological types that are either not in Ariozna or are the same ecological types as those invaded in Arizona.
Sources of information: See the draft California *Rubus armeniacus and R. discolor* plant assessment by P. Warner (available online at: http://www.cal-ipc.org/list_revision/completed_pafs.html; information current as of August 27, 2004). Note: Warner considered *R. discolor* a synonym of *Rubus armeniacus.*

Question 3.1 Ecological amplitude *Score:* **C** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Native to western Europe; first introduced to North America in 1885 as a cultivated crop. By 1945 it had naturalized along the west coast (Bailey 1945 in Hoshovsky 1989). Occurs mainly in areas with an average annual rainfall greater than 76 cm, at altitudes up to 1800 m, and on both acidic and alkaline soils (Amor 1974 in Hoshovsky 1989). Blackberries grow well on a variety of barren, infertile soil types (Brinkman 1974). These shrubs tolerate a wide range of soil pH and texture, but do require adequate soil moisture (Core 1974). The Himalayan blackberry appears to be tolerant of periodic flooding by brackish or fresh water (Willoughby and Davilla 1984). Introduced to the area of West Fork of Oak Creek Canyon between 1915 and 1945 (K Watters, personal communication, 2004).
Rationale: In Arizona occurs to >1800m in elevation (Kearney and Peebles 1960). Records in SEINet (2004) indicate it can be found along streams characteristic of southwestern interior riparian and montane riparian. Earliest record in SEINet (2004) is 1969. Occurs along the West Fork of Oak Creek,

several sites in Verde Valley, and along Fossil Creek in Camp Verde (B. Phillips and L. Moser, personal communications, 2004). In the Grand Canyon National Park populations exist in Indian Gardens and Garden Creek (Makarick 2001).
Sources of information: See cited literature. Also considered personal communications with L. Moser (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2004), B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004), and K. Watters (Research Technician, Grand Canyon National Park, Flagstaff, Arizona, 2004) and information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed October 2004).

Question 3.2 Distribution	*Score:* **D** *Doc'n Level:* **Obs.**
Describe distribution: In Arizona Himalayan blackberry is limited to a low percentage of occurrences within riparian ecological types.	
Rationale: See Worksheet B.	
Sources of information: Considered personal communications with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004), L. Makarick (Below the Rim Vegetation Program Manager, Grand Canyon National Park, Science Center, Flagstaff, Arizona, 2004), and K. Watters (Research Technician, Grand Canyon National Park, Flagstaff, Arizona, 2004).	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**[Yes]**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 9 Total unknowns: 1		
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	**D**
	montane riparian	**D**
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Amor, R.L. 1972. A study of the ecology and control of blackberry (*Rubus fuiticosus* L. agg.). J. Austral. Inst. Agric. Sci. 38:294.

Amor, R.L. 1973. Ecology and control of blackberry (*Rubus fruticosus* L. agg.): I. *Rubus* spp. as weeds in Victoria. Weed Res. 13:218–223.

Amor, R.L. 1974. Ecology and control of blackberry (*Rubus fruiticosus* L. agg.): II. Reproduction. Weed Res. 14:231–238.

Bailey, L. 1945. The genus *Rubus* in North America. Gentes Herbarium 5:851–854.

Barber, W.H., Jr. 1976. An Autecological Study of Salmonberry (*Rubus spectabilis,* Pursh*)* in Western Washington. Master's thesis. University of Washington, Seattle. 154 p.

Bernard, S.R, and K.F. Brown. 1977. Distribution of Mammals, Reptiles, and Amphibians by BLM Physiographic Regions and A.W. Kuchler's Associations for the Eleven Western States. Tech. Note 301. U.S. Department of the Interior, Bureau of Land Management, Denver, Colorado. 169 p.

Brinkman, K.A. 1974. *Rubus* L. blackberry, raspberry. Pages 738–743 in C.S. Schopmeyer (ed.), Seeds of Woody Plants in the United States. Agriculture Handbook No. 450. U.S. Department of Agriculture, Forest Service, Washington, DC.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Ceska, A. 1999. *Rubus armeniacus*—a correct name for Himalayan blackberries. Botantical Electronic News ISSN 1188–603X. 3 p. Available online at: http://www.ou.edu.cas/botany-micro/ben/ben230.html.

Core, E.L. 1974. Brambles. Pages 16–19 in J.D. Gill and W.M. Healy (compilers), Shrubs and Vines for Northeastern Wildlife. Gen. Tech. Rep. NE-9. U.S. Department of Agriculture, Forest Service, Broomall, Pennsylvania.

Crane, M.B. 1940. Reproductive versatility in *Rubus.* I. Morphology and inheritence. Journal of Genetics 40:109–118.

Crisp, D. 2000. Species Action Plan, Himalayann Blackberry, *Rubus procerus*.

Dale, N. 1986. Flowering Plants: The Santa Monica Mountains, Coastal and Chaparral Regions of Southern California. Capra Press, Santa Barbara, California. In cooperation with the California Native Plant Society. 239 p.

Francis, J.K. 2003. *Rubus discolor* Weihe & Nees, Himalayan Blackberry. U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry, San Juan, Puerto Rico. In cooperation with the University of Puerto Rico, Rio Piedras. Available online at: http://www.fs.fed.us/gov/iitf/pdf/shrubs/Rubus%20discolor.pdf; accessed October 2004.

Harper, J.A. 1962. Daytime feeding habits of Roosevelt elk on Boyes Prairie, California. Journal of Wildlife 26:97−100.

Hitchcock, L.C., and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle. 730 p.

Hoshovsky, M. 1989. *Rubus discolor*, Himalaya berry. Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Lyon, L.J, and P.F. Stickney. 1976. Early vegetal succession following large northern Rocky Mountain wildfires. Pages 355−373 in Proceedings, Tall Timbers Fire Ecology Conference and Intermountain Fire Research Council Fire and Land Management Symposium. No. 14. October 8−10, 1974, Missoula, Montana. Tall Timbers Research Station, Tallahassee, Florida.

Makarick, L. 2001. Final Project Report: NRPP Intermountain Region Natural Resource Management Fund. Himalayan Blackberry Control at Garden Creek, Grand Canyon National Park, Arizona. PMIS#56966, FY2000–01.

Northcroft, E.G. 1927. The blackberry pest. I. Biology of the plant. N.Z. J. Agric. 34:376–388.

Soll, J. 2004. Controlling Himalayan blackberry in the Pacific Northwest. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/moredocs/rubdis01.pdf; accessed October 2004.

Tirmenstein, D. 1989. *Rubus discolor*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed June 2004.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Van Dersal, W.R. 1938. Native Woody Plants of the United States, Their Erosion-Control and Wildlife Values. U.S. Department of Agriculture, Washington, DC. 362 p.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Willoughby, J.W., and W. Davilla. 1984. Plant species composition and life form spectra of tidal streambanks and adjacent riparian woodlands along the lower Sacramento River. Pages 642−651 in R.E. Warner and K.M. Hendrix (eds.), California Riparian Systems: Ecology, Conservation, and Productive Management: Proceedings of a Conference. September 17−19, 1981, Davis, California. University of California Press, Berkeley.

Other References of Interest Not Cited in the Text

Bailey, L. 1923. Certain cultivated *Rubus*. Gentes Herbarium 1:196–197.

DiTomaso, J.M. 2002. Wild Blackberries: Integrated Pest Management for Home Gardeners and Landscape Professionals. Publ. No. 7434. University of California Cooperative Extension.

Hoshovsky, M.C. 2000. *Rubus discolor*. Pages 277–281 in C.C. Bossard, J.M. Randall, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Rubus armeniacus* Focke; *Rubus discolor* Weihe & Nees (USDA 2005)
Synonyms:	*Rubus armeniacus*: None listed in USDA (2005); *Rubus discolor: Rubus procerus* auct. non P.J. Muell. ex Genev (USDA 2005).
Common names:	Himalayan blackberry, Himilaya-berry (names apply to both species)
Evaluation date (mm/dd/yy)**:**	06/01/04
Evaluator #1 Name/Title:	Christopher S. Laws / Consv. Bio. Intern
Affiliation:	The University of Arizona
Phone numbers:	(520) 573–3994
Email address:	cslaws@email.arizona.edu
Address:	7881 W. Schoolhill Pl. Tucson, Arizona 85743
Evaluator #2 Name/Title:	Dana Backer
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85713

List committee members:	06/23/04: W. Albrecht, D. Backer, J. Brock, J. Hall, C. Laws, L. Moser, B. Phillips, K. Watters 12/17/04: W. Albrecht, D. Backer, J. Crawford, D. Crisp, S. Harger, F. Northam, T. Olson, B. Phillips, S. Masek-Lopez
Committee review date:	06/23/04 and 12/17/04
List date:	12/17/04
Re-evaluation date(s):	

Taxonomic Comment

Some authorities maintain that the species of *Rubus* introduced to the United States and referred to as Himalayan blackberry is actually *R. armeniacus* Focke (Ceska 1999 in Francis 2003). To accommodate this possibility, we treat *R. armeniacus* and *R. discolor* together, though the literature in general refers to *R. discolor*.

Table 2. Scores, Designations, and Documentation Levels

Question		Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Observational	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **Alert**
1.2	Impact on plant community	**A**	Other published material		
1.3	Impact on higher trophic levels	**C**	Other published material		
1.4	Impact on genetic integrity	**U**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **16 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**A**	Other published material		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**A**	Other published material		
2.5	Potential for human-caused dispersal	**C**	Observational		
2.6	Potential for natural long-distance dispersal	**A**	Other published material		
2.7	Other regions invaded	**A**	Observational		RED FLAG **NO** Something you should know.
3.1	Ecological amplitude	**C**	Observational	**"Distribution"** **Section 3 Score:** **C**	
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Obs**.
Impact: Blocks sunlight, cools surface temperature, increase fuel load
Rationale: From Hoshovsky (1989): Himalayan blackberry creates thick impenetrable stands that create a substantial amount of litter and standing dead stems (Amor 1972). Hoshovsky (1989) inferred that these stands can become a fire hazard, but there was no mention of this in Tirmenstein (1989). Himalayan blackberry thickets produce large quantities of hard and dry litter as well as standing dead canes which do not readily decompose (Crisp 2000). This decomposition process may differ from the natural process. Dead biomass will increase the fuel load (inference). Dense thickets can compete with low-stature vegetation and can prevent the establishment of shade-intolerant trees (such as Douglas fir, ponderosa pine) (Soll 2004 and other authors). This implies that the thickets block sunlight from penetrating and the soil and microclimate may be cooler in temperature. Working Group members commented that these stands of blackberry are so thick that they block sunlight from penetrating and their massiveness consumes available moisture (personal observations by Working Group members).
Sources of information: See cited literature. Score based on Working Group member observations and inference from the literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: *Rubus discolor* impacts structure (forming thickets), composition (excluding shade-intolerant species), and interactions (competition for resources).
Rationale: Through rapid growth and reproduction, *R. discolor* forms dense thickets that compete with other plants for moisture, light and nutrients (Crisp 2000, various Working Group member observations). From Hoshovsky (1989): Plant community composition is impacted because Himalayan blackberry is a scrambling, vining species that smothers local plant growth and replaces it with a dense monotypic thicket. Stems grow to 40 cm before arching over and trailing on the ground (Amor 1974, observed in Australia). Each stem tip that touches the ground then forms roots at the nodes, leading to rapid formation of dense stands that may inhibit native plant growth or competition. Although stems only survive for 2 to 3 years, they can reach a density of 525 canes per square meter. Re-entry of stems back into the central mass creates daughter plants that in turn produces an impenetrable conglomerate of dead stems and litter leading to thicket densities.A large quantity of litter and standing dead canes develops in old thickets (Amor 1972). Canes of *R. discolor* can grow to lengths of up to 7 m in a single season. At one site observed by Amor (1974), the mean horizontal projection of 50 first-year canes was 3.3 m. Ninety-six percent of these canes had daughter plants at their apices. In less than two years a cane cutting can produce a thicket 5 m in diameter (Amor 1973). Roots, while not deep maximum depth of 90 cm, can reach 10 m or more (Northcroft 1927). In the Pacific Northwest (Soll 2004), "once *R. discolor* becomes well established, it out competes low stature native vegetation and can prevent establishment of shade intolerant trees (such as Douglas fir, ponderosa pine and Oregon white oak), leading to the formation of apparently permanent thickets with little other vegetation present. In some places in Arizona (Oak Creek Canyon for example), it has >75% cover (B. Phillips, personal communication, 2004).

Sources of information: See cited literature. Also considered personal communication with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004).

Question 1.3 Impact on higher trophic levels *Score:* **C** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Minor alterations; positive alterations (provide forage and cover) and negative alterations (impenetrable).
Rationale: From Tirmenstein (1989): The Himalayan blackberry provides food and cover for many wildlife species. Fruits of blackberries are eaten by numerous birds, including the northern bobwhite, scaled quail, ruffed grouse, sharp-tailed grouse, California quail, ring-necked pheasant, blue grouse, gray (Hungarian) partridge, band-tailed pigeon, gray catbird, northern cardinal, American robin, yellow-breasted chat, pine grosbeak, summer tanager, orchard oriole, brown thrasher, thrushes, and towhees (Van Dersal 1938, Core 1974, Bernard and Brown 1977). Mammals such, as the coyote, common opossum, red squirrel, raccoon, gray fox, red fox, skunks, squirrels, chipmunks, and black bear, also feed on blackberries (Van Dersal 1938, Core 1974). Deer, rabbits, and mountain beaver consume the buds, stems, and leaves of blackberries (Van Dersal 1938, Core 1974). The Himalayan blackberry is considered a primary elk browse in parts of California, where it is used primarily during the winter months (Harper 1962). Porcupines and beaver feed on the cambium, buds, and stems of many species of blackberries (Van Dersal 1938). The dense thickets (Pacific Northwest) can limit movement of large animals from meadow to forest and vice versa, reducing the utility of small openings and meadows as foraging areas (Hoshovsky 1989, Soll 2004). These impenetrable thickets can physically block animals (Crisp 2000, Soll 2004). Thorny stems can cause injury to grazing animals (Crisp 2000).
Sources of information: See cited literature. Score reflects a net accounting between the positive and negative impacts and is also a reflection of the Working Group member observations and various unpublished plant profiles.

Question 1.4 Impact on genetic integrity *Score:* **U** *Doc'n Level:* **Other pub.**
Identify impacts: *Rubus discolor* hybridizes with *R. thyrsiger, R. calvatus,* and *R. schlechtendalii* (Tirmenstein 1989).
Rationale: There are native *Rubus* species in Arizona, but there are no known studies or documentation of hybridization between the native and the non-native *Rubus* species in Arizona.
Sources of information: See cited literature; also see Kearney and Peebles (1960) for identification of native *Rubus* species.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Occasionally establishes in undisturbed areas but readily establishes with disturbance.
Rationale: Himalayan blackberry prefers disturbed, open, and abandoned sites that are exposed to sunlight. The seeds are shade intolerant; in Australia Amor (1974) observed that seeds receiving less than 44% full sunlight died. From Tirmenstein (1989): "Rapid vegetative spread occurs even in the absence of disturbance. Open spaces that are degraded, fire-damaged, or recently abandon are susceptible to invasion for their lack of mature shrubs, trees, or grass, that would otherwise shade-out blackberry seeds. Flooded riparian areas become susceptible when stream and river soil becomes exposed to sunlight. Himalayan blackberry

responds favorably to fire due to on-site seed banks unaffected by fire, and its ability to reproduce and regenerate vegetatively by roots, rootstocks, and rhizomes (Dale 1986, Hitchcock and Cronquist 1973, Lyon and Stickney 1976)." Roadsides, degraded pastures, right-of-ways, creek gullies, fencelines, and abandoned lots become suitable germination areas for *Rubus discolor*.
Sources of information: See cited literature; also see Soll (2004) and Crisp (2000).

Question 2.2 Local rate of spread with no management *Score:* **A** *Doc'n Level:* **Other pub.**
Describe rate of spread: Doubles in < 10 years.
Rationale: A survey conducted in 1992 in the Garden Creek area of Grand Canyon National Park reported that Himalayan blackberry colonized ~four acres of riparian habitat and by 1996 it had spread to ~1.5 miles of riparian zone along Garden Creek (Makarick 2001). Rapid vegetative spread occurs even in the absence of disturbance (Tirmenstein 1989). Increasing spread has also been observed in Oak Creek (B. Phillips, personal communication, 2004). The plant itself can have trailing canes that spread 20 to 40 feet, frequently rooting at the tips (Soll 2004).
Sources of information: See cited literature. Also considered personal communication with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004).

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n Level:* **Obs.**
Describe trend: Stable. Restricted to riparian areas in northern Arizona (at this time).
Rationale: Himalayan blackberry is actively managed where it is found (L. Makarick, personal communication, 2004). Although Himalayan blackberry maybe increasing within its range, the Working Group does not think it is expanding its range.
Sources of information: Score based on personal communication with L. Makarick (Below the Rim Vegetation Program Manager, Grand Canyon National Park, Science Center, Flagstaff, Arizona, 2004), Working Group member observations, and inference.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: Reproduces vegetatively, sexually, and asexually; produces large numbers of seeds, fragments easily.
Rationale: *Rubus discolor* regenerates vegetatively, stems develop typically from the creeping stems and perennial rootstocks. *Rubus discolor* spreads aggressively by its trailing stems which root at the nodes. From Tirmenstein (1989): "The Himalayan blackberry is capable of extensive and vigorous vegetative regeneration (Willoughby and Davilla 1984). Sexual reproduction may also be important. Reproductive versatility is well represented in the *Rubus* genus, with sexual reproduction, parthenogenesis (development of the egg withoutfertilization), pseudogamy (a form of apomixis in which pollination is required), and parthenocarpy (production of fruit without fertilization), occurring widely (Crane 1940). The following types of reproduction have been documented in blackberries: (1) sexual reproduction, (2) nonreduction at meiosis on the female, male, or both sides, (3) apomixis (seeds contain embryos of maternal, rather than sexual origin) with segregation, (4) apomixis without segregation, and (5) haploid parthenogenesis (Crane 1940). These modes of asexual reproduction contribute significantly to the aggressive, vigorous spread of blackberries.Seeds of most blackberries can remain viable when stored in the soil for a period of at least several years (Bernard and Brown 1977). However, the specific length of viability has not been documented for the Himalayan blackberry."

Blackberries also readily propagate from root pieces and cane cuttings (Amor 1974). In Victoria, Australia stands of Himalayan blackberry were estimated to produce 7,000 to 13,000 seeds/m^2 / year (Amor 1974).
Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **C** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Historically, *R. discolor* was used for erosion control and cultivated for its berries.
Rationale: Historically this plant was planted at homesteads and used locally. Currently, the plants are localized in Arizona and are harvested on site (Working Group discussion). Blackberry was once used for erosion control on infertile, barren, and disturbed sites (Van Dersal 1938, Brinkman 1974 in Tirmenstein 1989) but is no longer recommended for such purpose. No specific cases of intentional plantings were found for this purpose in Arizona.
Sources of information: See cited literature. Score based on Working Group discussion.

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Consumption by a wide variety of animals and birds (see question 1.3). Berries are buoyant.
Rationale: Blackberry is an important food source for a wide range of animals (most mammals are known to eat the fruit, as are many birds) (Barber 1976 and Van Dersal 1938 in Tiermenstein 1989).
Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **A** *Doc'n Level:* **Obs.**
Identify other regions: Ecological types invaded in California but not in Arizona include meadows, marshes, riparian scrub (desert washes), lower montane coniferous forests.
Rationale: According to the draft California plant assessment for *Rubus armeniacus and R. discolor* by P. Warner (reviewed by the California list committee on August 27, 2004), Himalayan blackberry invades the above mentioned ecological types in California, as well as many other ecological types that are either not in Ariozna or are the same ecological types as those invaded in Arizona.
Sources of information: See the draft California *Rubus armeniacus and R. discolor* plant assessment by P. Warner (available online at: http://www.cal-ipc.org/list_revision/completed_pafs.html; information current as of August 27, 2004). Note: Warner considered *R. discolor* a synonym of *Rubus armeniacus.*

Question 3.1 Ecological amplitude *Score:* **C** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Native to western Europe; first introduced to North America in 1885 as a cultivated crop. By 1945 it had naturalized along the west coast (Bailey 1945 in Hoshovsky 1989). Occurs mainly in areas with an average annual rainfall greater than 76 cm, at altitudes up to 1800 m, and on both acidic and alkaline soils (Amor 1974 in Hoshovsky 1989). Blackberries grow well on a variety of barren, infertile soil types (Brinkman 1974). These shrubs tolerate a wide range of soil pH and texture, but do require adequate soil moisture (Core 1974). The Himalayan blackberry appears to be tolerant of periodic flooding by brackish or fresh water (Willoughby and Davilla 1984). Introduced to the area of West Fork of Oak Creek Canyon between 1915 and 1945 (K Watters, personal communication, 2004).
Rationale: In Arizona occurs to >1800m in elevation (Kearney and Peebles 1960). Records in SEINet (2004) indicate it can be found along streams characteristic of southwestern interior riparian and montane riparian. Earliest record in SEINet (2004) is 1969. Occurs along the West Fork of Oak Creek,

several sites in Verde Valley, and along Fossil Creek in Camp Verde (B. Phillips and L. Moser, personal communications, 2004). In the Grand Canyon National Park populations exist in Indian Gardens and Garden Creek (Makarick 2001).
Sources of information: See cited literature. Also considered personal communications with L. Moser (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2004), B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004), and K. Watters (Research Technician, Grand Canyon National Park, Flagstaff, Arizona, 2004) and information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed October 2004).

Question 3.2 Distribution	*Score:* **D** *Doc'n Level:* **Obs.**
Describe distribution: In Arizona Himalayan blackberry is limited to a low percentage of occurrences within riparian ecological types.	
Rationale: See Worksheet B.	
Sources of information: Considered personal communications with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004), L. Makarick (Below the Rim Vegetation Program Manager, Grand Canyon National Park, Science Center, Flagstaff, Arizona, 2004), and K. Watters (Research Technician, Grand Canyon National Park, Flagstaff, Arizona, 2004).	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**[Yes]**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 9	**Total unknowns: 1**	
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	**D**
	montane riparian	**D**
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Amor, R.L. 1972. A study of the ecology and control of blackberry (*Rubus fuiticosus* L. agg.). J. Austral. Inst. Agric. Sci. 38:294.

Amor, R.L. 1973. Ecology and control of blackberry (*Rubus fruticosus* L. agg.): I. *Rubus* spp. as weeds in Victoria. Weed Res. 13:218–223.

Amor, R.L. 1974. Ecology and control of blackberry (*Rubus fruiticosus* L. agg.): II. Reproduction. Weed Res. 14:231–238.

Bailey, L. 1945. The genus *Rubus* in North America. Gentes Herbarium 5:851–854.

Barber, W.H., Jr. 1976. An Autecological Study of Salmonberry (*Rubus spectabilis,* Pursh*)* in Western Washington. Master's thesis. University of Washington, Seattle. 154 p.

Bernard, S.R, and K.F. Brown. 1977. Distribution of Mammals, Reptiles, and Amphibians by BLM Physiographic Regions and A.W. Kuchler's Associations for the Eleven Western States. Tech. Note 301. U.S. Department of the Interior, Bureau of Land Management, Denver, Colorado. 169 p.

Brinkman, K.A. 1974. *Rubus* L. blackberry, raspberry. Pages 738–743 in C.S. Schopmeyer (ed.), Seeds of Woody Plants in the United States. Agriculture Handbook No. 450. U.S. Department of Agriculture, Forest Service, Washington, DC.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Ceska, A. 1999. *Rubus armeniacus*—a correct name for Himalayan blackberries. Botantical Electronic News ISSN 1188–603X. 3 p. Available online at: http://www.ou.edu.cas/botany-micro/ben/ben230.html.

Core, E.L. 1974. Brambles. Pages 16–19 in J.D. Gill and W.M. Healy (compilers), Shrubs and Vines for Northeastern Wildlife. Gen. Tech. Rep. NE-9. U.S. Department of Agriculture, Forest Service, Broomall, Pennsylvania.

Crane, M.B. 1940. Reproductive versatility in *Rubus.* I. Morphology and inheritence. Journal of Genetics 40:109–118.

Crisp, D. 2000. Species Action Plan, Himalayann Blackberry, *Rubus procerus*.

Dale, N. 1986. Flowering Plants: The Santa Monica Mountains, Coastal and Chaparral Regions of Southern California. Capra Press, Santa Barbara, California. In cooperation with the California Native Plant Society. 239 p.

Francis, J.K. 2003. *Rubus discolor* Weihe & Nees, Himalayan Blackberry. U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry, San Juan, Puerto Rico. In cooperation with the University of Puerto Rico, Rio Piedras. Available online at: http://www.fs.fed.us/gov/iitf/pdf/shrubs/Rubus%20discolor.pdf; accessed October 2004.

Harper, J.A. 1962. Daytime feeding habits of Roosevelt elk on Boyes Prairie, California. Journal of Wildlife 26:97−100.

Hitchcock, L.C., and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle. 730 p.

Hoshovsky, M. 1989. *Rubus discolor*, Himalaya berry. Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Lyon, L.J, and P.F. Stickney. 1976. Early vegetal succession following large northern Rocky Mountain wildfires. Pages 355−373 in Proceedings, Tall Timbers Fire Ecology Conference and Intermountain Fire Research Council Fire and Land Management Symposium. No. 14. October 8−10, 1974, Missoula, Montana. Tall Timbers Research Station, Tallahassee, Florida.

Makarick, L. 2001. Final Project Report: NRPP Intermountain Region Natural Resource Management Fund. Himalayan Blackberry Control at Garden Creek, Grand Canyon National Park, Arizona. PMIS#56966, FY2000–01.

Northcroft, E.G. 1927. The blackberry pest. I. Biology of the plant. N.Z. J. Agric. 34:376–388.

Soll, J. 2004. Controlling Himalayan blackberry in the Pacific Northwest. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/moredocs/rubdis01.pdf; accessed October 2004.

Tirmenstein, D. 1989. *Rubus discolor*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed June 2004.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Van Dersal, W.R. 1938. Native Woody Plants of the United States, Their Erosion-Control and Wildlife Values. U.S. Department of Agriculture, Washington, DC. 362 p.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Willoughby, J.W., and W. Davilla. 1984. Plant species composition and life form spectra of tidal streambanks and adjacent riparian woodlands along the lower Sacramento River. Pages 642−651 in R.E. Warner and K.M. Hendrix (eds.), California Riparian Systems: Ecology, Conservation, and Productive Management: Proceedings of a Conference. September 17−19, 1981, Davis, California. University of California Press, Berkeley.

Other References of Interest Not Cited in the Text

Bailey, L. 1923. Certain cultivated *Rubus*. Gentes Herbarium 1:196–197.

DiTomaso, J.M. 2002. Wild Blackberries: Integrated Pest Management for Home Gardeners and Landscape Professionals. Publ. No. 7434. University of California Cooperative Extension.

Hoshovsky, M.C. 2000. *Rubus discolor*. Pages 277–281 in C.C. Bossard, J.M. Randall, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Saccharum ravennae* (L.) L. (USDA 2005)
Synonyms:	*Erianthus ravennae* (L.) Beauv., *Erianthus ravennae* (L.) Beauv. var. *purpurascens* (Anderss.) Hack. (USDA 2005)
Common names:	Ravennagrass
Evaluation date (mm/dd/yy)**:**	04/15/05
Evaluator #1 Name/Title:	Dr. Ed Northam
Affiliation:	Northam Weed Science Consulting
Phone numbers:	(480) 947–3882
Email address:	fnortham@msn.com
Address:	216 E. Taylor, Tempe, Arizona 85281
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	J. Hall, H. Messing, B. Munda, F. Northam, J. Ward
Committee review date:	04/15/05
List date:	04/15/05
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Other published material	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **Alert**
1.2	Impact on plant community	**B**	Observational		
1.3	Impact on higher trophic levels	**U**	No information		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Observational	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **13 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**B**	Observational		
2.5	Potential for human-caused dispersal	**B**	Observational		
2.6	Potential for natural long-distance dispersal	**C**	Other published material		
2.7	Other regions invaded	**B**	Other published material		RED FLAG **NO** Something you should know.
3.1	Ecological amplitude	**D**	Observational	**"Distribution"** **Section 3 Score:** **D**	
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Other pub.**	
Identify ecosystem processes impacted: Alters fire dynamics, interferes with sunlight penetration to soil surface, and alters moisture and nutrient content of wetland or riparian habitat soils.	
Rationale: Ravennagrass plants produce densely tufted, perennial clumps with flowering stalks 2 to 4 meters tall (Welsh et al. 1987). Foliage of individual plants in Phoenix, Arizona can mature into clumps that are 1 meter tall and 1 to 1.5 meters in diameter with dozens of densely intertwined leaves (F. Northam, personal observation, 2005). Based on inferences from observations and published taxonomic information, ravennagrass appears capable of adding additional vegetation to streambank and moist floodplain plant communities, which could increase fire frequency and intensity in riparian areas. Large, multi-leafed clumps shade soil surfaces and disrupt natural light conditions near ground level; this shading may displace short stature native vegetation. Dense extensive infestations in small stream corridors will probably impede storm water flow, which will increase sediment and organic matter deposition. Root systems required to support ravennagrass plants may limit soil moisture and nutrient availability to native plants. Because ravennagrass has growth and habitat requirements similar to pampas grass (*Cortaderia sellona*), as described in DiTomaso (2000) and Gadcil et al. (1984), the Working Group inferred that similar impacts (fire and flood) are potential natural detriments if ravennagrass populations establish large infestations.	
Sources of information: See cited literature. Also considered personal observations of ravennagrass biology in Arizona by F. Northam (Weed Biology Consultant, Tempe, Arizona, 2005) and inference drawn from the literature.	

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **B** *Doc'n Level:* **Obs.**	
Identify type of impact or alteration: Reduce survival of natives plant seedlings; adds another another vegetative layer to riparian plant communities.	
Rationale: Aboitic impacts listed in question 1.1 may cause seedling mortality of native plants by reducing sunlight under or adjacent to ravennagrass canopies. Removal of soil moisture and nutrients by ravennagrass roots are also possible competitive impacts that may be harmful to native seedling growth and health of established native plants. Stevens (Undated) reported ravennagrass as highly competitive in Grand Canyon riparian zones, but gave no documentation. Makarick (1999) identified ravennagrass as highly competitive and capable of altering plant succession along Grand Canyon stream banks.	
Sources of information: See cited literature. Also see sources cited in question 1.1 and information in Stevens, L. Undated. Controlling the Aliens: Ravenna Grass in Grand Canyon. Grand Canyon River Guides, Flagstaff, Arizona. Available online at www.gcrg.org/bqr/6-4/ravenna.htm; accessed April 14, 2005.	

Question 1.3 Impact on higher trophic levels *Score:* **U** *Doc'n Level:* **No info.**	
Identify type of impact or alteration: Unknown.	
Rationale: None.	
Sources of information: None.	

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: No known hybridization.
Rationale: No other species of *Saccharum* in Arizona (Kearney and Peebles 1960).
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Obs..**
Describe role of disturbance: Natural and human disturbance is involved in establishment.
Rationale: Arizona populations occur in areas where unstable stream conditions (floods) or human activities cause ground disturbance including the Colorado River within the Grand Canyon (Makarick, 1999), a drainage ditch within a municipal park (F. Northam, personal observation, 2005), and along canal banks (Hitchcock 1950).
Sources of information: See cited literature. Also considered personal observations of ravennagrass biology in Arizona by F. Northam (Weed Biology Consultant, Tempe, Arizona, 2005).

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**
Describe rate of spread: New populations have been identified in southwestern Arizona during the past five years in riparian areas along the lower Colorado River.
Rationale: Grand Canyon populations are subjected to a control program (Makarick 1999). A ditch bank population in a Tempe, Arizona park has doubled in three years, but another park population appears stable since a specimen was collected in 1966 (F. Northam, personal observation, 2005). Populations near Yuma, Arizona that were not present 10 years ago are now recorded on Bureau of Land Management land, but do not appear to be expanding rapidly (F. Northam, personal observation, 2005).
Sources of information: See cited literature. Also considered personal observations of ravennagrass biology in Arizona by F. Northam (Weed Biology Consultant, Tempe, Arizona, 2005).

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**
Describe trend: Some increase in area has been detected, but less than doubling in <10 years.
Rationale: New populations of a few plants have been recorded in Colorado River area near Yuma within the last five years, but this is only a small increase in total range of this species across the state (F. Northam, personal observation, 2005). Colorado River populations in the Grand Canyon were identified in early 1980s (Stevens Undated). Ravennagrass was identified on the Virgin River in 1986 (http://seinet.asu.edu).
Sources of information: Personal observations of ravennagrass biology in Arizona by F. Northam (Weed Biology Consultant, Tempe, Arizona, 2005), information in Stevens, L. (Undated. Controlling the Aliens: Ravenna Grass in Grand Canyon. Grand Canyon River Guides, Flagstaff, Arizona. Available online at www.gcrg.org/bqr/6-4/ravenna.htm; accessed April 14, 2005), and SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed March 17, 2005).

Question 2.4 Innate reproductive potential *Score:* **B** *Doc'n Level:* **Obs..**
Describe key reproductive characteristics: Seeds (caryopses) are the only reported form of reproduction in wildlands.
Rationale: Horticultural manuals note that ravennagrass readily self-sows in warm climates (Meyer 1975, Darke 1999). Answers to reproductive questions in Worksheet A are the results of ravennagrass observations in Canal Park, Tempe, Arizona (F. Northam, personal observation, 2005).
Sources of information: See cited literature. Also considered personal observations of ravennagrass biology in Arizona by F. Northam (Weed Biology Consultant, Tempe, Arizona, 2005).

Question 2.5 Potential for human-caused dispersal *Score:* **B** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: This species is sold as an ornamental product across the southern U.S.
Rationale: Numerous vendors can be accessed on internet websites and several garden websites give horticultural advice for growing ravennagrass including the Kemper Center for Home Gardening at Missouri Botanical Garden in St. Louis, Missouri (available online at: http://www.mobot.org/gardeninghelp/plantfinder/Plant.asp?code=A410). Even though this species has been in Arizona for over 50 years, it does not seem to be a popular garden plant. Ravennagrass needs continual watering during the hottest part of Arizona's growing season and is killed by extended frost periods. Therefore, current distribution indicates limited use and dispersal from human-caused activities.
Sources of information: Personal observations by F. Northam (Weed Biology Consultant, Tempe, Arizona, 2005).

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Wind.
Rationale: Caryopses are enclosed in 3.5 to 7 mm spikelets that have long silky hairs (Baldwin et al. 2002). When spikelets disarticulate from panicles, spikelet hairs enable dispersal by air currents. Natural long distance dispersal would require a strong wind phenomenon, such as large whirlwinds to keep spikelets airborne for one kilometer (F. Northam, personal observation, 2005).
Sources of information: See cited literature. Also considered personal observations of ravennagrass biology in Arizona by F. Northam (Weed Biology Consultant, Tempe, Arizona, 2005).

Question 2.7 Other regions invaded ***Score:*** **B** *Doc'n Level:* **Other pub.**
Identify other regions: Infests two other minor ecological types that exist in Arizona , but are not yet invaded in Arizona: Mohave desertscrub in Utah and Sonoran desertscrub in California.
Rationale: Occurs on open slopes at 610 to 910 feet in Mohave desertscrub, Washington County, Utah (Welsh et al. 1987). Occurs in Lower Colorado subdivision Sonoran desertscrub at the Algogones Dunes east of Brawley, California on Bureau of Land Management land (Calflora 2005).
Sources of information: See cited literature. Also considered information from the Calflora plant species occurrence database (available at: http://www.calflora.org/species/; accessed 2005).

Question 3.1 Ecological amplitude *Score:* **D** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: One minor ecological type: Sonoran riparian.
Rationale: New populations of a few plants have been recorded in Colorado River area near Yuma, Arizona within the last five years (F. Northam, personal observation, 2005). Colorado River populations in the Grand Canyon were identified in early 1980s (Stevens Undated). Ravennagrass was identified on the Virgin River in 1986 (SEINet 2005). The oldest ravennagrass herbarium specimen for Arizona is 1942 from the Arizona Canal (Gould 1973). Non-wildland and wildland collections in Arizona that are escapes from horticultural situations were observed in sites having water during the hot, dry months of summer (SEINet 2005). Ravennagrass is an ornamental species with limited distribution in Arizona wildlands. Plants that have escaped from horticultural settings have been present in Arizona for at least 60 years, but few escapes have established in wildlands. Summer drought in desert regions and winter temperatures at elevations above 5000 feet limit establishment and population maintenance in Arizona.

The population in northwest Tempe, Arizona occurs along a desert wash that has water flowing through it for at least eight months of the year due to urban runoff from a city water-treatment plant and lawn/garden irrigation. Ravennagrass plants grow at the margin of the water's edge during low flow conditions; as a result, they are frequently inundated for a time when flash flood events occur. They apparently can tolerate some degree of flooding, but do not require standing water to survive (F. Northam, personal observation, 2005).
Sources of information: See cited literature. Also considered personal observations of ravennagrass biology in Arizona by F. Northam (Weed Biology Consultant, Tempe, Arizona, 2005), information in Stevens, L. (Undated. Controlling the Aliens: Ravenna Grass in Grand Canyon. Grand Canyon River Guides, Flagstaff, Arizona. Available online at www.gcrg.org/bqr/6-4/ravenna.htm; accessed April 14, 2005), and SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed March 17, 2005).

Question 3.2 Distribution *Score:* **D** *Doc'n Level:* **Obs.**
Describe distribution: Currently known ravennagrass infestations in Arizona are limited to wet areas along streams, rivers and riparian areas adjacent to rivers and streams (SEINet 2005; F. Northam, personal observation, 2005).
Rationale: Known locations of ravennagrass in Arizona do not occupy large tracts of land. Most sites are composed of several plants covering a few dozen square meters. Large infestations (found in Colorado River floodplain areas in Grand Canyon) cover only a few acres.
Sources of information: Personal observations of ravennagrass biology in Arizona by F. Northam (Weed Biology Consultant, Tempe, Arizona, 2005) and SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed March 17, 2005).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**No**	**0 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**No**	**0 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 5 Total unknowns: 2		
	Score : B		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**D**
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Baldwin, B.G., S. Boyd, B.J. Ertter, R.W. Patterson, T.J. Rosatti, and D.H. Wilken. 2002. The Jepson Desert Manual. University of California Press, Berkeley. 596 p.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Darke, R. 1999. The Color Encyclopedia of Ornamental Grasses. Timber Press, Portland, Oregon. 273 p.

DiTomaso, J. 2000. *Cortaderia selloana*. Pages 128−133 in C.C. Bossard, J.M. Randal, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Gadcil, R.L., A L. Knowles, and J.A. Zabkiewiez. 1984. Pampas: a new forest weed problem. Proceedings New Zealand Weed and Pest Control Conference 37:187−190.

Gould, F.W. 1973. Grasses of Southwestern United States. University of Arizona Press, Tucson. 300 p.

Hitchcock, A.S. 1950. Manual of the Grasses of the United States. 2nd edition revised by A. Chase. Miscellaneous Publication No. 200. U.S. Department of Agriculture. U.S. Government Printing Office, Washington DC. 746 p.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Makarick, L.J. 1999 Draft Exotic Plants for Grand Canyon National Park. National Park Service, Grand Canyon National Park, Arizona.

Meyer, M.H. 1975. Ornamental Grasses. Charles Scribner's Sons, New York. 78 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Welch, S.L., N.A. Atwood, L.C. Higgins, and S. Goodrich. 1987. A Utah Flora. Brigham Young University, Provo, Utah. 773 p.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Salsola collina* Pallas; *Salsola paulsenii* Litv.; *Salsola tragus* L. (USDA 2005).
Synonyms:	*Salsola collina*: None listed in USDA (2005); *Salsola paulsenii*: None listed in USDA (2005); *Salsola tragus*: *Salsola australis* R. Br., *Salsola iberica* (Sennen & Pau) Botsch. ex Czerepanov, *Salsola kali* L. ssp. *ruthenica* (Iljin) Soó, *Salsola kali* L. ssp. *tragus* (L.) Celak., *Salsola kali* L. ssp. *tenuifolia* Moq., *Salsola pestifer* A. Nels., *Salsola ruthenica* Iljin (USDA 2005).
Common names:	*Salsola collina*: Slender Russian thistle, spineless Russian thistle; *Salsola paulsenii*: Barbwire Russian thistle; *Salsola tragus*: Prickly Russian thistle, common Russian thistle, tumbling thistle, tumbleweed
Evaluation date (mm/dd/yy)**:**	08/23/03, 05/04, and 07/04
Evaluator #1 Name/Title:	Dr. Kathryn A. Thomas
Affiliation:	USGS, Southwest Biological Science Center
Phone numbers:	(928) 556–7327
Email address:	Kathryn.Thomas@usgs.gov
Address:	2255 N. Gemini Drive, Flagstaff, Arizona 86001
Evaluator #2 Name/Title:	Janice K. Busco
Affiliation:	U.S. Geological Survey
Phone numbers:	See above
Email address:	Janice.Busco@nau.edu
Address:	See above

List committee members:	08/26/03: W. Austin, D. Backer, R. Hiebert, L. Makarick, L. Moser, T. Olson, B. Phillips, K. Thomas, K. Watters 06/23/04: W. Albrecht, D. Backer, J. Brock, J. Busco, J. Hall, C. Laws, L. Moser, B. Phillips, K. Watters
Committee review date:	08/26/03 and 06/23/04
List date:	06/23/04
Re-evaluation date(s):	

Taxonomic Comment

Salsola tragus is the correct name for the widespread, narrow-leaved, weedy representative of the *S. kali* aggregate (Mosyakin 1996 and Rilke 1999 in Flora of North America Editorial Committee 2004). *Salsola tragus*, however, has been known in North American and European botanical literature under numerous names (for detailed synonymy see Mosyakin 1996 and Rilke 1999 in Flora of North America Editorial Committee 2004). *Salsola tragus* is an extremely polymorphic species consisting of several more or less distinct races (subspecies or segregate species). Several varieties may be recognized within *S. tragus*; many of them are just morphological variants of little or no taxonomic value (Flora of North America Editorial Committee 2004).

According to USDA (2005) and the Flora of North America Editorial Committee (2004), *S. kali* L. is comprised of the subspecies ssp. *kali* and ssp. *pontica* and does not occur in Arizona. In some references the name *Salsola kali* ssp. *tragus* has frequently been truncated to *S. kali* resulting in confusion; however, USDA (2005) identifies *S. kali* ssp. *tragus* as a synonym for *S. tragus*.

Some additional taxonomic confusion also is possible. For example, the name *S. kali* has often been misapplied to other species in this aggregate, *S. collina* has frequently been misidentified *as S. tragus*, and intermediate and possibly hybrid forms between *S. paulsenii* and *S. tragus* are common along margins of the range of the species and in secondary, synanthropic (human altered) localities (Flora of North America Editorial Committee 2004).

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Other published material	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**B**	Other published material		
1.3	Impact on higher trophic levels	**D**	Reviewed scientific publication		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **15 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Other published material		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Other published material		
2.6	Potential for natural long-distance dispersal	**A**	Other published material		
2.7	Other regions invaded	**C**	Observational		RED FLAG NO Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**B**	Observational		

Table 3. Documentation

Note: All three *Salsola* species occurring in Arizona are evaluated collectively herein based on the assumption that they each behave ecologically similar in Arizona and that often the literature doesn't distinguish one species from another.

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Other pub.**
Identify ecosystem processes impacted: Hydrologic regime (streamflow) may be altered; fire size and frequency may be increased when the plant is present.
Rationale: Skeletons of plants can block stream channels (Morisawa 1999, Wallace et al. 1968); burns easily because stems arranged so much air circulation within plant (Young 1991 in Howard 1992), increases fuel load of an area by retaining original shape for some time before decomposing (Evans and Young 1970) and increases the rate of spread of fires when burning skeletons roll into unburned areas (Young 1991 in Howard 1992).
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition, structure, interactions *Score:* **B** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Competition with native plants probable, particularly in drought circumstances; can accelerate revegetation in certain circumstances; competes with agricultural plants for space, water, nutrients (Wallace et al. 1968). It has positive as well as negative effects; it will grow where no other plant species will (Howard 1992). Increases to dominant on Navajo Nation, Petrified Forest National Monument, Colorado River in drought years (documentation below in rationale). Can potentially be a vector for fire (Evans and Young 1970, Young 1991 in Howard 1992) thus changing plant communities that are not well-adapted to fire.
Rationale: Barbara Phillips (personal communication, 2004) reports, and Daniella Roth (personal communication, 2004) confirms, that during drought *Salsola* spp. are some of the only plants surviving in washes on the Navajo Nation. Kate Watters (personal communication, 2004) reports increase of *Salsola* spp. on the Colorado River with drought and disturbance and of individual populations along the Colorado River with and without control. Kathryn Thomas (personal observations, 2004) reports increase of *Salsola* spp. in monitoring plots at Petrified Forest National Monument in drought years. Fire ecology: Russian thistle aids in spreading fire. It burns easily because the stems are spaced in an arrangement that allows for maximum air circulation (Young 1991 in Howard 1992). In addition, dead plants contribute to fuel load by retaining their original shape for some time before decomposing (Evans and Young 1970). The rolling action of the plant spreads prairie wildfire quickly. Russian thistle colonizes a burn when off-site; abscised plants blow across it, spreading seed (Young 1991 in Howard 1992). Presence of Russian thistle on disturbed sites if topsoil present. Roots are readily invaded with mychorrhizal fungi which are pathogenic to root since association is not formed. Russian thistle declines while mychorrhizal fungi population increases and are present to augment successional species next moving into disturbed site (Allen and Allen 1988). Dead Russian thistle provides microshading for other establishing plant species (Grilz et al. 1988). Species in this family may get curly top virus as it is an alternate host for beet leafhopper that vectors curly-top virus of sugar beets, tomatoes, and curcurbits (DeLoach et al. 1986, CDFA 2004). Competitive with native plants (Morisawa 1999); although no specific studies cited for native plants, it is known competitor with agricultural plants for space, water, nutrients (Wallace et al. 1968). Impact on native plant populations may be more severe on sandy substrates and during drought (Thomas et al. 2003).

Sources of information: See cited literature. Also considered personal observations by K. Thomas (Vegetation Ecologist, U.S. Department of the Interior, U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona, 2004) and personal communications with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004), D. Roth (Botanist, Navajo Nation, Flagstaff, Arizona, 2004), and K. Watters (Research Technician, National Park Service, Southern Colorado Plateau Network, Flagstaff, Arizona, 2004).

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: Negligible impact; causes no perceivable change in higher trophic level populations, communities or interactions.
Rationale: Minor component in bison, mule deer and elk diet (DeLoach et al 1986, Peden et al. 1974, Short 1979, USDA 1937), important prairie dog food (Bonham and Lerwick 1976), pronghorn show high preference for summer growth in years with high precipitation (Beale and Smith 1970), seeds eaten by granivorous birds, including scaled and Gambel's quail (Anderson and Ohmart 1984, DeLoach et al. 1986, Disano et al. 1984), small mammals consume seeds (DeLoach et al. 1986), provides hiding cover for small mammals, songbirds, upland game birds and waterfowl (Dittberner and Olson 1983), sage grouse have used it for nesting cover (Hulet et al. 1986), eaten by cattle and sheep (DeLoach et al 1986, Young 1991 in Howard 1992); can cause mouth ulcerations in young lambs and rain softened Russian thistle has laxative effect on livestock which can harm weakened animals (Cook et al. 1954, USDA 1937). Found in desert tortoise habitat in Mojave Desert (Brooks and DeFalco 1999); eaten by Gambel and scaled quail on the Santa Rita Experimental Range (Medina 2003).
Sources of information: See cited literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: There are no known native *Salsola* species in North America. No known impact.
Rationale: No reference to genetic impacts to *Salsola* species. Hybridization occurs between *Salsola* species, but there are no native *Salsola* species in North America (Kearney and Peebles 1960, Flora of North America Editorial Committee 2004).
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Moderate invasive potential with natural and anthropogenic disturbance. This species can readily establish in areas with natural disturbance and colonizes burns from off site.
Rationale: Grazing, drought, and disturbed soil facilitates Russian thistle establishment. *Salsola* spp. are early successional species adapted to disturbed lands (Rutledge and McLendon 1996 [cited as 2002] in Guertin and Halvorson 2003, Thomas et al. 2003). *Salsola* spp. colonize burns from off site (Young 1991 in Howard 1992).
Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Other pub.**
Describe rate of spread: Increasing but less rapidly than doubling in <10 years.
Rationale: Drought conditions in Arizona may be causing increase in populations (Thomas et al. 2003). Populations will naturally die out in areas with topsoil. *Salsola* spp. are also shade intolerant so they will die out if shaded (DeLoach et al. 1986, Allen and Allen 1988, Allen et al. 1989, and Grilz et al. 1988 in Howard 1992). Unknown population longevity in sandy soils and where plant species are more widely spread (Thomas et al. 2003). Increased seed germination and establishment with available soil nitrogen (Crompton and Bassett 1985). In Nevada pulses of nitrate-rich dust, synchronous with spring emergence, and other nutrient additions via aeolian dust may have stimulated invasion of dune-mantled

uplands by *S. paulsenii* (Blank et al 1999). Drought conditions in Arizona may be causing increase in populations (Thomas et al. 2003).
Sources of information: See cited literature.

Question 2.3 Recent trend in total range infested within state *Score:* **C** *Doc'n Level:* **Obs.**
Describe trend: Stable.
Rationale: *Salsola tragus was* first noted in Arizona in 1893 (Guertin and Halvorson 2003) and was well established by 1913 (Burgess et al. 1991 in Guertin and Halvorson 2003), was noted as common along northern Arizona railways in 1904 (Burgess et al. 1991). *Salsola paulsenii* was probably introduced to the far western United States between 1891 and 1913 and was collected near Barstow, California in 1913 (Beatley 1973). *Salsola collina* was collected in Kansas in 1923, but misidentified and subsequently reported for the first time in North America from Minnesota in 1938; reports for California are based based on specimens cited by S. Rilke (1999 in Flora of North America Editorial Committee 2004). The actual distribution of *S. collina* seems to be underestimated due to the common and constant confusion with atypical forms of *S. tragus. Salsola tragus* is an extremely polymorphic species consisting of several more or less distinct races (subspecies or segregate species). Several varieties may be recognized within *S. tragus*: however, these deviant forms are just morphological variants of little or no taxonomic value (Flora of North America Editorial Committee 2004).
Sources of information: See cited literature. Score based on inference drawn from the literature and Working Group consensus.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: High reproductive potential. Large number of seeds produced, up to 250,000 per plant (Young 1991 in Howard 1992). Seeds do not have high viability: a year (Young 1991 in Howard 1992) to several years (Parker 1972 and Rutledge and McLendon 1996 [cited as 2002] in Guertin and Halvorson 2003). Seed germination from soil seed bank drops off sharply after first year and was not found to occur after year three in a four-year study in Canada (Crompton and Bassett 1985).
Rationale: See Worksheet A.
Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Skeletons caught by vehicles, trains (Sauer 1988 in Guertin and Halvorson 2003); skeletons caught by fences; transported in ship ballast (Drezner et al 2001, Ridley 1930 in Guertin and Halvorson 2003) and contaminated crop seeds (Rutledge and McLendon 1996 [cited as 2002] in Guertin and Halvorson 2003).
Rationale: High, there are numerous opportunities for dispersal to new areas.
Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: The skeletons of dead plants readily breaks at the plant stem and rolls across landscape with wind, dispersing seeds as it moves. Winged seeds also provide additional long distance dispersal mechanism. (Crompton and Bassett 1985).
Rationale: Frequent long-distance dispersal
Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Obs.**

Identify other regions: It is difficult to determine the extent of each species invasion because species identifications are so muddled. Munz (1974 in Guertin and Halvorson 2003) first reported *Salsola paulsenii* from North America in 1968. Its current range is in California, Nevada, Utah, and Arizona. It may be expected in the future also in New Mexico and Texas (Flora of North America Editorial Committee 2004). According to Howard (1992), *Salsola tragus* is native to Eurasia and is distributed throughout most arid and semiarid regions of the world. In North America, Russian thistle occurs from British Columbia east to Labrador and south through the conterminous United States to northern Mexico (Hitchcock and Cronquist 1964, DeLoach et al 1986). It is most common in central and western regions of Canada and the United States and along the Atlantic and Gulf coasts. Limited southern and eastern inland populations occur along waste areas and railroad tracks (Young 1991 in Howard 1992). Russian-thistle is adventitious in Hawaii (St John 1973).

From the Flora of North America Editorial Committee (2004 and references therein): *Salsola collina* was reported in North America for the first time from Minnesota. It was collected in Kansas in 1923, but misidentified. Later it was discovered in Colorado, Iowa and Missouri. Reports of *S. collina* for Arizona and New York are based on specimens cited by Rilke (1999). Its actual distribution seems to be underestimated due to the common and constant confusion with deviant forms of *S. tragus*. In the future, *S. collina* may be found to occur within the major portion of the present range of *S. tragus.*

Rationale: *Salsola* spp. invade elsewhere, but only in ecological types already invaded within the state. These species have been within the state for over 100 years. Their ranges may be filled and all communities that can be invaded have been. Another line of thought, however, is that the extent of invasion may not be complete since continued disturbance and ongoing drought may be encouraging the species proliferation and spread (Guertin and Halvorson 2003).

Sources of information: See cited literature. Score based on inference drawn from the literature.

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Obs.**

Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: *Salsola* spp. have a broad ecological amplitude that probably includes all but the highest elevations within the state. *Salsola* spp. were introduced into the state over 100 years ago. As demonstrated in the literature, it is capable of establishing in many plant communities that are within a certain elevation. *Salsola* spp. are prevalent in disturbed areas. In addition to direct anthropogenic disturbances, in the southwest there are a number of natural disturbances that potentially favor *Salsola* spp. invasion into natural communities including drought, wind, and high grazing pressure.

Salsola tragus was first noted in Arizona in 1893 (Guertin and Halvorson 2003) and was well established by 1913 (Burgess et al. 1991 in Guertin and Halvorson 2003). It was noted as common along northern Arizona railways in 1904 (Burgess et al. 1991). *Salsola tragus* is found in disturbed areas, roadsides, cultivated fields, coastal and riparian sands, semi-deserts, deserts, eroded slopes; 0 to 2500 m throughout North America (except the southeast). Parker (1972) lists *Salsola tragus* as occurring in chaparral (scrublands, more specifically southwestern interior chaparral scrub), grasslands, freshwater systems and woodlands (pinyon juniper and forests (yellow pine) in Arizona. *Salsola tragus* is found in the pinyon-juniper woodland on land in the Arizona strip administered by BLM (ERI 2003).

Salsola collina was collected in Kansas in 1923, but misidentified and subsequently reported for the first time in North America from Minnesota in 1938; reports for California are based on specimens cited by Rilke (1999). *Salsola collina* is found in waste places, roadsides, railway areas, cultivated fields,

disturbed natural and semi-natural plant communities, 100 to 2000 m elevation, with patchy distribution throughout northeastern and north central North America and patches within the four corners states. *Salsola paulsenii* was probably introduced to the far western United States between 1891 and 1913 and was collected near Barstow, California in 1913 (Beatley 1973). *Salsola paulsenii* is found in sandy soils, disturbed natural and semi-natural plant communities, semi-deserts, deserts, eroded slopes, sand dunes and sandy waste places at 0 to 1900 m in Arizona, California, Colorado, Nevada, and Utah (Flora of North America Editorial Committee 2004). *Salsola paulsenii* has been found on upland dunes that are not highly disturbed or degraded. Occurs within an *Achnatherum hymenoides, Psorothamnus polydenius* and *Atriplex confertifolia* community adjacent to a Lake Lahontan playa in Nevada since 1990 (Blank et al. 1999).
Rationale: Present in five major and seven minor ecological types and possibly occurs in more. See Worksheet B.
Sources of information: See cited literature. Score based on inference drawn from the literature and the observations of Working Group members. Also considered information for *S. paulsenii* from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2005).

Question 3.2 Distribution	*Score:* **B** *Doc'n Level:* **Obs.**
Describe distribution: Russian thistle is known to occur in many ecological types; however, its distribution within each type has not been explicitly quantified. It is highly likely that it can occur in any of the ecological types within Arizona outside of tundra; however, the severity of infestation will likely differ depending upon local conditions.	
Rationale: The Southwest Exotic Plant Mapping Program (SWEPIC 2003) database shows *Salsola* spp. distributed within eight major ecological types; however, data points are coarse and observations have not been made by the authors of this assessment (K. Thomas and J. Busco) and other Working Group members that document the presence of Russian thistle among wildland occurrences of three of these major ecological types: Non-Riparian Wetlands, Riparian, and Forests. No systematic survey of *Salsola* spp. has been made throughout the state to quantify all ecological types in which *Salsola* spp. occur, nor can any accurate estimate be made of the percentage of those ecological systems that are actually invaded. The percentage values in Worksheet B are estimates. Recent surveys in national parks indicate that *Salsola* spp. may be more prevalent than previously considered (SWEPIC 2003).	
Sources of information: See cited literature. Also considered observations by K. Thomas (Vegetation Ecologist, U.S. Department of the Interior, U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona, 2004), J. Busco (U.S. Department of the Interior, U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona, 2004), and other Working Group members.	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**[No]**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**[No]**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**[No]**	**1 pt.**
	Total pts: 7 Total unknowns: 0		
	Score : A		

Note any related traits: Main stems break at ground after senescence and roll with wind or get caught in mobile objects (i.e., trains), thus aiding dispersal.

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	**D**
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	**B**
Desertlands	Great Basin desertscrub	**B**
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	**B**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	**D**
	semi-desert grassland	**D**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	**C**
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Allen, E.B., and M.F. Allen. 1988. Facilitation of succession by the nonmycothrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany 75:257–266.

Allen, M.F., E.B. Allen, and C.F. Friese. 1989. Responses of the non-mycotrophic plant *Salsola kali* to invasion by vesicular-arbuscular mycorrhizal fungi. New Phytologist 111:45–49.

Anderson, B.W., and R.D. Ohmart. 1984. Avian use of revegetated riparian zones. Pages 626–631 in R.E. Warner and K.M. Hendrix (eds.), California Riparian Systems: Ecology, Conservation, and Productive Management: Proceedings of a Conference. September 17–19, 1981, Davis, California. University of California Press, Berkeley.

Beale, D.M., and A.D. Smith. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. Journal of Wildlife Management 34:570–582.

Beatley, J.C. 1973. Russian-thistle (*Salsola*) species in Western United States. Journal of Range Management 26:225–226.

Blank, R.R., J.A. Young, and F.L. Allen. 1999. Aeolian dust in a saline playa environment, Nevada, USA. Journal of Arid Environments 41:365–381.

Bonham, C.D., and A. Lerwick. 1976. Vegetation changes induced by prairie dogs on shortgrass range. Journal of Range Management 29:221–225.

Brooks, M.L., and L DeFalco. 1999. Exotic Plant Species in Desert Tortoise Habitat. In Twenty-Fourth Annual Meeeting and Symposium of the Desert Tortoise Council, March 5–8 1999. Available online at: http://www.deserttortoise.org/abstract/abstracts1999/sgabs3.html; accessed March 2004.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burgess, T.L., J.E. Bowers, and R.M. Turner. 1991. Exotic plants at the desert laboratory, Tucson, Arizona. Madrono 38:96–114.

[CDFA] California Department of Food and Agriculture. 2004 Russian thistle (*Salsola* spp.). In E.A. Healy, S. Enloe, J.M. DiTomaso, B. Roberson, N. Dechoretz, S. Schoenig, P. Akers, L. Butler, and J. Garvin (eds.), Encycloweedia. University of California, Department of Vegetable Crops, Weed Science Program, Non-Cropland Weed Group, University of California Extension Service, Davis. Available online at:
http://www.cdfa.ca.gov/phpps/ipc/weedinfo/salsola.htm; accessed March 2004

Cook, C.W., L.A. Stoddart, and L.E. Harris. 1954. The nutritive value of winter range plants in the Great Basin as determined with digestion trials with sheep. Bulletin 372. Utah State University, Agricultural Experiment Station, Logan. 56 p.

Crompton, C.W. and L.G. Bassett. 1985. The biology of Canadian weeds. 65. *Salsola pestifer* A. Nels. Canadian Journal of Plant Science 65:379–388.

DeLoach, C.J., P.E. Boldt, H.A. Cjordo [and others]. 1986. Weeds common to Mexican and U.S. rangelands: proposals for biological control and ecological studies. Pages 49–68 in D.R. Patton, V. Gonzales, C.E. Medina, L. Alvin [and others] (technical coordinators), Management and Utilization of Arid Land Plants: Symposium Proceedings. February 18–22, 1985, Saltillo, Mexico. Gen. Tech. Rep. RM-135. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Dittberner, P.L., and M.R. Olson. 1983. The plant information network (PIN) data base: Colorado, Montana, North Dakota, Utah, and Wyoming. FWS/OBS-83/86. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC. 786 p.

Disano, J. B., W. Anderson, J.K. Meents, and R.D. Ohmart.1984. Compatibility of biofuel production with wildlife habitat enhancement. Pages 739–743 In R.E. Warner and K.M. Hendrix (eds.), California Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkley.

Drezner, T.D., P.L. Fall, and J.C. Stromberg. 2001. Plant distribution and dispersal mechanisms at the Hassayampa River Preserve, Arizona, USA. Global Ecology and Biogeography 10:205–217.

[ERI] Ecological Restoration Institute. 2003. Arizona Strip District Pinyon-Juniper Treatment Demonstration Project Environmental Assessment EA-AZ-010-03-14. Available online at: http://azwww.az.blm.gov/env_docs/old/pinyon_junip_ea.pdf; accessed March 2004.

Evans, R.A., and J.A. Young. 1970. Plant litter and establishment of alien annual weed species in rangeland communities. Weed Science 18:697–703.

Flora of North America Editorial Committee (eds.) 2004. Flora of North America North of Mexico. Volume 4. Magnoliophyta: Caryophyllidae, Part 1. Flora of North America Association, New York and Oxford. Available online at: http://www.efloras.org/volume_page.aspx?volume_id=1004, go to Chenopodiaceae, *Salsola*; accessed May 2004.

Grilz, P., L. Delanoy, and G. Grismer. 1988. Site preparation, seeding, nurse crop methods tested in dune restoration (Saskatchewan). Restoration and Management Notes 6:47–48.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Surevy, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Hitchcock, C.L., and A. Cronquist. 1964. Vascular plants of the Pacific Northwest. Part 2: Salicaceae to Saxifragaceae. University of Washington Press, Seattle. 597 p.

Howard, J.L. 1992. *Salsola kali*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, Montana (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed July 2004.

Hulet, B.V., J.T. Flinders, J.S. Green [and others]. 1986. Seasonal movements and habitat selection of sage grouse in southern Idaho. Pages 168–175 in E.D. McArthur and B.L. Welch (compilers), Proceedings—Symposium on the Biology of *Artemisia* and *Chrysothamnus.* July 9–13, 1984, Provo, Utah. Gen. Tech. Rep. INT-200. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Medina, A. 2003. Gambel and scaled quail diets on the Santa Rita Experimental Range. Pages 133–140 M.P.McClaran, P.F. Ffolliott, and C.B. Edminster (technical coordinators), Santa Rita Experimental Range: 100 Years (1903 to 2003) of Accomplishments and Contributions. Conference Proceedings, October 30—November 1, 2003, Tucson, Arizona. RMRS-P-30. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, Utah.

Morisawa, T. 1999. Weed Notes: *Salsola kali*. The Nature Conservancy, Wildland Invasive Species Team. Available online at: http://tncweeds.ucdavis.edu/moredocs/salkal10.html; accessed March 2004.

Mosyakin, S. L. 1996. A taxonomic synopsis of the genus *Salsola* (Chenopodiaceae) in North America. Ann. Missouri Bot. Gard. 83:387–395.

Munz, P.A. 1974. A Flora of Southern California. University of California Press, Berkeley. 1086 p.

Parker, K.F. 1972. An Illustrated Guide to Arizona Weeds. The University of Arizona Press, Tucson, Arizona. 338 p.

Peden, D.G., G.M. Van Dyne, R.W. Rice, and R.M. Hansen. 1974. The trophic ecology of *Bison bison* L. on shortgrass plains. Journal of Applied Ecology 11:489–497.

Ridley, H.N. 1930. The Dispersal of Plants throughout the World. L. Reeve and Co., Ltd., Ashfork, Kent United Kingdom.

Rilke, S. 1999. Revision der Sektion *Salsola* s.l. der Gattung *Salsola* (Chenopodiaceae). Bibliotheca Botanica (Stuttgart) 149:1–190.

Rutledge, C.R., and T. McLendon. 1996. An Assessment of Exotic Plant Species of Rocky Mountain National Park. Department of Rangeland Ecosystem Science, Colorado State University. 97 p. Available online from the Northern Prairie Wildlife Research Center, Jamestown, North Dakota at: http://www.npwrc.usgs.gov/resource/othrdata/explant/explant.htm. (Version 15Dec98). Go to the Literature Review Summary Information for Remaining Exotic Species and then click on *Sasola iberica*. Accessed March 2004.

Sauer, J.D. 1988. Plant Migration: The Dynamics of Geographic Patterning in Seed Plant Species. University of California Press, Berkeley. 282 pp.

Short, H.L. 1979. Deer in Arizona and New Mexico: Their Ecology and a Theory Explaining Recent Population Decreases. General Technical Report RM-70. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 25 p.

St. John, H. 1973. List and Summary of the Flowering Plants in the Hawaiian Islands. Cathay Press Limited, Hong Kong. 519 p.

[SWEPIC] Southwest Exotic Plant Information Clearinghouse. 2003. Southwest Exotic Mapping Program database. Available online at: http://www.usgs.nau.edu/swepic/swemp/maps.html); accessed May 2004.

Thomas, K., B.D. Anderson, and R. Hunt. 2003. Petrified Forest National Park Weed Inventory and Mapping Project. Annual Report FY 2002. U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona. 52 p.

[USDA] U.S. Department of Agriculture, Forest Service. 1937. Range Plant Handbook. Washington, DC. 532 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Wallace, A., W.A. Rhods, and E.F. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal 60:76–78.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Young, J.A. 1991. Tumbleweed. Scientific American 264:82–87.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Salsola collina* Pallas; *Salsola paulsenii* Litv.; *Salsola tragus* L. (USDA 2005).
Synonyms:	*Salsola collina*: None listed in USDA (2005); *Salsola paulsenii*: None listed in USDA (2005); *Salsola tragus*: *Salsola australis* R. Br., *Salsola iberica* (Sennen & Pau) Botsch. ex Czerepanov, *Salsola kali* L. ssp. *ruthenica* (Iljin) Soó, *Salsola kali* L. ssp. *tragus* (L.) Celak., *Salsola kali* L. ssp. *tenuifolia* Moq., *Salsola pestifer* A. Nels., *Salsola ruthenica* Iljin (USDA 2005).
Common names:	*Salsola collina*: Slender Russian thistle, spineless Russian thistle; *Salsola paulsenii*: Barbwire Russian thistle; *Salsola tragus*: Prickly Russian thistle, common Russian thistle, tumbling thistle, tumbleweed
Evaluation date (mm/dd/yy)**:**	08/23/03, 05/04, and 07/04
Evaluator #1 Name/Title:	Dr. Kathryn A. Thomas
Affiliation:	USGS, Southwest Biological Science Center
Phone numbers:	(928) 556–7327
Email address:	Kathryn.Thomas@usgs.gov
Address:	2255 N. Gemini Drive, Flagstaff, Arizona 86001
Evaluator #2 Name/Title:	Janice K. Busco
Affiliation:	U.S. Geological Survey
Phone numbers:	See above
Email address:	Janice.Busco@nau.edu
Address:	See above

List committee members:	08/26/03: W. Austin, D. Backer, R. Hiebert, L. Makarick, L. Moser, T. Olson, B. Phillips, K. Thomas, K. Watters 06/23/04: W. Albrecht, D. Backer, J. Brock, J. Busco, J. Hall, C. Laws, L. Moser, B. Phillips, K. Watters
Committee review date:	08/26/03 and 06/23/04
List date:	06/23/04
Re-evaluation date(s):	

Taxonomic Comment

Salsola tragus is the correct name for the widespread, narrow-leaved, weedy representative of the *S. kali* aggregate (Mosyakin 1996 and Rilke 1999 in Flora of North America Editorial Committee 2004). *Salsola tragus*, however, has been known in North American and European botanical literature under numerous names (for detailed synonymy see Mosyakin 1996 and Rilke 1999 in Flora of North America Editorial Committee 2004). *Salsola tragus* is an extremely polymorphic species consisting of several more or less distinct races (subspecies or segregate species). Several varieties may be recognized within *S. tragus*; many of them are just morphological variants of little or no taxonomic value (Flora of North America Editorial Committee 2004).

According to USDA (2005) and the Flora of North America Editorial Committee (2004), *S. kali* L. is comprised of the subspecies ssp. *kali* and ssp. *pontica* and does not occur in Arizona. In some references the name *Salsola kali* ssp. *tragus* has frequently been truncated to *S. kali* resulting in confusion; however, USDA (2005) identifies *S. kali* ssp. *tragus* as a synonym for *S. tragus*.

Some additional taxonomic confusion also is possible. For example, the name *S. kali* has often been misapplied to other species in this aggregate, *S. collina* has frequently been misidentified *as S. tragus*, and intermediate and possibly hybrid forms between *S. paulsenii* and *S. tragus* are common along margins of the range of the species and in secondary, synanthropic (human altered) localities (Flora of North America Editorial Committee 2004).

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Other published material	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**B**	Other published material		
1.3	Impact on higher trophic levels	**D**	Reviewed scientific publication		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **15 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Other published material		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Other published material		
2.6	Potential for natural long-distance dispersal	**A**	Other published material		
2.7	Other regions invaded	**C**	Observational		RED FLAG **NO** Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**B**	Observational		

Table 3. Documentation

Note: All three *Salsola* species occurring in Arizona are evaluated collectively herein based on the assumption that they each behave ecologically similar in Arizona and that often the literature doesn't distinguish one species from another.

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Other pub.**
Identify ecosystem processes impacted: Hydrologic regime (streamflow) may be altered; fire size and frequency may be increased when the plant is present.
Rationale: Skeletons of plants can block stream channels (Morisawa 1999, Wallace et al. 1968); burns easily because stems arranged so much air circulation within plant (Young 1991 in Howard 1992), increases fuel load of an area by retaining original shape for some time before decomposing (Evans and Young 1970) and increases the rate of spread of fires when burning skeletons roll into unburned areas (Young 1991 in Howard 1992).
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition, structure, interactions *Score:* **B** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Competition with native plants probable, particularly in drought circumstances; can accelerate revegetation in certain circumstances; competes with agricultural plants for space, water, nutrients (Wallace et al. 1968). It has positive as well as negative effects; it will grow where no other plant species will (Howard 1992). Increases to dominant on Navajo Nation, Petrified Forest National Monument, Colorado River in drought years (documentation below in rationale). Can potentially be a vector for fire (Evans and Young 1970, Young 1991 in Howard 1992) thus changing plant communities that are not well-adapted to fire.
Rationale: Barbara Phillips (personal communication, 2004) reports, and Daniella Roth (personal communication, 2004) confirms, that during drought *Salsola* spp. are some of the only plants surviving in washes on the Navajo Nation. Kate Watters (personal communication, 2004) reports increase of *Salsola* spp. on the Colorado River with drought and disturbance and of individual populations along the Colorado River with and without control. Kathryn Thomas (personal observations, 2004) reports increase of *Salsola* spp. in monitoring plots at Petrified Forest National Monument in drought years. Fire ecology: Russian thistle aids in spreading fire. It burns easily because the stems are spaced in an arrangement that allows for maximum air circulation (Young 1991 in Howard 1992). In addition, dead plants contribute to fuel load by retaining their original shape for some time before decomposing (Evans and Young 1970). The rolling action of the plant spreads prairie wildfire quickly. Russian thistle colonizes a burn when off-site; abscised plants blow across it, spreading seed (Young 1991 in Howard 1992). Presence of Russian thistle on disturbed sites if topsoil present. Roots are readily invaded with mychorrhizal fungi which are pathogenic to root since association is not formed. Russian thistle declines while mychorrhizal fungi population increases and are present to augment successional species next moving into disturbed site (Allen and Allen 1988). Dead Russian thistle provides microshading for other establishing plant species (Grilz et al. 1988). Species in this family may get curly top virus as it is an alternate host for beet leafhopper that vectors curly-top virus of sugar beets, tomatoes, and curcurbits (DeLoach et al. 1986, CDFA 2004). Competitive with native plants (Morisawa 1999); although no specific studies cited for native plants, it is known competitor with agricultural plants for space, water, nutrients (Wallace et al. 1968). Impact on native plant populations may be more severe on sandy substrates and during drought (Thomas et al. 2003).

Sources of information: See cited literature. Also considered personal observations by K. Thomas (Vegetation Ecologist, U.S. Department of the Interior, U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona, 2004) and personal communications with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004), D. Roth (Botanist, Navajo Nation, Flagstaff, Arizona, 2004), and K. Watters (Research Technician, National Park Service, Southern Colorado Plateau Network, Flagstaff, Arizona, 2004).

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: Negligible impact; causes no perceivable change in higher trophic level populations, communities or interactions.
Rationale: Minor component in bison, mule deer and elk diet (DeLoach et al 1986, Peden et al. 1974, Short 1979, USDA 1937), important prairie dog food (Bonham and Lerwick 1976), pronghorn show high preference for summer growth in years with high precipitation (Beale and Smith 1970), seeds eaten by granivorous birds, including scaled and Gambel's quail (Anderson and Ohmart 1984, DeLoach et al. 1986, Disano et al. 1984), small mammals consume seeds (DeLoach et al. 1986), provides hiding cover for small mammals, songbirds, upland game birds and waterfowl (Dittberner and Olson 1983), sage grouse have used it for nesting cover (Hulet et al. 1986), eaten by cattle and sheep (DeLoach et al 1986, Young 1991 in Howard 1992); can cause mouth ulcerations in young lambs and rain softened Russian thistle has laxative effect on livestock which can harm weakened animals (Cook et al. 1954, USDA 1937). Found in desert tortoise habitat in Mojave Desert (Brooks and DeFalco 1999); eaten by Gambel and scaled quail on the Santa Rita Experimental Range (Medina 2003).
Sources of information: See cited literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: There are no known native *Salsola* species in North America. No known impact.
Rationale: No reference to genetic impacts to *Salsola* species. Hybridization occurs between *Salsola* species, but there are no native *Salsola* species in North America (Kearney and Peebles 1960, Flora of North America Editorial Committee 2004).
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Moderate invasive potential with natural and anthropogenic disturbance. This species can readily establish in areas with natural disturbance and colonizes burns from off site.
Rationale: Grazing, drought, and disturbed soil facilitates Russian thistle establishment. *Salsola* spp. are early successional species adapted to disturbed lands (Rutledge and McLendon 1996 [cited as 2002] in Guertin and Halvorson 2003, Thomas et al. 2003). *Salsola* spp. colonize burns from off site (Young 1991 in Howard 1992).
Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Other pub.**
Describe rate of spread: Increasing but less rapidly than doubling in <10 years.
Rationale: Drought conditions in Arizona may be causing increase in populations (Thomas et al. 2003). Populations will naturally die out in areas with topsoil. *Salsola* spp. are also shade intolerant so they will die out if shaded (DeLoach et al. 1986, Allen and Allen 1988, Allen et al. 1989, and Grilz et al. 1988 in Howard 1992). Unknown population longevity in sandy soils and where plant species are more widely spread (Thomas et al. 2003). Increased seed germination and establishment with available soil nitrogen (Crompton and Bassett 1985). In Nevada pulses of nitrate-rich dust, synchronous with spring emergence, and other nutrient additions via aeolian dust may have stimulated invasion of dune-mantled

uplands by *S. paulsenii* (Blank et al 1999). Drought conditions in Arizona may be causing increase in populations (Thomas et al. 2003).
Sources of information: See cited literature.

Question 2.3 Recent trend in total range infested within state *Score:* **C** *Doc'n Level:* **Obs.**
Describe trend: Stable.
Rationale: *Salsola tragus was* first noted in Arizona in 1893 (Guertin and Halvorson 2003) and was well established by 1913 (Burgess et al. 1991 in Guertin and Halvorson 2003), was noted as common along northern Arizona railways in 1904 (Burgess et al. 1991). *Salsola paulsenii* was probably introduced to the far western United States between 1891 and 1913 and was collected near Barstow, California in 1913 (Beatley 1973). *Salsola collina* was collected in Kansas in 1923, but misidentified and subsequently reported for the first time in North America from Minnesota in 1938; reports for California are based based on specimens cited by S. Rilke (1999 in Flora of North America Editorial Committee 2004). The actual distribution of *S. collina* seems to be underestimated due to the common and constant confusion with atypical forms of *S. tragus. Salsola tragus* is an extremely polymorphic species consisting of several more or less distinct races (subspecies or segregate species). Several varieties may be recognized within *S. tragus*: however, these deviant forms are just morphological variants of little or no taxonomic value (Flora of North America Editorial Committee 2004).
Sources of information: See cited literature. Score based on inference drawn from the literature and Working Group consensus.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: High reproductive potential. Large number of seeds produced, up to 250,000 per plant (Young 1991 in Howard 1992). Seeds do not have high viability: a year (Young 1991 in Howard 1992) to several years (Parker 1972 and Rutledge and McLendon 1996 [cited as 2002] in Guertin and Halvorson 2003). Seed germination from soil seed bank drops off sharply after first year and was not found to occur after year three in a four-year study in Canada (Crompton and Bassett 1985).
Rationale: See Worksheet A.
Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Skeletons caught by vehicles, trains (Sauer 1988 in Guertin and Halvorson 2003); skeletons caught by fences; transported in ship ballast (Drezner et al 2001, Ridley 1930 in Guertin and Halvorson 2003) and contaminated crop seeds (Rutledge and McLendon 1996 [cited as 2002] in Guertin and Halvorson 2003).
Rationale: High, there are numerous opportunities for dispersal to new areas.
Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: The skeletons of dead plants readily breaks at the plant stem and rolls across landscape with wind, dispersing seeds as it moves. Winged seeds also provide additional long distance dispersal mechanism. (Crompton and Bassett 1985).
Rationale: Frequent long-distance dispersal
Sources of information: See cited literature.

Question 2.7 Other regions invaded	*Score:* **C** *Doc'n Level:* **Obs.**
Identify other regions: It is difficult to determine the extent of each species invasion because species identifications are so muddled. Munz (1974 in Guertin and Halvorson 2003) first reported *Salsola paulsenii* from North America in 1968. Its current range is in California, Nevada, Utah, and Arizona. It may be expected in the future also in New Mexico and Texas (Flora of North America Editorial Committee 2004). According to Howard (1992), *Salsola tragus* is native to Eurasia and is distributed throughout most arid and semiarid regions of the world. In North America, Russian thistle occurs from British Columbia east to Labrador and south through the conterminous United States to northern Mexico (Hitchcock and Cronquist 1964, DeLoach et al 1986). It is most common in central and western regions of Canada and the United States and along the Atlantic and Gulf coasts. Limited southern and eastern inland populations occur along waste areas and railroad tracks (Young 1991 in Howard 1992). Russian-thistle is adventitious in Hawaii (St John 1973). From the Flora of North America Editorial Committee (2004 and references therein): *Salsola collina* was reported in North America for the first time from Minnesota. It was collected in Kansas in 1923, but misidentified. Later it was discovered in Colorado, Iowa and Missouri. Reports of *S. collina* for Arizona and New York are based on specimens cited by Rilke (1999). Its actual distribution seems to be underestimated due to the common and constant confusion with deviant forms of *S. tragus*. In the future, *S. collina* may be found to occur within the major portion of the present range of *S. tragus.*	
Rationale: *Salsola* spp. invade elsewhere, but only in ecological types already invaded within the state. These species have been within the state for over 100 years. Their ranges may be filled and all communities that can be invaded have been. Another line of thought, however, is that the extent of invasion may not be complete since continued disturbance and ongoing drought may be encouraging the species proliferation and spread (Guertin and Halvorson 2003).	
Sources of information: See cited literature. Score based on inference drawn from the literature.	

Question 3.1 Ecological amplitude	*Score:* **A** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: *Salsola* spp. have a broad ecological amplitude that probably includes all but the highest elevations within the state. *Salsola* spp. were introduced into the state over 100 years ago. As demonstrated in the literature, it is capable of establishing in many plant communities that are within a certain elevation. *Salsola* spp. are prevalent in disturbed areas. In addition to direct anthropogenic disturbances, in the southwest there are a number of natural disturbances that potentially favor *Salsola* spp. invasion into natural communities including drought, wind, and high grazing pressure. *Salsola tragus* was first noted in Arizona in 1893 (Guertin and Halvorson 2003) and was well established by 1913 (Burgess et al. 1991 in Guertin and Halvorson 2003). It was noted as common along northern Arizona railways in 1904 (Burgess et al. 1991). *Salsola tragus* is found in disturbed areas, roadsides, cultivated fields, coastal and riparian sands, semi-deserts, deserts, eroded slopes; 0 to 2500 m throughout North America (except the southeast). Parker (1972) lists *Salsola tragus* as occurring in chaparral (scrublands, more specifically southwestern interior chaparral scrub), grasslands, freshwater systems and woodlands (pinyon juniper and forests (yellow pine) in Arizona. *Salsola tragus* is found in the pinyon-juniper woodland on land in the Arizona strip administered by BLM (ERI 2003). *Salsola collina* was collected in Kansas in 1923, but misidentified and subsequently reported for the first time in North America from Minnesota in 1938; reports for California are based on specimens cited by Rilke (1999). *Salsola collina* is found in waste places, roadsides, railway areas, cultivated fields,	

disturbed natural and semi-natural plant communities, 100 to 2000 m elevation, with patchy distribution throughout northeastern and north central North America and patches within the four corners states. *Salsola paulsenii* was probably introduced to the far western United States between 1891 and 1913 and was collected near Barstow, California in 1913 (Beatley 1973). *Salsola paulsenii* is found in sandy soils, disturbed natural and semi-natural plant communities, semi-deserts, deserts, eroded slopes, sand dunes and sandy waste places at 0 to 1900 m in Arizona, California, Colorado, Nevada, and Utah (Flora of North America Editorial Committee 2004). *Salsola paulsenii* has been found on upland dunes that are not highly disturbed or degraded. Occurs within an *Achnatherum hymenoides, Psorothamnus polydenius* and *Atriplex confertifolia* community adjacent to a Lake Lahontan playa in Nevada since 1990 (Blank et al. 1999).
Rationale: Present in five major and seven minor ecological types and possibly occurs in more. See Worksheet B.
Sources of information: See cited literature. Score based on inference drawn from the literature and the observations of Working Group members. Also considered information for *S. paulsenii* from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2005).

Question 3.2 Distribution *Score:* **B** *Doc'n Level:* **Obs.**
Describe distribution: Russian thistle is known to occur in many ecological types; however, its distribution within each type has not been explicitly quantified. It is highly likely that it can occur in any of the ecological types within Arizona outside of tundra; however, the severity of infestation will likely differ depending upon local conditions.
Rationale: The Southwest Exotic Plant Mapping Program (SWEPIC 2003) database shows *Salsola* spp. distributed within eight major ecological types; however, data points are coarse and observations have not been made by the authors of this assessment (K. Thomas and J. Busco) and other Working Group members that document the presence of Russian thistle among wildland occurrences of three of these major ecological types: Non-Riparian Wetlands, Riparian, and Forests. No systematic survey of *Salsola* spp. has been made throughout the state to quantify all ecological types in which *Salsola* spp. occur, nor can any accurate estimate be made of the percentage of those ecological systems that are actually invaded. The percentage values in Worksheet B are estimates. Recent surveys in national parks indicate that *Salsola* spp. may be more prevalent than previously considered (SWEPIC 2003).
Sources of information: See cited literature. Also considered observations by K. Thomas (Vegetation Ecologist, U.S. Department of the Interior, U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona, 2004), J. Busco (U.S. Department of the Interior, U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona, 2004), and other Working Group members.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**[No]**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**[No]**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**[No]**	**1 pt.**
	Total pts: 7 Total unknowns: 0		
	Score : A		

Note any related traits: Main stems break at ground after senescence and roll with wind or get caught in mobile objects (i.e., trains), thus aiding dispersal.

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	**D**
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	**B**
Desertlands	Great Basin desertscrub	**B**
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	**B**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	**D**
	semi-desert grassland	**D**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	**C**
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Allen, E.B., and M.F. Allen. 1988. Facilitation of succession by the nonmycothrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany 75:257–266.

Allen, M.F., E.B. Allen, and C.F. Friese. 1989. Responses of the non-mycotrophic plant *Salsola kali* to invasion by vesicular-arbuscular mycorrhizal fungi. New Phytologist 111:45–49.

Anderson, B.W., and R.D. Ohmart. 1984. Avian use of revegetated riparian zones. Pages 626–631 in R.E. Warner and K.M. Hendrix (eds.), California Riparian Systems: Ecology, Conservation, and Productive Management: Proceedings of a Conference. September 17–19, 1981, Davis, California. University of California Press, Berkeley.

Beale, D.M., and A.D. Smith. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. Journal of Wildlife Management 34:570–582.

Beatley, J.C. 1973. Russian-thistle (*Salsola*) species in Western United States. Journal of Range Management 26:225–226.

Blank, R.R., J.A. Young, and F.L. Allen. 1999. Aeolian dust in a saline playa environment, Nevada, USA. Journal of Arid Environments 41:365–381.

Bonham, C.D., and A. Lerwick. 1976. Vegetation changes induced by prairie dogs on shortgrass range. Journal of Range Management 29:221–225.

Brooks, M.L., and L DeFalco. 1999. Exotic Plant Species in Desert Tortoise Habitat. In Twenty-Fourth Annual Meeeting and Symposium of the Desert Tortoise Council, March 5–8 1999. Available online at: http://www.deserttortoise.org/abstract/abstracts1999/sgabs3.html; accessed March 2004.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burgess, T.L., J.E. Bowers, and R.M. Turner. 1991. Exotic plants at the desert laboratory, Tucson, Arizona. Madrono 38:96–114.

[CDFA] California Department of Food and Agriculture. 2004 Russian thistle (*Salsola* spp.). In E.A. Healy, S. Enloe, J.M. DiTomaso, B. Roberson, N. Dechoretz, S. Schoenig, P. Akers, L. Butler, and J. Garvin (eds.), Encycloweedia. University of California, Department of Vegetable Crops, Weed Science Program, Non-Cropland Weed Group, University of California Extension Service, Davis. Available online at:
http://www.cdfa.ca.gov/phpps/ipc/weedinfo/salsola.htm; accessed March 2004

Cook, C.W., L.A. Stoddart, and L.E. Harris. 1954. The nutritive value of winter range plants in the Great Basin as determined with digestion trials with sheep. Bulletin 372. Utah State University, Agricultural Experiment Station, Logan. 56 p.

Crompton, C.W. and L.G. Bassett. 1985. The biology of Canadian weeds. 65. *Salsola pestifer* A. Nels. Canadian Journal of Plant Science 65:379–388.

DeLoach, C.J., P.E. Boldt, H.A. Cjordo [and others]. 1986. Weeds common to Mexican and U.S. rangelands: proposals for biological control and ecological studies. Pages 49–68 in D.R. Patton, V. Gonzales, C.E. Medina, L. Alvin [and others] (technical coordinators), Management and Utilization of Arid Land Plants: Symposium Proceedings. February 18–22, 1985, Saltillo, Mexico. Gen. Tech. Rep. RM-135. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Dittberner, P.L., and M.R. Olson. 1983. The plant information network (PIN) data base: Colorado, Montana, North Dakota, Utah, and Wyoming. FWS/OBS-83/86. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC. 786 p.

Disano, J. B., W. Anderson, J.K. Meents, and R.D. Ohmart.1984. Compatibility of biofuel production with wildlife habitat enhancement. Pages 739–743 In R.E. Warner and K.M. Hendrix (eds.), California Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkley.

Drezner, T.D., P.L. Fall, and J.C. Stromberg. 2001. Plant distribution and dispersal mechanisms at the Hassayampa River Preserve, Arizona, USA. Global Ecology and Biogeography 10:205–217.

[ERI] Ecological Restoration Institute. 2003. Arizona Strip District Pinyon-Juniper Treatment Demonstration Project Environmental Assessment EA-AZ-010-03-14. Available online at: http://azwww.az.blm.gov/env_docs/old/pinyon_junip_ea.pdf; accessed March 2004.

Evans, R.A., and J.A. Young. 1970. Plant litter and establishment of alien annual weed species in rangeland communities. Weed Science 18:697–703.

Flora of North America Editorial Committee (eds.) 2004. Flora of North America North of Mexico. Volume 4. Magnoliophyta: Caryophyllidae, Part 1. Flora of North America Association, New York and Oxford. Available online at: http://www.efloras.org/volume_page.aspx?volume_id=1004, go to Chenopodiaceae, *Salsola*; accessed May 2004.

Grilz, P., L. Delanoy, and G. Grismer. 1988. Site preparation, seeding, nurse crop methods tested in dune restoration (Saskatchewan). Restoration and Management Notes 6:47–48.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Surevy, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Hitchcock, C.L., and A. Cronquist. 1964. Vascular plants of the Pacific Northwest. Part 2: Salicaceae to Saxifragaceae. University of Washington Press, Seattle. 597 p.

Howard, J.L. 1992. *Salsola kali*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, Montana (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed July 2004.

Hulet, B.V., J.T. Flinders, J.S. Green [and others]. 1986. Seasonal movements and habitat selection of sage grouse in southern Idaho. Pages 168–175 in E.D. McArthur and B.L. Welch (compilers), Proceedings—Symposium on the Biology of *Artemisia* and *Chrysothamnus.* July 9–13, 1984, Provo, Utah. Gen. Tech. Rep. INT-200. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Medina, A. 2003. Gambel and scaled quail diets on the Santa Rita Experimental Range. Pages 133–140 M.P.McClaran, P.F. Ffolliott, and C.B. Edminster (technical coordinators), Santa Rita Experimental Range: 100 Years (1903 to 2003) of Accomplishments and Contributions. Conference Proceedings, October 30—November 1, 2003, Tucson, Arizona. RMRS-P-30. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, Utah.

Morisawa, T. 1999. Weed Notes: *Salsola kali*. The Nature Conservancy, Wildland Invasive Species Team. Available online at: http://tncweeds.ucdavis.edu/moredocs/salkal10.html; accessed March 2004.

Mosyakin, S. L. 1996. A taxonomic synopsis of the genus *Salsola* (Chenopodiaceae) in North America. Ann. Missouri Bot. Gard. 83:387–395.

Munz, P.A. 1974. A Flora of Southern California. University of California Press, Berkeley. 1086 p.

Parker, K.F. 1972. An Illustrated Guide to Arizona Weeds. The University of Arizona Press, Tucson, Arizona. 338 p.

Peden, D.G., G.M. Van Dyne, R.W. Rice, and R.M. Hansen. 1974. The trophic ecology of *Bison bison* L. on shortgrass plains. Journal of Applied Ecology 11:489–497.

Ridley, H.N. 1930. The Dispersal of Plants throughout the World. L. Reeve and Co., Ltd., Ashfork, Kent United Kingdom.

Rilke, S. 1999. Revision der Sektion *Salsola* s.l. der Gattung *Salsola* (Chenopodiaceae). Bibliotheca Botanica (Stuttgart) 149:1–190.

Rutledge, C.R., and T. McLendon. 1996. An Assessment of Exotic Plant Species of Rocky Mountain National Park. Department of Rangeland Ecosystem Science, Colorado State University. 97 p. Available online from the Northern Prairie Wildlife Research Center, Jamestown, North Dakota at: http://www.npwrc.usgs.gov/resource/othrdata/explant/explant.htm. (Version 15Dec98). Go to the Literature Review Summary Information for Remaining Exotic Species and then click on *Sasola iberica*. Accessed March 2004.

Sauer, J.D. 1988. Plant Migration: The Dynamics of Geographic Patterning in Seed Plant Species. University of California Press, Berkeley. 282 pp.

Short, H.L. 1979. Deer in Arizona and New Mexico: Their Ecology and a Theory Explaining Recent Population Decreases. General Technical Report RM-70. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 25 p.

St. John, H. 1973. List and Summary of the Flowering Plants in the Hawaiian Islands. Cathay Press Limited, Hong Kong. 519 p.

[SWEPIC] Southwest Exotic Plant Information Clearinghouse. 2003. Southwest Exotic Mapping Program database. Available online at: http://www.usgs.nau.edu/swepic/swemp/maps.html); accessed May 2004.

Thomas, K., B.D. Anderson, and R. Hunt. 2003. Petrified Forest National Park Weed Inventory and Mapping Project. Annual Report FY 2002. U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona. 52 p.

[USDA] U.S. Department of Agriculture, Forest Service. 1937. Range Plant Handbook. Washington, DC. 532 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Wallace, A., W.A. Rhods, and E.F. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal 60:76–78.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Young, J.A. 1991. Tumbleweed. Scientific American 264:82–87.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Salsola collina* Pallas; *Salsola paulsenii* Litv.; *Salsola tragus* L. (USDA 2005).
Synonyms:	*Salsola collina*: None listed in USDA (2005); *Salsola paulsenii*: None listed in USDA (2005); *Salsola tragus*: *Salsola australis* R. Br., *Salsola iberica* (Sennen & Pau) Botsch. ex Czerepanov, *Salsola kali* L. ssp. *ruthenica* (Iljin) Soó, *Salsola kali* L. ssp. *tragus* (L.) Celak., *Salsola kali* L. ssp. *tenuifolia* Moq., *Salsola pestifer* A. Nels., *Salsola ruthenica* Iljin (USDA 2005).
Common names:	*Salsola collina*: Slender Russian thistle, spineless Russian thistle; *Salsola paulsenii*: Barbwire Russian thistle; *Salsola tragus*: Prickly Russian thistle, common Russian thistle, tumbling thistle, tumbleweed
Evaluation date (mm/dd/yy):	08/23/03, 05/04, and 07/04
Evaluator #1 Name/Title:	Dr. Kathryn A. Thomas
Affiliation:	USGS, Southwest Biological Science Center
Phone numbers:	(928) 556–7327
Email address:	Kathryn.Thomas@usgs.gov
Address:	2255 N. Gemini Drive, Flagstaff, Arizona 86001
Evaluator #2 Name/Title:	Janice K. Busco
Affiliation:	U.S. Geological Survey
Phone numbers:	See above
Email address:	Janice.Busco@nau.edu
Address:	See above

List committee members:	08/26/03: W. Austin, D. Backer, R. Hiebert, L. Makarick, L. Moser, T. Olson, B. Phillips, K. Thomas, K. Watters 06/23/04: W. Albrecht, D. Backer, J. Brock, J. Busco, J. Hall, C. Laws, L. Moser, B. Phillips, K. Watters
Committee review date:	08/26/03 and 06/23/04
List date:	06/23/04
Re-evaluation date(s):	

Taxonomic Comment

Salsola tragus is the correct name for the widespread, narrow-leaved, weedy representative of the *S. kali* aggregate (Mosyakin 1996 and Rilke 1999 in Flora of North America Editorial Committee 2004). *Salsola tragus*, however, has been known in North American and European botanical literature under numerous names (for detailed synonymy see Mosyakin 1996 and Rilke 1999 in Flora of North America Editorial Committee 2004). *Salsola tragus* is an extremely polymorphic species consisting of several more or less distinct races (subspecies or segregate species). Several varieties may be recognized within *S. tragus*; many of them are just morphological variants of little or no taxonomic value (Flora of North America Editorial Committee 2004).

According to USDA (2005) and the Flora of North America Editorial Committee (2004), *S. kali* L. is comprised of the subspecies ssp. *kali* and ssp. *pontica* and does not occur in Arizona. In some references the name *Salsola kali* ssp. *tragus* has frequently been truncated to *S. kali* resulting in confusion; however, USDA (2005) identifies *S. kali* ssp. *tragus* as a synonym for *S. tragus*.

Some additional taxonomic confusion also is possible. For example, the name *S. kali* has often been misapplied to other species in this aggregate, *S. collina* has frequently been misidentified *as S. tragus*, and intermediate and possibly hybrid forms between *S. paulsenii* and *S. tragus* are common along margins of the range of the species and in secondary, synanthropic (human altered) localities (Flora of North America Editorial Committee 2004).

Table 2. Scores, Designations, and Documentation Levels

<table>
<tr><th colspan="2">Question</th><th>Score</th><th>Documentation Level</th><th>Section Scores</th><th>Overall Score & Designations</th></tr>
<tr><td>1.1</td><td>Impact on abiotic ecosystem processes</td><td>B</td><td>Other published material</td><td rowspan="4">“Impact”

Section 1 Score:

B</td><td rowspan="12">“Plant Score”

Overall Score:

Medium

Alert Status:

None</td></tr>
<tr><td>1.2</td><td>Impact on plant community</td><td>B</td><td>Other published material</td></tr>
<tr><td>1.3</td><td>Impact on higher trophic levels</td><td>D</td><td>Reviewed scientific publication</td></tr>
<tr><td>1.4</td><td>Impact on genetic integrity</td><td>D</td><td>Other published material</td></tr>
<tr><td colspan="4"></td><td></td></tr>
<tr><td>2.1</td><td>Role of anthropogenic and natural disturbance</td><td>B</td><td>Other published material</td><td rowspan="7">“Invasiveness”

For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:

15 pts

Section 2 Score:

B</td></tr>
<tr><td>2.2</td><td>Local rate of spread with no management</td><td>B</td><td>Other published material</td></tr>
<tr><td>2.3</td><td>Recent trend in total area infested within state</td><td>C</td><td>Observational</td></tr>
<tr><td>2.4</td><td>Innate reproductive potential</td><td>A</td><td>Reviewed scientific publication</td></tr>
<tr><td>2.5</td><td>Potential for human-caused dispersal</td><td>A</td><td>Other published material</td></tr>
<tr><td>2.6</td><td>Potential for natural long-distance dispersal</td><td>A</td><td>Other published material</td></tr>
<tr><td>2.7</td><td>Other regions invaded</td><td>C</td><td>Observational</td><td rowspan="4">
RED FLAG
NO

Something you should know.</td></tr>
<tr><td colspan="4"></td><td></td></tr>
<tr><td>3.1</td><td>Ecological amplitude</td><td>A</td><td>Observational</td><td rowspan="2">“Distribution”

Section 3 Score:

A</td></tr>
<tr><td>3.2</td><td>Distribution</td><td>B</td><td>Observational</td></tr>
</table>

Table 3. Documentation

Note: All three *Salsola* species occurring in Arizona are evaluated collectively herein based on the assumption that they each behave ecologically similar in Arizona and that often the literature doesn't distinguish one species from another.

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Other pub.**
Identify ecosystem processes impacted: Hydrologic regime (streamflow) may be altered; fire size and frequency may be increased when the plant is present.
Rationale: Skeletons of plants can block stream channels (Morisawa 1999, Wallace et al. 1968); burns easily because stems arranged so much air circulation within plant (Young 1991 in Howard 1992), increases fuel load of an area by retaining original shape for some time before decomposing (Evans and Young 1970) and increases the rate of spread of fires when burning skeletons roll into unburned areas (Young 1991 in Howard 1992).
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition, structure, interactions *Score:* **B** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Competition with native plants probable, particularly in drought circumstances; can accelerate revegetation in certain circumstances; competes with agricultural plants for space, water, nutrients (Wallace et al. 1968). It has positive as well as negative effects; it will grow where no other plant species will (Howard 1992). Increases to dominant on Navajo Nation, Petrified Forest National Monument, Colorado River in drought years (documentation below in rationale). Can potentially be a vector for fire (Evans and Young 1970, Young 1991 in Howard 1992) thus changing plant communities that are not well-adapted to fire.
Rationale: Barbara Phillips (personal communication, 2004) reports, and Daniella Roth (personal communication, 2004) confirms, that during drought *Salsola* spp. are some of the only plants surviving in washes on the Navajo Nation. Kate Watters (personal communication, 2004) reports increase of *Salsola* spp. on the Colorado River with drought and disturbance and of individual populations along the Colorado River with and without control. Kathryn Thomas (personal observations, 2004) reports increase of *Salsola* spp. in monitoring plots at Petrified Forest National Monument in drought years. Fire ecology: Russian thistle aids in spreading fire. It burns easily because the stems are spaced in an arrangement that allows for maximum air circulation (Young 1991 in Howard 1992). In addition, dead plants contribute to fuel load by retaining their original shape for some time before decomposing (Evans and Young 1970). The rolling action of the plant spreads prairie wildfire quickly. Russian thistle colonizes a burn when off-site; abscised plants blow across it, spreading seed (Young 1991 in Howard 1992). Presence of Russian thistle on disturbed sites if topsoil present. Roots are readily invaded with mychorrhizal fungi which are pathogenic to root since association is not formed. Russian thistle declines while mychorrhizal fungi population increases and are present to augment successional species next moving into disturbed site (Allen and Allen 1988). Dead Russian thistle provides microshading for other establishing plant species (Grilz et al. 1988). Species in this family may get curly top virus as it is an alternate host for beet leafhopper that vectors curly-top virus of sugar beets, tomatoes, and curcurbits (DeLoach et al. 1986, CDFA 2004). Competitive with native plants (Morisawa 1999); although no specific studies cited for native plants, it is known competitor with agricultural plants for space, water, nutrients (Wallace et al. 1968). Impact on native plant populations may be more severe on sandy substrates and during drought (Thomas et al. 2003).

Sources of information: See cited literature. Also considered personal observations by K. Thomas (Vegetation Ecologist, U.S. Department of the Interior, U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona, 2004) and personal communications with B. Phillips (Zone Botanist, U.S. Department of Agriculture, Forest Service, Coconino, Kaibab, and Prescott National Forests, 2004), D. Roth (Botanist, Navajo Nation, Flagstaff, Arizona, 2004), and K. Watters (Research Technician, National Park Service, Southern Colorado Plateau Network, Flagstaff, Arizona, 2004).

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: Negligible impact; causes no perceivable change in higher trophic level populations, communities or interactions.
Rationale: Minor component in bison, mule deer and elk diet (DeLoach et al 1986, Peden et al. 1974, Short 1979, USDA 1937), important prairie dog food (Bonham and Lerwick 1976), pronghorn show high preference for summer growth in years with high precipitation (Beale and Smith 1970), seeds eaten by granivorous birds, including scaled and Gambel's quail (Anderson and Ohmart 1984, DeLoach et al. 1986, Disano et al. 1984), small mammals consume seeds (DeLoach et al. 1986), provides hiding cover for small mammals, songbirds, upland game birds and waterfowl (Dittberner and Olson 1983), sage grouse have used it for nesting cover (Hulet et al. 1986), eaten by cattle and sheep (DeLoach et al 1986, Young 1991 in Howard 1992); can cause mouth ulcerations in young lambs and rain softened Russian thistle has laxative effect on livestock which can harm weakened animals (Cook et al. 1954, USDA 1937). Found in desert tortoise habitat in Mojave Desert (Brooks and DeFalco 1999); eaten by Gambel and scaled quail on the Santa Rita Experimental Range (Medina 2003).
Sources of information: See cited literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: There are no known native *Salsola* species in North America. No known impact.
Rationale: No reference to genetic impacts to *Salsola* species. Hybridization occurs between *Salsola* species, but there are no native *Salsola* species in North America (Kearney and Peebles 1960, Flora of North America Editorial Committee 2004).
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**
Describe role of disturbance: Moderate invasive potential with natural and anthropogenic disturbance. This species can readily establish in areas with natural disturbance and colonizes burns from off site.
Rationale: Grazing, drought, and disturbed soil facilitates Russian thistle establishment. *Salsola* spp. are early successional species adapted to disturbed lands (Rutledge and McLendon 1996 [cited as 2002] in Guertin and Halvorson 2003, Thomas et al. 2003). *Salsola* spp. colonize burns from off site (Young 1991 in Howard 1992).
Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Other pub.**
Describe rate of spread: Increasing but less rapidly than doubling in <10 years.
Rationale: Drought conditions in Arizona may be causing increase in populations (Thomas et al. 2003). Populations will naturally die out in areas with topsoil. *Salsola* spp. are also shade intolerant so they will die out if shaded (DeLoach et al. 1986, Allen and Allen 1988, Allen et al. 1989, and Grilz et al. 1988 in Howard 1992). Unknown population longevity in sandy soils and where plant species are more widely spread (Thomas et al. 2003). Increased seed germination and establishment with available soil nitrogen (Crompton and Bassett 1985). In Nevada pulses of nitrate-rich dust, synchronous with spring emergence, and other nutrient additions via aeolian dust may have stimulated invasion of dune-mantled

uplands by *S. paulsenii* (Blank et al 1999). Drought conditions in Arizona may be causing increase in populations (Thomas et al. 2003).	
Sources of information: See cited literature.	

Question 2.3 Recent trend in total range infested within state	*Score:* **C** *Doc'n Level:* **Obs.**
Describe trend: Stable.	
Rationale: *Salsola tragus was* first noted in Arizona in 1893 (Guertin and Halvorson 2003) and was well established by 1913 (Burgess et al. 1991 in Guertin and Halvorson 2003), was noted as common along northern Arizona railways in 1904 (Burgess et al. 1991). *Salsola paulsenii* was probably introduced to the far western United States between 1891 and 1913 and was collected near Barstow, California in 1913 (Beatley 1973). *Salsola collina* was collected in Kansas in 1923, but misidentified and subsequently reported for the first time in North America from Minnesota in 1938; reports for California are based based on specimens cited by S. Rilke (1999 in Flora of North America Editorial Committee 2004). The actual distribution of *S. collina* seems to be underestimated due to the common and constant confusion with atypical forms of *S. tragus. Salsola tragus* is an extremely polymorphic species consisting of several more or less distinct races (subspecies or segregate species). Several varieties may be recognized within *S. tragus*: however, these deviant forms are just morphological variants of little or no taxonomic value (Flora of North America Editorial Committee 2004).	
Sources of information: See cited literature. Score based on inference drawn from the literature and Working Group consensus.	

Question 2.4 Innate reproductive potential	*Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: High reproductive potential. Large number of seeds produced, up to 250,000 per plant (Young 1991 in Howard 1992). Seeds do not have high viability: a year (Young 1991 in Howard 1992) to several years (Parker 1972 and Rutledge and McLendon 1996 [cited as 2002] in Guertin and Halvorson 2003). Seed germination from soil seed bank drops off sharply after first year and was not found to occur after year three in a four-year study in Canada (Crompton and Bassett 1985).	
Rationale: See Worksheet A.	
Sources of information: See cited literature.	

Question 2.5 Potential for human-caused dispersal	*Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Skeletons caught by vehicles, trains (Sauer 1988 in Guertin and Halvorson 2003); skeletons caught by fences; transported in ship ballast (Drezner et al 2001, Ridley 1930 in Guertin and Halvorson 2003) and contaminated crop seeds (Rutledge and McLendon 1996 [cited as 2002] in Guertin and Halvorson 2003).	
Rationale: High, there are numerous opportunities for dispersal to new areas.	
Sources of information: See cited literature.	

Question 2.6 Potential for natural long-distance dispersal	*Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: The skeletons of dead plants readily breaks at the plant stem and rolls across landscape with wind, dispersing seeds as it moves. Winged seeds also provide additional long distance dispersal mechanism. (Crompton and Bassett 1985).	
Rationale: Frequent long-distance dispersal	
Sources of information: See cited literature.	

Question 2.7 Other regions invaded	*Score:* **C** *Doc'n Level:* **Obs.**
Identify other regions: It is difficult to determine the extent of each species invasion because species identifications are so muddled. Munz (1974 in Guertin and Halvorson 2003) first reported *Salsola paulsenii* from North America in 1968. Its current range is in California, Nevada, Utah, and Arizona. It may be expected in the future also in New Mexico and Texas (Flora of North America Editorial Committee 2004). According to Howard (1992), *Salsola tragus* is native to Eurasia and is distributed throughout most arid and semiarid regions of the world. In North America, Russian thistle occurs from British Columbia east to Labrador and south through the conterminous United States to northern Mexico (Hitchcock and Cronquist 1964, DeLoach et al 1986). It is most common in central and western regions of Canada and the United States and along the Atlantic and Gulf coasts. Limited southern and eastern inland populations occur along waste areas and railroad tracks (Young 1991 in Howard 1992). Russian-thistle is adventitious in Hawaii (St John 1973). From the Flora of North America Editorial Committee (2004 and references therein): *Salsola collina* was reported in North America for the first time from Minnesota. It was collected in Kansas in 1923, but misidentified. Later it was discovered in Colorado, Iowa and Missouri. Reports of *S. collina* for Arizona and New York are based on specimens cited by Rilke (1999). Its actual distribution seems to be underestimated due to the common and constant confusion with deviant forms of *S. tragus*. In the future, *S. collina* may be found to occur within the major portion of the present range of *S. tragus.*	
Rationale: *Salsola* spp. invade elsewhere, but only in ecological types already invaded within the state. These species have been within the state for over 100 years. Their ranges may be filled and all communities that can be invaded have been. Another line of thought, however, is that the extent of invasion may not be complete since continued disturbance and ongoing drought may be encouraging the species proliferation and spread (Guertin and Halvorson 2003).	
Sources of information: See cited literature. Score based on inference drawn from the literature.	

Question 3.1 Ecological amplitude	*Score:* **A** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: *Salsola* spp. have a broad ecological amplitude that probably includes all but the highest elevations within the state. *Salsola* spp. were introduced into the state over 100 years ago. As demonstrated in the literature, it is capable of establishing in many plant communities that are within a certain elevation. *Salsola* spp. are prevalent in disturbed areas. In addition to direct anthropogenic disturbances, in the southwest there are a number of natural disturbances that potentially favor *Salsola* spp. invasion into natural communities including drought, wind, and high grazing pressure. *Salsola tragus* was first noted in Arizona in 1893 (Guertin and Halvorson 2003) and was well established by 1913 (Burgess et al. 1991 in Guertin and Halvorson 2003). It was noted as common along northern Arizona railways in 1904 (Burgess et al. 1991). *Salsola tragus* is found in disturbed areas, roadsides, cultivated fields, coastal and riparian sands, semi-deserts, deserts, eroded slopes; 0 to 2500 m throughout North America (except the southeast). Parker (1972) lists *Salsola tragus* as occurring in chaparral (scrublands, more specifically southwestern interior chaparral scrub), grasslands, freshwater systems and woodlands (pinyon juniper and forests (yellow pine) in Arizona. *Salsola tragus* is found in the pinyon-juniper woodland on land in the Arizona strip administered by BLM (ERI 2003). *Salsola collina* was collected in Kansas in 1923, but misidentified and subsequently reported for the first time in North America from Minnesota in 1938; reports for California are based on specimens cited by Rilke (1999). *Salsola collina* is found in waste places, roadsides, railway areas, cultivated fields,	

disturbed natural and semi-natural plant communities, 100 to 2000 m elevation, with patchy distribution throughout northeastern and north central North America and patches within the four corners states. *Salsola paulsenii* was probably introduced to the far western United States between 1891 and 1913 and was collected near Barstow, California in 1913 (Beatley 1973). *Salsola paulsenii* is found in sandy soils, disturbed natural and semi-natural plant communities, semi-deserts, deserts, eroded slopes, sand dunes and sandy waste places at 0 to 1900 m in Arizona, California, Colorado, Nevada, and Utah (Flora of North America Editorial Committee 2004). *Salsola paulsenii* has been found on upland dunes that are not highly disturbed or degraded. Occurs within an *Achnatherum hymenoides, Psorothamnus polydenius* and *Atriplex confertifolia* community adjacent to a Lake Lahontan playa in Nevada since 1990 (Blank et al. 1999).
Rationale: Present in five major and seven minor ecological types and possibly occurs in more. See Worksheet B.
Sources of information: See cited literature. Score based on inference drawn from the literature and the observations of Working Group members. Also considered information for *S. paulsenii* from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2005).

Question 3.2 Distribution	*Score:* **B** *Doc'n Level:* **Obs.**
Describe distribution: Russian thistle is known to occur in many ecological types; however, its distribution within each type has not been explicitly quantified. It is highly likely that it can occur in any of the ecological types within Arizona outside of tundra; however, the severity of infestation will likely differ depending upon local conditions.	
Rationale: The Southwest Exotic Plant Mapping Program (SWEPIC 2003) database shows *Salsola* spp. distributed within eight major ecological types; however, data points are coarse and observations have not been made by the authors of this assessment (K. Thomas and J. Busco) and other Working Group members that document the presence of Russian thistle among wildland occurrences of three of these major ecological types: Non-Riparian Wetlands, Riparian, and Forests. No systematic survey of *Salsola* spp. has been made throughout the state to quantify all ecological types in which *Salsola* spp. occur, nor can any accurate estimate be made of the percentage of those ecological systems that are actually invaded. The percentage values in Worksheet B are estimates. Recent surveys in national parks indicate that *Salsola* spp. may be more prevalent than previously considered (SWEPIC 2003).	
Sources of information: See cited literature. Also considered observations by K. Thomas (Vegetation Ecologist, U.S. Department of the Interior, U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona, 2004), J. Busco (U.S. Department of the Interior, U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona, 2004), and other Working Group members.	

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**[No]**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**[No]**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**[No]**	**1 pt.**
	Total pts: 7 Total unknowns: 0		
	Score : A		

Note any related traits: Main stems break at ground after senescence and roll with wind or get caught in mobile objects (i.e., trains), thus aiding dispersal.

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	**D**
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	**B**
Desertlands	Great Basin desertscrub	**B**
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	**B**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	**D**
	semi-desert grassland	**D**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	**C**
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Allen, E.B., and M.F. Allen. 1988. Facilitation of succession by the nonmycothrophic colonizer *Salsola kali* (Chenopodiaceae) on a harsh site: effects of mycorrhizal fungi. American Journal of Botany 75:257–266.

Allen, M.F., E.B. Allen, and C.F. Friese. 1989. Responses of the non-mycotrophic plant *Salsola kali* to invasion by vesicular-arbuscular mycorrhizal fungi. New Phytologist 111:45–49.

Anderson, B.W., and R.D. Ohmart. 1984. Avian use of revegetated riparian zones. Pages 626–631 in R.E. Warner and K.M. Hendrix (eds.), California Riparian Systems: Ecology, Conservation, and Productive Management: Proceedings of a Conference. September 17–19, 1981, Davis, California. University of California Press, Berkeley.

Beale, D.M., and A.D. Smith. 1970. Forage use, water consumption, and productivity of pronghorn antelope in western Utah. Journal of Wildlife Management 34:570–582.

Beatley, J.C. 1973. Russian-thistle (*Salsola*) species in Western United States. Journal of Range Management 26:225–226.

Blank, R.R., J.A. Young, and F.L. Allen. 1999. Aeolian dust in a saline playa environment, Nevada, USA. Journal of Arid Environments 41:365–381.

Bonham, C.D., and A. Lerwick. 1976. Vegetation changes induced by prairie dogs on shortgrass range. Journal of Range Management 29:221–225.

Brooks, M.L., and L DeFalco. 1999. Exotic Plant Species in Desert Tortoise Habitat. In Twenty-Fourth Annual Meeeting and Symposium of the Desert Tortoise Council, March 5–8 1999. Available online at: http://www.deserttortoise.org/abstract/abstracts1999/sgabs3.html; accessed March 2004.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burgess, T.L., J.E. Bowers, and R.M. Turner. 1991. Exotic plants at the desert laboratory, Tucson, Arizona. Madrono 38:96–114.

[CDFA] California Department of Food and Agriculture. 2004 Russian thistle (*Salsola* spp.). In E.A. Healy, S. Enloe, J.M. DiTomaso, B. Roberson, N. Dechoretz, S. Schoenig, P. Akers, L. Butler, and J. Garvin (eds.), Encycloweedia. University of California, Department of Vegetable Crops, Weed Science Program, Non-Cropland Weed Group, University of California Extension Service, Davis. Available online at:
http://www.cdfa.ca.gov/phpps/ipc/weedinfo/salsola.htm; accessed March 2004

Cook, C.W., L.A. Stoddart, and L.E. Harris. 1954. The nutritive value of winter range plants in the Great Basin as determined with digestion trials with sheep. Bulletin 372. Utah State University, Agricultural Experiment Station, Logan. 56 p.

Crompton, C.W. and L.G. Bassett. 1985. The biology of Canadian weeds. 65. *Salsola pestifer* A. Nels. Canadian Journal of Plant Science 65:379–388.

DeLoach, C.J., P.E. Boldt, H.A. Cjordo [and others]. 1986. Weeds common to Mexican and U.S. rangelands: proposals for biological control and ecological studies. Pages 49–68 in D.R. Patton, V. Gonzales, C.E. Medina, L. Alvin [and others] (technical coordinators), Management and Utilization of Arid Land Plants: Symposium Proceedings. February 18–22, 1985, Saltillo, Mexico. Gen. Tech. Rep. RM-135. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Dittberner, P.L., and M.R. Olson. 1983. The plant information network (PIN) data base: Colorado, Montana, North Dakota, Utah, and Wyoming. FWS/OBS-83/86. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC. 786 p.

Disano, J. B., W. Anderson, J.K. Meents, and R.D. Ohmart.1984. Compatibility of biofuel production with wildlife habitat enhancement. Pages 739–743 In R.E. Warner and K.M. Hendrix (eds.), California Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkley.

Drezner, T.D., P.L. Fall, and J.C. Stromberg. 2001. Plant distribution and dispersal mechanisms at the Hassayampa River Preserve, Arizona, USA. Global Ecology and Biogeography 10:205–217.

[ERI] Ecological Restoration Institute. 2003. Arizona Strip District Pinyon-Juniper Treatment Demonstration Project Environmental Assessment EA-AZ-010-03-14. Available online at: http://azwww.az.blm.gov/env_docs/old/pinyon_junip_ea.pdf; accessed March 2004.

Evans, R.A., and J.A. Young. 1970. Plant litter and establishment of alien annual weed species in rangeland communities. Weed Science 18:697–703.

Flora of North America Editorial Committee (eds.) 2004. Flora of North America North of Mexico. Volume 4. Magnoliophyta: Caryophyllidae, Part 1. Flora of North America Association, New York and Oxford. Available online at: http://www.efloras.org/volume_page.aspx?volume_id=1004, go to Chenopodiaceae, *Salsola*; accessed May 2004.

Grilz, P., L. Delanoy, and G. Grismer. 1988. Site preparation, seeding, nurse crop methods tested in dune restoration (Saskatchewan). Restoration and Management Notes 6:47–48.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Surevy, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Hitchcock, C.L., and A. Cronquist. 1964. Vascular plants of the Pacific Northwest. Part 2: Salicaceae to Saxifragaceae. University of Washington Press, Seattle. 597 p.

Howard, J.L. 1992. *Salsola kali*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, Montana (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed July 2004.

Hulet, B.V., J.T. Flinders, J.S. Green [and others]. 1986. Seasonal movements and habitat selection of sage grouse in southern Idaho. Pages 168–175 in E.D. McArthur and B.L. Welch (compilers), Proceedings—Symposium on the Biology of *Artemisia* and *Chrysothamnus.* July 9–13, 1984, Provo, Utah. Gen. Tech. Rep. INT-200. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Medina, A. 2003. Gambel and scaled quail diets on the Santa Rita Experimental Range. Pages 133–140 M.P.McClaran, P.F. Ffolliott, and C.B. Edminster (technical coordinators), Santa Rita Experimental Range: 100 Years (1903 to 2003) of Accomplishments and Contributions. Conference Proceedings, October 30—November 1, 2003, Tucson, Arizona. RMRS-P-30. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, Utah.

Morisawa, T. 1999. Weed Notes: *Salsola kali*. The Nature Conservancy, Wildland Invasive Species Team. Available online at: http://tncweeds.ucdavis.edu/moredocs/salkal10.html; accessed March 2004.

Mosyakin, S. L. 1996. A taxonomic synopsis of the genus *Salsola* (Chenopodiaceae) in North America. Ann. Missouri Bot. Gard. 83:387–395.

Munz, P.A. 1974. A Flora of Southern California. University of California Press, Berkeley. 1086 p.

Parker, K.F. 1972. An Illustrated Guide to Arizona Weeds. The University of Arizona Press, Tucson, Arizona. 338 p.

Peden, D.G., G.M. Van Dyne, R.W. Rice, and R.M. Hansen. 1974. The trophic ecology of *Bison bison* L. on shortgrass plains. Journal of Applied Ecology 11:489–497.

Ridley, H.N. 1930. The Dispersal of Plants throughout the World. L. Reeve and Co., Ltd., Ashfork, Kent United Kingdom.

Rilke, S. 1999. Revision der Sektion *Salsola* s.l. der Gattung *Salsola* (Chenopodiaceae). Bibliotheca Botanica (Stuttgart) 149:1–190.

Rutledge, C.R., and T. McLendon. 1996. An Assessment of Exotic Plant Species of Rocky Mountain National Park. Department of Rangeland Ecosystem Science, Colorado State University. 97 p. Available online from the Northern Prairie Wildlife Research Center, Jamestown, North Dakota at: http://www.npwrc.usgs.gov/resource/othrdata/explant/explant.htm. (Version 15Dec98). Go to the Literature Review Summary Information for Remaining Exotic Species and then click on *Sasola iberica*. Accessed March 2004.

Sauer, J.D. 1988. Plant Migration: The Dynamics of Geographic Patterning in Seed Plant Species. University of California Press, Berkeley. 282 pp.

Short, H.L. 1979. Deer in Arizona and New Mexico: Their Ecology and a Theory Explaining Recent Population Decreases. General Technical Report RM-70. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 25 p.

St. John, H. 1973. List and Summary of the Flowering Plants in the Hawaiian Islands. Cathay Press Limited, Hong Kong. 519 p.

[SWEPIC] Southwest Exotic Plant Information Clearinghouse. 2003. Southwest Exotic Mapping Program database. Available online at: http://www.usgs.nau.edu/swepic/swemp/maps.html); accessed May 2004.

Thomas, K., B.D. Anderson, and R. Hunt. 2003. Petrified Forest National Park Weed Inventory and Mapping Project. Annual Report FY 2002. U.S. Geological Survey, Southwest Biological Science Center, Flagstaff, Arizona. 52 p.

[USDA] U.S. Department of Agriculture, Forest Service. 1937. Range Plant Handbook. Washington, DC. 532 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Wallace, A., W.A. Rhods, and E.F. Frolich. 1968. Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. Agronomy Journal 60:76–78.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Young, J.A. 1991. Tumbleweed. Scientific American 264:82–87.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Salvinia molesta* Mitchell (USDA 2005)
Synonyms:	None identified in USDA (2005).
Common names:	Giant salvinia, salvinia, water fern, kariba-weed, African paval
Evaluation date (mm/dd/yy)**:**	09/18/03
Evaluator #1 Name/Title:	Dr. Ed Northam, Weed Biologist
Affiliation:	
Phone numbers:	(480) 947–3882
Email address:	fnortham@msn.com
Address:	216 E. Taylor Street Tempe Arizona 85281
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	09/19/03: D. Backer, C. Barclay, K. Brown, D. Casper, P. Guertin, F. Northam, R. Paredes, W. Sommers, J. Ward, P. Warren 03/26/04: D. Backer, K. Brown, P. Guertin, J. Hall, B. Munda, F. Northam, M. Quinn, J. Ward
Committee review date:	09/19/03 and 03/26/04
List date:	03/26/04
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**A**	Other published material	**"Impact"** **Section 1 Score:** **A**	**"Plant Score"** **Overall Score:** **High** **Alert Status:** **Alert**
1.2	Impact on plant community	**A**	Other published material		
1.3	Impact on higher trophic levels	**A**	Other published material		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Observational	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **15 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**A**	Observational		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**B**	Other published material		
2.5	Potential for human-caused dispersal	**A**	Other published material		
2.6	Potential for natural long-distance dispersal	**B**	Observational		
2.7	Other regions invaded	**C**	Other published material		
3.1	Ecological amplitude	**C**	Observational	**"Distribution"** **Section 3 Score:** **C**	 Something you should know.
3.2	Distribution	**D**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n Level:* **Other pub.**
Identify ecosystem processes impacted: Reduces availability of light and dissolved oxygen.
Rationale: Under favorable conditions can form dense mats more than 0.5m thick completely covering water surface (DiTomaso and Healy 2003). Thereby decreasing light availability and dissolved oxygen while increasing dead plant material. Where *Salvinia molesta* is carefully managed, it can remove excess nutrients and other pollutants from water (DiTomaso and Healy 2003). It can also diminish water quality (unspecified type of impact; DiTomaso and Healy 2003). But if left in the water, these excess nutrients and other pollutants will not be removed. Giant salvinia has the potential to alter aquatic ecosystems in several ways. Rapidly expanding populations can overgrow and replace native plants. Resulting dense surface cover prevents light and atmospheric oxygen from entering the water. Meanwhile, decomposing material drops to the bottom, greatly consuming dissolved oxygen needed by fish and other aquatic life (Thomas and Room 1986 in Jacono 2003).
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Dense shade resulting from thick *S. molesta* mats removes an essential component to photosynthesis (sunlight) and jeopardizes survival of submerged plant communities (including algae).
Rationale: Without adequate sunlight, plants can not produce the biochemical materials necessary to exist. Rapidly growing *S. molesta* colonies produce mats up to 0.5 m thick including deep foliage layers and dead plant material; these submerged layers block the energy (sunlight) needed to sustain plant life. Experimental evidence suggests submersed leaves may sometimes associate with nitrogen-fixing blue-green algae (DiTomaso and Healy 2003). Giant salvinia has the potential to alter aquatic ecosystems in several ways. Rapidly expanding populations can overgrow and replace native plants. Resulting dense surface cover prevents light and atmospheric oxygen from entering the water. Meanwhile, decomposing material drops to the bottom, greatly consuming dissolved oxygen needed by fish and other aquatic life (Thomas and Room 1986 in Jacono 2003).
Sources of information: See cited literature; see also Jacono and Pitman (2001).

Question 1.3 Impact on higher trophic levels *Score:* **A** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Extensive growth of *S. molesta* produces biomass that eventually decomposes in aquatic habitats and removes dissolved oxygen form the water and renders the water unsuitable for non-plant aquatic organisms (fish, mollusks and arthropods).
Rationale: Decomposition of mats formed by *S. molesta* creates an oxygen deficient (anaerobic conditions) in water bodies where *S. molesta* infestations cover large areas of water surfaces. Oxygen is an essential element that aquatic heterotrophic organism must have to survive. Giant *Salvinia* has the potential to alter aquatic ecosystems in several ways. Rapidly expanding populations can overgrow and replace native plants. Resulting dense surface cover prevents light and atmospheric oxygen from entering the water. Meanwhile, decomposing material drops to the bottom, greatly consuming dissolved oxygen needed by fish and other aquatic life (Thomas and Room 1986 in Jacono 2003).

Sources of information: See cited literature; also see Jacono and Pitman (2001) and DiTomaso and Healy (2003).

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: No known hybridization.
Rationale: In Arizona, there are no known native congeners (Kearney and Peebles 1960).
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Obs.**
Describe role of disturbance: Requires humans (not necessarily a disturbance) to move into other streams or water sources, but it can move down stream and establish with normal natural disturbance processes.
Rationale: Once established in North American fresh water habitats, its innate rapid vegetative reproduction makes it possible for *S. molesta* to be disseminated downstream by water currents. Escaped cultivation and spreading throughout southern U.S. (DiTomaso and Healy 2003).
Sources of information: See cited literature; also see Jacono (2003). Score based on observations of Working Group members and inference drawn from the literature.

Question 2.2 Local rate of spread with no management *Score:* **A** *Doc'n Level:* **Obs.**
Describe rate of spread: Rapid, population densities can double in a few days.
Rationale: One locality of *S. molesta* was documented in an irrigation canal near Blythe, California in 1999. Now this plant is a common contaminant of Colorado River still-water habitats from Cibola National Wildlife Refuge south of Ehrenberg, Arizona to Morelos Dam west of Yuma, Arizona. This means *S. molesta* has moved >50 miles down stream and become well-established in dozens of sites within a four-year period. As of September 2003, hundreds of thousands of square meters of *S. molesta* mats are present within the infested portion of Colorado River (F. Northam, personal observation, 2003; T. Olson, personal communication, 2003). From Jacono (2003): under optimal conditions (light, temperature and nutrient) in the laboratory, plant populations have been found to double in size every 2 to 4 days (Gaudet 1973). Under favorable natural conditions, biomass doubled in about one week to 10 days (Mitchell and Tur 1975, Mitchell and Rose 1979).
Sources of information: See cited literature. Also considered observations by F. Northam (at the time Noxious Weed Program Coordinator for the Arizona Department of Agriculture, 2003) and personal communication with T. Olson (Wildlife Biologist, Bureau of Reclamation, Boulder City, Nevada, 2003). Score based on observations and inference drawn from the literature.

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**
Describe trend: Rapid increase, but less than doubling in area infested in <10 years.
Rationale: Although *S. molesta* has spread rapidly and aggressively in the lower Colorado River, on a state-wide basis, this invader's spread has been negligible. At this time, it has not moved into other aquatic habitats (requires humans to move it from one stream system to another).
Sources of information: Observations by F. Northam (at the time Noxious Weed Program Coordinator for the Arizona Department of Agriculture, 2003) and personal communication with T. Olson (Wildlife Biologist, Bureau of Reclamation, Boulder City, Nevada, 2003).

Question 2.4 Innate reproductive potential *Score:* **B** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: *Salvinia* molesta reproduction is strictly by vegetative (clonal) growth. It is an extremely efficient converter of nutrients, sunlight, and carbon dioxide into new plants.
Rationale: As water temperatures warm through spring, new growth resumes in April or May and by June exponential population growth occurs until temperature and light intensity declines in late summer. *Salvinia molesta* effectively reproduces through vegetative means. Stems fragment spontaneously as plants mature. New branches develop from apical and lateral buds. Each node harbors up to five serial lateral buds, adding to the high potential for growth and dormancy (Jacono 2003).
Sources of information: See cited literature; also see Mitchell and Tur (1975).

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: (1) Water recreation craft and vehicles, (2) aquatic plant markets—aquarium or pond ornamental, (3) recreation (fishing, water activities, etc.), and (4) irrigation delivery systems.
Rationale: This plant is sold as an ornamental, may be released with other aquarium species, and it can be moved on aquatic recreational vehicles and equipment (DiTomaso and Healy 2003). Other observed forms of human dispersal observed include in bait buckets and in irrigation diversion systems into and out of rivers and streams along the Colorado River. *Salvinia molesta* requires humans to move it from one freshwater system to another; no naturally means to move from one system to another.
Sources of information: See cited literature. Also considered Working Group member observations of dispersal.

Question 2.6 Potential for natural long-distance dispersal *Score:* **B** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Fragments can disperse downstream in the water.
Rationale: Occasional dispersal >1 km within infested habitats as the result of flowing water and can only go in one direction, downstream. Although it is extremely efficient at downstream dispersal, it will not spread upstream without human intervention. *Salvinia molesta* tends to infest down stream areas within 1km but there is occasional dispersal greater than 1 km.
Sources of information: Observations by F. Northam (Consulting Weed Biologist, Tempe, Arizona, 2004).

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Other pub.**
Identify other regions: Aquatic habitats in California, Texas, Louisiana, Alabama, Georgia, Florida, South Carolina, Florida are invaded; however, similar habitats are already invaded in Arizona.
Rationale: *Salvinia molesta* is strictly a freshwater species and does not tolerate brackish or marine environments. Typical habitat is still and slow-moving waters of lakes, ponds, reservoirs, rivers, marshes, ditches, and rice fields, with water temperature >60°F. Tolerates mild temperate conditions and occasional frost but not prolonged periods of freezing. Dense mats do not develop at temperatures below 10°C (DiTomaso and Healy 2003). *Salvinia molesta* will withstand periods of stress, both low temperature and dewatering, through latent buds (Jacono 2003). Found in lakes and marshes in Texas (Jacono 2003).
Sources of information: See cited literature.

Question 3.1 Ecological amplitude *Score:* **C** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Limited. Establishment and persistence requires permanent fresh (i.e., non-saline) aquatic environment that is an extremely limited ecological type in Arizona. First

Arizona records of *S. molesta* were reported in 1999 (Arizona Department of Agriculture, Noxious Weed/Invasive Plant Distribution Database: *Salvinia molesta*).

Colorado River populations reproduce extremely quickly during June through September. Small mats usually less than 2 m^2 each survive winter in protected areas such as the interior of large cattail and common reed patches (F. Northam, personal observation, 2004).

Rationale: An extremely small portion of Arizona's natural areas are susceptible to invasion by *S. molesta.* Limited to one major (Freshwater Systems) and two minor ecological type: rivers (Colorado) and lakes (Martinez and Squaw).

Sources of information: Arizona Department of Agriculture, Noxious Weed/Invasive Plant Distribution Database: *Salvinia molesta*. Also considered observations by F. Northam (Consulting Weed Biologist, Tempe, Arizona, 2004) and personal communication with T. Olson (Wildlife Biologist, Bureau of Reclamation, Boulder City, Nevada, 2003).

Question 3.2 Distribution *Score:* **D** *Doc'n Level:* **Obs.**

Describe distribution: Limited

Rationale: Only a small portion of each of two minor ecological types, which occupy a small portion of Arizona's ecological landscapes.

Sources of information: Arizona Department of Agriculture, Noxious Weed/Invasive Plant Distribution Database: *Salvinia molesta*. Also considered observations by F. Northam (Consulting Weed Biologist, Tempe, Arizona, 2004) and personal communication with T. Olson (Wildlife Biologist, Bureau of Reclamation, Boulder City, Nevada, 2003).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	[Yes]	No	1 pt.
Dense infestations produce >1,000 viable seed per square meter	Yes	[No]	2 pt.
Populations of this species produce seeds every year.	Yes	[No]	1 pt.
Seed production sustained for 3 or more months within a population annually	Yes	[No]	1 pt.
Seeds remain viable in soil for three or more years	Yes	[No]	2 pt.
Viable seed produced with *both* self-pollination and cross-pollination	Yes	[No]	1 pt.
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	[Yes]	No	1 pt.
Fragments easily and fragments can become established elsewhere	[Yes]	No	2 pt.
Resprouts readily when cut, grazed, or burned	[Yes]	No	1 pt.

Total pts: 5 Total unknowns: 0

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	**D**
	rivers, streams	**D**
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

DiTomaso, J.M., and E.A. Healy. 2003. Aquatic and Riparian Weeds of the West. Sponsored by the California Weed Science Society. Publication 3421. University of California, Agriculture and Natural Resources, Oakland.

Gaudet, J.J. 1973. Growth of a floating aquatic weed, *Salvinia*, under standard conditions. Hydrobiologia 41:77−106.

Jacono, C. 2003. *Salvinia molesta* D.S. Mitchell. U.S. Department of the Interior, U.S. Geological Survey. Available online at: http://salvinia.er.usgs.gov/html/identification.html; accessed September 2003.

Jacono, C., and R. Pitman. 2001. *Salvinia molesta*: around the world in 70 years. Aquatic Nuisance Species Digest 4:13−16.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Mitchell, D.S., and D.J Rose. 1979 Factors affecting fluctuations in extent of *Salvinia molesta* on Lake Kariba. Pans 25:171−177.

Mitchell, D.S., and N.M. Tur. 1975. The growth rate of *Salvinia molesta* in laboratory and natural conditions. Journal of Applied Ecology 2:213−225.

Thomas, P.A., and P.M. Room 1986. Taxonomy and control of *Salvinia molesta*. Nature 320:541−584.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Schismus arabicus* Nees; *Schismus barbatus* (Loefl. ex L.) Thellung (USDA 2005).
Synonyms:	*Schismus arabicus*: None listed in USDA (2005); *Schismus barbatus*: *Festuca barbata* Loefl. ex L. (USDA 2005).
Common names:	*Schismus arabicus*: Arabian schismus, Mediterranean grass; *Schismus barbatus*: Common Mediterranean grass, Mediterranean grass.
Evaluation date (mm/dd/yy)**:**	09/15/03
Evaluator #1 Name/Title:	Katy Brown
Affiliation:	The Nature Conservancy (Volunteer)
Phone numbers:	(520) 327–6862
Email address:	Pbrown5@mindspring.com
Address:	4357 E. Monte Vista, Tucson, Arizona 85712
Evaluator #2 Name/Title:	Dana Backer
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861: ext. 3437
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85719

List committee members:	09/19/03: D. Backer, C. Barclay, Katy Brown, P. Guertin, F. Northam, R. Parades, W. Sommers, J. Ward, P. Warren 03/01/05: D. Baker, D. Casper, J. Filar, E. Geiger, J. Hall, H. Messing, B. Munda, F. Northam
Committee review date:	09/19/03 and 03/01/05
List date:	09/19/03; revised 03/01/05 (addressed Consistency Review Panel comments)
Re-evaluation date(s):	

Taxonomic Comment

Schismus arabicus and *S. barbatus* are prevalent in parts of the Sonoran Desert and most of the Mohave Desert. These species are difficult to distinguish in the field and their taxonomic uniqueness is in question (P. Jenkins, University of Arizona Herbarium, personal communication, 1999 in Esque and Schwalbe 2002). These two *Schismus* species are often referred to together and will be treated collectively in this evaluation, with the exception of ecological amplitude (question 3.1).

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Reviewed scientific publication	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**A**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**C**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **11 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**C**	Other published material		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**C**	Observational		
2.6	Potential for natural long-distance dispersal	**C**	Other published material		
2.7	Other regions invaded	**C**	Observational		RED FLAG **NO** Something you should know.
3.1	Ecological amplitude	**A**	Other published material	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Rev. sci. pub.**
Identify ecosystem processes impacted: Provides increased fuel for fire and readily re-establishes after fire, creating a fuel/fire positive cycle. May also alter soil ecology.
Rationale: Fire: *Schismus* occupy spaces between shrubs (Brooks 1998) and individual plants can remain rooted and upright for up to two years following death, thus accumulating biomass that potentially contributes to increased frequency and fire extent (Brooks 1998, 1999, 2000; studies conducted in Mojave Desert). Esque 1999 (in Guertin and Halvorson 2003) states that "*Schismus barbatus* (and *S. arabicus*) are the primary species fueling desert wildfires in the upland habitats of the Mojave Desert, potentially threatening the biodiversity of the desert." (This is supported in Brooks and Esque 2002). Fires in the Sonoran Desert up to elevations of 3500 feet have been fueled to a large extent by non-native annual grasses, including *Schismus* (Esque and Schwalbe 2002). However, the Sonoran Desert rain pattern produces less winter rain than the Mojave Desert and the density of *Schismus* is not as great in the Sonoran area (relative to Mojave); as a result, the impact of *Schismus* by itself may have a lesser impact on the fire regime (Working Group discussion). However, the Working Group also noted that *Schismus* occurs with a suite of other non-native annuals in the Sonoran Desert, which in combination contribute to the ability to fuel fire and produce a continuous coverage of fuel. The role alien annual grasses can play in community change is well documented for the Great Basin Desert (Billings 1990); Esque and Schwalbe (2002) suggest *Bromus rubens* (red brome) and *Schismus* to be those species with the most potential in the Sonoran desert. Soil ecology: "…*Schismus barbatus* can use soil nitrogen at increased levels and at faster rates than the native species, inhibiting their growth rate; this may be due to the plant's increased consumption of soil water (Brooks 1998 in Brooks and Pyke 2000). It is not clear if this is a significant alteration of the soil ecology, or simply a competitive edge.
Sources of information: See cited literature and inference by the Working Group members.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: Reduces the presence and germination of native annual plants and altars structure and composition. Long term effects are unknown.
Rationale: Displacement of native species by *Schismus* has not been documented (Brooks and Esque 2002). Brooks (2000) cites personal communications with Clarke (University of California, Riverside, 1998) that indicates *Schismus*, in arid and semi arid regions of California, had risen from relative obscurity to one of the dominant annual grasses during the 1940s, while the similar native annual grass, six-weeks fescue (*Vulpia octoflora*), became less common. Felger (2000) observed *Schismus* to form dense stands during years of favorable winter rains sometimes to the exclusion of native ephemerals. The first stems and leaves often spread out close to the ground, excluding or preventing other plants from sprouting (Guertin and Halvorson 2003). Brooks and Esque (2002) suggested densely packed *Schismus* seedlings and accumulated plant litter may inhibit germination of native annual plants as has been documented with other alien seedlings (Inouye 1980). After good rains, mass germination of *Schismus barbatus*, *Bromus rubens*, and *Hordeum murinum* produce dense stands that suppress other ephemerals (Burgess et al. 1991) Seed bank studies by Pake and Venable (1996) and Loria and Noy-Meir (1979–1980 in Gutterman 1996a, as cited in Guertin and Halvorson 2003) show that *Schismus* uses a seed banking strategy for survival through unfavorable times. During the study periods, numbers and percentage of *Schismus* seed in the seed bank increased (conditions were favorable), while the number of seed species in the seedbank went down. Germination studies show less than 25% germination rate for the seed per season.

Native desert plant communities are often poorly adapted to fire (Brooks and Esque 2002) and in some desert ecosystems fire is not a natural component (Humphrey 1974). This suggests that native annual plants, in particular native annual grasses, do not form the continuous fine fuel beds to facilitate fire. This is in contrast to *Schismus*, which forms continuous coverage of upright and rooted vegetation as discussed by Brooks (1998, 2000). Thus, it is inferred that the plant community structure and composition is being altered not only by the presence of *Schismus* but by introducing fire to non-fire adapted plant communities.

Because *Schismus* is one of the fastest-maturing desert annuals, proceeding from germination to reproduction faster than many other desert annuals (Szarek et al. 1982), it can effectively compete for limiting nutrients with native annual plants (Brooks 1998 in Brooks 2000). "…*Schismus barbatus* can use soil nitrogen at increased levels and at faster rates than the native species, inhibiting their growth rate; this may be due to the plant's increased consumption of soil water (Brooks 1998 in Brooks and Pyke 2000).

Sources of information: See cited literature. Also considered Working Group inference.

Question 1.3 Impact on higher trophic levels *Score:* **C** *Doc'n Level:* **Obs.**

Identify type of impact or alteration: Impact on desert tortoise nutrition, health, and habitat.

Rationale: From Oftedal (2003): Tortoises have adapted to certain desert areas with an available plant diet sufficiently high in PEP (Potassium Excretion Potential), which is necessary to maintain health during times when sufficient water for drinking is not available. Oftedal hypothesizes that *Schismus,* based on its potential to out compete higher PEP value native plants during summer rainy seasons, causes an impact on desert tortoise nutrition and health due to the lower PEP value available. This agrees with Avery's hypothesis (2003) that exotic plant introductions lead to a reduction in food choices for desert tortoises and a nutrient imbalance due to the consumption of lower quality forage plants.

Schismus barbatus seeds are eaten by rodents (Brooks 1995 in Wilken and Hannah 1998). Leaves of *Schismus* (of low nutritional quality) and other plant parts are eaten by desert tortoises (Barboza 1995, Nagy et al. 1998 in Wilken and Hannah 1998, Oftedal et al. 2000). Brooks and Esque (2002) suggest the desert tortoise is one species threatened by altered fire regimes due to alien plant invasions.

Sources of information: See cited literature. Score based on inference from the literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**

Identify impacts: No known impact; no hybridization with natives.

Rationale: *Schismus arabicus* and *S. barbatus* produce viable hybrids with each other (Faruqi and Quraish 1979 in Guertin and Halvorson 2003), but no mention was found of hybridization with native species. There are no native *Schismus* in Arizona (Kearney and Peebles 1960).

Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**

Describe role of disturbance: Moderate invasive potential.

Rationale: Abundant where grazing, off-roach vehicle use, or construction of linear corridors—for example, right of ways—has reduced shrub cover and disturbed the soil (Brooks 2000). Wind and sheet flooding are primary dispersal mechanisms (Brooks 2000, Gutterman 2003 in Guertin and Halvorson 2003 [cited as In Press]). *Schismus* presence along roadsides and in arroyos/washes (Felger 1990 in Guertin and Halvorson 2003) suggests both natural and/or anthropogenic disturbance are required for establishment. Beatley (1966 in Esque and Schwalbe 2002) from work in Nevada suggests *Schismus* can invade and establish in relatively undisturbed communities. In Arizona it can self-seed in undisturbed habitats (Burgess et al. 1991).

Sources of information: See cited literature. Score based in part on inference from literature and personal observations of Working Group members.

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**
Describe rate of spread: Increases, but less rapidly than doubling in 10 years.
Rationale: Due to competition with other annual plants (alien or non-native) and the dependence on seasonal rainfall, the local rate of spread is increasing but not doubling in less than ten years. Abundant by 1940s in Sonoran and Mojave deserts (Esque and Schwalbe 2002).
Sources of information: See cited literature. Score based on inference from the literature.

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n Level:* **Other pub.**
Describe trend: Stable.
Rationale: *Schismus barbatus* was naturalized in central Arizona by 1931 (Felger 1990, Kearney 1931 in Burgess et al. 1991) and in southern Arizona by 1949 (Gould 1949 in Burgess et al. 1991). By the 1970s *Schismus* species were found in all of the desert counties of Arizona in great abundance (Esque and Schwalbe 2002). *Schismus arabicus* and *S. barbatus* are presently listed among the most abundant of annual plant species in the Lower Colorado River Valley subdivision of the Sonoran Desert and into the Arizona Upland subdivision (Burgess et al. 1991and Pake and Venable 1995 in Esque and Schwalbe 2002).
Sources of information: See cited literature.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: Winter germinating annual, self-pollinating, self-fertilizing; (Faruqi and Quraish 1979 in Guertin and Halvorson 2003) producing an average (in one study) of 112.4 seeds per plant (Loria and Noy-Meir 1979–1980 in Gutterman 1996a, as cited in Guertin and Halvorson 2003). Small seeds escape being eaten. Wind carries the seeds or blows the senesced plants, which drop seeds as they go. Seeds and plant parts carrying seeds are also dispersed by sheet water. Differentiated germination rates. Seed banking studies (Pake and Venable 1996) show that *Schismus* uses a seed banking strategy with a less than full germination rate per season. Whereas Pake and Venable (1996) did not specifically study the seed viability after 3 years, it is inferred that the seed will last that long as a survival strategy to survive drought years. It has been observed that *Schismus* reappears in an area after unfavorable years.
Rationale: Seeds have been germinated after being stored two or more years (Gutterman papers [various] in Guertin and Halvorson 2003). Also see Worksheet A.
Sources of information: See cited literature. Also considered inference by the Working Group members.

Question 2.5 Potential for human-caused dispersal *Score:* **C** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: None specifically cited.
Rationale: No mention was made in the literature of specific human dispersal means; however, Brooks (2000) states that in areas of human disturbance, such as off road vehicle use, grazing or construction of linear corridors, *Schismus* abundance is higher. Seeds are small and are dispersed by water or when the senesced plant is blown about by wind.
Sources of information: Score based on observations and inference from various Working Group members.

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Wind and sheet water disperses seed, but may not be as far as 1 km on an occasional basis.

Rationale: Different sizes of dispersal units (caryopsis, bracts, and spikelets) limit the distance that they can disperse from the parent. Plants are low to the ground and seeds become trapped in soil cracks. Larger "units" are trapped by other land features and litter, (Gutterman papers [various] in Guertin and Halvorson 2003). Wind: "seed is often retained within the inflorescence, and will disperse when detached from the plant and is blown along the ground for short distances" (Brooks 2000). Drezner et al. (2001 in Guertin and Halvorson 2003) report that on the Hassayampa River Preserve in Arizona*, S. barbatus* is dispersed by animals but the mechanism was not stated.
Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Obs.**
Identify other regions: No ecological types have been invaded outside of Arizona other than those that have already been invaded here.
Rationale: Occurs only in ecological types already invaded in Arizona.
Sources of information: Score based on information from various authors and Working Group members.

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: *Schismus* grasses were first documented in Arizona (floodplain of Gila River, near Sacaton in 1926 (Felger 1990). *Schismus arabicus* was present in Arizona by 1933 with the first collection made at the Desert Laboratory in Tucson 1968 (Burgess et al. 1991).
Rationale: By the 1970s *Schismus* species were found in all of the desert counties of Arizona in great abundance (Esque and Schwalbe 2002). *Schismus arabicus* and *S. barbatus* are presently listed among the most abundant of annual plant species in the Lower Colorado River Valley subdivision of the Sonoran Desert and into the Arizona Upland subdivision (Burgess et al. 1991 and Pake and Venable 1995 in Esque and Schwalbe 2002). *Schismus barbatus* reported in Mohave, Yavapi, Gila, Pinal, Maricopa, Yuma, Pima, and Santa Cruz counties (Gould 1951). Highly successful invaders in Sonoran and Mojave deserts (Burgess et al. 1991). Abiotic preferences: *Schismus* prefers sandy soils on desert sand flats (Kearney and Peebles 1960, Felger 1990). Occupy elevational range of 1000 to 4000 feet for *S. barbatus* and 1000 to 2500 for *S. arabicus* (Kearney and Peebles 1960). *Schismus arabicus*, but not *S. barbatus*, is found in dune habitat (Warren and Laurenzi 1987, Felger et al. 2003).
Sources of information: See cited literature. Also considered personal observations by Working Group members.

Question 3.2 Distribution *Score:* **A** *Doc'n Level:* **Obs.**
Describe distribution: See question 3.1 and Worksheet B.
Rationale: See question 3.1 and Worksheet B.
Sources of information: See cited literature in question 3.1. Primarily considered personal observations by Working Group members.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**[No]**	**1 pt.**
	Total pts: 8 Total unknowns: 0		
	Score : A		

Note any related traits: Exact number of years of seed viability not known. Direct studies were not found, but studies using seed 2+ years old were found (Gutterman [various]; see other references). Pake and Venable (1996) show that *Schismus* uses a seed banking strategy.

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	**B** (*S. arabicus* only)
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	**A**
	Chihuahuan desertscrub	**C**
	Sonoran desertscrub	**A**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	**C**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Avery, H.W. 2003. Challenges to a changing plant community: food selectivity and digestive performance of desert tortoises fed native vs. exotic forage plants. Poster session: Ecology, Conservation, and Husbandry. Available at http://nytts.org/proceedings/posters.htm; accessed September 2003.

Barboza, P. 1995. Nutrient balances and maintenance requirements for nitrogen ad energy in desert tortoises (*Xerobates agassizii*) consuming forages. Comparative Biochemistry and Physiology 112:537–545.

Beatley, J.C. 1966. Ecological status of introduced brome grasses (*Bromus* spp.) in desert vegetation of southern Nevada. Ecology 47:548–554.

Billings, W.D. 1990. *Bromus tectorum*, a biotic cause of ecosystem impoverishment in the Great Basin. In G.M. Woodell (ed.), The earth in Transition: Patterns and Processes of Biotic Impoverishment. Cambridge University Press, Cambridge.

Brooks, M. 1995. Benefits of protective fencing to plant and rodent communities of the Western Mojave Desert, California. Environmental Management 19:65–74.

Brooks, M.L. 1998. Ecology of a Biological Invasion: Alien Annual Plants in the Mojave Desert. Doctoral dissertation. University of California, Riverside.

Brooks, M.L. 1999. Alien annual grasses and fire in the Mojave Desert. Madroño 46:13–19.

Brooks, M.L. 2000. *Schismus arabicus* Nees; *Schismus barbatus* (L.) Thell. Pages 287–291 in C.C. Bossard, J.M. Randall, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Brooks, M.L., and D.A. Pyke. 2000. Invasive plants and fire in the deserts of North America. Pages 1–14 in K.E. Galley and T.P. Wilson (eds.), Proceedings of the Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species. Fire Conference 2000. The First National Congress on Fire Ecology, Prevention, and Management, Nov. 27-Dec. 1, 2000. Miscellaneous Publication No. 11. Tall Timbers Research Station, Tallahassee, Florida.

Brooks, M.L., and T.C. Esque, 2002. Alien plants and fire in desert tortoise (*Gopherus agassizii*) habitat of the Mojave and Colorado Deserts. Chelonian Conservation and Biology 4:330–340.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burgess, T.L., J.E. Bowers, and R.M. Turner. 1991. Exotic plants at the desert laboratory, Tucson, Arizona. Madroño 38:96–114.

Drezner, T.D., P.L. Fall, and J.C. Stromberg. 2001 Plant distribution and dispersal mechanisms at the Hassayampa River Preserve, Arizona, USA. Global Ecology and Biogeography 10:205–217.

Esque, T.C. 1999. Managing fire and invasive plants in the Mojave Desert: defining an integrated research program to address knowledge gaps. In Presentation Abstracts, Mojave Desert Science Symposium, February 25–27, 1999. U.S. Geological Survey, Western Ecological Research Center. Available online at: http://www.werc.usgs.gov/mojave-symposium/abstracts.html; accessed September 2003.

Esque, T.C., and C.R. Schwalbe. 2002. Alien annual grasses and their relationships to fire and biotic change in Sonoran desertscrub. Pages 165–194 in B. Tellman (ed.), Invasive Exotic Species in the Sonoran Region. The University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson, Arizona

Faruqi, S.A., and H.B. Quraish. 1979. Studies on Libyan grasses. V. Population variability and distribution of *Schismus arabicus* and *S. barbatus* in Libya. Pakistan Journal of Botany 11:167–172.

Felger, R.S. 1990. Non-Native Plants of Organ Pipe Cactus National Monument, Arizona. Technical Report No. 31. U.S. Geological Survey, Cooperative Park Studies Unit, The University of Arizona and National Park Service, Organ Pipe Cactus National Monument. 93 p.

Felger, R.S. 2000. Flora of the Gran Desierto and Rio Colorado of Northwestern Mexico. The University of Arizona Press, Tucson. 673 p.

Felger, R.S., D.S. Turner, and M.F. Wilson. 2003. Flora and vegetation of the Mohawk Dunes, Arizona. *Sida* 20:1155–1187.

Gould, F. 1949. Arizona plant records—II. Leaflets in Western Botany 5:167–170.

Gould, F.W. 1951. Grasses of the Southwestern United States. The University of Arizona Press, Tucson. 352 p.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13.

Gutterman, Y. 1996a. Temperatures during storage, light and wetting affecting caryopses germinability of *Schismus arabicus*, a common desert annual grass. Journal of Arid Environments 33:73–85.

Gutterman, Y. 2003. The inhibitory effect of Negev Desert loess soil on the fast germinating caryopses of *Schismus arabicus* (Poaceae). Journal of Arid Environments 54:619–631.

Humphrey, R.R. 1974. Fire in the deserts and desert grassland of North America. Pages 365–400 in T.T. Kozlowski and C.E. Ahlgren (eds.), Fire and Ecosystems. Academic Press, New York.

Inouye, R.S. 1980. Density-dependent germination response by seeds of desert annuals. Oecologia 6:235–238.

Kearney, T.H. 1931. Plants new to Arizona. Journal of the Washington Academy of Science 21:63–80.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Loria, M., and I. Noy-Meir. 1979–1980. Dynamics of Some Annual Populations in a Desert Loess Plain, Israel Journal of Botany 28:211–225.

Nagy, K., B. Henen, and D. Vyas. 1998. Nutritional quality of native and introduced food plants of wild desert tortoises. Journal of Herpetology 32:260–267.

Oftedal, O.T., S. Hillard, and D. Morafka. 2000. Juvenile Desert Tortoises Enhance Nutritional Status by Foraging Choice: Data from the 1998 El Nino at the Fort Irwin Study Site. 25th Annual Meeting and Symposium of the Desert Tortoise Council, April 21–24, 2000. Abstracts.

Oftedal, O.T. 2003. Are Desert Tortoises Nutritionally Constrained by a Shortage of High PEP Plants, and if so, what do we do? 28th Annual Meeting and Symposium of the Desert Tortoise Council, February 21–23, 2003, Abstracts.

Pake, C. E., and E. L. Venable. 1995. Is coexistence in Sonoran Desert annual plants mediated by temporal variation in reproductive success. Ecology 76:246–261.

Pake, C.E., and D.L Venable. 1996. Seed banks in desert annuals: implications for persistence and coexistence in variable environments. Ecology 77:1427–1435.

Szarek, S.R., S.D. Smith, and R.D. Ryan. 1982. Moisture stress effects on biomass partitioning in two Sonoran Desert annuals. American Midland Naturalist 108:338–345.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Warren, P.L., and A.W. Laurenzi. 1987 Rare Plant Survey of the Yuma District. Final report of P.O. No. AZ-950-PH6-0540, U.S. Bureau of Land Management, Yuma District Office.

Wilken, D., and L. Hannah. 1998. *Schismus arabicus* Nees (Poaceae) Mediterranean Grass; Santa Barbara Botanic Garden, for Channel Islands National Park. Available online at http://usgssrv/.usgs.nau.edu/swepic/factsheets/schismus_spp.pdf; accessed September 2003.

Other References of Interest Not Cited in the Text

Gutterman's citations are numerous and Guertin and Halvorson's (2003) review of Gutterman's work was referenced in some places in the text as a collection of Gutterman's work on *Schismus*. In addition to specifically cited papers, the following papers were reviewed by Guertin and Halvorson (2003):

Gutterman, Y. 1989. *Schismus arabicus*. In A.H. Halevy (ed.), CRC Handbook of Flowering. Vol. VI. CRC Press, Boca Raton, Florida. 753 p.

Gutterman, Y. 1993. Seed germination in desert plants. Springer-Verlag, Berlin. 253 p.

Gutterman, Y. 1994. Strategies for seed dispersal and germination in plants inhabiting deserts. The Botanical Review 60:373–425.

Gutterman, Y. 1996b. Effect of day length during plant development and caryopsis maturation on flowering and germination, in addition to temperature during dry storage and light during wetting, of *Schismus arabicus* (Poaceae) Journal of Arid Environments 33:439–448.

Gutterman, Y. 2000. Environmental factors and survival strategies of annual plant species in the Negev Desert, Israel. Plant Species Biology 15:113−125.

Gutterman, Y. 2001a. The drought tolerance of the dehydrated root of *Schismus arabicus* seedling and regrowth after rehydration, affected by caryopsis size, darkness and duration of dehydration. Israel Journal of Plant Sciences 49:123−128.

Gutterman, Y. 2001b. Phenotypic germination plasticity according to caryopsis size in *Schismus arabicus*, a common annual grass occurring in the Negev Desert of Israel. Seed Science Research 11:173−178.

Gutterman, Y., and G.P. Chapman. 1992. Ecophysiology of Negev upland annual grasses. Pages 145−162 in Desertified Grasslands: Their Biology and Management. Papers presented at an International Symposium, February 27 to March 1, 1991, London, England. Linnean Society Symposium Series No. 13. Academic Press, London, England.

Gutterman, Y., and M. Evanari. 1994. The influences of amounts and distribution of irrigation during the hot and dry season on emergence and survival of some desert winter annual plants in the Negev Desert of Israel. Israel Journal of Plant Science 42:1−14.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Schismus arabicus* Nees; *Schismus barbatus* (Loefl. ex L.) Thellung (USDA 2005).
Synonyms:	*Schismus arabicus*: None listed in USDA (2005); *Schismus barbatus*: *Festuca barbata* Loefl. ex L. (USDA 2005).
Common names:	*Schismus arabicus*: Arabian schismus, Mediterranean grass; *Schismus barbatus*: Common Mediterranean grass, Mediterranean grass.
Evaluation date (mm/dd/yy)**:**	09/15/03
Evaluator #1 Name/Title:	Katy Brown (Volunteer)
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 327–6862
Email address:	Pbrown5@mindspring.com
Address:	4357 E. Monte Vista, Tucson, Arizona 85712
Evaluator #2 Name/Title:	Dana Backer
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861: ext. 3437
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85719

List committee members:	09/19/03: D. Backer, C. Barclay, Katy Brown, P. Guertin, F. Northam, R. Parades, W. Sommers, J. Ward, P. Warren 03/01/05: D. Baker, D. Casper, J. Filar, E. Geiger, J. Hall, H. Messing, B. Munda, F. Northam
Committee review date:	09/19/03 and 03/01/05
List date:	09/19/03; revised 03/01/05 (addressed Consistency Review Panel comments)
Re-evaluation date(s):	

Taxonomic Comment

Schismus arabicus and *S. barbatus* are prevalent in parts of the Sonoran Desert and most of the Mohave Desert. These species are difficult to distinguish in the field and their taxonomic uniqueness is in question (P. Jenkins, University of Arizona Herbarium, personal communication, 1999 in Esque and Schwalbe 2002). These two *Schismus* species are often referred to together and will be treated collectively in this evaluation, with the exception of ecological amplitude (question 3.1).

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Reviewed scientific publication	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**A**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**C**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **11 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**C**	Other published material		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**C**	Observational		
2.6	Potential for natural long-distance dispersal	**C**	Other published material		
2.7	Other regions invaded	**C**	Observational		 Something you should know.
3.1	Ecological amplitude	**B**	Other published material	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Rev. sci. pub.**	
Identify ecosystem processes impacted: Provides increased fuel for fire and readily re-establishes after fire, creating a fuel/fire positive cycle. May also alter soil ecology.	
Rationale: Fire: *Schismus* occupy spaces between shrubs (Brooks 1998) and individual plants can remain rooted and upright for up to two years following death, thus accumulating biomass that potentially contributes to increased frequency and fire extent (Brooks 1998, 1999, 2000; studies conducted in Mojave Desert). Esque 1999 (in Guertin and Halvorson 2003) states that "*Schismus barbatus* (and *S. arabicus*) are the primary species fueling desert wildfires in the upland habitats of the Mojave Desert, potentially threatening the biodiversity of the desert." (This is supported in Brooks and Esque 2002). Fires in the Sonoran Desert up to elevations of 3500 feet have been fueled to a large extent by non-native annual grasses, including *Schismus* (Esque and Schwalbe 2002). However, the Sonoran Desert rain pattern produces less winter rain than the Mojave Desert and the density of *Schismus* is not as great in the Sonoran area (relative to Mojave); as a result, the impact of *Schismus* by itself may have a lesser impact on the fire regime (Working Group discussion). However, the Working Group also noted that *Schismus* occurs with a suite of other non-native annuals in the Sonoran Desert, which in combination contribute to the ability to fuel fire and produce a continuous coverage of fuel. The role alien annual grasses can play in community change is well documented for the Great Basin Desert (Billings 1990); Esque and Schwalbe (2002) suggest *Bromus rubens* (red brome) and *Schismus* to be those species with the most potential in the Sonoran desert. Soil ecology: "…*Schismus barbatus* can use soil nitrogen at increased levels and at faster rates than the native species, inhibiting their growth rate; this may be due to the plant's increased consumption of soil water (Brooks 1998 in Brooks and Pyke 2000). It is not clear if this is a significant alteration of the soil ecology, or simply a competitive edge.	
Sources of information: See cited literature and inference by the Working Group members.	

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**	
Identify type of impact or alteration: Reduces the presence and germination of native annual plants and altars structure and composition. Long term effects are unknown.	
Rationale: Displacement of native species by *Schismus* has not been documented (Brooks and Esque 2002). Brooks (2000) cites personal communications with Clarke (University of California, Riverside, 1998) that indicates *Schismus*, in arid and semi arid regions of California, had risen from relative obscurity to one of the dominant annual grasses during the 1940s, while the similar native annual grass, six-weeks fescue (*Vulpia octoflora*), became less common. Felger (2000) observed *Schismus* to form dense stands during years of favorable winter rains sometimes to the exclusion of native ephemerals. The first stems and leaves often spread out close to the ground, excluding or preventing other plants from sprouting (Guertin and Halvorson 2003). Brooks and Esque (2002) suggested densely packed *Schismus* seedlings and accumulated plant litter may inhibit germination of native annual plants as has been documented with other alien seedlings (Inouye 1980). After good rains, mass germination of *Schismus barbatus*, *Bromus rubens*, and *Hordeum murinum* produce dense stands that suppress other ephemerals (Burgess et al. 1991) Seed bank studies by Pake and Venable (1996) and Loria and Noy-Meir (1979−1980 in Gutterman 1996a, as cited in Guertin and Halvorson 2003) show that *Schismus* uses a seed banking strategy for survival through unfavorable times. During the study periods, numbers and percentage of *Schismus* seed in the seed bank increased (conditions were favorable), while the number of seed species in the seedbank went down. Germination studies show less than 25% germination rate for the seed per season.	

Native desert plant communities are often poorly adapted to fire (Brooks and Esque 2002) and in some desert ecosystems fire is not a natural component (Humphrey 1974). This suggests that native annual plants, in particular native annual grasses, do not form the continuous fine fuel beds to facilitate fire. This is in contrast to *Schismus*, which forms continuous coverage of upright and rooted vegetation as discussed by Brooks (1998, 2000). Thus, it is inferred that the plant community structure and composition is being altered not only by the presence of *Schismus* but by introducing fire to non-fire adapted plant communities.

Because *Schismus* is one of the fastest-maturing desert annuals, proceeding from germination to reproduction faster than many other desert annuals (Szarek et al. 1982), it can effectively compete for limiting nutrients with native annual plants (Brooks 1998 in Brooks 2000). "…*Schismus barbatus* can use soil nitrogen at increased levels and at faster rates than the native species, inhibiting their growth rate; this may be due to the plant's increased consumption of soil water (Brooks 1998 in Brooks and Pyke 2000).

Sources of information: See cited literature. Also considered Working Group inference.

Question 1.3 Impact on higher trophic levels *Score:* **C** *Doc'n Level:* **Obs.**

Identify type of impact or alteration: Impact on desert tortoise nutrition, health, and habitat.

Rationale: From Oftedal (2003): Tortoises have adapted to certain desert areas with an available plant diet sufficiently high in PEP (Potassium Excretion Potential), which is necessary to maintain health during times when sufficient water for drinking is not available. Oftedal hypothesizes that *Schismus,* based on its potential to out compete higher PEP value native plants during summer rainy seasons, causes an impact on desert tortoise nutrition and health due to the lower PEP value available. This agrees with Avery's hypothesis (2003) that exotic plant introductions lead to a reduction in food choices for desert tortoises and a nutrient imbalance due to the consumption of lower quality forage plants.

Schismus barbatus seeds are eaten by rodents (Brooks 1995 in Wilken and Hannah 1998). Leaves of *Schismus* (of low nutritional quality) and other plant parts are eaten by desert tortoises (Barboza 1995, Nagy et al. 1998 in Wilken and Hannah 1998, Oftedal et al. 2000). Brooks and Esque (2002) suggest the desert tortoise is one species threatened by altered fire regimes due to alien plant invasions.

Sources of information: See cited literature. Score based on inference from the literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**

Identify impacts: No known impact; no hybridization with natives.

Rationale: *Schismus arabicus* and *S. barbatus* produce viable hybrids with each other (Faruqi and Quraish 1979 in Guertin and Halvorson 2003), but no mention was found of hybridization with native species. There are no native *Schismus* in Arizona (Kearney and Peebles 1960).

Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**

Describe role of disturbance: Moderate invasive potential.

Rationale: Abundant where grazing, off-roach vehicle use, or construction of linear corridors—for example, right of ways—has reduced shrub cover and disturbed the soil (Brooks 2000). Wind and sheet flooding are primary dispersal mechanisms (Brooks 2000, Gutterman 2003 in Guertin and Halvorson 2003 [cited as In Press]). *Schismus* presence along roadsides and in arroyos/washes (Felger 1990 in Guertin and Halvorson 2003) suggests both natural and/or anthropogenic disturbance are required for establishment. Beatley (1966 in Esque and Schwalbe 2002) from work in Nevada suggests *Schismus* can invade and establish in relatively undisturbed communities. In Arizona it can self-seed in undisturbed habitats (Burgess et al. 1991).

Sources of information: See cited literature. Score based in part on inference from literature and personal observations of Working Group members.

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**
Describe rate of spread: Increases, but less rapidly than doubling in 10 years.
Rationale: Due to competition with other annual plants (alien or non-native) and the dependence on seasonal rainfall, the local rate of spread is increasing but not doubling in less than ten years. Abundant by 1940s in Sonoran and Mojave deserts (Esque and Schwalbe 2002).
Sources of information: See cited literature. Score based on inference from the literature.

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n Level:* **Other pub.**
Describe trend: Stable.
Rationale: *Schismus barbatus* was naturalized in central Arizona by 1931 (Felger 1990, Kearney 1931 in Burgess et al. 1991) and in southern Arizona by 1949 (Gould 1949 in Burgess et al. 1991). By the 1970s *Schismus* species were found in all of the desert counties of Arizona in great abundance (Esque and Schwalbe 2002). *Schismus arabicus* and *S. barbatus* are presently listed among the most abundant of annual plant species in the Lower Colorado River Valley subdivision of the Sonoran Desert and into the Arizona Upland subdivision (Burgess et al. 1991and Pake and Venable 1995 in Esque and Schwalbe 2002).
Sources of information: See cited literature.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: Winter germinating annual, self-pollinating, self-fertilizing; (Faruqi and Quraish 1979 in Guertin and Halvorson 2003) producing an average (in one study) of 112.4 seeds per plant (Loria and Noy-Meir 1979−1980 in Gutterman 1996a, as cited in Guertin and Halvorson 2003). Small seeds escape being eaten. Wind carries the seeds or blows the senesced plants, which drop seeds as they go. Seeds and plant parts carrying seeds are also dispersed by sheet water. Differentiated germination rates. Seed banking studies (Pake and Venable 1996) show that *Schismus* uses a seed banking strategy with a less than full germination rate per season. Whereas Pake and Venable (1996) did not specifically study the seed viability after 3 years, it is inferred that the seed will last that long as a survival strategy to survive drought years. It has been observed that *Schismus* reappears in an area after unfavorable years.
Rationale: Seeds have been germinated after being stored two or more years (Gutterman papers [various] in Guertin and Halvorson 2003). Also see Worksheet A.
Sources of information: See cited literature. Also considered inference by the Working Group members.

Question 2.5 Potential for human-caused dispersal *Score:* **C** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: None specifically cited.
Rationale: No mention was made in the literature of specific human dispersal means; however, Brooks (2000) states that in areas of human disturbance, such as off road vehicle use, grazing or construction of linear corridors, *Schismus* abundance is higher. Seeds are small and are dispersed by water or when the senesced plant is blown about by wind.
Sources of information: Score based on observations and inference from various Working Group members.

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Wind and sheet water disperses seed, but may not be as far as 1 km on an occasional basis.

Rationale: Different sizes of dispersal units (caryopsis, bracts, and spikelets) limit the distance that they can disperse from the parent. Plants are low to the ground and seeds become trapped in soil cracks. Larger "units" are trapped by other land features and litter, (Gutterman papers [various] in Guertin and Halvorson 2003). Wind: "seed is often retained within the inflorescence, and will disperse when detached from the plant and is blown along the ground for short distances" (Brooks 2000). Drezner et al. (2001 in Guertin and Halvorson 2003) report that on the Hassayampa River Preserve in Arizona, *S. barbatus* is dispersed by animals but the mechanism was not stated.
Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Obs.**
Identify other regions: No ecological types have been invaded outside of Arizona other than those that have already been invaded here.
Rationale: Occurs only in ecological types already invaded in Arizona.
Sources of information: Score based on information from various authors and Working Group members.

Question 3.1 Ecological amplitude *Score:* **B** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: *Schismus* grasses were first documented in Arizona (floodplain of Gila River, near Sacaton in 1926 (Felger 1990). *Schismus arabicus* was present in Arizona by 1933 with the first collection made at the Desert Laboratory in Tucson 1968 (Burgess et al. 1991).
Rationale: By the 1970s *Schismus* species were found in all of the desert counties of Arizona in great abundance (Esque and Schwalbe 2002). *Schismus arabicus* and *S. barbatus* are presently listed among the most abundant of annual plant species in the Lower Colorado River Valley subdivision of the Sonoran Desert and into the Arizona Upland subdivision (Burgess et al. 1991 and Pake and Venable 1995 in Esque and Schwalbe 2002). *Schismus barbatus* reported in Mohave, Yavapi, Gila, Pinal, Maricopa, Yuma, Pima, and Santa Cruz counties (Gould 1951). Highly successful invaders in Sonoran and Mojave deserts (Burgess et al. 1991). Abiotic preferences: *Schismus* prefers sandy soils on desert sand flats (Kearney and Peebles 1960, Felger 1990). Occupy elevational range of 1000 to 4000 feet for *S. barbatus* and 1000 to 2500 for *S. arabicus* (Kearney and Peebles 1960). *Schismus arabicus*, but not *S. barbatus*, is found in dune habitat (Warren and Laurenzi 1987, Felger et al. 2003).
Sources of information: See cited literature. Also considered personal observations by Working Group members.

Question 3.2 Distribution *Score:* **A** *Doc'n Level:* **Obs.**
Describe distribution: See question 3.1 and Worksheet B.
Rationale: See question 3.1 and Worksheet B.
Sources of information: See cited literature in question 3.1. Primarily considered personal observations by Working Group members.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**[No]**	**1 pt.**
	Total pts: 8 Total unknowns: 0		
	Score : A		

Note any related traits: Exact number of years of seed viability not known. Direct studies were not found, but studies using seed 2+ years old were found (Gutterman [various]; see other references). Pake and Venable (1996) show that *Schismus* uses a seed banking strategy.

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	**B** (*S. arabicus* only)
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	**A**
	Chihuahuan desertscrub	**C**
	Sonoran desertscrub	**A**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	**C**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Avery, H.W. 2003. Challenges to a changing plant community: food selectivity and digestive performance of desert tortoises fed native vs. exotic forage plants. Poster session: Ecology, Conservation, and Husbandry. Available at http://nytts.org/proceedings/posters.htm; accessed September 2003.

Barboza, P. 1995. Nutrient balances and maintenance requirements for nitrogen ad energy in desert tortoises (*Xerobates agassizii*) consuming forages. Comparative Biochemistry and Physiology 112:537–545.

Beatley, J.C. 1966. Ecological status of introduced brome grasses (*Bromus* spp.) in desert vegetation of southern Nevada. Ecology 47:548–554.

Billings, W.D. 1990. *Bromus tectorum*, a biotic cause of ecosystem impoverishment in the Great Basin. In G.M. Woodell (ed.), The earth in Transition: Patterns and Processes of Biotic Impoverishment. Cambridge University Press, Cambridge.

Brooks, M. 1995. Benefits of protective fencing to plant and rodent communities of the Western Mojave Desert, California. Environmental Management 19:65–74.

Brooks, M.L. 1998. Ecology of a Biological Invasion: Alien Annual Plants in the Mojave Desert. Doctoral dissertation. University of California, Riverside.

Brooks, M.L. 1999. Alien annual grasses and fire in the Mojave Desert. Madroño 46:13–19.

Brooks, M.L. 2000. *Schismus arabicus* Nees; *Schismus barbatus* (L.) Thell. Pages 287–291 in C.C. Bossard, J.M. Randall, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Brooks, M.L., and D.A. Pyke. 2000. Invasive plants and fire in the deserts of North America. Pages 1–14 in K.E. Galley and T.P. Wilson (eds.), Proceedings of the Invasive Species Workshop: The Role of Fire in the Control and Spread of Invasive Species. Fire Conference 2000. The First National Congress on Fire Ecology, Prevention, and Management, Nov. 27-Dec. 1, 2000. Miscellaneous Publication No. 11. Tall Timbers Research Station, Tallahassee, Florida.

Brooks, M.L., and T.C. Esque, 2002. Alien plants and fire in desert tortoise (*Gopherus agassizii*) habitat of the Mojave and Colorado Deserts. Chelonian Conservation and Biology 4:330–340.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burgess, T.L., J.E. Bowers, and R.M. Turner. 1991. Exotic plants at the desert laboratory, Tucson, Arizona. Madroño 38:96–114.

Drezner, T.D., P.L. Fall, and J.C. Stromberg. 2001 Plant distribution and dispersal mechanisms at the Hassayampa River Preserve, Arizona, USA. Global Ecology and Biogeography 10:205–217.

Esque, T.C. 1999. Managing fire and invasive plants in the Mojave Desert: defining an integrated research program to address knowledge gaps. In Presentation Abstracts, Mojave Desert Science Symposium, February 25–27, 1999. U.S. Geological Survey, Western Ecological Research Center. Available online at: http://www.werc.usgs.gov/mojave-symposium/abstracts.html; accessed September 2003.

Esque, T.C., and C.R. Schwalbe. 2002. Alien annual grasses and their relationships to fire and biotic change in Sonoran desertscrub. Pages 165–194 in B. Tellman (ed.), Invasive Exotic Species in the Sonoran Region. The University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson, Arizona

Faruqi, S.A., and H.B. Quraish. 1979. Studies on Libyan grasses. V. Population variability and distribution of *Schismus arabicus* and *S. barbatus* in Libya. Pakistan Journal of Botany 11:167–172.

Felger, R.S. 1990. Non-Native Plants of Organ Pipe Cactus National Monument, Arizona. Technical Report No. 31. U.S. Geological Survey, Cooperative Park Studies Unit, The University of Arizona and National Park Service, Organ Pipe Cactus National Monument. 93 p.

Felger, R.S. 2000. Flora of the Gran Desierto and Rio Colorado of Northwestern Mexico. The University of Arizona Press, Tucson. 673 p.

Felger, R.S., D.S. Turner, and M.F. Wilson. 2003. Flora and vegetation of the Mohawk Dunes, Arizona. *Sida* 20:1155–1187.

Gould, F. 1949. Arizona plant records—II. Leaflets in Western Botany 5:167–170.

Gould, F.W. 1951. Grasses of the Southwestern United States. The University of Arizona Press, Tucson. 352 p.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13.

Gutterman, Y. 1996a. Temperatures during storage, light and wetting affecting caryopses germinability of *Schismus arabicus*, a common desert annual grass. Journal of Arid Environments 33:73–85.

Gutterman, Y. 2003. The inhibitory effect of Negev Desert loess soil on the fast germinating caryopses of *Schismus arabicus* (Poaceae). Journal of Arid Environments 54:619–631.

Humphrey, R.R. 1974. Fire in the deserts and desert grassland of North America. Pages 365–400 in T.T. Kozlowski and C.E. Ahlgren (eds.), Fire and Ecosystems. Academic Press, New York.

Inouye, R.S. 1980. Density-dependent germination response by seeds of desert annuals. Oecologia 6:235–238.

Kearney, T.H. 1931. Plants new to Arizona. Journal of the Washington Academy of Science 21:63–80.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Loria, M., and I. Noy-Meir. 1979–1980. Dynamics of Some Annual Populations in a Desert Loess Plain, Israel Journal of Botany 28:211–225.

Nagy, K., B. Henen, and D. Vyas. 1998. Nutritional quality of native and introduced food plants of wild desert tortoises. Journal of Herpetology 32:260–267.

Oftedal, O.T., S. Hillard, and D. Morafka. 2000. Juvenile Desert Tortoises Enhance Nutritional Status by Foraging Choice: Data from the 1998 El Nino at the Fort Irwin Study Site. 25th Annual Meeting and Symposium of the Desert Tortoise Council, April 21–24, 2000. Abstracts.

Oftedal, O.T. 2003. Are Desert Tortoises Nutritionally Constrained by a Shortage of High PEP Plants, and if so, what do we do? 28th Annual Meeting and Symposium of the Desert Tortoise Council, February 21–23, 2003, Abstracts.

Pake, C. E., and E. L. Venable. 1995. Is coexistence in Sonoran Desert annual plants mediated by temporal variation in reproductive success. Ecology 76:246–261.

Pake, C.E., and D.L Venable. 1996. Seed banks in desert annuals: implications for persistence and coexistence in variable environments. Ecology 77:1427–1435.

Szarek, S.R., S.D. Smith, and R.D. Ryan. 1982. Moisture stress effects on biomass partitioning in two Sonoran Desert annuals. American Midland Naturalist 108:338–345.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Warren, P.L., and A.W. Laurenzi. 1987 Rare Plant Survey of the Yuma District. Final report of P.O. No. AZ-950-PH6-0540, U.S. Bureau of Land Management, Yuma District Office.

Wilken, D., and L. Hannah. 1998. *Schismus arabicus* Nees (Poaceae) Mediterranean Grass; Santa Barbara Botanic Garden, for Channel Islands National Park. Available online at http://usgssrv/.usgs.nau.edu/swepic/factsheets/schismus_spp.pdf; accessed September 2003.

Other References of Interest Not Cited in the Text

Gutterman's citations are numerous and Guertin and Halvorson's (2003) review of Gutterman's work was referenced in some places in the text as a collection of Gutterman's work on *Schismus*. In addition to specifically cited papers, the following papers were reviewed by Guertin and Halvorson (2003):

Gutterman, Y. 1989. *Schismus arabicus*. In A.H. Halevy (ed.), CRC Handbook of Flowering. Vol. VI. CRC Press, Boca Raton, Florida. 753 p.

Gutterman, Y. 1993. Seed germination in desert plants. Springer-Verlag, Berlin. 253 p.

Gutterman, Y. 1994. Strategies for seed dispersal and germination in plants inhabiting deserts. The Botanical Review 60:373–425.

Gutterman, Y. 1996b. Effect of day length during plant development and caryopsis maturation on flowering and germination, in addition to temperature during dry storage and light during wetting, of *Schismus arabicus* (Poaceae) Journal of Arid Environments 33:439–448.

Gutterman, Y. 2000. Environmental factors and survival strategies of annual plant species in the Negev Desert, Israel. Plant Species Biology 15:113−125.

Gutterman, Y. 2001a. The drought tolerance of the dehydrated root of *Schismus arabicus* seedling and regrowth after rehydration, affected by caryopsis size, darkness and duration of dehydration. Israel Journal of Plant Sciences 49:123−128.

Gutterman, Y. 2001b. Phenotypic germination plasticity according to caryopsis size in *Schismus arabicus*, a common annual grass occurring in the Negev Desert of Israel. Seed Science Research 11:173−178.

Gutterman, Y., and G.P. Chapman. 1992. Ecophysiology of Negev upland annual grasses. Pages 145−162 in Desertified Grasslands: Their Biology and Management. Papers presented at an International Symposium, February 27 to March 1, 1991, London, England. Linnean Society Symposium Series No. 13. Academic Press, London, England.

Gutterman, Y., and M. Evanari. 1994. The influences of amounts and distribution of irrigation during the hot and dry season on emergence and survival of some desert winter annual plants in the Negev Desert of Israel. Israel Journal of Plant Science 42:1−14.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Sonchus asper* (L.) Hill; *Sonchus oleraceus* L. (USDA 2005).
Synonyms:	*Sonchus asper:* None listed in USDA (2005); *Sonchus oleraceus*: None listed in USDA (2005).
Common names:	*Sonchus asper:* Spiny sowthistle; prickly sowthistle; *Sonchus oleraceus*: Annual sowthistle, common sowthistle, sowthistle, pualele.
Evaluation date (mm/dd/yy)**:**	03/25/04; updated 02/05
Evaluator #1 Name/Title:	Dana Backer, Conservation Ecologist
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85719
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	03/26/04: D. Backer, K. Brown, P. Guertin, J. Hall, B. Munda, F. Northam, M. Quinn, J. Ward 03/01/05: D. Baker, D. Casper, J. Filar, E. Geiger, J. Hall, H. Messing, B. Munda, F. Northam
Committee review date:	03/26/04 and 03/01/05
List date:	03/26/04; revised 03/01/05 (addressed Consistency Review Panel comments)
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**D**	Observational	**"Impact"** **Section 1 Score:** **C**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**B**	Observational		
1.3	Impact on higher trophic levels	**D**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Observational	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **13 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**A**	Other published material		
2.5	Potential for human-caused dispersal	**C**	Observational		
2.6	Potential for natural long-distance dispersal	**B**	Other published material		
2.7	Other regions invaded	**C**	Observational		 Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Table 3. Documentation

Note: Most of the literature discussing sowthistles grouped the annuals *Sonchus asper* and *S. oleraceus* with the perennial *S. arvensis* (which includes the subspecies *S. arvensis arvensis* and *S. arvensis uliginosus* [USDA 2005]). *Sonchus arvensis* is listed as a noxious weed in many states, including Arizona. Impacts, growth responses, and invasiveness are not distinguished between the different species of *Sonchus*. Most of the descriptions simply refer to sowthistle and the assumption is that in general the authors are likely referring to *S. arvensis*.

Sonchus asper and *S. oleraceus* are evaluated together because they are similar in most respects with the exception of a few subtle morphology characteristics. They are often difficult to distinguish because of the high degree of within species variability. Both sowthistles have a milky sap that is secreted if the stem is broken. *Sonchus asper* is more abundant in Arizona than is *S. oleraceus* (Makarick 1999).

Question 1.1 Impact on abiotic ecosystem processes *Score:* **D** *Doc'n Level:* **Obs.**
Identify ecosystem processes impacted: Negligible.
Rationale: Based on the facts that 1) sowthistles have been present in North America since the late 1800s; 2) various research has been conducted on these species (see below and Hutchinson et al. 1984) with none mentioning abiotic impacts; and 3) no documentation exits suggesting there are any impacts on abiotic ecosystems, it is inferred that the impacts are negligible.
Sources of information: See cited literature. Score based on inference based on the literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **B** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Native plant displacement and competition for resources.
Rationale: Lori Makarick (personal communication, 2005) has observed that along the upper stretches of the Colorado River within the Grand Canyon National Park, "populations exist that exclude everything else. Tiny rosettes blanket an entire area." With monotype stand formations, there would be direct competition for resources. This information refers to *S. asper and S. oleraceus,* but *S. arvensis* has also been found along the Colorado River and side canyons. In Zollinger and Parker (1999) [Note: the following information is assumed to be for *Sonchus arvensis* because most papers published by Zollinger and collaborators in Zollinger and Parker (1999) are about this perennial species.]: most competitive under abundant precipitation, high soil moisture, and moderate climates; however it can tolerate low moisture levels. Abundant moisture allows established plants to expand rapidly, choking out natural and existing vegetation. "Sowthistle can dominate plant communities by allelopathic processes (Putman and Tang 1986, Zollinger and Kells 1993). Substances that inhibit other plant's seed germination and plant growth are produced by underground roots and the accumulation of toxins from decaying residue from the previous year's growth. As sowthistle infestations expand, allelochems destroy existing vegetation allowing sowthistle rapidly to capture soil space." Most of the impact is to agricultural crops (Holm et al. 1991).
Sources of information: See cited literature. Score based on observations by L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center Flagstaff, Arizona, 2005) along the Grand Canyon and its tributaries and inferences based on the literature.

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Potential interference with native pollinators yet considered negligible. Sowthistle provides forage.
Rationale: In Zollinger and Parker (1999): sowthistle is a minor element in the diet of some North American birds (Martin et al. 1951). Some achenes may germinate after ingestion and excretion by birds and animals, serving as minor dispersal agents (Stevens 1926, Salisbury 1964).
Sources of information: See cited literature. Score based on inference based on the literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: No known hybridization.
Rationale: No known native congeners (Kearney and Peebles 1960). Hybridization between *S. asper and S. oleraceus* is not known.
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Obs.**
Describe role of disturbance: Requires natural and/or anthropogenic disturbance to establish.
Rationale: Pioneering species invading natural habitats and disturbed sites (Zollinger and Parker 1999). *Sonchus asper* and *S. oleraceus* are pioneer species, invading human-disturbed sites, over-grazed sites, and naturally disturbed sites; without disturbance, they have a limited habitation on a site (Watt 1981 in Hutchinson et al. 1984). Original discussion and score (**C**) was based on the literature and Working Group member observations that sowthistle first needs to have a human disturbance (typically agriculture or garden) in the area before it can become established under natural disturbance. After further discussion with L. Makarick (personal communication, 2005), the score was changed to a **B** based on observations in the Grand Canyon National Park. Makarick has observed populations in side canyons where there is no human disturbance and only natural disturbance (flash flooding).
Sources of information: See cited literature. Also considered personal communication with by L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center Flagstaff, Arizona, 2005).

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**
Describe rate of spread: Increasing but not doubling in <10years.
Rationale: According to observations in Grand Canyon National Park (L. Makarick, personal communication, 2004), populations continue to spread, particularly up side canyons. In some areas, particularly areas with excess moisture, *Sonchus* spp. is increasing (L. Makarick, personal communication, 2005). In Zollinger and Parker (1999): two biocontrol insects have been released in Canada to control annual and perennial sowthistles. A limited number of pathogens are available that are specific to sowthistle in North America (Conners 1967). Only one nematode and one virus are known to affect sowthistle.
Sources of information: See cited literature. Also considered personal communications with by L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center Flagstaff, Arizona, 2004 and 2005).

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**
Describe trend: Increasing, but not doubling area infested in <10 years.

Rationale: Three sowthistle species, S. *asper*, S. *oleraceus*, and S. *arvensis,* are found within the inner canyon of the Grand Canyon National Park. Observations by L. Makarick during 2004 and 2005 (personal communication, 2004 and 2005) suggested that this species is moving into new territory, such as up drainages and to higher up the canyon because of increased stream flows and increased precipitation.

Sonchus spp. is widespread in North America and most likely within Arizona (except S. arvensis [USDA 2005]); all niches where sowthistles can invade seem to be invaded (Parker 1972, Zollinger and Parker 1999). *Sonchus asper* was documented in almost all Arizona counties by 1960 (Kearney and Peebles 1960) and all counties by 1972 (Parker 1972). *Sonchus oleraceaus* was listed in six counties by Kearney and Peebles (1960).

Sources of information: See cited literature. Also considered personal communications with by L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center Flagstaff, Arizona, 2004 and 2005).

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Other pub.**

Describe key reproductive characteristics: Reproduces annually and only by seed; self- and cross-pollination; >1000 seeds per plant.

Rationale: *Sonchus asper* and *S. oleraceus* germinate each spring, bolt, flower, set seed and complete their life cycle each summer (Boulos 1960 in Zollinger and Parker 1999). See Worksheet A.

Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **C** *Doc'n Level:* **Obs.**

Identify dispersal mechanisms: Low-human dispersal is infrequent or inefficient

Rationale: Positive human uses noted in Zollinger and Parker (1999) including eaten as a salad green and fed to animals (Holm et al. 1991). Used medicinally and as food (Zollinger and Parker 1999); evaluated as a potential crop for petrochemical production; contains glycosylglycerides (lipids used for industrial and pharmaceutical purposes (Zollinger and Parker 1999). Although these uses have been demonstrated, no documentation indicates intentional planting.

Sources of information: See cited literature. Also considered information from the Illinois Plant Information Network for *S. asper* and *S. ol*eraceus (D. Ketzner and J. Karnes [data compilers], Illinois Natural History Survey, Champaign, Illinois; available online at: http://www.fs.fed.us/ne/delaware/ilpin/2846.co [and 2847.co, respectively]; accessed March 2004). Score based on inference based on the literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **B** *Doc'n Level:* **Other pub.**

Identify dispersal mechanisms: Wind (primarily); animals; water.

Rationale: In Zollinger and Parker (1999): "pappus-born seeds allow for long-distance travel;… pappus may tangle in the feathers of birds or the wool and hair of animals, aiding in long-range dispersal" (see also Hutchinson et al. 1984). Some achenes may germinate after ingestion and excretion by birds and animals, serving as minor dispersal agents (Stevens 1926, Salisbury 1964). Seeds carried by wind or water (Holm et al. 1991); observed floating on water for three days (Ridley 1930 in Guertin and Halvorson 2003). It is also noted that *Sonchus* spp. seeds may be dispersed by animals after ingestion and passage through their digestive tracts (Salisbury 1964 in Hutchinson et al. 1984). Seed morphology is designed for traveling long distances.

Sources of information: See literature cited.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Obs.**

Identify other regions: Only those ecological types that are also invaded in Arizona.

Rationale: All sources consulted indicated that this plant has been here since the 19^{th} century (possibly earlier in other parts of North America) and both *S. asper* and *S. ol*eraceus exist in all U.S. contiguous states (USDA 2005). Origin is Europe (Stevens 1926 in Zollinger and Parker 1999, Hutchinson et al 1984, Holm et al. 1991) and North Africa (Hutchinson et al 1984, Holm et al. 1991) and tropical and temperate Asia (Hutchinson et al 1984). Introduced to North America in contaminated crops (Boulos 1961 in Zollinger and Parker 1999). Also occurs in Canada, Asia, Africa, Australia, New Zealand (numerous authors; see Zollinger and Parker 1999). Little information available on climatic limitations; “cosmopolitan” distribution indicates a broad tolerance of variation (Zollinger and Parker 1999).	
Sources of information: See cited literature. Score based on inference based on the literature.	

Question 3.1 Ecological amplitude	*Score:* **A** *Doc’n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: *Sonchus asper* and *S. ol*eraceus have broad ecological amplitudes. each occurs within a number of ecological types. Earliest record for *S. asper* is 1892 (Pima County, Tucson in association with riparian desertscrub) and for *S. oleraceus* the earliest record is 1882 (Pima County, Tucson) (SEINet 2004). *Sonchus oleraceus* was established in California by 1824 (Frenkel 1977 in Burgess et al. 1991). It was present in Tucson, Arizona by 1897 (Toumey 1897 in Burgess et al. 1991).	
Rationale: Both *S. asper* and *S. ol*eraceus are found throughout the West (several authors). *Sonchus asper* occurs at elevations that range from 150 to 8000 feet and flowers February through August. It is present in Apache, Cochise, Coconino, Santa Cruz, Pima, and Yuma Counties (Kearney and Peebles 1960). *Sonchus oleraceus* flowers March through September. It is present in Graham, Cochise, Coconino, Mohave, Pima, and Yuma Counties (Kearney and Peebles 1960). Also see Distribution (question 3.2). Both *S. asper* and *S. ol*eraceus are found primarily in cultivated fields, gardens, orchards, lawns, roadside and waste places (numerous authors).	
Sources of information: See cited literature; also see information in question 3.2. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed March 1, 2004; note all records have not yet been entered into the database).	

Question 3.2 Distribution	*Score:* **A** *Doc’n Level:* **Obs.**
Describe distribution: See below.	
Rationale: *Sonchus asper* occurs at elevations that range from 150 to 8000 feet and is present in Apache, Cochise, Coconino, Santa Cruz, Pima, and Yuma Counties (Kearney and Peebles 1960). At Organ Pipe Cactus National Monument, *S. asper* can be found in wet places near springs and ponds, along washes, in old fields, under trees, and less frequently on sandy flats (Felger 1990). *Sonchus oleraceus* is present in Graham, Cochise, Coconino, Mohave, Pima, Yuma counties (Kearney and Peebles 1960). At Organ Pipe Cactus National Monument, *Sonchus oleraceus* can be found with *S. asper* in wet places and riparian habitat near springs and ponds, and along washes; and only in exceptionally wet years is it observed away from wetland habitats (Felger 1990). Van Devender et al. (1997) identifies *S. oleraceus* as a riparian zone species. In the Grand Canyon National Park, *S. asper* is listed as occurring in disturbed areas, beaches and dry creek beds in the Inner Canyon from 1200 to 2850 feet. The park herbarium has three specimens: one from Clear Creek from the dry stream bed near Bright Angel Creek and one at Tapeats. The Bright Angel and Tapeats occurrences are in riparian or wetland type of areas. This species is not that abundant in the canyon, but it potentially occurs in all of the desertscrub communities in addition to riparian). *Sonchus oleraceus* occurs in disturbed areas in the Inner Canyon, but was also found in disturbed areas on the South Rim. It was listed at 104 Mile Canyon and on the South Rim near the El Tovar (Ponderosa	

Pine, which may be a recently recorded occurrence) (L. Makarick, personal communication, 2004). Parker (1972) states *S. asper* is widespread through out the state especially in the southern counties. Guertin and Halvorson (2003) and Kearney and Peebles (1960) do not document *S. oleraceus* as present in all Arizona counties.
Sources of information: See cited literature cited. Also considered personal communication with by L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center Flagstaff, Arizona, 2004). Score based on Working Group member observations.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**[No]**	**1 pt.**
	Total pts: 8	**Total unknowns: 0**	
	Score : A		

Note any related traits: In Zollinger and Parker (1999): annual sowthistles germinate each spring, bolt, flower, set seed and complete their life cycle each summer (Boulos 1960). Mowing annually once per season will control only annual sowthistles. Broken roots activates new shoot growth, repeated soil disturbance killed plants by causing a relative exhaustion of the vegetation system (various authors). In Parker (1972): reproduces only from seeds. Flowers nearly throughout the year in Arizona, though primarily November to May (*S. asper*) and from November to February (*S. oleraceus*). In Guertin and Halvorson (2003): Hutchinson and others (1984) note that both species are self-compatible, and seeds are produced through self-pollination as well as by insect pollinators (bees and flies). *Sonchus asper* was observed to average 198 achenes/capitulum with the mean number of capitula per plant being 105; the plants produced 23,000±2600 achenes/plant (Salisbury 1942). *Sonchus oleraceus* was observed to average 140 achenes/capitulum with the mean number of capitula per plant being 44; the plants produced 6100±750 achenes/plant (Salisbury 1942). Seeds remain viable in the soil for more than 5 years (Makarick 1999). *S. oleraceaus*- seeds remain viable for 8 years or more (Holm et al. 1991).

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	**U**
	Mohave desertscrub	**U**
	Chihuahuan desertscrub	
	Sonoran desertscrub	**U**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	**A**
	semi-desert grassland	**A**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	**B**
	southwestern interior wetlands	**B**
	montane wetlands	**U**
	playas	
Riparian	Sonoran riparian	**A**
	southwestern interior riparian	**A**
	montane riparian	**A**
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	**A**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	**D**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Boulos, L. 1960. Cytotaxonomic studies in the genus *Sonchus*.2. The genus *Sonchus*, a general systematic treatment. Bot. Notiser 113:400–420.

Boulos, L. 1961. Cytotaxonomic studies in the genus *Sonchus*.3. On cytotaxonomy and distribution of *Sonchus arvensis* L. Bot. Notiser 114:57–64.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burgess, T.L., J.E. Bowers, and R.M. Turner. 1991. Exotic plants at the desert laboratory, Tucson, Arizona. Madroño 38:96–114.

Conners, I.L. 1967. An annotated list of diseases in Canada, and fungi recorded on plants in Alaska, Canada, and Greenland. Publ. 1251. Canada Department of Agriculture, Research Branch. 381 p.

Felger, R.S. 1990. Non-Native Plants of Organ Pipe Cactus National Monument, Arizona. Technical Report No. 31. U.S. Geological Survey, Cooperative Park Studies Unit, The University of Arizona and National Park Service, Organ Pipe Cactus National Monument. 93 p.

Frenkel, R.E. 1977. Ruderal Vegetation Along Some California Roadsides. University of California Press, Berkeley.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Holm, L.G., D.L. Plucknett, J.V. Pancho, J.P. Herberger. 1991. The World's Worst Weeds. Reprint of 1977 edition. Krieger Publishing Company, Malabar, Florida. 609p.

Hutchinson, I., J. Colosi, and R.A. Lewin. 1984. The biology of Canadian weeds. 63. *Sonchus asper* (L.) Hill and *S. oleraceus* L. Canadian Journal of Plant Science 64:731–744.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Makarick, L.J. 1999 Draft Exotic Plant for Grand Canyon National Park. National Park Service, Grand Canyon National Park, Arizona.

Martin, A.C., H.A. Zim, and A.L. Nelson. 1951. American Wildlife and Plants. A Guide to Wildlife Food Habits. Dover, New York. 500 p.

Parker, K.F. 1972. An Illustrated Guide to Arizona Weeds. The University of Arizona Press, Tucson. 338 p. Available online at: http://www.uapress.arizona.edu/online.bks/weeds/; accessed March 2004.

Putnam, A.R., and C.S. Tang 1986. Allelopathy: State of the Science. John Wiley and Sons, Inc., New York.

Ridley, H.N. 1930. The dispersal of plants throughout the world. L. Reeve and Co., Ltd., Ashford, Kent. 744 p.

Salisbury, E.J. 1942. The reproductive capacity of plants. G. Bell, London. 244 p.

Salisbury, E.J. 1964. Weeds and Aliens. Collins, London.

Stevens, O.A. 1926. The sowthistles. Circular 32. North Dakota Agriculture Experiment Station. 16 p.

Toumey, J.J. 1897. Something about Weeds. Bulletin No. 22. University of Arizona Agriculture Experiment Station.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Van Devender, T.R., R.S. Felger, and A. Burquez M. 1997. Exotic plants in the Sonoran Desert region, Arizona and Sonora. 1997 Symposium Proceedings, California Exotic Pest Plant Council. Available online at: http://www.caleppc.org/symposia/97symposium/VanDevender.PDF.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Watt, A.S. 1981. A comparison of grazed and ungrazed Grassland A in East Anglican Breckland. Journal of Ecology 69:499–508.

Zollinger, R.K., and J.J. Kells. 1993. Perennial sowthistle (*Sonchus arvensis* L.) interference in soybean (*Glycine max*) and dry edible bean (*Phaseolus vulgaris*). Weed Technol. 7:52–57.

Zollinger, R.K. and R. Parker. 1999. Sowthistles. Pages 336–349 in R.L Sheley and J.K. Petroff (eds.), Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis, Oregon.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Sonchus asper* (L.) Hill; *Sonchus oleraceus* L. (USDA 2005).
Synonyms:	*Sonchus asper:* None listed in USDA (2005); *Sonchus oleraceus*: None listed in USDA (2005).
Common names:	*Sonchus asper:* Spiny sowthistle; prickly sowthistle; *Sonchus oleraceus*: Annual sowthistle, common sowthistle, sowthistle, pualele.
Evaluation date (mm/dd/yy)**:**	03/25/04; updated 02/05
Evaluator #1 Name/Title:	Dana Backer, Conservation Ecologist
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85719
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	03/26/04: D. Backer, K. Brown, P. Guertin, J. Hall, B. Munda, F. Northam, M. Quinn, J. Ward 03/01/05: D. Baker, D. Casper, J. Filar, E. Geiger, J. Hall, H. Messing, B. Munda, F. Northam
Committee review date:	03/26/04 and 03/01/05
List date:	03/26/04; revised 03/01/05 (addressed Consistency Review Panel comments)
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**D**	Observational	**"Impact"** **Section 1 Score:** **C**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**B**	Observational		
1.3	Impact on higher trophic levels	**D**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Observational	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **13 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**A**	Other published material		
2.5	Potential for human-caused dispersal	**C**	Observational		
2.6	Potential for natural long-distance dispersal	**B**	Other published material		
2.7	Other regions invaded	**C**	Observational		 Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Table 3. Documentation

Note: Most of the literature discussing sowthistles grouped the annuals *Sonchus asper* and *S. oleraceus* with the perennial *S. arvensis* (which includes the subspecies *S. arvensis arvensis* and *S. arvensis uliginosus* [USDA 2005]). *Sonchus arvensis* is listed as a noxious weed in many states, including Arizona. Impacts, growth responses, and invasiveness are not distinguished between the different species of *Sonchus*. Most of the descriptions simply refer to sowthistle and the assumption is that in general the authors are likely referring to *S. arvensis*.

Sonchus asper and *S. oleraceus* are evaluated together because they are similar in most respects with the exception of a few subtle morphology characteristics. They are often difficult to distinguish because of the high degree of within species variability. Both sowthistles have a milky sap that is secreted if the stem is broken. *Sonchus asper* is more abundant in Arizona than is *S. oleraceus* (Makarick 1999).

Question 1.1 Impact on abiotic ecosystem processes *Score:* **D** *Doc'n Level:* **Obs.**
Identify ecosystem processes impacted: Negligible.
Rationale: Based on the facts that 1) sowthistles have been present in North America since the late 1800s; 2) various research has been conducted on these species (see below and Hutchinson et al. 1984) with none mentioning abiotic impacts; and 3) no documentation exits suggesting there are any impacts on abiotic ecosystems, it is inferred that the impacts are negligible.
Sources of information: See cited literature. Score based on inference based on the literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **B** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Native plant displacement and competition for resources.
Rationale: Lori Makarick (personal communication, 2005) has observed that along the upper stretches of the Colorado River within the Grand Canyon National Park, "populations exist that exclude everything else. Tiny rosettes blanket an entire area." With monotype stand formations, there would be direct competition for resources. This information refers to *S. asper and S. oleraceus,* but *S. arvensis* has also been found along the Colorado River and side canyons. In Zollinger and Parker (1999) [Note: the following information is assumed to be for *Sonchus arvensis* because most papers published by Zollinger and collaborators in Zollinger and Parker (1999) are about this perennial species.]: most competitive under abundant precipitation, high soil moisture, and moderate climates; however it can tolerate low moisture levels. Abundant moisture allows established plants to expand rapidly, choking out natural and existing vegetation. "Sowthistle can dominate plant communities by allelopathic processes (Putman and Tang 1986, Zollinger and Kells 1993). Substances that inhibit other plant's seed germination and plant growth are produced by underground roots and the accumulation of toxins from decaying residue from the previous year's growth. As sowthistle infestations expand, allelochems destroy existing vegetation allowing sowthistle rapidly to capture soil space." Most of the impact is to agricultural crops (Holm et al. 1991).
Sources of information: See cited literature. Score based on observations by L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center Flagstaff, Arizona, 2005) along the Grand Canyon and its tributaries and inferences based on the literature.

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Potential interference with native pollinators yet considered negligible. Sowthistle provides forage.
Rationale: In Zollinger and Parker (1999): sowthistle is a minor element in the diet of some North American birds (Martin et al. 1951). Some achenes may germinate after ingestion and excretion by birds and animals, serving as minor dispersal agents (Stevens 1926, Salisbury 1964).
Sources of information: See cited literature. Score based on inference based on the literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: No known hybridization.
Rationale: No known native congeners (Kearney and Peebles 1960). Hybridization between *S. asper and S. oleraceus* is not known.
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Obs.**
Describe role of disturbance: Requires natural and/or anthropogenic disturbance to establish.
Rationale: Pioneering species invading natural habitats and disturbed sites (Zollinger and Parker 1999). *Sonchus asper* and *S. oleraceus* are pioneer species, invading human-disturbed sites, over-grazed sites, and naturally disturbed sites; without disturbance, they have a limited habitation on a site (Watt 1981 in Hutchinson et al. 1984). Original discussion and score (**C**) was based on the literature and Working Group member observations that sowthistle first needs to have a human disturbance (typically agriculture or garden) in the area before it can become established under natural disturbance. After further discussion with L. Makarick (personal communication, 2005), the score was changed to a **B** based on observations in the Grand Canyon National Park. Makarick has observed populations in side canyons where there is no human disturbance and only natural disturbance (flash flooding).
Sources of information: See cited literature. Also considered personal communication with by L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center Flagstaff, Arizona, 2005).

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**
Describe rate of spread: Increasing but not doubling in <10years.
Rationale: According to observations in Grand Canyon National Park (L. Makarick, personal communication, 2004), populations continue to spread, particularly up side canyons. In some areas, particularly areas with excess moisture, *Sonchus* spp. is increasing (L. Makarick, personal communication, 2005). In Zollinger and Parker (1999): two biocontrol insects have been released in Canada to control annual and perennial sowthistles. A limited number of pathogens are available that are specific to sowthistle in North America (Conners 1967). Only one nematode and one virus are known to affect sowthistle.
Sources of information: See cited literature. Also considered personal communications with by L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center Flagstaff, Arizona, 2004 and 2005).

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**
Describe trend: Increasing, but not doubling area infested in <10 years.

Rationale: Three sowthistle species, S. *asper*, S. *oleraceus*, and S. *arvensis,* are found within the inner canyon of the Grand Canyon National Park. Observations by L. Makarick during 2004 and 2005 (personal communication, 2004 and 2005) suggested that this species is moving into new territory, such as up drainages and to higher up the canyon because of increased stream flows and increased precipitation. *Sonchus* spp. is widespread in North America and most likely within Arizona (except S. arvensis [USDA 2005]); all niches where sowthistles can invade seem to be invaded (Parker 1972, Zollinger and Parker 1999). *Sonchus asper* was documented in almost all Arizona counties by 1960 (Kearney and Peebles 1960) and all counties by 1972 (Parker 1972). *Sonchus oleraceaus* was listed in six counties by Kearney and Peebles (1960).	
Sources of information: See cited literature. Also considered personal communications with by L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center Flagstaff, Arizona, 2004 and 2005).	

Question 2.4 Innate reproductive potential	*Score:* **A** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: Reproduces annually and only by seed; self- and cross-pollination; >1000 seeds per plant.	
Rationale: *Sonchus asper* and *S. oleraceus* germinate each spring, bolt, flower, set seed and complete their life cycle each summer (Boulos 1960 in Zollinger and Parker 1999). See Worksheet A.	
Sources of information: See cited literature.	

Question 2.5 Potential for human-caused dispersal	*Score:* **C** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Low-human dispersal is infrequent or inefficient	
Rationale: Positive human uses noted in Zollinger and Parker (1999) including eaten as a salad green and fed to animals (Holm et al. 1991). Used medicinally and as food (Zollinger and Parker 1999); evaluated as a potential crop for petrochemical production; contains glycosylglycerides (lipids used for industrial and pharmaceutical purposes (Zollinger and Parker 1999). Although these uses have been demonstrated, no documentation indicates intentional planting.	
Sources of information: See cited literature. Also considered information from the Illinois Plant Information Network for *S. asper* and *S. ol*eraceus (D. Ketzner and J. Karnes [data compilers], Illinois Natural History Survey, Champaign, Illinois; available online at: http://www.fs.fed.us/ne/delaware/ilpin/2846.co [and 2847.co, respectively]; accessed March 2004). Score based on inference based on the literature.	

Question 2.6 Potential for natural long-distance dispersal	*Score:* **B** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Wind (primarily); animals; water.	
Rationale: In Zollinger and Parker (1999): "pappus-born seeds allow for long-distance travel;… pappus may tangle in the feathers of birds or the wool and hair of animals, aiding in long-range dispersal" (see also Hutchinson et al. 1984). Some achenes may germinate after ingestion and excretion by birds and animals, serving as minor dispersal agents (Stevens 1926, Salisbury 1964). Seeds carried by wind or water (Holm et al. 1991); observed floating on water for three days (Ridley 1930 in Guertin and Halvorson 2003). It is also noted that *Sonchus* spp. seeds may be dispersed by animals after ingestion and passage through their digestive tracts (Salisbury 1964 in Hutchinson et al. 1984). Seed morphology is designed for traveling long distances.	
Sources of information: See literature cited.	

Question 2.7 Other regions invaded	*Score:* **C** *Doc'n Level:* **Obs.**
Identify other regions: Only those ecological types that are also invaded in Arizona.	

Rationale: All sources consulted indicated that this plant has been here since the 19th century (possibly earlier in other parts of North America) and both *S. asper* and *S. ol*eraceus exist in all U.S. contiguous states (USDA 2005). Origin is Europe (Stevens 1926 in Zollinger and Parker 1999, Hutchinson et al 1984, Holm et al. 1991) and North Africa (Hutchinson et al 1984, Holm et al. 1991) and tropical and temperate Asia (Hutchinson et al 1984). Introduced to North America in contaminated crops (Boulos 1961 in Zollinger and Parker 1999). Also occurs in Canada, Asia, Africa, Australia, New Zealand (numerous authors; see Zollinger and Parker 1999). Little information available on climatic limitations; "cosmopolitan" distribution indicates a broad tolerance of variation (Zollinger and Parker 1999).	
Sources of information: See cited literature. Score based on inference based on the literature.	

Question 3.1 Ecological amplitude	*Score:* **A** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: *Sonchus asper* and *S. ol*eraceus have broad ecological amplitudes. each occurs within a number of ecological types. Earliest record for *S. asper* is 1892 (Pima County, Tucson in association with riparian desertscrub) and for *S. oleraceus* the earliest record is 1882 (Pima County, Tucson) (SEINet 2004). *Sonchus oleraceus* was established in California by 1824 (Frenkel 1977 in Burgess et al. 1991). It was present in Tucson, Arizona by 1897 (Toumey 1897 in Burgess et al. 1991).	
Rationale: Both *S. asper* and *S. ol*eraceus are found throughout the West (several authors). *Sonchus asper* occurs at elevations that range from 150 to 8000 feet and flowers February through August. It is present in Apache, Cochise, Coconino, Santa Cruz, Pima, and Yuma Counties (Kearney and Peebles 1960). *Sonchus oleraceus* flowers March through September. It is present in Graham, Cochise, Coconino, Mohave, Pima, and Yuma Counties (Kearney and Peebles 1960). Also see Distribution (question 3.2). Both *S. asper* and *S. ol*eraceus are found primarily in cultivated fields, gardens, orchards, lawns, roadside and waste places (numerous authors).	
Sources of information: See cited literature; also see information in question 3.2. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed March 1, 2004; note all records have not yet been entered into the database).	

Question 3.2 Distribution	*Score:* **A** *Doc'n Level:* **Obs.**
Describe distribution: See below.	
Rationale: *Sonchus asper* occurs at elevations that range from 150 to 8000 feet and is present in Apache, Cochise, Coconino, Santa Cruz, Pima, and Yuma Counties (Kearney and Peebles 1960). At Organ Pipe Cactus National Monument, *S. asper* can be found in wet places near springs and ponds, along washes, in old fields, under trees, and less frequently on sandy flats (Felger 1990). *Sonchus oleraceus* is present in Graham, Cochise, Coconino, Mohave, Pima, Yuma counties (Kearney and Peebles 1960). At Organ Pipe Cactus National Monument, *Sonchus oleraceus* can be found with *S. asper* in wet places and riparian habitat near springs and ponds, and along washes; and only in exceptionally wet years is it observed away from wetland habitats (Felger 1990). Van Devender et al. (1997) identifies *S. oleraceus* as a riparian zone species. In the Grand Canyon National Park, *S. asper* is listed as occurring in disturbed areas, beaches and dry creek beds in the Inner Canyon from 1200 to 2850 feet. The park herbarium has three specimens: one from Clear Creek from the dry stream bed near Bright Angel Creek and one at Tapeats. The Bright Angel and Tapeats occurrences are in riparian or wetland type of areas. This species is not that abundant in the canyon, but it potentially occurs in all of the desertscrub communities in addition to riparian). *Sonchus oleraceus* occurs in disturbed areas in the Inner Canyon, but was also found in disturbed areas on the South Rim. It was listed at 104 Mile Canyon and on the South Rim near the El Tovar (Ponderosa	

Pine, which may be a recently recorded occurrence) (L. Makarick, personal communication, 2004). Parker (1972) states *S. asper* is widespread through out the state especially in the southern counties. Guertin and Halvorson (2003) and Kearney and Peebles (1960) do not document *S. oleraceus* as present in all Arizona counties.
Sources of information: See cited literature cited. Also considered personal communication with by L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center Flagstaff, Arizona, 2004). Score based on Working Group member observations.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**[No]**	**1 pt.**
	Total pts: 8	**Total unknowns: 0**	
	Score : A		

Note any related traits: In Zollinger and Parker (1999): annual sowthistles germinate each spring, bolt, flower, set seed and complete their life cycle each summer (Boulos 1960). Mowing annually once per season will control only annual sowthistles. Broken roots activates new shoot growth, repeated soil disturbance killed plants by causing a relative exhaustion of the vegetation system (various authors). In Parker (1972): reproduces only from seeds. Flowers nearly throughout the year in Arizona, though primarily November to May (*S. asper*) and from November to February (*S. oleraceus*). In Guertin and Halvorson (2003): Hutchinson and others (1984) note that both species are self-compatible, and seeds are produced through self-pollination as well as by insect pollinators (bees and flies). *Sonchus asper* was observed to average 198 achenes/capitulum with the mean number of capitula per plant being 105; the plants produced 23,000±2600 achenes/plant (Salisbury 1942). *Sonchus oleraceus* was observed to average 140 achenes/capitulum with the mean number of capitula per plant being 44; the plants produced 6100±750 achenes/plant (Salisbury 1942). Seeds remain viable in the soil for more than 5 years (Makarick 1999). *S. oleraceaus*- seeds remain viable for 8 years or more (Holm et al. 1991).

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	**U**
	Mohave desertscrub	**U**
	Chihuahuan desertscrub	
	Sonoran desertscrub	**U**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	**A**
	semi-desert grassland	**A**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	**B**
	southwestern interior wetlands	**B**
	montane wetlands	**U**
	playas	
Riparian	Sonoran riparian	**A**
	southwestern interior riparian	**A**
	montane riparian	**A**
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	**A**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	**D**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Boulos, L. 1960. Cytotaxonomic studies in the genus *Sonchus*.2. The genus *Sonchus*, a general systematic treatment. Bot. Notiser 113:400–420.

Boulos, L. 1961. Cytotaxonomic studies in the genus *Sonchus*.3. On cytotaxonomy and distribution of *Sonchus arvensis* L. Bot. Notiser 114:57–64.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burgess, T.L., J.E. Bowers, and R.M. Turner. 1991. Exotic plants at the desert laboratory, Tucson, Arizona. Madroño 38:96–114.

Conners, I.L. 1967. An annotated list of diseases in Canada, and fungi recorded on plants in Alaska, Canada, and Greenland. Publ. 1251. Canada Department of Agriculture, Research Branch. 381 p.

Felger, R.S. 1990. Non-Native Plants of Organ Pipe Cactus National Monument, Arizona. Technical Report No. 31. U.S. Geological Survey, Cooperative Park Studies Unit, The University of Arizona and National Park Service, Organ Pipe Cactus National Monument. 93 p.

Frenkel, R.E. 1977. Ruderal Vegetation Along Some California Roadsides. University of California Press, Berkeley.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Holm, L.G., D.L. Plucknett, J.V. Pancho, J.P. Herberger. 1991. The World's Worst Weeds. Reprint of 1977 edition. Krieger Publishing Company, Malabar, Florida. 609p.

Hutchinson, I., J. Colosi, and R.A. Lewin. 1984. The biology of Canadian weeds. 63. *Sonchus asper* (L.) Hill and *S. oleraceus* L. Canadian Journal of Plant Science 64:731–744.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Makarick, L.J. 1999 Draft Exotic Plant for Grand Canyon National Park. National Park Service, Grand Canyon National Park, Arizona.

Martin, A.C., H.A. Zim, and A.L. Nelson. 1951. American Wildlife and Plants. A Guide to Wildlife Food Habits. Dover, New York. 500 p.

Parker, K.F. 1972. An Illustrated Guide to Arizona Weeds. The University of Arizona Press, Tucson. 338 p. Available online at: http://www.uapress.arizona.edu/online.bks/weeds/; accessed March 2004.

Putnam, A.R., and C.S. Tang 1986. Allelopathy: State of the Science. John Wiley and Sons, Inc., New York.

Ridley, H.N. 1930. The dispersal of plants throughout the world. L. Reeve and Co., Ltd., Ashford, Kent. 744 p.

Salisbury, E.J. 1942. The reproductive capacity of plants. G. Bell, London. 244 p.

Salisbury, E.J. 1964. Weeds and Aliens. Collins, London.

Stevens, O.A. 1926. The sowthistles. Circular 32. North Dakota Agriculture Experiment Station. 16 p.

Toumey, J.J. 1897. Something about Weeds. Bulletin No. 22. University of Arizona Agriculture Experiment Station.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Van Devender, T.R., R.S. Felger, and A. Burquez M. 1997. Exotic plants in the Sonoran Desert region, Arizona and Sonora. 1997 Symposium Proceedings, California Exotic Pest Plant Council. Available online at: http://www.caleppc.org/symposia/97symposium/VanDevender.PDF.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Watt, A.S. 1981. A comparison of grazed and ungrazed Grassland A in East Anglican Breckland. Journal of Ecology 69:499–508.

Zollinger, R.K., and J.J. Kells. 1993. Perennial sowthistle (*Sonchus arvensis* L.) interference in soybean (*Glycine max*) and dry edible bean (*Phaseolus vulgaris*). Weed Technol. 7:52–57.

Zollinger, R.K. and R. Parker. 1999. Sowthistles. Pages 336–349 in R.L Sheley and J.K. Petroff (eds.), Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis, Oregon.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Sorghum halepense* (L.) Pers. (USDA 2005)
Synonyms:	*Holcus halepensis* L., *Sorghum miliaceum* (Roxb.) Snowden (USDA 2005)
Common names:	Johnsongrass
Evaluation date (mm/dd/yy)**:**	03/31/03
Evaluator #1 Name/Title:	Peter Warren
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	pwarren@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85719
Evaluator #2 Name/Title:	Dana Backer
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	dbacker@tnc.org
Address:	same as above

List committee members:	D. Backer, J. Brock, D. Casper, P. Guertin, J. Hall, R. Parades, S. Rutman, J. Ward
Committee review date:	05/20/03
List date:	05/20/03
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Observational	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**A**	Other published material		
1.3	Impact on higher trophic levels	**B**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **15 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**B**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Other published material		
2.6	Potential for natural long-distance dispersal	**B**	Other published material		
2.7	Other regions invaded	**C**	Observational		 Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**B**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Obs.**
Identify ecosystem processes impacted: Hydrologic regime altered (surface flow); altered light availability; surface and subsurface temperature changes. "Large plants which dry out during summer heat may become an extreme fire hazard" (Newman 1993).
Rationale: Potential surface flow alteration due to basal structure of *S. halepense* compared to sacaton (*Sporobolus* sp.); growth form and root structure of *S. halepense* are different than native vegetation therefore the amount of light and space between plants is reduced; *S. halepense* can form monotypic stands.
Sources of information: Impacted abiotic processes are based on Working Group member observations and discussions, as well as inference based on the literature identified in question 1.2 below.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **A** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Ability to form monotypic stands; crowd out other plants slowing natural succession along forest edges; shades out other plants; decreases nutrient and moisture availability to others plants; produces allelopathic chemicals inhibiting seed germination and seedling development (greenhouse, unknown in the field); intraspecific competition.
Rationale: Competitive edge due to massive size-photosynthetic surface area; rhizomes grow more rapidly, are more extensive, and deeper than rhizomes of native plants; allelopathic chemical production; forming dense spreading patches.
Sources of information: From Newman (1993): Findlay (1975) and Friedman and Horowitz (1970), Holm et al. (1977), Warwick and Black (1983); see also VDCR (1999) and CDFA (2002).

Question 1.3 Impact on higher trophic levels *Score:* **B** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Probably replaces or decreases native forage; toxic stems and leaves under certain conditions. Potential interference with animal movement and interference with predator-prey relations.
Rationale: Only relevant if native ungulates forage on the native grass that Johnson grass is displacing (most likely sacaton) and if native wildlife forage on Johnsongrass when it is toxic. Known to be toxic to cattle and horses. Toxic when premature drought or frost due to prussic acid accumulation (Ruyle and Young 1997). Speculation for native forage displacement-livestock usually contained and have limited alternate forage versus native herbivores have more freedom of movement. Because Johnsongrass can form dense monotypic stands potentially altering habitat for fauna dependent on open space, complex community structure, and plant diversity.
Sources of information: See cited literature. Score based on inference of impacts to trophic levels based on Working Group discussion and literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: None.
Rationale: No known native members of the genus *Sorghum* in Arizona. Can cross with other grain sorghums.
Sources of information: Kearney and Peebles (1960).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n Level:* **Other pub.**

Describe role of disturbance: Soil disturbance by humans, vehicles, livestock, etc.; seasonal flooding.

Rationale: Disturbed areas with sufficient moisture; recreational vehicles in riparian areas. Johnson grass is often abundant along irrigation canals, edges of irrigated fields, roadsides, pastures, orchards, and cultivated fields (Parker 1972, Ruyle and Young 1997).

From Newman (1993): Although no formal studies have been conducted, personal observations have indicated that Johnsongrass does not usually invade non-disturbed sites (Gould 1951, D. Diamond and J. Weigel, personal communications in Newman 1993). Many of the introduced species, including Johnsongrass, invade disturbed areas much more readily than they do natural areas (J. Cox, personal communication in Newman 1993). Once the area is disturbed continuation of the disturbance will intensify the problem.

Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**

Describe rate of spread: Seems to require disturbance and moisture to become established; abandoned agriculture fields.

Rationale: "Can increase by 1.3 m^2 per month resulting in patches 17 m^2 in 2.5 years from single Johnsongrass sprigs" (Horowitz 1973 in Newman 1993).

Sources of information: See cited literature. Score based on observations at Patagonia-Sonoita Creek Preserve and other areas throughout Arizona by P. Warren (The Nature Conservancy, Tucson, Arizona, 1995 to 2002).

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Obs.**

Describe trend: Increasing, but not doubling in <10 years.

Rationale: From Newman (1993): ability to survive in a wide range of environmental conditions (Holm et al. 1977, Monagham 1979, Warwick and Black 1983).

Sources of information: See cited literature. Score based on observations by P. Warren (The Nature Conservancy, Tucson, Arizona, 1995 to 2002) and Working Group consensus.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Describe key reproductive characteristics: Prolific seed production, extensive rhizomes, sprouting from fragmented rhizomes and ability to grow in range of environments.

Rationale: See Worksheet A.

Sources of information: Horowitz (1972), Monagham (1979), Warwick and Black (1983).

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Other pub.**

Identify dispersal mechanisms: Vehicles especially off-road vehicles; transportation equipment; contaminated machinery; livestock; contaminated hay movement; some areas cultivated for forage.

Rationale: Seeds pass unharmed through cattle. Johnsongrass is often abundant along irrigation canals, edges of irrigated fields, roadsides, pastures, orchards, and cultivated fields (Parker 1972, Ruyle and Young 1997): suggests human's are often involved in disperal.

Sources of information: See cited literature; also see literature in Newman (1993): Holm et al. (1977) and Warwick and Black (1983).

Question 2.6 Potential for natural long-distance dispersal *Score:* **B** *Doc'n Level:* **Other pub.**

Identify dispersal mechanisms: Wind (seed), water (seed and fragmented rhizomes) and animals (seed).

Rationale: Seeds pass unharmed through birds

Sources of information: From Newman (1993): Holm et al. (1977) and Warwick and Black 1983.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Obs.**

Identify other regions: From Guertin and Halvorson (2003): cold tolerant ecotypes have been found in northern U.S. and southern Canada (Warwick and Black 1983). Can invade native grasslands subjected to unnatural frequent flooding (Harrington and Capel 1978 in Synder 1992). In Ontario, found on arable land, edges of cultivated fields, in orchards, open waste ground, roadsides, pastures, irrigated canals and edges of irrigated fields (Findlay 1975, Holm et al. 1977).

Rationale: Prior to 1977, *S. halepense* died during cold winters in Canada. In 1977 the first vegetative structure survived the winter from a newly evolved cold tolerant ecotype (Alex et al. 1979).

Sources of information: See cited literature. Score based on inference based on literature and Working Group member observations.

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Obs.**

Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: From Guertin and Halvorson (2003): in the Sonoran Desert, *Sorghum halepense* is a riparian zone weed (Van Devender et al. 1997); in urban areas, it prefers catchments and moist sites (Martin 2002). *Sorghum halepense* occurs up to 6000 feet (1829 m) in Arizona (Kearney and Peebles 1960, Parker 1972), on sites where moisture is favorable to growth.

In 1969 *S. halepense* was listed as one of the top ten weeds of field crops. Introduced into U.S. as forage/pasture grass in early 1800s. By 1890 in the Salt River Valley, it was reportedly a pest on local farms (Tellman 2002). Earliest collection record from SEINet (2004) is 1903. Records from Arizona herbaria in SEINet as of July 2004 indicate Johnsongrass collections from Sonoran Desert National Monument, Tucson Mountain Park (1.2 miles from Gates Pass Road crest), and Arivaca Cienega.

Rationale: Ecological associations are identified in Guertin and Halvorson (2003): the seeds require approximately 18°F (10°C) higher temperatures to germinate than rhizomes require for sprouting (Horowitz 1972 in Newman 1993). Optimum plant growth occurs with light intensities 30 to 40% of full daylight with photoperiods of 16 hours; growth inhibition occurs at 20% or less of full daylight (CDFA 2002). *Sorghum halepense* grows in a pH range of 5 to 7.5 (Looker 1981 in Warwick and Black 1983).

Sorghum halepense grows best on in warm temperate to sub-tropical regions, having some warm season moisture available (CDFA 2002). *Sorghum halepense* is best adapted to porous, fertile lowlands preferring these rich soils, and least adapted to poorly drained clay soils, yet will grow on a wide array of soil types (CDFA 2002).

In central Arizona, when establishment trials were run for 21 to 28 years in various climate types in pinyon-juniper subtypes on sites protected from grazing, *Sorghum halepense* did not survive 10 years and failed on a cold-moist site (Peterson Flat) and a cold-dry site (Dog knobs), performing poorly to fairly. It also failed, but had excellent growth on a warm-moist site (Pleasant Valley) and on a warm-dry site (Drake). It survived 10 years having good growth, and spread vegetatively, on one warm-moist site (Pine Creek) (Lavin and Johnsen 1977).

Sources of information: See cited literature; also see Guertin and Halvorson (2003). Also considered observations by P. Warren (The Nature Conservancy, Tucson, Arizona, 1990s to 2002), observations by P. Guertin (Research Specialist, U.S. Geological Survey, Sonoran Desert Research Station, Tucson,

Arizona, observations made on the Coronado National Monument bajada-semidesert grasslands during the duration of weed distribution mapping for the U.S. Geological Survey's Weeds in the West project occurring in the southern Arizona National Park Service management areas. May 1999 to June 2001), and information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed July 2004). See collection records from http://seinet.asu.edu/ as of July 2004.

Question 3.2 Distribution *Score:* **B** *Doc'n Level:* **Obs.**
Describe distribution: Found throughout the state up to 6000 feet. Widespread throughout U.S. and Canada mostly associated with agriculture fields.
Rationale: Occurrence information based on Working Group observations and consensus. See Worksheet B.
Sources of information: Working Group observations. Also see the following: Gould (1951), Kearney and Peebles (1960), McDougall (1973), Parker (1972), and Ruyle and Young (1997).

Research Needs (identified in Newman 1993)

Management Research Programs:

No specific research on Johnsongrass control in natural plant communities is being conducted. However ongoing research on the eradication of Johnsongrass with the use of newly synthesized herbicides in the agricultural milieu takes place in most of the southern land-grant universities (K. Hamilton, personal communication in Newman 1993).

Management Research Needs:

An extensive amount of information on *Sorghum halepense* is available. The phenology, life-cycle, history, genetics, environmental requirements, beneficial and deleterious characteristics and control techniques of Johnsongrass are all well documented. However, most of the information on controlling this weed deals with problems in agricultural fields. The techniques for agricultural control are most often not financially or practically feasible in a natural setting. Range management information on Johnson grass does not address control of this forage crop.

Information on controlling *Sorghum halepense* in a natural setting is needed. Two aspects of control appear to be essential in reducing the amount of Johnsongrass: (1) destructive manipulation of Johnson grass which would allow for (2) natural competitors to become established.

Information on both optimal manipulation and native competitor establishment must be specific for the problem site. The temperature, precipitation, humidity and elevation will determine the optimal control technique. Introduced species in low elevation sites with little precipitation and high temperatures are often difficult to control (J. Cox, personal communication in Newman 1993).

Experimental plots should be employed for long term studies of various manipulation techniques including burning, mowing and tilling. Spring burns conducted during the first three weeks of shoot growth, when the carbohydrate supply is at a minimum level, followed by weekly mowings for one to several years may provide maximum control. If possible, the plots should be separated enough (greater than 10 m apart) to reduce the likelihood that two stems from the same underground plant system would be exposed to two different treatments.

How many years of control are necessary before re-vegetation projects can begin? The depth and dormancy (apical suppression) characteristics of the rhizomes may make it essentially impossible to completely eradicate Johnsongrass. Once *Sorghum halepense* is eliminated, what are the best ways to rapidly establish native plants in order to prevent the establishment of the remaining Johnsongrass fragments and other invasive weeds? Which natives fill the same niche as Johnsongrass? Are there any of these natives present in the location? If not, research to determine what plants were originally growing at the site before the land was disturbed must be conducted and then a source of seeds must be located. Determination of the optimal conditions for germination and establishment of seeds is essential in re-seeding experiments (Martin and Cox 1984). The long term survival of the native plants should be analyzed before elaborate re-vegetation projects take place.

Spot herbicide treatments, rather than large scale eradication techniques, may be sufficient for stable areas with small quantities of Johnsongrass intermixed with established native plants. The combination of manipulation techniques and maintenance of established native plants must be studied. Will there be deleterious effects on the natives when the Johnsongrass is manipulated? Winter burning is detrimental to sacaton (*Sporobulus wrightii*) growth (Cox and Morton 1986). What type of control would aid in reducing the number of Johnson grass plants without disrupting the established native plants?

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**[Yes]**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 10	**Total unknowns: 0**	
	Score : A		

Note any related traits: From Guertin and Halvorson (2003): 37 to 352 seeds on a panicle (Warwick and Black 1983); hundreds of seeds are produced on each panicle throughout the summer flowering period (Monaghan 1979); average plant produces 1.1 kg seeds per season (Horowitz 1972, Warwick and Black 1983). *Sorghum halepense* overwinters as rhizomes (primary rhizome) or seeds (Warwick and Black 1983). *Sorghum halepense* seeds reportedly germinate slightly after rhizomes sprout; rhizome sprouts are reported to grow more rapidly than seedlings (Warwick and Black 1983). Flowering begins approximatley two months after growth commences and continues throughout growing season (Warwick and Black 1983); self-compatibility (Warwick and Black 1983); five year old seeds displayed 50% viability (Warwick and Black 1983); estimates suggest some seed remains viable up to 15 years (CDFA 2002); viable seed after seven years in dry storage (Holm et al. 1977); single plant produces 200 to 300 feet of rhizomes in one month and 10 bushels of seed can be produced on one acre in a single growing season (McWhorter 1981); in Arizona, flowering occurs from April through November (Kearney and Peebles 1960). Reproduces freely, and only by seed on wet sites (Martin 2002).

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	**D**
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	**D**
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**B**
	southwestern interior riparian	**B**
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Other comments: Plasticity under different environmental conditions, including a rapid rate of growth at low light levels (McWhorter and Jordan 1976 in Warwick and Black 1983); large variability with may contribute to the rapid adaptability of the species to more northern climates (Burt and Wedderspoon 1971 in Warwick and Black 1983).

Literature Cited

Alex, J., R. McLaren, and A. Hamill. 1979. Occurence and winter survival of Johnson grass (*Sorghum halepense*) in Ontario. Canadian Journal of Plant Science 59:1173–1176.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burt, G.W., and I.M. Wedderspoon. 1971. Growth of johnsongrass selections under different temperatures and dark periods. Weed Science 19:419–423.

[CDFA] California Department of Food and Agriculture. 2002. Encycloweedia. Available online at http://pi.cdfa.ca.gov/weedinfo/SORGHUM2.html; accessed May 2003.

Cox, J., and H. Morton. 1986. Big sacaton (*Sporobolus wrightii*) riparian grassland management: annual winter burning, annual winter mowing, and spring-summer grazing. Applied Agricultural Research 1:105–111.

Findlay, R.M. 1975. Potential menace of Johnsongrass. New Zealand Journal of Agriculture 130:40–41.

Friedman, T., and M. Horowitz. 1970. Phytotoxicity of subterranean residues of three perennial weeds. Weed Research 10:382–385.

Gould, F. 1951. Grasses of Southwestern United States. University of Arizona, Tucson. 343 p.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Harrington, G., and S. Capel. 1978. Effects of a water resource development projects on native prairie in the Flint Hills of Kansas. Pages 166–168 in D.C. Glenn-Lewin and R.Q. Landers, Jr. (eds.), Proceedings, 5th Midwest Prairie Conference, August 22–24, 1976, Ames, Iowa. Iowa State University, Ames.

Holm, L.G., P. Donald, J.V. Pancho, and J.P. Herberger. 1977. The World's Worst Weeds: Distribution and Biology. The University Press of Hawaii, Honolulu. 609 p.

Horowitz, M. 1972. Early development of Johnson grass. Weed Science 20:271–273.

Horowitz, M. 1973. Spatial growth of *Sorghum halepense*. Weed Research 13:200–208.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Lavin, F., and T.N. Johnsen, Jr. 1977. Species adapted for planting Arizona pinyon-juniper woodland. Journal of Range Management 30:410–415.

Looker, D. 1981. Johnson grass has an Achilles heel. New Farm 3:40–47.

Martin, C.A. 2002. *Sorghum halepense* (Johnson grass). Arizona State University, Department of Plant Biology, Environmental Landscape Management, PLB 370. Available online at: http://lsvl.la.asu.edu/plb370/johnsongrass.html.

Martin, M.H., and J.R. Cox. 1984. Germination profiles of introduced lovegrasses at six constant temperatures. Journal of Range Management 37:507−509.

McDougall, W.B. 1973. Seed Plants of Northern Arizona. The Museum of Northern Arizona, Flagstaff. 594 p.

McWhorter, C. 1981. Johnson grass as a weed. USDA Farmers Bulletin 1537:3−19.

McWhorter, C.G., and T.N. Jordan. 1976. Comparative morphological development of six johnsongrass ecotypes. Weed Science 24:270–275.

Monaghan, N. 1979. The biology of Johnson grass (*Sorghum halepense*). Weed Research 19:261−267.

Newman, D. 1993. *Sorghum halepense* Element Stewardship Abstract. The Nature Conservancy. Available online at http://tncweeds.ucdavis/edu/esadocs/documents/sorghal.html.

Parker, K.F. 1972. An Illustrated Guide to Arizona Weeds. The University of Arizona Press, Tucson. 338 p. Available online at: http://www.uapress.arizona.edu/online.bks/weeds/; accessed May 2003.

Ruyle, G.B., and D.J. Young (eds.). 1997. Arizona Range Grasses. University of Arizona, College of Agriculture, Cooperative Extension, Tucson. Publication AZ97105. Available online at http://ag.arizona.edu/pubs/natresources/az97105/johnson_grass.html; accessed May 2003.

Snyder, S.A. 1992. *Sorghum halepense*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/plants/graminoid/sorhal/all.html; accessed April 2003.

Tellman, B. 2002. Human introduction of exotic species in the Sonoran Desert. Pages 25−46 in B. Tellman (ed.), Invasive Exotic Species in the Sonoran Region. The University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson. 424 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

[VDCR] Virginia Department of Conservation and Recreation. 1999. Invasive Alien Plants Species of Virginia. Johnson grass (*Sorghum halepense* (L.) Persoon). Department of Conservation and Recreation and the Virginia Native Plant Society. Available online at: http://www.dcr.state.va.us/dnh/invlist.htm; accessed May 2003.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native

Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Warwick, S., and L. Black. 1983. The biology of Canadian weeds—*Sorghum halepense*. Canadian Journal of Plant Science 63:997–1014.

Van Devender, T.R., R.S. Felger, and A. Burquez M. 1997. Exotic plants in the Sonoran Desert region, Arizona and Sonora. 1997 Symposium Proceedings, California Exotic Pest Plant Council. Available online at: http://www.caleppc.org/symposia/97symposium/VanDevender.pdf.

Other References of Interest Not Cited in the Text

Howard, J.L. 2004. *Sorghum halepense*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/. (Update of Snyder 1992).

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Tamarix aphylla* (L.) Karst. (USDA 2005)
Synonyms:	*Tamarix articulata* Vahl (USDA 2005)
Common names:	Athel tamarisk
Evaluation date (mm/dd/yy)**:**	09/24/04
Evaluator #1 Name/Title:	Kate Watters
Affiliation:	Northern Arizona University
Phone numbers:	(928) 523–8518
Email address:	Kw6@dana.ucc.nau.edu
Address:	P.O. Box 5765 Flagstaff, Arizona 86011–5765
Evaluator #2 Name/Title:	Patty Guertin / Reseacrh Specialist (botany)
Affiliation:	U.S. Geological Service, Sonoran Desert Field Station
Phone numbers:	(520) 670–6885; (520) 621–1174
Email address:	pguertin@nexus.srnr.arizona.edu
Address:	University of Arizona, 125 Biological Sciences East, Tucson, Arizona 85721
Evaluator #3 Name/Title:	F. E. Northam
Affiliation:	Weed Biologist
Phone numbers:	(480) 947–3882
Email address:	fnortham@msn.com
Address:	216 E. Taylor St., Tempe, Arizona 85281

List committee members:	D. Backer, J. Brock, D. Casper, J. Hall, K. Klementowski, H. Messing, B. Munda, F. Northam, J. Ward
Committee review date:	09/24/04
List date:	09/24/04
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Observational	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Low** **Alert Status:** **None**
1.2	Impact on plant community	**B**	Other published material		
1.3	Impact on higher trophic levels	**U**	No Information		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**C**	Observational	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **6 pts** **Section 2 Score:** **C**	
2.2	Local rate of spread with no management	**C**	Observational		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**C**	Other published material		
2.5	Potential for human-caused dispersal	**C**	Observational		
2.6	Potential for natural long-distance dispersal	**C**	Observational		
2.7	Other regions invaded	**U**	Other published material		 Something you should know.
3.1	Ecological amplitude	**D**	Other published material	**"Distribution"** **Section 3 Score:** **D**	
3.2	Distribution	**D**	Observational		

Red Flag Annotation

Tamarix aphylla currently has a limited distribution within Arizona wildlands even though many thousands of populations are present in agricultural and urban areas of southwestern Arizona. The species was introduced to provide windbreaks for homesteads. Until recently seeds were thought to be sterile and the only means of spread into wildlands was via vegetative reproduction. It is now known that *T. aphylla* can hybridize with other *Tamarix* spp. One documented occurrence of this is along the Gila River in western Maricopa County. It is unclear at this point what the morphology, physiology, reproduction by seed, and invasiveness of the hybrids will be, as well as the attributes of any subsequent backcross progeny.

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **B** *Doc'n Level:* **Obs.**
Identify ecosystem processes impacted: Dense canopies of mature plants intercept sunlight and provide wind barriers. Root growth by this species has a detrimental effect on availability of soil moisture and nutrients. Litter production by athel tamarisk is similar to what has been reported for other *Tamarix* spp.
Rationale: Athel tamarisk forms dense canopied evergreen trees 30 to 50 feet tall by 25 to 50 feet wide (Brenzel 2001). Mature plants which have established along desert stream corridors form an extremely shaded area in a radius of 3 to 7 meters around root crown and in most cases no other vegetation grows in this shaded area (F. Northam, personal communication, 2004). Due to copious litter production, it is assumed salt also becomes concentrated in the litters as with other *Tamarix* spp. (Carpenter 1998). Root growth makes this species a poor choice for planting near cultivated gardens. Thus, horticultural advisors recognize how detrimental athel tamarisk is to adjacent plants (Brenzel 2001). Guertin and Halvorson (2003) reviewed reports and books containing descriptions of biological traits common to the genus *Tamarix*; extensive root growth which makes these species more efficient at acquiring moisture and nutrients than native plants was identified as one trait allowing tamarisk woodlands to dominate southwestern desert waterways. It is assumed athel tamarisk roots have the same competitive advantage.
Sources of information: See cited literature. Also considered personal communication with F. Northam (Weed Biologist, Tempe, Arizona, 2004; field observations made while serving as the Arizona Department of Agriculture, Noxious Weed Coordinator, 2000 to 2003). Score based on inference drawn from the literature.

Question 1.2 Impact on plant community composition, structure, and interaction *Score:* **B** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Athel tamarisk's aggressive growth and its adaptability to disturbed floodplain sites bestow competitive advantages that result in replacement of natural communities. Tamarisk species accumulate salts in their foliage and litter.
Rationale: Patches of athel tamarisk in flood plains of Santa Cruz, Gila River and Salt Rivers have no herbaceous species or native shrubs growing within the areas covered by canopies of this species (F. Northam, personal communication, 2004). Soil beneath mature athel tamarisk trees are covered with a layer of litter, and it is assumed that this salt and litter production by athel tamarisk is similar to what has been reported for other *Tamarix* spp (Carpenter 1998). In other words, unnatural salt accumulation occurs in and under the litter which inhibits establishment of native species. Horticultural assessments agree with this conclusion (Duffield and Jones 1998).
Sources of information: See cited literature. Also considered personal communication with F. Northam (Weed Biologist, Tempe, Arizona, 2004; field observations made while serving as the Arizona Department of Agriculture, Noxious Weed Coordinator, 2000 to 2003).

Question 1.3 Impact on higher trophic levels *Score:* **U** *Doc'n Level:* **No info.**
Identify type of impact or alteration: None indentified.
Rationale: Impact unknown.
Sources of information: None.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**

Identify impacts: No known hybridization.

Rationale: No native plants in the same genus are known to exist in Arizona (Kearney and Peebles 1960).

Sources of information: See cited literature.

Question 2.1 Role of anthropogenic & natural disturbance in establishment *Score:* **C** *Doc'n Level:* **Obs.**

Describe role of disturbance: A combination of human intervention and a specific natural disturbance (intensive flood event) is necessary for establishment.

Rationale: Most athel tamarisk seed produced in Arizona is sterile (Guertin and Halvorson 2003). Vegetative dispersal of live limbs and root fragments in natural conditions depends on some force capable of breaking, transporting and burying fragments from live trees. Violent flash floods in desert water courses are the likely energy source for moving this species in natural conditions, and probably explains why escaped populations in southern and southwestern Arizona are found on desert floodplains downstream from urban or farm lands (F. Northam, personal communication, 2004). Thus, observed distributions in riparian areas/stream corridors, plus the lack of viable seed, are assumed to account for the limited occurrences in non-cultivated desert floodplains in southern and southwestern Arizona

Recent field studies have demonstrated three cases of viable seed production and hybridization with other *Tamrix* spp. in Arizona, California and Nevada (Gaskin and Shafroth 2005). Because this constitutes a significant change from historical concepts concerning this species reproduction in Arizona, establishment of athel tamarisk may be shifting toward less dependence on disturbance. This aspect of *T. aphylla* biology needs to be closely monitored in Arizona riparian areas during the next few years.

Sources of information: See cited literature. Also considered personal communication with F. Northam (Weed Biologist, Tempe, Arizona, 2004; field observations made while serving as the Arizona Department of Agriculture, Noxious Weed Coordinator, 2000 to 2003).

Question 2.2 Local rate of spread with no management *Score:* **C** *Doc'n Level:* **Obs.**

Describe rate of spread: Stable.

Rationale: Observations of athel tamarisk populations around old farm and ranch homesteads indicate this species has been present for many decades in the agricultural areas of central, south-central and southwestern Arizona. However, this species' dispersal into wildland stream corridors is limited to small populations scattered across several hundred acres (F. Northam, personal communication, 2004). Makarick (1999) also reported limited opportunity to spread in Colorado River riparian areas in the Grand Canyon.

Sources of information: See cited literature. Also considered personal communication with F. Northam (Weed Biologist, Tempe, Arizona, 2004; field observations made while serving as the Arizona Department of Agriculture, Noxious Weed Coordinator, 2000 to 2003).

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n Level:* **Obs.**

Describe trend: No published reports were found indicating this species has increased its range in Arizona during the past 30 years.

Rationale: Discussions in the rationale sections of questions 2.1 and 2.2 indicate that there is limited probability for athel tamarisk to increase its range in Arizona. Climate zone adaptability cited for athel tamarisk in Brenzel (2001) indicates this species will not tolerate winters above 5000 feet in Arizona. Because mature stands of this species have been present in Arizona several decades with no

documentation of movement beyond current range, it is concluded that athel tamarisk is far less intrusive than deciduous *Tamarix* spp. (Carpenter 1998).
Sources of information: See cited literature. Score based on inference drawn from the literature.

Question 2.4 Innate reproductive potential *Score:* **C** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: Viable seed production is rare. Vegetative reproduction is limited by natural environmental factors and human intervention.
Rationale: Historical population trends indicate innate reproductive potential has been low in Arizona (Guertin and Halvorson 2003; F. Northam, personal communication, 2004). Recent research by Gaskin and Shafroth (2005) has identified a site on the Gila River in Maricopa County where *T. aphylla-Tamarix* spp. hybrids were growing. This suggests a potential for seed production and dispersal that have not been previously reported for this species.
Sources of information: See cited literature. Also considered personal communication with F. Northam (Weed Biologist, Tempe, Arizona, 2004; field observations made while serving as the Arizona Department of Agriculture, Noxious Weed Coordinator, 2000 to 2003). See also the discussion in the rationale section of question 2.1.

Question 2.5 Potential for human-caused dispersal *Score:* **C** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Human-planted populations.
Rationale: Thousands of athel tamarisk populations are present in agricultural and urban areas of southwest Arizona. These plants (located around farm homesteads, in parks, along field borders, etc) were planted and many are still maintained by human efforts (F. Northam, personal communication, 2004). However, recent field studies of *Tamarix* spp. hybridization in the southwestern U.S. indicates *T. aphylla* dispersal may be shifting to natural seed dissemination (Gaskin and Shafroth 2005).
Sources of information: See cited literature. Also considered personal communication with F. Northam (Weed Biologist, Tempe, Arizona, 2004; field observations made while serving as the Arizona Department of Agriculture, Noxious Weed Coordinator, 2000 to 2003).

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Intense flooding in desert water courses.
Rationale: See discussion in rational section of question 2.1. Flood events capable of breaking fragments from athel tamarisk trees are rare in Arizona's climatic zones where this species was introduced and now thrives (F. Northam, personal communication, 2004).
Sources of information: See Guertin and Halvorson (2003) and Gaskin and Shafroth (2005). Also considered personal communication with F. Northam (Weed Biologist, Tempe, Arizona, 2004; field observations made while serving as the Arizona Department of Agriculture, Noxious Weed Coordinator, 2000 to 2003).

Question 2.7 Other regions invaded *Score:* **U** *Doc'n Level:* **Other pub.**
Identify other regions: Athel tamarisk is originally from Africa and the middle East (Welsh et al. 1987) and now occurs in Utah, California, New Mexico, Nevada, and Texas (USDA 2005). Ecosystems invaded in western United States include Ponderosa pine, sagebrush, desertshrub, chaparral-mountain shrub, pinyon-juniper, and desert grasslands (Tesky 1992).
Rationale: Even though athel tamrisk is reported in other states, information is not available to determine whether this species has escaped from ornamental, landscaped, or agricultural situations into ecosystems equivalent to non-infested Arizona wildlands.
Sources of information See cited literature.

Question 3.1 Ecological amplitude *Score:* **D** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Athel tamarisk was introduced into Arizona at the beginning of the 20th century by J.J. Thornber, University of Arizona, and was used for windbreaks and homestead ornamentals (Benson and Darrow 1981). According to Tesky (1992), athel tamarisk has established outside cultivation on salt flats, springs, and other saline habitats, especially along streams and rivers. In Arizona it has been found along the saline portions of the lower Colorado and Gila Rivers and in the Salton Sea Basin in California. This species is a facultative phreatophyte that is drought tolerant and adapted to saline and alkaline soils in regions with less than 16 inches annual rainfall. Observations in Sonoran desert riparian areas indicate athel tamarisk can establish and thrive in regions with less than 10 inches rainfall when floods provide adequate moisture for vegetative reproduction (F. Northam, personal communication, 2004).
Rationale: Observations of established athel tamarisk in land which has not had native vegetation cleared for agricultural, urban, right-of-way, industrial, recreation or horticultural uses has been limited to watercourses in the Sonoran or Mohave deserts.
Sources of information. See cited literature. Also considered personal communication with F. Northam (Weed Biologist, Tempe, Arizona, 2004; field observations made while serving as the Arizona Department of Agriculture, Noxious Weed Coordinator, 2000 to 2003).

Question 3.2 Distribution *Score:* **D** *Doc'n Level:* **Obs.**
Describe distribution: Observations of established athel tamarisk in land which has not had native vegetation cleared for agricultural, urban, right-of-way, industrial, recreational or horticultural uses has been limited to floodplains and banks of watercourses in the Sonoran or Mohave deserts.
Rationale: Observations of athel tamarisk populations around old farm and ranch homesteads indicate this species has been present for many decades in the agricultural areas of central, south-central and southwestern Arizona. However, this species' dispersal into wildland stream corridors is limited to small populations scattered across several hundred acres of Sonoran and Mohave Desert region (F. Northam, personal communication, 2004). Violent flash floods in desert water courses are the likely energy source for moving this species in natural conditions, and probably explains why escaped populations in southern and southwestern Arizona are found on desert floodplains downstream from urban or farm lands. Thus, present distributions in non-cultivated desert floodplains and riparian areas/stream corridors are assumed to depend on flood dynamics and deep soil moisture sources that maintain vegetative growth of dislodged limbs or roots (F. Northam, personal communication, 2004). **Note:** Recent documentation of athel tamarisk hybridization and seed production may change the historical concept of this plant being dispersed only by vegetative means (Gaskin and Shafroth 2005).
Sources of information: See cited literature. Also considered personal communication with F. Northam (Weed Biologist, Tempe, Arizona, 2004; field observations made while serving as the Arizona Department of Agriculture, Noxious Weed Coordinator, 2000 to 2003).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**[No]**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**[No]**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 3 Total unknowns: 0		
	Score : C		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**D**
	southwestern interior riparian	
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Benson, L., and R.A. Darrow. 1981. Trees and Shrubs of the Southwestern Deserts. 3rd edition. The University of Arizona Press, Tucson.

Brenzel, K.N. (ed.). 2001. Sunset Western Garden Book. Sunset Publishing Company, Menlo Park, California.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Carpenter, A.T. 1998. *Tamarix ramosissima* Ledebour, *Tamarix pentandra* Pallas, *Tamarix chinensis* Loureiro, and *Tamarix parviflora* De Candolle. Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documnts/tamaram.html; accessed September 23, 2004.

Duffield, M.R., and W.D. Jones. 1998. Plants for Dry Climates. How to Select, Grow and Enjoy. Fisher Books, Tucson, Arizona. 192 p.

Gaskin, J.F., and P.B. Shafroth. 2005. Hybridization of *Tamarix ramosissima* and *T. chinensis* (saltcedars) with *T. aphyalla* (athel) (family Tamaricaceae) in the southwestern USA determined from DNA sequence data. Madrono 52:1–10.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Renewable Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenue&lib=2&sublib=13; accessed September 23, 2004.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Makarick, L.J. 1999. Draft Exotic Plants for Grand Canyon National Park. National Park Service, Grand Canyon National Park, Arizona.

Tesky, J.L. 1992. *Tamarix aphylla*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences laboratory, Missoula, Montana (Producer). Available online at: http://www/fs.fed.us/database/feis/; accessed September 23, 2004.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Welsh, S.L., N.D. Atwood, L.C. Higgins, and S. Goodrich. 1987. A Utah Flora. Brigham Young University, Provo, Utah. 610 p.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial):	*Tamarix chinensis* Lour.; *Tamarix parviflora* DC.; *Tamarix ramosissima* Ledeb. (USDA 2005)
Synonyms:	*Tamarix chinensis* Lour.: None listed in USDA (2005); *Tamarix parviflora* DC.: *Tamarix tetrandra* auct. non Pallas (USDA 2005); *Tamarix ramosissima* Ledeb.: None listed in USDA (2005)
Common names:	*Tamarix chinensis* Lour.: Fivestamen tamarisk, tamarisk, saltcedar; *Tamarix parviflora* DC.: Smallflower tamarisk, tamarisk, saltcedar; *Tamarix ramosissima* Ledeb.: saltcedar, tamarisk
Evaluation date (mm/dd/yy):	04/22/04
Evaluator #1 Name/Title:	Kate Watters
Affiliation:	Northern Arizona University
Phone numbers:	(928) 523–8518
Email address:	Kw6@dana.ucc.nau.edu
Address:	P.O. Box 5765 Flagstaff, Arizona 86011–5765
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	W. Albrecht, W. Austin, D. Backer, J. Hall, L. Moser, B. Phillips, F. Northam, J. Schalau, K. Watters
Committee review date:	08/06/04
List date:	08/06/04
Re-evaluation date(s):	

Taxonomic Comment

Some taxonomic confusion exits for *Tamarix* spp. in the U.S., as several species were introduced. T*amarix ramosissima* and *T. chinensis* are allopatric in Asia; however, in the U.S. they are synpatric and their hybrid, which has not been found in Asia, is common. *Tamarix parviflora*, although recognized as a separate species, readily hybridizes with *T. ramosissima* and other closely related *Tamarix* spp. The significant amount of hybridization makes these species difficult to tell apart in the U.S. For the purposes of this assessment, all three species are evaluated here collectively with an emphasis on *T. ramosissima*, as the most common species. *Tamarix aphylla* is treated in a separate assessment. Preceding information is based on a personal communication with J. Gaskin (North America Flora author, *Tamarix*, 2004).

Table 2. Scores, Designations, and Documentation Levels

Question		Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**A**	Reviewed scientific publication	**"Impact"** **Section 1 Score:** **A**	**"Plant Score"** **Overall Score:** **High** **Alert Status:** **None**
1.2	Impact on plant community	**A**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**A**	Reviewed scientific publication		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**A**	Reviewed scientific publication	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **19 pts** **Section 2 Score:** **A**	
2.2	Local rate of spread with no management	**A**	Observational		
2.3	Recent trend in total area infested within state	**B**	Other published material		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Reviewed scientific publication		
2.6	Potential for natural long-distance dispersal	**A**	Other published material		
2.7	Other regions invaded	**B**	Other published material		RED FLAG **YES** Something you should know.
3.1	Ecological amplitude	**A**	Other published material	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Red Flag Annotation

The ecological impacts associated with invasion by *Tamarix* spp. should be considered within the context of the specific riparian community invaded. In addition, such impacts may be mediated by previous changes to a variety of ecological processes associated with the particular riparian community. Land managers planning riparian restoration projects involving the control of *Tamarix* spp. should consider and address, as appropriate, other factors, such as existing hydrologic regimes, fluvial processes, and whether

Tamarix spp. stands are providing habitat for southwestern willow flycatchers (*Empidonax traillii extimus*), before proceeding with such projects.

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Identify ecosystem processes impacted: Tamarisk dominance in riparian areas changes hydrology by increasing overbank flooding and alters geomorphologic process. With the dominance of tamarisk, riparian areas have seen increases in fire frequency. Tamarisk's deep root and lateral branching enables it to draw down the water table and dense populations increase the salinity of the soil surface.

Rationale: Many reviews indicate that tamarisk reduces the width, depth, and water-holding capacity of river channels by trapping and stabilizing alluvial sediments, and thus increases the frequency and severity of overbank flooding (Dudley et al. 2000, Lovich 2000).

Studies along the Green and Yampa rivers by Cooper et al. (2003) suggests that tamarisk stems change the landscape properties of gravel and cobble islands and bars, as well as those of adjacent channels. Near-bed flow velocities decreased and the sheer stress required to remobilize the channel bed increased. The dense woody roots of tamarisk increased the gravel bar's resistance to mobilization (Cooper et al. 2003).

Fire appears to be less common in riparian ecosystems where tamarisk has not invaded. On dammed rivers, the structure of tamarisk stands may be more favorable to carry fire. Increases in fire size and frequency in riparian areas are attributed to a number of factors including an increase in ignition sources, increased fire frequency in surrounding uplands, and increased abundance of fuels (Busch and Smith 1993).

Drier floodplain environments are the result of altered disturbance regimes such as dams and diversions, groundwater pumping, agriculture, and urban development, which have contributed to lower base flows, reduced water tables and changes in the frequency, timing and severity of flooding (Zouhar 2003). Tamarisk is a facultative phreatophyte and halophyte with a deep, extensive root system that extends to the water table, and is also capable of extracting water from unsaturated soil layers. Its primary root grows with little branching until it reaches the water table, at which point secondary root branching is profuse (Brotherson and Winkel 1986). Tamarisk evapotranspiration rates are among the highest levels of any phreatophyte evaluated in southwestern North America, including other native riparian trees. Several reviews and studies suggest that tamarisk has high transpiration rates and that tamarisk stands use more water than native vegetation, thus drawing down water tables, desiccating floodplains, and lowering flow rates of waterways (Brotherson and Field 1987).

It is reported that tamarisk contains 41,000 ppm dissolved solids in its guttation sap (DiTomaso 1998). Tamarisk accumulates salt in special glands in its leaves, and then excretes it onto the leaf surface. These salts accumulate in the surface layer of soil when plants drop their leaves (Mozingo 1987). Brotherson and Field (1987) concluded that tamarisk deposited NaCl beneath its canopy as an allelochemical agent. Along regulated rivers that no longer experience annual flooding and scouring, surface soils become more saline over time (Busch and Smith 1993).

Sources of information: See cited literature.

Question 1.2 Impact on plant community composition**,** structure, and interactions *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Identify type of impact or alteration: In altered riparian systems, tamarisk forms dense monotypic stands that compete with and replace native vegetation such as cottonwood and willow species. Despite similar competitive abilities, tamarisk is more tolerant of ground water declines than native species,

which may facilitate its establishment over native species. Tamarisk disrupts natural succession in native plant communities. It reduces seedling recruitment of other species through deposition of salts on the soil surface and creation of a new structural layer of litter. Native species are not adapted to increased fire frequency in tamarisk-dominated areas.

Rationale: Tamarisk communities are commonly associated with disruptions in historic disturbance regimes. Damming and subsequent management on most western rivers for water and electric power have resulted in increased evaporation and associated salinity, changes in erosion and sedimentation rates, and other physicochemical changes (Zouhar 2003).

Tamarisk dominated communities are often monotypic, though arrowweed and screwbean mesquite (*P. pubescens*) are common associates, and big saltbrush (*Atriplex lentiformis*) may occur in saline areas (Hasse 1972). Anderson et al 1977 described salt cedar communities along the lower Colorado River with salt cedar constituting 95 to 100% of the total trees. Cottonwood communities along the Colorado River, for example, have decreased from over 5,000 acres (2,000 ha) in the 1600s to less than 500 acres (200 ha) in 1998 (Briggs and Cornelius 1998). Tamarisk has since replaced up to 90% of the riparian communities historically dominated by cottonwood-willow forests. Tamarisk has almost completely replaced the native forest that historically dominated the riparian corridor from the Grand Canyon to the delta on the Gulf of California. It is by far the most abundant plant in the Colorado River delta, accounting for 40% of total ground cover (Westbrooks 1998).

In disturbed riparian environments where salinities are elevated or water tables depressed, tamarisk's deep root system gives it a competitive advantage over native, obligate phreatophytes (e.g. cottonwood and willow). Studies demonstrate that tamarisk is more tolerant of ground water declines that the native Goodings willow (*Salix goodingii*). Tamarisk is a facultative phreatophyte, with the ability to draw from the alluvial water table, but is also capable of surviving by extracting water, thus surviving indefinitely on unsaturated soils. In contrast, Goodings willow is an obligate phreatophyte, relying solely on the groundwater (Turner 1974, Stromberg 1997). Tamarisk seedlings are better able to survive water stress (i.e., low flows) and are more likely to survive until water becomes available, in contrast to *Salix* seedlings. This is one way that tamarisk is able to out-compete native vegetation and successfully invade disturbed riparian habitats (Horton and Clark 2001).

Tamarisk is less sensitive to changes in ground water availability than native riparian trees with which it is commonly associated. Greater tolerance of water stress can lead to tamarisk dominance on relatively dry riparian sites (Zouhar 2003). The longer a community has been invaded by tamarisk, the more xeric in nature are the plant species that occupy the understory. Deposits of salt-encrusted needle-like leaves are at times more than 1 m deep and can inhibit the germination of other species (Di Tomaso 1998). Research by Stromberg (1998) suggests that the functional role of tamarisk is context-specific and variable among rivers. In a study on a free-flowing river, understory herbaceous cover and species richness (including exotics) were significantly greater than in cottonwood stands, perhaps due to soil differences that developed between the two stand types (e.g., higher clay content in salt cedar soils). Stem densities of velvet mesquite (*Prosopis velutina*) and other woody successional species did not differ between tamarisk and cottonwood stands. However, stem densities for this group increased with stand age only for cottonwood, raising the possibility that tamarisk may disrupt successional pathways (Stromberg 1998).

Massive accumulations of duff found under tamarisk canopies (up to 1.5 m) prevented seeds of other species (including tamarisk) from reaching the soil surface. It was also observed that both in field and laboratory studies soils beneath tamarisk canopies were strongly hydrophobic. By water-proofing the soil with the resins and/or sugars of foliage, tamarisk reduces the survival of seedlings (including its own) beneath its canopy (Stevens 2001).

Competition was measured between tamarisk and coyote willow (*Salix exigua*) at various stages of growth. Neither species significantly reduced the germination of the other, but at the end of the second year, tamarisk seedlings growing in the presences of coyote willow suffered reduced growth and 15% higher mortality than in controls. In older class (5 year old) plants, coyote willow suppressed salt cedar growth only slightly (Stevens 2001).

In the Southwest among the few species that thrive in a tamarisk understory are 3 non-native brome grasses (*Bromus* spp.). A nonnative, honeydew-producing leafhopper found on tamarisk interacts with a fungus to change soil characteristics increasing saline conditions, so that plant recruitment is virtually eliminated under a tamarisk canopy (Simberloff and VanHolle 1999).

With the occupation of tamarisk some riparian areas have seen an increase in fire frequency, compared to the infrequent fires of low- to mid-elevation southwestern riparian plant communities dominated by cottonwood, willow and/or mesquite. While cottonwood and willow species can resprout following fire, tamarisk may be better adapted to the post-fire environment than native species, especially on dammed rivers. This creates an advantage for tamarisk over native species (Busch and Smith 1993).

Sources of information: See cited literature.

Question 1.3 Impact on higher trophic levels *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Identify type of impact or alteration: Tamarisk displaces native vegetation thus reducing the value of critical habitat for wildlife, including some endangered species. Studies also report that tamarisk plays an important ecological role for wildlife.

Rationale: It is debated as to whether tamarisk provides habitat and nest sites for some wildlife (e.g. white-winged dove), however, most authors have concluded that it has little value to most native amphibians, reptiles, birds, and mammals (Chen 2001).

Several studies conclude that tamarisk sustains only poor avian and invertebrate herbivore fauna (Cohan et al. 1978, Hunter et al. 1985, Johnson 1986), whereas other studies report tamarisk as playing a valuable ecological role by supporting herbivores and bird life (Beidieman 1971, Stevens 1976b, Brush 1983, Brown et al. 1984, Stevens and Waring 1985, Warren and Schwalbe 1985, Brotherson and Field 1987, Brown 1987).

Tamarisk has replaced the function of native tree species such as cottonwood (*Populus fremontii*) and Goodding willow (*Salix gooddingii*), to a point where some ecologists believe that tamarisk removal could have undesirable effects on endangered species such as the Southwest willow flycatcher (*Empidonax traillii extimus)* (D'Antonio 2000). The flycatcher has been documented as utilizing tamarisk for breeding and nesting purposes, even though reproductive success is lower in tamarisk as compared to native trees (Dudley et al. 2000).

At sites throughout the Middle Rio Grande Bewick's wrens nested only in native tree species, especially large cottonwoods (*Populus deltoides*). Analysis of data from 70 sites found wren abundance to be highest at sites dominated by cottonwoods, especially at sites having salt cedar (*Tamarix chinensis*) understories. However, at sites dominated by tamarisk, Bewick's wren abundance was low (Taylor 2003).

According to Johnson et al. (1999), the decreasing population of federally listed Southwest willow flycatchers coincides with changing vegetation communities in the bosque community. A bosque is a habitat with extremely moist soil, usually arising from mist, rains, or snow melt, with evergreen shrubs, willows, and an absence of trees. Formerly dominated by native cottonwood and willow, the banks of

the Rio Grande are now dominated by Russian olives and tamarisk, both introduced species. The flycatcher prefers the widely spaced branching of the willows where the bird scans for its prey of local insects. The flycatcher also prefers areas of the bosque covered by standing water or saturated soil (Buckley 1995).

A literature review by Stephenson and Calcarone (1999) suggests that in some cases tamarisk invasions have reduced or eliminated water supplies for bighorn sheep, pupfish, and salamanders. Tamarisk may have negative impacts on threatened and endangered species such as Amargosa pupfish, warm springs pupfish, and speckled dace in Ash Meadows National Wildlife Refuge, Nevada; desert tortoise, and Nelson bighorn sheep, in Lake Mead National Recreation Area, Nevada (Chen 2001).

In the Grand Canyon, tamarisk blossomed abundantly in early June, when few other flowers were available for pollinators. Several invertebrates were observed using tamarisk flowers (Thysanoptera, Coleoptera, some Lepidoptera, Diptera, and Hymenoptera). The significance of this resource for invertebrates could be important but has not been investigated. In a comparison of invertebrate herbivore communities associated with coyote willow and tamarisk, Stevens (1985) found that both species supported equivalent numbers of invertebrate herbivores, but coyote willow supported a more evenly distributed herbivore community with nearly 4 times as many species and a much lower standing crop than tamarisk (Stevens 1985).

Sources of information: See cited literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**

Identify impacts: No known hybridization.

Rationale: There are no native species within the family *Tamaricaceae* in North America. However, introduced species within the genus do hybridize readily with each other.

Sources of information: Kearney and Peebles (1960). Also considered personal communication with J. Gaskin (North America Flora author, *Tamarix*, 2004).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Describe role of disturbance: The construction of dams alter the hydrology and severely impact natural river flows, thus creating a climate for tamarisk invasion. The rate of tamarisk establishment increases with human and natural disturbance regimes, but it can establish independent of any known human or anthropogenic disturbance.

Rationale: The damming of rivers fed by snowmelt has shifted the time of peak discharge below the dams from spring to summer. This alteration creates conditions favorable to tamarisk seedling establishment, as seeds are just ripening in time with high flows, thus assisting establishment (Shafroth et al. 2002). The creation of lakes and reservoirs with large areas of fine sediment, provide the ideal substrate for tamarisk colonization along the margins. Reduced flood frequency downstream of reservoirs and more stabilized base flows in rivers due to reservoir construction have also created favorable conditions for tamarisk invasion (Everitt 1980). The clearing and plowing of floodplains and associated agricultural activity also aided tamarisk colonization during the 1800s. Tamarisk is also reported to rapidly infest riparian areas exposed to heavy grazing (Stromberg 1998). Once established, wind-borne seed dispersal can become established in otherwise undisturbed areas (DiTomaso 1998).

Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **A** *Doc'n Level:* **Obs.**

Describe rate of spread: Infestations are doubling in <10 years.

Rationale: Since its introduction to the United States in the late 1890s tamarisk has established in nearly every lower-elevation streambed from northern Mexico to southern Canada and recent estimates

indicate infestations in the southwestern U.S. exceed 600,000 hectares (Brotherson and Field 1987). This increase represents at least a 4% increase per year. Tamarisk spread was calculated to be about 20 km of river length per year in the Colorado and Green River systems (Di Tomaso 1998). Working Group members inferred that southwestern trends reflect Arizona's populations of tamarisk.
Sources of information: See cited literature. Score based on inference.

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Other pub.**
Describe trend: Increasing, but less rapidly than doubling area infested in <10 years.
Rationale: Because much of the riparian habitat in the western U.S. has been invaded by tamarisk, the rate of increase particularly in Arizona has slowed down. However, much of the Salt River through the Tempe and Phoenix area is characterized by scattered individuals of salt cedar, as well as along the Verde River. Salt cedar also occurs along the shore of the San Carlos reservoir and the San Pedro River in southern Arizona Salt cedar also co-dominates with camelthorn (*Alhagi maurorum*) at several sites at Wupatki National Monument in north-central Arizona (Zouhar 2003). The range of tamarisk is continuing to extend northward to Montana and Canada, and southward into northwestern Mexico (DeLoach 1989).
Sources of information: See cited literature.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: Tamarisk reproduce vegetatively and prolifically by seed. A single tamarisk tree produces a half million seeds a year.
Rationale: Tamarisk saplings mature rapidly, and some can flower after the first year of growth, but most individuals begin to reproduce in their third year. An Arizona study demonstrated that dense tamarisk stands can generate 100 seeds per square inch (Warren and Turner 1975). Seeds remain viable for several weeks and will germinate on saturated soils or while afloat. It can vegetatively resprout after fire, severe flood, or treatment with herbicides and it is able to accommodate wide variations in soil and mineral gradients in its environment (DiTomaso 1998). Tamarisk is largely insect-pollinated and wind pollination does not occur at a large extent (Stevens 2001).
Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify dispersal mechanisms: Anthropogenic factors that facilitate the spread of tamarisk include: intentional tamarisk plantings designed to protect stream banks, control erosion and act as wind breaks; conversion of native riparian forests to agricultural uses. Tamarisk is planted as an ornamental and shade tree and is still widely planted in Mexico. Today the largest human-caused dispersal of tamarisk is facilitated by dam management.
Rationale: Although wind dispersal and ornamental plantings cannot be ruled out as primary transport mechanisms, research on tamarisk dispersal from the Bighorn /Yellowstone River system suggest that boats and machinery transported propagules. Pearce and Smith (2003) studied concentrations and ages of saltcedar at the Musselshell River and Fort Peck Reservoir in Northern Montana to identify concentrations of plants that could be used to infer introduction location, establishment year, and mechanisms of dispersal. Their research suggests that seeds and other plant propagules were also transported to the reservoir by earth-moving equipment during site construction between 1966 and the mid-1980s and later by boats and their towing vehicles. Stromberg (1998) found that conditions that favor cottonwood establishment (frequent winter flooding, high rates of stream flow during spring, exclusion of livestock, employed on the San Pedro River may have led to a decline of tamarisk. This demonstrates that tamarisk dispersal could be lessened by managing rivers toward a natural cycle in which conditions are favorable to cottonwood and willow establishment (Stromberg 1998).

Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Lightweight seeds can travel long distances in the wind. Flooding events can move stem and root fragments more than 1 km.
Rationale: Tamarisk seeds are tiny with long hairs that facilitate distribution via the wind, and are carried and deposited along sandbars and riverbanks by water. Stevens (2001) found that tamarisk germination was completed in less than one day after absorption of fluid and subsequent swelling. Stem and root fragments can also float downstream after fragmentation due to flooding events and establish in new areas.
Sources of information: See cited literature; also see DiTomaso (1998) and Lovich (2000).

Question 2.7 Other regions invaded *Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: The genus *Tamarix* occurs naturally from western Europe and the Mediterranean to North Africa, northeastern China, India, and Japan. Since its escape from cultivation, salt cedar has spread primarily in the southwestern U.S., Texas and Mexico, although its distribution extends to many other parts of North America. It is especially pervasive in Arizona, New Mexico, western Texas, Nevada, and Utah but is also widespread in southern California, the Rocky Mountain states, the western Plains states, and parts of Oregon, Montana and Idaho. It occurs throughout broad regions of northwestern Mexico and is spreading along the Gulf of Mexico into the coastal prairie (Westbrooks 1998). Tamarisk is a problem in Ash Meadows Wildlife Refuge in Nevada, a montane wetland ecological type.
Rationale: Invades elsewhere but mostly in riparian ecological types that have already been invaded in Arizona. Montane wetlands are an exception. Further investigation should be made into whether tamarisk occurs in montane wetlands and playas in Arizona.
Sources of information: See cited literature; also see Zouhar (2003).

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Tamarisk was not identified in the western U.S. until the 1800s when it was introduced for sale as an ornamental shrub and a windbreak species. It was available in New York City in 1823, in Philadelphia in 1828, and in several nurseries along the eastern seaboard during the 1930s. Tamarisk was listed for sale by nurseries in California as early as 1856. First Arizona record for Tamarisk was from 1916 in Cochise County.
Rationale: Tamarisk is found in riparian communities dominated by green ash (*Fraxinus pennsylvanica*), Arizona sycamore (*Platanus wrightii*), Fremont cottonwood, and Goodding willow (*Salix gooddingii*) in Arizona (and New Mexico).
Sources of information: See Zouhar (2003). Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed February 10, 2004).

Question 3.2 Distribution *Score:* **A** *Doc'n Level:* **Obs.**
Describe distribution: In the southwestern United States, tamarisk occurs in every major watershed, in a variety of community types, many of them dominated by cottonwood (*Populus* spp.) and willow (*Salix* spp.).
Rationale: In Arizona tamarisk is abundant along streams in most of the state below 5,000 feet (1,525 m) and, though it grows in the Southwest at elevation up to 11,000 feet (3350 m), it does not spread rapidly above 4,000 feet (1220 m) (Kartesz and Meacham1999).

Sources of information: See cited literature; also see Zouhar (2003). Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed February 10, 2004) and Southwest Exotic Plant Mapping Program (SWEMP)-Cain Crisis map (available online at: http://cain.nbii.gov/cgibin/mapserv?map=../html/cain/crisis/crisismaps/crisis.map&mode=browse&layer=state&layer=county; accessed on February 10, 2004).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**Yes**	**[No]**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**[No]**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**[No]**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 7 Total unknowns: 0		
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	**C**
	southwestern interior wetlands	**D**
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**A**
	southwestern interior riparian	**B**
	montane riparian	**D**
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Anderson, B.W., A. Higgins, and R.D. Ohmart. 1977. Avian use of salt cedar communities in the lower Colorado River Valley. Pages 128−145 in R.R. Johnson and D.A. Jones (tech. coords.), Importance, Preservation and Management of Riparian Habitat: A Symposium. July 9, 1977, Tucson, Arizona. Gen. Tech. Rep. RM-43. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Beidieman, R.C. 1971. Cottonwood-salt cedar riverbottom. American Birds 25:646−648.

Briggs, M.K., and S. Cornelius. 1998. Opportunities for ecological improvement along the lower Colorado River and delta. Wetlands 18:513−529.

Brotherson, J.D., and D. Field. 1987. *Tamarix*: Impacts of a successful weed. Rangelands 9:110−112.

Brotherson, J.D., and V. Winkel. 1986. Habitat relationships of salt cedar (*Tamarix ramosissima*). The Great Basin Naturalist 46:535−541.

Brown, B.T., S.W. Carothers, and R.R. Johnson. 1984. Breeding range expansion of Bell's Vireo in Grand Canyon, Arizona Condor 85 499−500.

Brown, B.T. 1987. Fluctuating flows from Glen Canyon Dam and their effect on breeding birds of the Colorado River. GCES Rept. No. 23 (NTIS No. PB88-183538/AS). Salt Lake City, Utah.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Brush, T. 1983. First nesting of a New-world woodpecker in salt cedar (*Tamarix chinensis*). The Southwestern Naturalist 28:113.

Busch, D.E., and S.D. Smith. 1993. Effects of fire on water salinity relations of riparian woody taxa. Oecologia 94:186−194.

Buckley, M. 1995. Bosque birds. Quantum 12:2.

Chen, Linus Y. 2001. Cost savings from properly managing endangered species habitats. Natural Areas Journal 21:197−203.

Cohan, D.R., B.W. Anderson, and R.D. Ohmart. 1978. Avian population responses to salt cedar along the lower Colorado River. Pages 371−382 in R.R. Johnson and J.F. McCormick (tech. coords.), Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems: Proceedings of the Symposium. December 11−13, 1978, Callaway Gardens, Geogia. Gen. Tech. Rep. WO-12. U.S. Department of Agriculture, Forest Service, Washington, DC.

Cooper, D.J., D.C. Anderson, and R.A. Chimner. 2003. Multiple pathways for woody plant establishment on floodplains at local to regional scales. Journal of Ecology 91:182−196.

D'Antonio, C.M. 2000. Fire, plant invasions, and global changes. Pages 65–93 in H.A. Mooney and R.J. Hobbs (eds.), Invasive Species in a Changing World. Island Press, Washington, DC.

DeLoach, C.J. 1989. Prospects for biological control of salt cedar (*Tamarix* spp.) in riparian habitats of the southwestern United States. Pages 307–314 in E.S. Delfosse (ed.), Proceedings VII International Symposium of the Biological Control of Weeds. 1988, Rome, Italy. 1st Sper. Patol. Veg. (MAF).

DiTomaso, J.M. 1998. Impact, biology and ecology of salt cedar (Tamarix spp.) in the southwestern United States. Weed Technology 12:236–336.

Dudley, T.L., C.J. DeLoach, J.E. Lovich, and R.I. Carruthers. 2000. Salt cedar invasion of western riparian areas: impacts and new prospects for control. Transactions of the North American Wildlife and Natural Resources Conference 65:345–381.

Everitt. B.L. 1980. Ecology of salt cedar—a plea for research Environmental Geology 3:77–84.

Haase, E.F. 1972. Survey of floodplain vegetation along the lower Gila River in southwestern Arizona. Journal of the Arizona Academy of Science 7:75–81.

Horton, J.L. and J.L. Clark. 2001. Water table decline alters growth and survival of *Salix gooddingii* and *Tamarix chinensis* seedlings. Forest Ecology and Management 140:239–247.

Hunter, W.C., B.W. Anderson, and R.D. Ohmart. 1985. Summer avian community composition of *Tamarix* habitats in three southwestern desert riparian systems. Pages 128–134 in R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre (tech. coords.), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. First North American Riparian Conference. April 16–18, 1985, Tucson, Arizona. Gen. Tech. Rep. RM-120. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Johnson, S. 1986 Can salt cedar be controlled? The Nature Conservancy News, Oct.-Nov.:19–20. The Nature Conservancy, Arlington, Virginia.

Johnson, K., P. Mehlhop, C. Black, and K. Score. 1999. Reproductive failure of endangered southwestern willow flycatchers on the Rio Grande, New Mexico. Southwestern Naturalist 44:226–231.

Kartesz, J.T., and C.A. Meacham. 1999. Synthesis of the North American flora (Windows Version 1.0), [CD-ROM]. Available from: North Carolina Botanical Garden. In cooperation with the Nature Conservancy, Natural Resources Conservation Service, and U.S. Fish and Wildlife Service.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Lovich, J. 2000. *Tamarix* spp. Pages 312–317 in C.C Bossard, J. Randall, and M. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Mozingo, H.N. 1987. Shrubs of the Great Basin: A natural History. University of Nevada Press, Reno. 342 p.

Pearce, C.M., D.G. Smith. 2003. Salt cedar: distribution, abundance, and dispersal mechanisms, northern Montana, USA. Wetlands 23:215 –228.

Simberloff, D., and B. Von Holle. 1999. Positive interactions of nonindigenous species: invasional meltdown. Biological Invasions 1:21 −32.

Shafroth, P.B., J.C. Stromberg, and D.T. Patten. 2002. Riparian vegetation response to altered disturbance and stress regimes. Ecological Applications 12:107−123.

Stephenson, J.R., and G.M. Calcarone. 1999. Mountain and foothills ecosystems: habitat and species conservation issues. Pages 15−60 in J.R. Stephenson and G.M. Calcarone (eds.), Southern California Mountains and Foothills Assessment. Gen. Tech. Rep. PSW-GTR-172. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.

Stevens, L.E. 1976b. Insect production on native and introduced dominant plant species. Pp. 146-154 in Carothers, S.W. and S.W. Aitchison (eds.). An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, AZ. Colorado River Research Tech. Rept. No. 10. National Park Service, Grand Canyon, National Park, Grand Canyon.

Stevens, L.E. 1985. Invertebrate Herbivore Community Dynmaics in *Tamarix chinensis* Loureiro and *Salix exigua* Nuttall in the Grand Canyon, Arizona. Master's thesis. Northern Arizona University, Flagstff.

Stevens, L.E. 2001. A synthesis of information on the ecology and management of salt cedar (*Tamarix ramosissima*), with emphasis on the Grand Canyon region. Final progress report prepared for the Arizona Water Protection Fund.

Stevens, L.E., and G.L.Waring. 1985. The effects of prolonged flooding on the riparian plant community in Grand Canyon. Pages 81−86 in R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre (tech. coords.), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. Gen. Tech. Rep. RM-120. First North American Riparian Conference. April 16−18, 1985, Tucson, Arizona. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Stromberg, J.C., 1997. Growth and survivorship of Fremont cottonwood, Goodding willow, and salt cedar seedlings after large floods in central Arizona. Great Basin Naturalist 57:198−208.

Stromberg, J.C. 1998.Functional equivalency of salt cedar (*Tamarix chinensis*) and fremont cottonwood (*Populus fremontii*) along a free-flowing river. Wetlands 18:675−686.

Taylor, R.V. 2003. Factors influencing expansion of the breeding distribution of Bewick's wren into riparian forests of the Rio Grande in central New Mexico. Southwestern Naturalist 48:373−382.

Turner, R.M., 1974. Quantitative and historical evidence of vegetation changes along the upper Gila River, Arizona. U.S. Geological Survey Professional Paper 655-(H). 20 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Warren, D.K., and R.M. Turner. 1975. Salt cedar (*Tamarix chinensis*) seed production, seedling establishment and response to inundation. J. AZ Academy of Science 10:135−144.

Warren, P.L., and C.R. Schwalbe. 1985. Herpetofauna in riparian habitats along the Colorado River in Grand Canyon. Pages 347−354 in R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre (tech. coords.), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. Gen. Tech. Rep. RM-120. First North American Riparian Conference. April 16−18, 1985, Tucson, Arizona. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Westbrooks, R.G. 1998. Invasive plants: changing the landscape of America. Fact Book. Federal Interagency Committee for the Management of Noxious and Exotic Weeds, Washington, DC. 109 p.

Zouhar, K. 2003. *Tamarix* spp. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed April 22, 2004.

Other References of Interest No Cited in the Text

Carpenter, A.T. 1998. *Tamarix ramosissima* Ledebour, *Tamarix pentandra* Pallas, *Tamarix chinensis* Loureiro, and *Tamarix parviflora* De Candolle. Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documnts/tamaram.html; accessed September 23, 2004.

D'Antonio, C., and L.A. Meyerson. 2002. Exotic plant species as problems and solutions in ecological restoration: a synthesis. Restoration Ecology 10:703−13.

Hem, J. D. 1967. Composition of saline residues on leaves and stems of salt cedar (*Tamarisk pentandra* Pallas). Geological Survey Professional Paper 491-C. U. S. Geological Survey, Reston, Virgina.

Stevens, L.E. 1976a. An insect inventory of Grand Canyon. Pages 141−145 in S.W. Carothers and S.W. Aitchison (eds.). An Ecological Survey of the Riparian Zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, AZ. Colorado River Research Tech. Rept. No. 10. National Park Service, Grand Canyon, National Park, Grand Canyon.

Stevens, L. E. 1990. Pages 99−105 in M.R. Kunzmann, R.R. Johnson, and P.S. Bennett (tech. coords.), Tamarisk Control in Southwestern United States, Proceedings of Tamarisk Conference. September 2−3, 1987, University of Arizona, Tucson, Arizona. Special Report No. 9. National Park Service, Cooperative National Park Resources Studies Unit, School of Renewable Natural Resources, University of Arizona, Tucson.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial):	*Tamarix chinensis* Lour.; *Tamarix parviflora* DC.; *Tamarix ramosissima* Ledeb. (USDA 2005)
Synonyms:	*Tamarix chinensis* Lour.: None listed in USDA (2005); *Tamarix parviflora* DC.: *Tamarix tetrandra* auct. non Pallas (USDA 2005); *Tamarix ramosissima* Ledeb.: None listed in USDA (2005)
Common names:	*Tamarix chinensis* Lour.: Fivestamen tamarisk, tamarisk, saltcedar; *Tamarix parviflora* DC.: Smallflower tamarisk, tamarisk, saltcedar; *Tamarix ramosissima* Ledeb.: saltcedar, tamarisk
Evaluation date (mm/dd/yy):	04/22/04
Evaluator #1 Name/Title:	Kate Watters
Affiliation:	Northern Arizona University
Phone numbers:	(928) 523–8518
Email address:	Kw6@dana.ucc.nau.edu
Address:	P.O. Box 5765 Flagstaff, Arizona 86011–5765
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	W. Albrecht, W. Austin, D. Backer, J. Hall, L. Moser, B. Phillips, F. Northam, J. Schalau, K. Watters
Committee review date:	08/06/04
List date:	08/06/04
Re-evaluation date(s):	

Taxonomic Comment

Some taxonomic confusion exits for *Tamarix* spp. in the U.S., as several species were introduced. T*amarix ramosissima* and *T. chinensis* are allopatric in Asia; however, in the U.S. they are synpatric and their hybrid, which has not been found in Asia, is common. *Tamarix parviflora*, although recognized as a separate species, readily hybridizes with *T. ramosissima* and other closely related *Tamarix* spp. The significant amount of hybridization makes these species difficult to tell apart in the U.S. For the purposes of this assessment, all three species are evaluated here collectively with an emphasis on *T. ramosissima*, as the most common species. *Tamarix aphylla* is treated in a separate assessment. Preceding information is based on a personal communication with J. Gaskin (North America Flora author, *Tamarix*, 2004).

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**A**	Reviewed scientific publication	**"Impact"** **Section 1 Score:** **A**	**"Plant Score"** **Overall Score:** **High** **Alert Status:** **None**
1.2	Impact on plant community	**A**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**A**	Reviewed scientific publication		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**A**	Reviewed scientific publication	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **19 pts** **Section 2 Score:** **A**	
2.2	Local rate of spread with no management	**A**	Observational		
2.3	Recent trend in total area infested within state	**B**	Other published material		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Reviewed scientific publication		
2.6	Potential for natural long-distance dispersal	**A**	Other published material		
2.7	Other regions invaded	**B**	Other published material		 Something you should know.
3.1	Ecological amplitude	**A**	Other published material	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Red Flag Annotation

The ecological impacts associated with invasion by *Tamarix* spp. should be considered within the context of the specific riparian community invaded. In addition, such impacts may be mediated by previous changes to a variety of ecological processes associated with the particular riparian community. Land managers planning riparian restoration projects involving the control of *Tamarix* spp. should consider and address, as appropriate, other factors, such as existing hydrologic regimes, fluvial processes, and whether

Tamarix spp. stands are providing habitat for southwestern willow flycatchers (*Empidonax traillii extimus*), before proceeding with such projects.

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify ecosystem processes impacted: Tamarisk dominance in riparian areas changes hydrology by increasing overbank flooding and alters geomorphologic process. With the dominance of tamarisk, riparian areas have seen increases in fire frequency. Tamarisk's deep root and lateral branching enables it to draw down the water table and dense populations increase the salinity of the soil surface.
Rationale: Many reviews indicate that tamarisk reduces the width, depth, and water-holding capacity of river channels by trapping and stabilizing alluvial sediments, and thus increases the frequency and severity of overbank flooding (Dudley et al. 2000, Lovich 2000). Studies along the Green and Yampa rivers by Cooper et al. (2003) suggests that tamarisk stems change the landscape properties of gravel and cobble islands and bars, as well as those of adjacent channels. Near-bed flow velocities decreased and the sheer stress required to remobilize the channel bed increased. The dense woody roots of tamarisk increased the gravel bar's resistance to mobilization (Cooper et al. 2003). Fire appears to be less common in riparian ecosystems where tamarisk has not invaded. On dammed rivers, the structure of tamarisk stands may be more favorable to carry fire. Increases in fire size and frequency in riparian areas are attributed to a number of factors including an increase in ignition sources, increased fire frequency in surrounding uplands, and increased abundance of fuels (Busch and Smith 1993). Drier floodplain environments are the result of altered disturbance regimes such as dams and diversions, groundwater pumping, agriculture, and urban development, which have contributed to lower base flows, reduced water tables and changes in the frequency, timing and severity of flooding (Zouhar 2003). Tamarisk is a facultative phreatophyte and halophyte with a deep, extensive root system that extends to the water table, and is also capable of extracting water from unsaturated soil layers. Its primary root grows with little branching until it reaches the water table, at which point secondary root branching is profuse (Brotherson and Winkel 1986). Tamarisk evapotranspiration rates are among the highest levels of any phreatophyte evaluated in southwestern North America, including other native riparian trees. Several reviews and studies suggest that tamarisk has high transpiration rates and that tamarisk stands use more water than native vegetation, thus drawing down water tables, desiccating floodplains, and lowering flow rates of waterways (Brotherson and Field 1987). It is reported that tamarisk contains 41,000 ppm dissolved solids in its guttation sap (DiTomaso 1998). Tamarisk accumulates salt in special glands in its leaves, and then excretes it onto the leaf surface. These salts accumulate in the surface layer of soil when plants drop their leaves (Mozingo 1987). Brotherson and Field (1987) concluded that tamarisk deposited NaCl beneath its canopy as an allelochemical agent. Along regulated rivers that no longer experience annual flooding and scouring, surface soils become more saline over time (Busch and Smith 1993).
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition**,** structure, and interactions *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: In altered riparian systems, tamarisk forms dense monotypic stands that compete with and replace native vegetation such as cottonwood and willow species. Despite similar competitive abilities, tamarisk is more tolerant of ground water declines than native species,

which may facilitate its establishment over native species. Tamarisk disrupts natural succession in native plant communities. It reduces seedling recruitment of other species through deposition of salts on the soil surface and creation of a new structural layer of litter. Native species are not adapted to increased fire frequency in tamarisk-dominated areas.

Rationale: Tamarisk communities are commonly associated with disruptions in historic disturbance regimes. Damming and subsequent management on most western rivers for water and electric power have resulted in increased evaporation and associated salinity, changes in erosion and sedimentation rates, and other physicochemical changes (Zouhar 2003).

Tamarisk dominated communities are often monotypic, though arrowweed and screwbean mesquite (*P. pubescens*) are common associates, and big saltbrush (*Atriplex lentiformis*) may occur in saline areas (Hasse 1972). Anderson et al 1977 described salt cedar communities along the lower Colorado River with salt cedar constituting 95 to 100% of the total trees. Cottonwood communities along the Colorado River, for example, have decreased from over 5,000 acres (2,000 ha) in the 1600s to less than 500 acres (200 ha) in 1998 (Briggs and Cornelius 1998). Tamarisk has since replaced up to 90% of the riparian communities historically dominated by cottonwood-willow forests. Tamarisk has almost completely replaced the native forest that historically dominated the riparian corridor from the Grand Canyon to the delta on the Gulf of California. It is by far the most abundant plant in the Colorado River delta, accounting for 40% of total ground cover (Westbrooks 1998).

In disturbed riparian environments where salinities are elevated or water tables depressed, tamarisk's deep root system gives it a competitive advantage over native, obligate phreatophytes (e.g. cottonwood and willow). Studies demonstrate that tamarisk is more tolerant of ground water declines that the native Goodings willow (*Salix goodingii*). Tamarisk is a facultative phreatophyte, with the ability to draw from the alluvial water table, but is also capable of surviving by extracting water, thus surviving indefinitely on unsaturated soils. In contrast, Goodings willow is an obligate phreatophyte, relying solely on the groundwater (Turner 1974, Stromberg 1997). Tamarisk seedlings are better able to survive water stress (i.e., low flows) and are more likely to survive until water becomes available, in contrast to *Salix* seedlings. This is one way that tamarisk is able to out-compete native vegetation and successfully invade disturbed riparian habitats (Horton and Clark 2001).

Tamarisk is less sensitive to changes in ground water availability than native riparian trees with which it is commonly associated. Greater tolerance of water stress can lead to tamarisk dominance on relatively dry riparian sites (Zouhar 2003). The longer a community has been invaded by tamarisk, the more xeric in nature are the plant species that occupy the understory. Deposits of salt-encrusted needle-like leaves are at times more than 1 m deep and can inhibit the germination of other species (Di Tomaso 1998). Research by Stromberg (1998) suggests that the functional role of tamarisk is context-specific and variable among rivers. In a study on a free-flowing river, understory herbaceous cover and species richness (including exotics) were significantly greater than in cottonwood stands, perhaps due to soil differences that developed between the two stand types (e.g., higher clay content in salt cedar soils). Stem densities of velvet mesquite (*Prosopis velutina*) and other woody successional species did not differ between tamarisk and cottonwood stands. However, stem densities for this group increased with stand age only for cottonwood, raising the possibility that tamarisk may disrupt successional pathways (Stromberg 1998).

Massive accumulations of duff found under tamarisk canopies (up to 1.5 m) prevented seeds of other species (including tamarisk) from reaching the soil surface. It was also observed that both in field and laboratory studies soils beneath tamarisk canopies were strongly hydrophobic. By water-proofing the soil with the resins and/or sugars of foliage, tamarisk reduces the survival of seedlings (including its own) beneath its canopy (Stevens 2001).

Competition was measured between tamarisk and coyote willow (*Salix exigua*) at various stages of growth. Neither species significantly reduced the germination of the other, but at the end of the second year, tamarisk seedlings growing in the presences of coyote willow suffered reduced growth and 15% higher mortality than in controls. In older class (5 year old) plants, coyote willow suppressed salt cedar growth only slightly (Stevens 2001).

In the Southwest among the few species that thrive in a tamarisk understory are 3 non-native brome grasses (*Bromus* spp.). A nonnative, honeydew-producing leafhopper found on tamarisk interacts with a fungus to change soil characteristics increasing saline conditions, so that plant recruitment is virtually eliminated under a tamarisk canopy (Simberloff and VanHolle 1999).

With the occupation of tamarisk some riparian areas have seen an increase in fire frequency, compared to the infrequent fires of low- to mid-elevation southwestern riparian plant communities dominated by cottonwood, willow and/or mesquite. While cottonwood and willow species can resprout following fire, tamarisk may be better adapted to the post-fire environment than native species, especially on dammed rivers. This creates an advantage for tamarisk over native species (Busch and Smith 1993).

Sources of information: See cited literature.

Question 1.3 Impact on higher trophic levels *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Identify type of impact or alteration: Tamarisk displaces native vegetation thus reducing the value of critical habitat for wildlife, including some endangered species. Studies also report that tamarisk plays an important ecological role for wildlife.

Rationale: It is debated as to whether tamarisk provides habitat and nest sites for some wildlife (e.g. white-winged dove), however, most authors have concluded that it has little value to most native amphibians, reptiles, birds, and mammals (Chen 2001).

Several studies conclude that tamarisk sustains only poor avian and invertebrate herbivore fauna (Cohan et al. 1978, Hunter et al. 1985, Johnson 1986), whereas other studies report tamarisk as playing a valuable ecological role by supporting herbivores and bird life (Beidieman 1971, Stevens 1976b, Brush 1983, Brown et al. 1984, Stevens and Waring 1985, Warren and Schwalbe 1985, Brotherson and Field 1987, Brown 1987).

Tamarisk has replaced the function of native tree species such as cottonwood (*Populus fremontii*) and Goodding willow (*Salix gooddingii*), to a point where some ecologists believe that tamarisk removal could have undesirable effects on endangered species such as the Southwest willow flycatcher (*Empidonax traillii extimus)* (D'Antonio 2000). The flycatcher has been documented as utilizing tamarisk for breeding and nesting purposes, even though reproductive success is lower in tamarisk as compared to native trees (Dudley et al. 2000).

At sites throughout the Middle Rio Grande Bewick's wrens nested only in native tree species, especially large cottonwoods (*Populus deltoides*). Analysis of data from 70 sites found wren abundance to be highest at sites dominated by cottonwoods, especially at sites having salt cedar (*Tamarix chinensis*) understories. However, at sites dominated by tamarisk, Bewick's wren abundance was low (Taylor 2003).

According to Johnson et al. (1999), the decreasing population of federally listed Southwest willow flycatchers coincides with changing vegetation communities in the bosque community. A bosque is a habitat with extremely moist soil, usually arising from mist, rains, or snow melt, with evergreen shrubs, willows, and an absence of trees. Formerly dominated by native cottonwood and willow, the banks of

the Rio Grande are now dominated by Russian olives and tamarisk, both introduced species. The flycatcher prefers the widely spaced branching of the willows where the bird scans for its prey of local insects. The flycatcher also prefers areas of the bosque covered by standing water or saturated soil (Buckley 1995).

A literature review by Stephenson and Calcarone (1999) suggests that in some cases tamarisk invasions have reduced or eliminated water supplies for bighorn sheep, pupfish, and salamanders. Tamarisk may have negative impacts on threatened and endangered species such as Amargosa pupfish, warm springs pupfish, and speckled dace in Ash Meadows National Wildlife Refuge, Nevada; desert tortoise, and Nelson bighorn sheep, in Lake Mead National Recreation Area, Nevada (Chen 2001).

In the Grand Canyon, tamarisk blossomed abundantly in early June, when few other flowers were available for pollinators. Several invertebrates were observed using tamarisk flowers (Thysanoptera, Coleoptera, some Lepidoptera, Diptera, and Hymenoptera). The significance of this resource for invertebrates could be important but has not been investigated. In a comparison of invertebrate herbivore communities associated with coyote willow and tamarisk, Stevens (1985) found that both species supported equivalent numbers of invertebrate herbivores, but coyote willow supported a more evenly distributed herbivore community with nearly 4 times as many species and a much lower standing crop than tamarisk (Stevens 1985).

Sources of information: See cited literature.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**

Identify impacts: No known hybridization.

Rationale: There are no native species within the family *Tamaricaceae* in North America. However, introduced species within the genus do hybridize readily with each other.

Sources of information: Kearney and Peebles (1960). Also considered personal communication with J. Gaskin (North America Flora author, *Tamarix*, 2004).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Describe role of disturbance: The construction of dams alter the hydrology and severely impact natural river flows, thus creating a climate for tamarisk invasion. The rate of tamarisk establishment increases with human and natural disturbance regimes, but it can establish independent of any known human or anthropogenic disturbance.

Rationale: The damming of rivers fed by snowmelt has shifted the time of peak discharge below the dams from spring to summer. This alteration creates conditions favorable to tamarisk seedling establishment, as seeds are just ripening in time with high flows, thus assisting establishment (Shafroth et al. 2002). The creation of lakes and reservoirs with large areas of fine sediment, provide the ideal substrate for tamarisk colonization along the margins. Reduced flood frequency downstream of reservoirs and more stabilized base flows in rivers due to reservoir construction have also created favorable conditions for tamarisk invasion (Everitt 1980). The clearing and plowing of floodplains and associated agricultural activity also aided tamarisk colonization during the 1800s. Tamarisk is also reported to rapidly infest riparian areas exposed to heavy grazing (Stromberg 1998). Once established, wind-borne seed dispersal can become established in otherwise undisturbed areas (DiTomaso 1998).

Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **A** *Doc'n Level:* **Obs.**

Describe rate of spread: Infestations are doubling in <10 years.

Rationale: Since its introduction to the United States in the late 1890s tamarisk has established in nearly every lower-elevation streambed from northern Mexico to southern Canada and recent estimates

indicate infestations in the southwestern U.S. exceed 600,000 hectares (Brotherson and Field 1987). This increase represents at least a 4% increase per year. Tamarisk spread was calculated to be about 20 km of river length per year in the Colorado and Green River systems (Di Tomaso 1998). Working Group members inferred that southwestern trends reflect Arizona's populations of tamarisk.
Sources of information: See cited literature. Score based on inference.

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Other pub.**
Describe trend: Increasing, but less rapidly than doubling area infested in <10 years.
Rationale: Because much of the riparian habitat in the western U.S. has been invaded by tamarisk, the rate of increase particularly in Arizona has slowed down. However, much of the Salt River through the Tempe and Phoenix area is characterized by scattered individuals of salt cedar, as well as along the Verde River. Salt cedar also occurs along the shore of the San Carlos reservoir and the San Pedro River in southern Arizona Salt cedar also co-dominates with camelthorn (*Alhagi maurorum*) at several sites at Wupatki National Monument in north-central Arizona (Zouhar 2003). The range of tamarisk is continuing to extend northward to Montana and Canada, and southward into northwestern Mexico (DeLoach 1989).
Sources of information: See cited literature.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: Tamarisk reproduce vegetatively and prolifically by seed. A single tamarisk tree produces a half million seeds a year.
Rationale: Tamarisk saplings mature rapidly, and some can flower after the first year of growth, but most individuals begin to reproduce in their third year. An Arizona study demonstrated that dense tamarisk stands can generate 100 seeds per square inch (Warren and Turner 1975). Seeds remain viable for several weeks and will germinate on saturated soils or while afloat. It can vegetatively resprout after fire, severe flood, or treatment with herbicides and it is able to accommodate wide variations in soil and mineral gradients in its environment (DiTomaso 1998). Tamarisk is largely insect-pollinated and wind pollination does not occur at a large extent (Stevens 2001).
Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify dispersal mechanisms: Anthropogenic factors that facilitate the spread of tamarisk include: intentional tamarisk plantings designed to protect stream banks, control erosion and act as wind breaks; conversion of native riparian forests to agricultural uses. Tamarisk is planted as an ornamental and shade tree and is still widely planted in Mexico. Today the largest human-caused dispersal of tamarisk is facilitated by dam management.
Rationale: Although wind dispersal and ornamental plantings cannot be ruled out as primary transport mechanisms, research on tamarisk dispersal from the Bighorn /Yellowstone River system suggest that boats and machinery transported propagules. Pearce and Smith (2003) studied concentrations and ages of saltcedar at the Musselshell River and Fort Peck Reservoir in Northern Montana to identify concentrations of plants that could be used to infer introduction location, establishment year, and mechanisms of dispersal. Their research suggests that seeds and other plant propagules were also transported to the reservoir by earth-moving equipment during site construction between 1966 and the mid-1980s and later by boats and their towing vehicles. Stromberg (1998) found that conditions that favor cottonwood establishment (frequent winter flooding, high rates of stream flow during spring, exclusion of livestock, employed on the San Pedro River may have led to a decline of tamarisk. This demonstrates that tamarisk dispersal could be lessened by managing rivers toward a natural cycle in which conditions are favorable to cottonwood and willow establishment (Stromberg 1998).

Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Lightweight seeds can travel long distances in the wind. Flooding events can move stem and root fragments more than 1 km.
Rationale: Tamarisk seeds are tiny with long hairs that facilitate distribution via the wind, and are carried and deposited along sandbars and riverbanks by water. Stevens (2001) found that tamarisk germination was completed in less than one day after absorption of fluid and subsequent swelling. Stem and root fragments can also float downstream after fragmentation due to flooding events and establish in new areas.
Sources of information: See cited literature; also see DiTomaso (1998) and Lovich (2000).

Question 2.7 Other regions invaded *Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: The genus *Tamarix* occurs naturally from western Europe and the Mediterranean to North Africa, northeastern China, India, and Japan. Since its escape from cultivation, salt cedar has spread primarily in the southwestern U.S., Texas and Mexico, although its distribution extends to many other parts of North America. It is especially pervasive in Arizona, New Mexico, western Texas, Nevada, and Utah but is also widespread in southern California, the Rocky Mountain states, the western Plains states, and parts of Oregon, Montana and Idaho. It occurs throughout broad regions of northwestern Mexico and is spreading along the Gulf of Mexico into the coastal prairie (Westbrooks 1998). Tamarisk is a problem in Ash Meadows Wildlife Refuge in Nevada, a montane wetland ecological type.
Rationale: Invades elsewhere but mostly in riparian ecological types that have already been invaded in Arizona. Montane wetlands are an exception. Further investigation should be made into whether tamarisk occurs in montane wetlands and playas in Arizona.
Sources of information: See cited literature; also see Zouhar (2003).

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Tamarisk was not identified in the western U.S. until the 1800s when it was introduced for sale as an ornamental shrub and a windbreak species. It was available in New York City in 1823, in Philadelphia in 1828, and in several nurseries along the eastern seaboard during the 1930s. Tamarisk was listed for sale by nurseries in California as early as 1856. First Arizona record for Tamarisk was from 1916 in Cochise County.
Rationale: Tamarisk is found in riparian communities dominated by green ash (*Fraxinus pennsylvanica*), Arizona sycamore (*Platanus wrightii*), Fremont cottonwood, and Goodding willow (*Salix gooddingii*) in Arizona (and New Mexico).
Sources of information: See Zouhar (2003). Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed February 10, 2004).

Question 3.2 Distribution *Score:* **A** *Doc'n Level:* **Obs.**
Describe distribution: In the southwestern United States, tamarisk occurs in every major watershed, in a variety of community types, many of them dominated by cottonwood (*Populus* spp.) and willow (*Salix* spp.).
Rationale: In Arizona tamarisk is abundant along streams in most of the state below 5,000 feet (1,525 m) and, though it grows in the Southwest at elevation up to 11,000 feet (3350 m), it does not spread rapidly above 4,000 feet (1220 m) (Kartesz and Meacham1999).

Sources of information: See cited literature; also see Zouhar (2003). Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed February 10, 2004) and Southwest Exotic Plant Mapping Program (SWEMP)-Cain Crisis map (available online at: http://cain.nbii.gov/cgibin/mapserv?map=../html/cain/crisis/crisismaps/crisis.map&mode=browse&layer=state&layer=county; accessed on February 10, 2004).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**Yes**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**Yes**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**No**	**1 pt.**
	Total pts: 7 Total unknowns: 0		
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	**C**
	southwestern interior wetlands	**D**
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**A**
	southwestern interior riparian	**B**
	montane riparian	**D**
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Anderson, B.W., A. Higgins, and R.D. Ohmart. 1977. Avian use of salt cedar communities in the lower Colorado River Valley. Pages 128−145 in R.R. Johnson and D.A. Jones (tech. coords.), Importance, Preservation and Management of Riparian Habitat: A Symposium. July 9, 1977, Tucson, Arizona. Gen. Tech. Rep. RM-43. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Beidieman, R.C. 1971. Cottonwood-salt cedar riverbottom. American Birds 25:646−648.

Briggs, M.K., and S. Cornelius. 1998. Opportunities for ecological improvement along the lower Colorado River and delta. Wetlands 18:513−529.

Brotherson, J.D., and D. Field. 1987. *Tamarix*: Impacts of a successful weed. Rangelands 9:110−112.

Brotherson, J.D., and V. Winkel. 1986. Habitat relationships of salt cedar (*Tamarix ramosissima*). The Great Basin Naturalist 46:535−541.

Brown, B.T., S.W. Carothers, and R.R. Johnson. 1984. Breeding range expansion of Bell's Vireo in Grand Canyon, Arizona Condor 85 499−500.

Brown, B.T. 1987. Fluctuating flows from Glen Canyon Dam and their effect on breeding birds of the Colorado River. GCES Rept. No. 23 (NTIS No. PB88-183538/AS). Salt Lake City, Utah.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Brush, T. 1983. First nesting of a New-world woodpecker in salt cedar (*Tamarix chinensis*). The Southwestern Naturalist 28:113.

Busch, D.E., and S.D. Smith. 1993. Effects of fire on water salinity relations of riparian woody taxa. Oecologia 94:186−194.

Buckley, M. 1995. Bosque birds. Quantum 12:2.

Chen, Linus Y. 2001. Cost savings from properly managing endangered species habitats. Natural Areas Journal 21:197−203.

Cohan, D.R., B.W. Anderson, and R.D. Ohmart. 1978. Avian population responses to salt cedar along the lower Colorado River. Pages 371−382 in R.R. Johnson and J.F. McCormick (tech. coords.), Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems: Proceedings of the Symposium. December 11−13, 1978, Callaway Gardens, Geogia. Gen. Tech. Rep. WO-12. U.S. Department of Agriculture, Forest Service, Washington, DC.

Cooper, D.J., D.C. Anderson, and R.A. Chimner. 2003. Multiple pathways for woody plant establishment on floodplains at local to regional scales. Journal of Ecology 91:182−196.

D'Antonio, C.M. 2000. Fire, plant invasions, and global changes. Pages 65−93 in H.A. Mooney and R.J. Hobbs (eds.), Invasive Species in a Changing World. Island Press, Washington, DC.

DeLoach, C.J. 1989. Prospects for biological control of salt cedar (*Tamarix* spp.) in riparian habitats of the southwestern United States. Pages 307−314 in E.S. Delfosse (ed.), Proceedings VII International Symposium of the Biological Control of Weeds. 1988, Rome, Italy. 1st Sper. Patol. Veg. (MAF).

DiTomaso, J.M. 1998. Impact, biology and ecology of salt cedar (Tamarix spp.) in the southwestern United States. Weed Technology 12:236−336.

Dudley, T.L., C.J. DeLoach, J.E. Lovich, and R.I. Carruthers. 2000. Salt cedar invasion of western riparian areas: impacts and new prospects for control. Transactions of the North American Wildlife and Natural Resources Conference 65:345−381.

Everitt. B.L. 1980. Ecology of salt cedar—a plea for research Environmental Geology 3:77−84.

Haase, E.F. 1972. Survey of floodplain vegetation along the lower Gila River in southwestern Arizona. Journal of the Arizona Academy of Science 7:75−81.

Horton, J.L. and J.L. Clark. 2001. Water table decline alters growth and survival of *Salix gooddingii* and *Tamarix chinensis* seedlings. Forest Ecology and Management 140:239−247.

Hunter, W.C., B.W. Anderson, and R.D. Ohmart. 1985. Summer avian community composition of *Tamarix* habitats in three southwestern desert riparian systems. Pages 128−134 in R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre (tech. coords.), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. First North American Riparian Conference. April 16−18, 1985, Tucson, Arizona. Gen. Tech. Rep. RM-120. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Johnson, S. 1986 Can salt cedar be controlled? The Nature Conservancy News, Oct.-Nov.:19−20. The Nature Conservancy, Arlington, Virginia.

Johnson, K., P. Mehlhop, C. Black, and K. Score. 1999. Reproductive failure of endangered southwestern willow flycatchers on the Rio Grande, New Mexico. Southwestern Naturalist 44:226–231.

Kartesz, J.T., and C.A. Meacham. 1999. Synthesis of the North American flora (Windows Version 1.0), [CD-ROM]. Available from: North Carolina Botanical Garden. In cooperation with the Nature Conservancy, Natural Resources Conservation Service, and U.S. Fish and Wildlife Service.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Lovich, J. 2000. *Tamarix* spp. Pages 312−317 in C.C Bossard, J. Randall, and M. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Mozingo, H.N. 1987. Shrubs of the Great Basin: A natural History. University of Nevada Press, Reno. 342 p.

Pearce, C.M., D.G. Smith. 2003. Salt cedar: distribution, abundance, and dispersal mechanisms, northern Montana, USA. Wetlands 23:215 −228.

Simberloff, D., and B. Von Holle. 1999. Positive interactions of nonindigenous species: invasional meltdown. Biological Invasions 1:21 −32.

Shafroth, P.B., J.C. Stromberg, and D.T. Patten. 2002. Riparian vegetation response to altered disturbance and stress regimes. Ecological Applications 12:107−123.

Stephenson, J.R., and G.M. Calcarone. 1999. Mountain and foothills ecosystems: habitat and species conservation issues. Pages 15−60 in J.R. Stephenson and G.M. Calcarone (eds.), Southern California Mountains and Foothills Assessment. Gen. Tech. Rep. PSW-GTR-172. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.

Stevens, L.E. 1976b. Insect production on native and introduced dominant plant species. Pp. 146-154 in Carothers, S.W. and S.W. Aitchison (eds.). An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, AZ. Colorado River Research Tech. Rept. No. 10. National Park Service, Grand Canyon, National Park, Grand Canyon.

Stevens, L.E. 1985. Invertebrate Herbivore Community Dynmaics in *Tamarix chinensis* Loureiro and *Salix exigua* Nuttall in the Grand Canyon, Arizona. Master's thesis. Northern Arizona University, Flagstff.

Stevens, L.E. 2001. A synthesis of information on the ecology and management of salt cedar (*Tamarix ramosissima*), with emphasis on the Grand Canyon region. Final progress report prepared for the Arizona Water Protection Fund.

Stevens, L.E., and G.L.Waring. 1985. The effects of prolonged flooding on the riparian plant community in Grand Canyon. Pages 81−86 in R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre (tech. coords.), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. Gen. Tech. Rep. RM-120. First North American Riparian Conference. April 16−18, 1985, Tucson, Arizona. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Stromberg, J.C., 1997. Growth and survivorship of Fremont cottonwood, Goodding willow, and salt cedar seedlings after large floods in central Arizona. Great Basin Naturalist 57:198−208.

Stromberg, J.C. 1998.Functional equivalency of salt cedar (*Tamarix chinensis*) and fremont cottonwood (*Populus fremontii*) along a free-flowing river. Wetlands 18:675−686.

Taylor, R.V. 2003. Factors influencing expansion of the breeding distribution of Bewick's wren into riparian forests of the Rio Grande in central New Mexico. Southwestern Naturalist 48:373−382.

Turner, R.M., 1974. Quantitative and historical evidence of vegetation changes along the upper Gila River, Arizona. U.S. Geological Survey Professional Paper 655-(H). 20 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Warren, D.K., and R.M. Turner. 1975. Salt cedar (*Tamarix chinensis*) seed production, seedling establishment and response to inundation. J. AZ Academy of Science 10:135−144.

Warren, P.L., and C.R. Schwalbe. 1985. Herpetofauna in riparian habitats along the Colorado River in Grand Canyon. Pages 347−354 in R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre (tech. coords.), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. Gen. Tech. Rep. RM-120. First North American Riparian Conference. April 16−18, 1985, Tucson, Arizona. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Westbrooks, R.G. 1998. Invasive plants: changing the landscape of America. Fact Book. Federal Interagency Committee for the Management of Noxious and Exotic Weeds, Washington, DC. 109 p.

Zouhar, K. 2003. *Tamarix* spp. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed April 22, 2004.

Other References of Interest No Cited in the Text

Carpenter, A.T. 1998. *Tamarix ramosissima* Ledebour, *Tamarix pentandra* Pallas, *Tamarix chinensis* Loureiro, and *Tamarix parviflora* De Candolle. Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documnts/tamaram.html; accessed September 23, 2004.

D'Antonio, C., and L.A. Meyerson. 2002. Exotic plant species as problems and solutions in ecological restoration: a synthesis. Restoration Ecology 10:703−13.

Hem, J. D. 1967. Composition of saline residues on leaves and stems of salt cedar (*Tamarisk pentandra* Pallas). Geological Survey Professional Paper 491-C. U. S. Geological Survey, Reston, Virgina.

Stevens, L.E. 1976a. An insect inventory of Grand Canyon. Pages 141−145 in S.W. Carothers and S.W. Aitchison (eds.). An Ecological Survey of the Riparian Zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, AZ. Colorado River Research Tech. Rept. No. 10. National Park Service, Grand Canyon, National Park, Grand Canyon.

Stevens, L. E. 1990. Pages 99−105 in M.R. Kunzmann, R.R. Johnson, and P.S. Bennett (tech. coords.), Tamarisk Control in Southwestern United States, Proceedings of Tamarisk Conference. September 2−3, 1987, University of Arizona, Tucson, Arizona. Special Report No. 9. National Park Service, Cooperative National Park Resources Studies Unit, School of Renewable Natural Resources, University of Arizona, Tucson.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Tamarix chinensis* Lour.; *Tamarix parviflora* DC.; *Tamarix ramosissima* Ledeb. (USDA 2005)
Synonyms:	*Tamarix chinensis* Lour.: None listed in USDA (2005); *Tamarix parviflora* DC.: *Tamarix tetrandra* auct. non Pallas (USDA 2005); *Tamarix ramosissima* Ledeb.: None listed in USDA (2005)
Common names:	*Tamarix chinensis* Lour.: Fivestamen tamarisk, tamarisk, saltcedar; *Tamarix parviflora* DC.: Smallflower tamarisk, tamarisk, saltcedar; *Tamarix ramosissima* Ledeb.: saltcedar, tamarisk
Evaluation date (mm/dd/yy)**:**	04/22/04
Evaluator #1 Name/Title:	Kate Watters
Affiliation:	Northern Arizona University
Phone numbers:	(928) 523–8518
Email address:	Kw6@dana.ucc.nau.edu
Address:	P.O. Box 5765 Flagstaff, Arizona 86011–5765
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	W. Albrecht, W. Austin, D. Backer, J. Hall, L. Moser, B. Phillips, F. Northam, J. Schalau, K. Watters
Committee review date:	08/06/04
List date:	08/06/04
Re-evaluation date(s):	

Taxonomic Comment

Some taxonomic confusion exits for *Tamarix* spp. in the U.S., as several species were introduced. T*amarix ramosissima* and *T. chinensis* are allopatric in Asia; however, in the U.S. they are synpatric and their hybrid, which has not been found in Asia, is common. *Tamarix parviflora*, although recognized as a separate species, readily hybridizes with *T. ramosissima* and other closely related *Tamarix* spp. The significant amount of hybridization makes these species difficult to tell apart in the U.S. For the purposes of this assessment, all three species are evaluated here collectively with an emphasis on *T. ramosissima*, as the most common species. *Tamarix aphylla* is treated in a separate assessment. Preceding information is based on a personal communication with J. Gaskin (North America Flora author, *Tamarix*, 2004).

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**A**	Reviewed scientific publication	**"Impact"** **Section 1 Score:** **A**	**"Plant Score"** **Overall Score:** **High** **Alert Status:** **None**
1.2	Impact on plant community	**A**	Reviewed scientific publication		
1.3	Impact on higher trophic levels	**A**	Reviewed scientific publication		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**A**	Reviewed scientific publication	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **19 pts** **Section 2 Score:** **A**	
2.2	Local rate of spread with no management	**A**	Observational		
2.3	Recent trend in total area infested within state	**B**	Other published material		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**A**	Reviewed scientific publication		
2.6	Potential for natural long-distance dispersal	**A**	Other published material		
2.7	Other regions invaded	**B**	Other published material		RED FLAG **YES** Something you should know.
3.1	Ecological amplitude	**A**	Other published material	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Red Flag Annotation

The ecological impacts associated with invasion by *Tamarix* spp. should be considered within the context of the specific riparian community invaded. In addition, such impacts may be mediated by previous changes to a variety of ecological processes associated with the particular riparian community. Land managers planning riparian restoration projects involving the control of *Tamarix* spp. should consider and address, as appropriate, other factors, such as existing hydrologic regimes, fluvial processes, and whether

Tamarix spp. stands are providing habitat for southwestern willow flycatchers (*Empidonax traillii extimus*), before proceeding with such projects.

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify ecosystem processes impacted: Tamarisk dominance in riparian areas changes hydrology by increasing overbank flooding and alters geomorphologic process. With the dominance of tamarisk, riparian areas have seen increases in fire frequency. Tamarisk's deep root and lateral branching enables it to draw down the water table and dense populations increase the salinity of the soil surface.
Rationale: Many reviews indicate that tamarisk reduces the width, depth, and water-holding capacity of river channels by trapping and stabilizing alluvial sediments, and thus increases the frequency and severity of overbank flooding (Dudley et al. 2000, Lovich 2000). Studies along the Green and Yampa rivers by Cooper et al. (2003) suggests that tamarisk stems change the landscape properties of gravel and cobble islands and bars, as well as those of adjacent channels. Near-bed flow velocities decreased and the sheer stress required to remobilize the channel bed increased. The dense woody roots of tamarisk increased the gravel bar's resistance to mobilization (Cooper et al. 2003). Fire appears to be less common in riparian ecosystems where tamarisk has not invaded. On dammed rivers, the structure of tamarisk stands may be more favorable to carry fire. Increases in fire size and frequency in riparian areas are attributed to a number of factors including an increase in ignition sources, increased fire frequency in surrounding uplands, and increased abundance of fuels (Busch and Smith 1993). Drier floodplain environments are the result of altered disturbance regimes such as dams and diversions, groundwater pumping, agriculture, and urban development, which have contributed to lower base flows, reduced water tables and changes in the frequency, timing and severity of flooding (Zouhar 2003). Tamarisk is a facultative phreatophyte and halophyte with a deep, extensive root system that extends to the water table, and is also capable of extracting water from unsaturated soil layers. Its primary root grows with little branching until it reaches the water table, at which point secondary root branching is profuse (Brotherson and Winkel 1986). Tamarisk evapotranspiration rates are among the highest levels of any phreatophyte evaluated in southwestern North America, including other native riparian trees. Several reviews and studies suggest that tamarisk has high transpiration rates and that tamarisk stands use more water than native vegetation, thus drawing down water tables, desiccating floodplains, and lowering flow rates of waterways (Brotherson and Field 1987). It is reported that tamarisk contains 41,000 ppm dissolved solids in its guttation sap (DiTomaso 1998). Tamarisk accumulates salt in special glands in its leaves, and then excretes it onto the leaf surface. These salts accumulate in the surface layer of soil when plants drop their leaves (Mozingo 1987). Brotherson and Field (1987) concluded that tamarisk deposited NaCl beneath its canopy as an allelochemical agent. Along regulated rivers that no longer experience annual flooding and scouring, surface soils become more saline over time (Busch and Smith 1993).
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition**,** structure, and interactions *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Identify type of impact or alteration: In altered riparian systems, tamarisk forms dense monotypic stands that compete with and replace native vegetation such as cottonwood and willow species. Despite similar competitive abilities, tamarisk is more tolerant of ground water declines than native species,

which may facilitate its establishment over native species. Tamarisk disrupts natural succession in native plant communities. It reduces seedling recruitment of other species through deposition of salts on the soil surface and creation of a new structural layer of litter. Native species are not adapted to increased fire frequency in tamarisk-dominated areas.

Rationale: Tamarisk communities are commonly associated with disruptions in historic disturbance regimes. Damming and subsequent management on most western rivers for water and electric power have resulted in increased evaporation and associated salinity, changes in erosion and sedimentation rates, and other physicochemical changes (Zouhar 2003).

Tamarisk dominated communities are often monotypic, though arrowweed and screwbean mesquite (*P. pubescens*) are common associates, and big saltbrush (*Atriplex lentiformis*) may occur in saline areas (Hasse 1972). Anderson et al 1977 described salt cedar communities along the lower Colorado River with salt cedar constituting 95 to 100% of the total trees. Cottonwood communities along the Colorado River, for example, have decreased from over 5,000 acres (2,000 ha) in the 1600s to less than 500 acres (200 ha) in 1998 (Briggs and Cornelius 1998). Tamarisk has since replaced up to 90% of the riparian communities historically dominated by cottonwood-willow forests. Tamarisk has almost completely replaced the native forest that historically dominated the riparian corridor from the Grand Canyon to the delta on the Gulf of California. It is by far the most abundant plant in the Colorado River delta, accounting for 40% of total ground cover (Westbrooks 1998).

In disturbed riparian environments where salinities are elevated or water tables depressed, tamarisk's deep root system gives it a competitive advantage over native, obligate phreatophytes (e.g. cottonwood and willow). Studies demonstrate that tamarisk is more tolerant of ground water declines that the native Goodings willow (*Salix goodingii*). Tamarisk is a facultative phreatophyte, with the ability to draw from the alluvial water table, but is also capable of surviving by extracting water, thus surviving indefinitely on unsaturated soils. In contrast, Goodings willow is an obligate phreatophyte, relying solely on the groundwater (Turner 1974, Stromberg 1997). Tamarisk seedlings are better able to survive water stress (i.e., low flows) and are more likely to survive until water becomes available, in contrast to *Salix* seedlings. This is one way that tamarisk is able to out-compete native vegetation and successfully invade disturbed riparian habitats (Horton and Clark 2001).

Tamarisk is less sensitive to changes in ground water availability than native riparian trees with which it is commonly associated. Greater tolerance of water stress can lead to tamarisk dominance on relatively dry riparian sites (Zouhar 2003). The longer a community has been invaded by tamarisk, the more xeric in nature are the plant species that occupy the understory. Deposits of salt-encrusted needle-like leaves are at times more than 1 m deep and can inhibit the germination of other species (Di Tomaso 1998). Research by Stromberg (1998) suggests that the functional role of tamarisk is context-specific and variable among rivers. In a study on a free-flowing river, understory herbaceous cover and species richness (including exotics) were significantly greater than in cottonwood stands, perhaps due to soil differences that developed between the two stand types (e.g., higher clay content in salt cedar soils). Stem densities of velvet mesquite (*Prosopis velutina*) and other woody successional species did not differ between tamarisk and cottonwood stands. However, stem densities for this group increased with stand age only for cottonwood, raising the possibility that tamarisk may disrupt successional pathways (Stromberg 1998).

Massive accumulations of duff found under tamarisk canopies (up to 1.5 m) prevented seeds of other species (including tamarisk) from reaching the soil surface. It was also observed that both in field and laboratory studies soils beneath tamarisk canopies were strongly hydrophobic. By water-proofing the soil with the resins and/or sugars of foliage, tamarisk reduces the survival of seedlings (including its own) beneath its canopy (Stevens 2001).

Competition was measured between tamarisk and coyote willow (*Salix exigua*) at various stages of growth. Neither species significantly reduced the germination of the other, but at the end of the second year, tamarisk seedlings growing in the presences of coyote willow suffered reduced growth and 15% higher mortality than in controls. In older class (5 year old) plants, coyote willow suppressed salt cedar growth only slightly (Stevens 2001).

In the Southwest among the few species that thrive in a tamarisk understory are 3 non-native brome grasses (*Bromus* spp.). A nonnative, honeydew-producing leafhopper found on tamarisk interacts with a fungus to change soil characteristics increasing saline conditions, so that plant recruitment is virtually eliminated under a tamarisk canopy (Simberloff and VanHolle 1999).

With the occupation of tamarisk some riparian areas have seen an increase in fire frequency, compared to the infrequent fires of low- to mid-elevation southwestern riparian plant communities dominated by cottonwood, willow and/or mesquite. While cottonwood and willow species can resprout following fire, tamarisk may be better adapted to the post-fire environment than native species, especially on dammed rivers. This creates an advantage for tamarisk over native species (Busch and Smith 1993).

Sources of information: See cited literature.

Question 1.3 Impact on higher trophic levels *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Identify type of impact or alteration: Tamarisk displaces native vegetation thus reducing the value of critical habitat for wildlife, including some endangered species. Studies also report that tamarisk plays an important ecological role for wildlife.

Rationale: It is debated as to whether tamarisk provides habitat and nest sites for some wildlife (e.g. white-winged dove), however, most authors have concluded that it has little value to most native amphibians, reptiles, birds, and mammals (Chen 2001).

Several studies conclude that tamarisk sustains only poor avian and invertebrate herbivore fauna (Cohan et al. 1978, Hunter et al. 1985, Johnson 1986), whereas other studies report tamarisk as playing a valuable ecological role by supporting herbivores and bird life (Beidieman 1971, Stevens 1976b, Brush 1983, Brown et al. 1984, Stevens and Waring 1985, Warren and Schwalbe 1985, Brotherson and Field 1987, Brown 1987).

Tamarisk has replaced the function of native tree species such as cottonwood (*Populus fremontii*) and Goodding willow (*Salix gooddingii*), to a point where some ecologists believe that tamarisk removal could have undesirable effects on endangered species such as the Southwest willow flycatcher (*Empidonax traillii extimus)* (D'Antonio 2000). The flycatcher has been documented as utilizing tamarisk for breeding and nesting purposes, even though reproductive success is lower in tamarisk as compared to native trees (Dudley et al. 2000).

At sites throughout the Middle Rio Grande Bewick's wrens nested only in native tree species, especially large cottonwoods (*Populus deltoides*). Analysis of data from 70 sites found wren abundance to be highest at sites dominated by cottonwoods, especially at sites having salt cedar (*Tamarix chinensis*) understories. However, at sites dominated by tamarisk, Bewick's wren abundance was low (Taylor 2003).

According to Johnson et al. (1999), the decreasing population of federally listed Southwest willow flycatchers coincides with changing vegetation communities in the bosque community. A bosque is a habitat with extremely moist soil, usually arising from mist, rains, or snow melt, with evergreen shrubs, willows, and an absence of trees. Formerly dominated by native cottonwood and willow, the banks of

the Rio Grande are now dominated by Russian olives and tamarisk, both introduced species. The flycatcher prefers the widely spaced branching of the willows where the bird scans for its prey of local insects. The flycatcher also prefers areas of the bosque covered by standing water or saturated soil (Buckley 1995). A literature review by Stephenson and Calcarone (1999) suggests that in some cases tamarisk invasions have reduced or eliminated water supplies for bighorn sheep, pupfish, and salamanders. Tamarisk may have negative impacts on threatened and endangered species such as Amargosa pupfish, warm springs pupfish, and speckled dace in Ash Meadows National Wildlife Refuge, Nevada; desert tortoise, and Nelson bighorn sheep, in Lake Mead National Recreation Area, Nevada (Chen 2001). In the Grand Canyon, tamarisk blossomed abundantly in early June, when few other flowers were available for pollinators. Several invertebrates were observed using tamarisk flowers (Thysanoptera, Coleoptera, some Lepidoptera, Diptera, and Hymenoptera). The significance of this resource for invertebrates could be important but has not been investigated. In a comparison of invertebrate herbivore communities associated with coyote willow and tamarisk, Stevens (1985) found that both species supported equivalent numbers of invertebrate herbivores, but coyote willow supported a more evenly distributed herbivore community with nearly 4 times as many species and a much lower standing crop than tamarisk (Stevens 1985).
Sources of information: See cited literature.
Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**

Identify impacts: No known hybridization.
Rationale: There are no native species within the family *Tamaricaceae* in North America. However, introduced species within the genus do hybridize readily with each other.
Sources of information: Kearney and Peebles (1960). Also considered personal communication with J. Gaskin (North America Flora author, *Tamarix*, 2004).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe role of disturbance: The construction of dams alter the hydrology and severely impact natural river flows, thus creating a climate for tamarisk invasion. The rate of tamarisk establishment increases with human and natural disturbance regimes, but it can establish independent of any known human or anthropogenic disturbance.
Rationale: The damming of rivers fed by snowmelt has shifted the time of peak discharge below the dams from spring to summer. This alteration creates conditions favorable to tamarisk seedling establishment, as seeds are just ripening in time with high flows, thus assisting establishment (Shafroth et al. 2002). The creation of lakes and reservoirs with large areas of fine sediment, provide the ideal substrate for tamarisk colonization along the margins. Reduced flood frequency downstream of reservoirs and more stabilized base flows in rivers due to reservoir construction have also created favorable conditions for tamarisk invasion (Everitt 1980). The clearing and plowing of floodplains and associated agricultural activity also aided tamarisk colonization during the 1800s. Tamarisk is also reported to rapidly infest riparian areas exposed to heavy grazing (Stromberg 1998). Once established, wind-borne seed dispersal can become established in otherwise undisturbed areas (DiTomaso 1998).
Sources of information: See cited literature.

Question 2.2 Local rate of spread with no management *Score:* **A** *Doc'n Level:* **Obs.**
Describe rate of spread: Infestations are doubling in <10 years.
Rationale: Since its introduction to the United States in the late 1890s tamarisk has established in nearly every lower-elevation streambed from northern Mexico to southern Canada and recent estimates

indicate infestations in the southwestern U.S. exceed 600,000 hectares (Brotherson and Field 1987). This increase represents at least a 4% increase per year. Tamarisk spread was calculated to be about 20 km of river length per year in the Colorado and Green River systems (Di Tomaso 1998). Working Group members inferred that southwestern trends reflect Arizona's populations of tamarisk.

Sources of information: See cited literature. Score based on inference.

Question 2.3 Recent trend in total area infested within state *Score:* **B** *Doc'n Level:* **Other pub.**

Describe trend: Increasing, but less rapidly than doubling area infested in <10 years.

Rationale: Because much of the riparian habitat in the western U.S. has been invaded by tamarisk, the rate of increase particularly in Arizona has slowed down. However, much of the Salt River through the Tempe and Phoenix area is characterized by scattered individuals of salt cedar, as well as along the Verde River. Salt cedar also occurs along the shore of the San Carlos reservoir and the San Pedro River in southern Arizona Salt cedar also co-dominates with camelthorn (*Alhagi maurorum*) at several sites at Wupatki National Monument in north-central Arizona (Zouhar 2003). The range of tamarisk is continuing to extend northward to Montana and Canada, and southward into northwestern Mexico (DeLoach 1989).

Sources of information: See cited literature.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Describe key reproductive characteristics: Tamarisk reproduce vegetatively and prolifically by seed. A single tamarisk tree produces a half million seeds a year.

Rationale: Tamarisk saplings mature rapidly, and some can flower after the first year of growth, but most individuals begin to reproduce in their third year. An Arizona study demonstrated that dense tamarisk stands can generate 100 seeds per square inch (Warren and Turner 1975). Seeds remain viable for several weeks and will germinate on saturated soils or while afloat. It can vegetatively resprout after fire, severe flood, or treatment with herbicides and it is able to accommodate wide variations in soil and mineral gradients in its environment (DiTomaso 1998). Tamarisk is largely insect-pollinated and wind pollination does not occur at a large extent (Stevens 2001).

Sources of information: See cited literature.

Question 2.5 Potential for human-caused dispersal *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**

Identify dispersal mechanisms: Anthropogenic factors that facilitate the spread of tamarisk include: intentional tamarisk plantings designed to protect stream banks, control erosion and act as wind breaks; conversion of native riparian forests to agricultural uses. Tamarisk is planted as an ornamental and shade tree and is still widely planted in Mexico. Today the largest human-caused dispersal of tamarisk is facilitated by dam management.

Rationale: Although wind dispersal and ornamental plantings cannot be ruled out as primary transport mechanisms, research on tamarisk dispersal from the Bighorn /Yellowstone River system suggest that boats and machinery transported propagules. Pearce and Smith (2003) studied concentrations and ages of saltcedar at the Musselshell River and Fort Peck Reservoir in Northern Montana to identify concentrations of plants that could be used to infer introduction location, establishment year, and mechanisms of dispersal. Their research suggests that seeds and other plant propagules were also transported to the reservoir by earth-moving equipment during site construction between 1966 and the mid-1980s and later by boats and their towing vehicles.

Stromberg (1998) found that conditions that favor cottonwood establishment (frequent winter flooding, high rates of stream flow during spring, exclusion of livestock, employed on the San Pedro River may have led to a decline of tamarisk. This demonstrates that tamarisk dispersal could be lessened by managing rivers toward a natural cycle in which conditions are favorable to cottonwood and willow establishment (Stromberg 1998).

Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **A** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Lightweight seeds can travel long distances in the wind. Flooding events can move stem and root fragments more than 1 km.
Rationale: Tamarisk seeds are tiny with long hairs that facilitate distribution via the wind, and are carried and deposited along sandbars and riverbanks by water. Stevens (2001) found that tamarisk germination was completed in less than one day after absorption of fluid and subsequent swelling. Stem and root fragments can also float downstream after fragmentation due to flooding events and establish in new areas.
Sources of information: See cited literature; also see DiTomaso (1998) and Lovich (2000).

Question 2.7 Other regions invaded *Score:* **B** *Doc'n Level:* **Other pub.**
Identify other regions: The genus *Tamarix* occurs naturally from western Europe and the Mediterranean to North Africa, northeastern China, India, and Japan. Since its escape from cultivation, salt cedar has spread primarily in the southwestern U.S., Texas and Mexico, although its distribution extends to many other parts of North America. It is especially pervasive in Arizona, New Mexico, western Texas, Nevada, and Utah but is also widespread in southern California, the Rocky Mountain states, the western Plains states, and parts of Oregon, Montana and Idaho. It occurs throughout broad regions of northwestern Mexico and is spreading along the Gulf of Mexico into the coastal prairie (Westbrooks 1998). Tamarisk is a problem in Ash Meadows Wildlife Refuge in Nevada, a montane wetland ecological type.
Rationale: Invades elsewhere but mostly in riparian ecological types that have already been invaded in Arizona. Montane wetlands are an exception. Further investigation should be made into whether tamarisk occurs in montane wetlands and playas in Arizona.
Sources of information: See cited literature; also see Zouhar (2003).

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Other pub.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Tamarisk was not identified in the western U.S. until the 1800s when it was introduced for sale as an ornamental shrub and a windbreak species. It was available in New York City in 1823, in Philadelphia in 1828, and in several nurseries along the eastern seaboard during the 1930s. Tamarisk was listed for sale by nurseries in California as early as 1856. First Arizona record for Tamarisk was from 1916 in Cochise County.
Rationale: Tamarisk is found in riparian communities dominated by green ash (*Fraxinus pennsylvanica*), Arizona sycamore (*Platanus wrightii*), Fremont cottonwood, and Goodding willow (*Salix gooddingii*) in Arizona (and New Mexico).
Sources of information: See Zouhar (2003). Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed February 10, 2004).

Question 3.2 Distribution *Score:* **A** *Doc'n Level:* **Obs.**
Describe distribution: In the southwestern United States, tamarisk occurs in every major watershed, in a variety of community types, many of them dominated by cottonwood (*Populus* spp.) and willow (*Salix* spp.).
Rationale: In Arizona tamarisk is abundant along streams in most of the state below 5,000 feet (1,525 m) and, though it grows in the Southwest at elevation up to 11,000 feet (3350 m), it does not spread rapidly above 4,000 feet (1220 m) (Kartesz and Meacham1999).

Sources of information: See cited literature; also see Zouhar (2003). Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed February 10, 2004) and Southwest Exotic Plant Mapping Program (SWEMP)-Cain Crisis map (available online at: http://cain.nbii.gov/cgibin/mapserv?map=../html/cain/crisis/crisismaps/crisis.map&mode=browse&layer=state&layer=county; accessed on February 10, 2004).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**Yes**	**[No]**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**[No]**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**[No]**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 7 Total unknowns: 0		
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	**C**
	southwestern interior wetlands	**D**
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**A**
	southwestern interior riparian	**B**
	montane riparian	**D**
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Anderson, B.W., A. Higgins, and R.D. Ohmart. 1977. Avian use of salt cedar communities in the lower Colorado River Valley. Pages 128–145 in R.R. Johnson and D.A. Jones (tech. coords.), Importance, Preservation and Management of Riparian Habitat: A Symposium. July 9, 1977, Tucson, Arizona. Gen. Tech. Rep. RM-43. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Beidieman, R.C. 1971. Cottonwood-salt cedar riverbottom. American Birds 25:646–648.

Briggs, M.K., and S. Cornelius. 1998. Opportunities for ecological improvement along the lower Colorado River and delta. Wetlands 18:513–529.

Brotherson, J.D., and D. Field. 1987. *Tamarix*: Impacts of a successful weed. Rangelands 9:110–112.

Brotherson, J.D., and V. Winkel. 1986. Habitat relationships of salt cedar (*Tamarix ramosissima*). The Great Basin Naturalist 46:535–541.

Brown, B.T., S.W. Carothers, and R.R. Johnson. 1984. Breeding range expansion of Bell's Vireo in Grand Canyon, Arizona Condor 85 499–500.

Brown, B.T. 1987. Fluctuating flows from Glen Canyon Dam and their effect on breeding birds of the Colorado River. GCES Rept. No. 23 (NTIS No. PB88-183538/AS). Salt Lake City, Utah.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Brush, T. 1983. First nesting of a New-world woodpecker in salt cedar (*Tamarix chinensis*). The Southwestern Naturalist 28:113.

Busch, D.E., and S.D. Smith. 1993. Effects of fire on water salinity relations of riparian woody taxa. Oecologia 94:186–194.

Buckley, M. 1995. Bosque birds. Quantum 12:2.

Chen, Linus Y. 2001. Cost savings from properly managing endangered species habitats. Natural Areas Journal 21:197–203.

Cohan, D.R., B.W. Anderson, and R.D. Ohmart. 1978. Avian population responses to salt cedar along the lower Colorado River. Pages 371–382 in R.R. Johnson and J.F. McCormick (tech. coords.), Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems: Proceedings of the Symposium. December 11–13, 1978, Callaway Gardens, Geogia. Gen. Tech. Rep. WO-12. U.S. Department of Agriculture, Forest Service, Washington, DC.

Cooper, D.J., D.C. Anderson, and R.A. Chimner. 2003. Multiple pathways for woody plant establishment on floodplains at local to regional scales. Journal of Ecology 91:182–196.

D'Antonio, C.M. 2000. Fire, plant invasions, and global changes. Pages 65−93 in H.A. Mooney and R.J. Hobbs (eds.), Invasive Species in a Changing World. Island Press, Washington, DC.

DeLoach, C.J. 1989. Prospects for biological control of salt cedar (*Tamarix* spp.) in riparian habitats of the southwestern United States. Pages 307−314 in E.S. Delfosse (ed.), Proceedings VII International Symposium of the Biological Control of Weeds. 1988, Rome, Italy. 1st Sper. Patol. Veg. (MAF).

DiTomaso, J.M. 1998. Impact, biology and ecology of salt cedar (Tamarix spp.) in the southwestern United States. Weed Technology 12:236−336.

Dudley, T.L., C.J. DeLoach, J.E. Lovich, and R.I. Carruthers. 2000. Salt cedar invasion of western riparian areas: impacts and new prospects for control. Transactions of the North American Wildlife and Natural Resources Conference 65:345−381.

Everitt. B.L. 1980. Ecology of salt cedar—a plea for research Environmental Geology 3:77−84.

Haase, E.F. 1972. Survey of floodplain vegetation along the lower Gila River in southwestern Arizona. Journal of the Arizona Academy of Science 7:75−81.

Horton, J.L. and J.L. Clark. 2001. Water table decline alters growth and survival of *Salix gooddingii* and *Tamarix chinensis* seedlings. Forest Ecology and Management 140:239−247.

Hunter, W.C., B.W. Anderson, and R.D. Ohmart. 1985. Summer avian community composition of *Tamarix* habitats in three southwestern desert riparian systems. Pages 128−134 in R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre (tech. coords.), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. First North American Riparian Conference. April 16−18, 1985, Tucson, Arizona. Gen. Tech. Rep. RM-120. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Johnson, S. 1986 Can salt cedar be controlled? The Nature Conservancy News, Oct.-Nov.:19−20. The Nature Conservancy, Arlington, Virginia.

Johnson, K., P. Mehlhop, C. Black, and K. Score. 1999. Reproductive failure of endangered southwestern willow flycatchers on the Rio Grande, New Mexico. Southwestern Naturalist 44:226–231.

Kartesz, J.T., and C.A. Meacham. 1999. Synthesis of the North American flora (Windows Version 1.0), [CD-ROM]. Available from: North Carolina Botanical Garden. In cooperation with the Nature Conservancy, Natural Resources Conservation Service, and U.S. Fish and Wildlife Service.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Lovich, J. 2000. *Tamarix* spp. Pages 312−317 in C.C Bossard, J. Randall, and M. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Mozingo, H.N. 1987. Shrubs of the Great Basin: A natural History. University of Nevada Press, Reno. 342 p.

Pearce, C.M., D.G. Smith. 2003. Salt cedar: distribution, abundance, and dispersal mechanisms, northern Montana, USA. Wetlands 23:215 −228.

Simberloff, D., and B. Von Holle. 1999. Positive interactions of nonindigenous species: invasional meltdown. Biological Invasions 1:21 −32.

Shafroth, P.B., J.C. Stromberg, and D.T. Patten. 2002. Riparian vegetation response to altered disturbance and stress regimes. Ecological Applications 12:107−123.

Stephenson, J.R., and G.M. Calcarone. 1999. Mountain and foothills ecosystems: habitat and species conservation issues. Pages 15−60 in J.R. Stephenson and G.M. Calcarone (eds.), Southern California Mountains and Foothills Assessment. Gen. Tech. Rep. PSW-GTR-172. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.

Stevens, L.E. 1976b. Insect production on native and introduced dominant plant species. Pp. 146-154 in Carothers, S.W. and S.W. Aitchison (eds.). An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, AZ. Colorado River Research Tech. Rept. No. 10. National Park Service, Grand Canyon, National Park, Grand Canyon.

Stevens, L.E. 1985. Invertebrate Herbivore Community Dynmaics in *Tamarix chinensis* Loureiro and *Salix exigua* Nuttall in the Grand Canyon, Arizona. Master's thesis. Northern Arizona University, Flagstff.

Stevens, L.E. 2001. A synthesis of information on the ecology and management of salt cedar (*Tamarix ramosissima*), with emphasis on the Grand Canyon region. Final progress report prepared for the Arizona Water Protection Fund.

Stevens, L.E., and G.L.Waring. 1985. The effects of prolonged flooding on the riparian plant community in Grand Canyon. Pages 81−86 in R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre (tech. coords.), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. Gen. Tech. Rep. RM-120. First North American Riparian Conference. April 16−18, 1985, Tucson, Arizona. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Stromberg, J.C., 1997. Growth and survivorship of Fremont cottonwood, Goodding willow, and salt cedar seedlings after large floods in central Arizona. Great Basin Naturalist 57:198−208.

Stromberg, J.C. 1998.Functional equivalency of salt cedar (*Tamarix chinensis*) and fremont cottonwood (*Populus fremontii*) along a free-flowing river. Wetlands 18:675−686.

Taylor, R.V. 2003. Factors influencing expansion of the breeding distribution of Bewick's wren into riparian forests of the Rio Grande in central New Mexico. Southwestern Naturalist 48:373−382.

Turner, R.M., 1974. Quantitative and historical evidence of vegetation changes along the upper Gila River, Arizona. U.S. Geological Survey Professional Paper 655-(H). 20 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Warren, D.K., and R.M. Turner. 1975. Salt cedar (*Tamarix chinensis*) seed production, seedling establishment and response to inundation. J. AZ Academy of Science 10:135−144.

Warren, P.L., and C.R. Schwalbe. 1985. Herpetofauna in riparian habitats along the Colorado River in Grand Canyon. Pages 347−354 in R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre (tech. coords.), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. Gen. Tech. Rep. RM-120. First North American Riparian Conference. April 16−18, 1985, Tucson, Arizona. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Westbrooks, R.G. 1998. Invasive plants: changing the landscape of America. Fact Book. Federal Interagency Committee for the Management of Noxious and Exotic Weeds, Washington, DC. 109 p.

Zouhar, K. 2003. *Tamarix* spp. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available online at: http://www.fs.fed.us/database/feis/; accessed April 22, 2004.

Other References of Interest No Cited in the Text

Carpenter, A.T. 1998. *Tamarix ramosissima* Ledebour, *Tamarix pentandra* Pallas, *Tamarix chinensis* Loureiro, and *Tamarix parviflora* De Candolle. Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documnts/tamaram.html; accessed September 23, 2004.

D'Antonio, C., and L.A. Meyerson. 2002. Exotic plant species as problems and solutions in ecological restoration: a synthesis. Restoration Ecology 10:703−13.

Hem, J. D. 1967. Composition of saline residues on leaves and stems of salt cedar (*Tamarisk pentandra* Pallas). Geological Survey Professional Paper 491-C. U. S. Geological Survey, Reston, Virgina.

Stevens, L.E. 1976a. An insect inventory of Grand Canyon. Pages 141−145 in S.W. Carothers and S.W. Aitchison (eds.). An Ecological Survey of the Riparian Zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, AZ. Colorado River Research Tech. Rept. No. 10. National Park Service, Grand Canyon, National Park, Grand Canyon.

Stevens, L. E. 1990. Pages 99−105 in M.R. Kunzmann, R.R. Johnson, and P.S. Bennett (tech. coords.), Tamarisk Control in Southwestern United States, Proceedings of Tamarisk Conference. September 2−3, 1987, University of Arizona, Tucson, Arizona. Special Report No. 9. National Park Service, Cooperative National Park Resources Studies Unit, School of Renewable Natural Resources, University of Arizona, Tucson.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Tribulus terrestris* L. (USDA 2005)
Synonyms:	None identified in USDA (2005).
Common names:	Puncturevine, bullhead, goathead, Mexican sandbur, Texas sandbur, caltrop, tackweed, ground burnut
Evaluation date (mm/dd/yy)**:**	05/01/03
Evaluator #1 Name/Title:	Katy Brown
Affiliation:	Nature Conservancy
Phone numbers:	(520) 622–3861
Email address:	pbrown5@mindspring.com
Address:	1510 E. Ft. Lowell Rd., Tucson, Arizona 85713
Evaluator #2 Name/Title:	Dana Backer, Conservation Ecologist
Affiliation:	Nature Conservancy
Phone numbers:	(520) 622–3861 ext 3473
Email address:	dbacker@tnc.org
Address:	1510 E. Ft. Lowell Rd., Tucson, Arizona 85713

List committee members:	D. Backer, C. Barclay, K. Brown, P. Guertin, F. Northam, R. Parades, W. Sommers, J. Ward, P. Warren
Committee review date:	09/19/03
List date:	09/19/03
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**D**	Other published material	**"Impact"** **Section 1 Score:** **D**	**"Plant Score"** **Overall Score:** **Evaluated but not listed** **Alert Status:** **None**
1.2	Impact on plant community	**D**	Other published material		
1.3	Impact on higher trophic levels	**D**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**C**	Other published material	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **9 pts** **Section 2 Score:** **C**	
2.2	Local rate of spread with no management	**U**	Observational		
2.3	Recent trend in total area infested within state	**D**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**B**	Other published material		
2.6	Potential for natural long-distance dispersal	**B**	Other published material		
2.7	Other regions invaded	**C**	Other published material		 Something you should know.
3.1	Ecological amplitude	**U**	Observational	**"Distribution"** **Section 3 Score:** **U**	
3.2	Distribution	**U**	Observational		

Table 3. Documentation

Note: Questions 3.1 and 3.2 below were each assigned a score of **U** based on Working Group consensus. A **U** score was assigned because *Tribulus terrestris* is naturalized—that is, self-sustaining populations occur without direct intervention by humans, but the species does not necessarily invade natural, semi-natural, human-made ecosystems (Richardson et al. 2000)—throughout Arizona and exists in association with several ecological types, but its known occurrences are within the anthropogenically disturbed areas where it is known to be present. Working Group members could not identify an ecological type outside of urban or wildland-urban interface areas where *T. terrestris* was known to invade or exist. This is not to say that it does not exist in natural areas or working landscapes. If a soil disturbance is present within an area, *T. terrestris* has the potential to invade. Criteria standards assign all species with a **D** rating in section one (questions 1.1 through 1.4) an overall score of "**Evaluated but not listed**." As a result, even if the responses to questions 3.1 and 3.1 were different—even including a score of **A** for both questions—they would not affect the overall score. Working Group follow-up on Consistency Review Panel comments did not alter the score for section one.

The Working Group concluded having the above documentation was relevant, because *T. terrestris* represents a unique case. It is distinguishable from those species that are clearly present within wildlands in a variety of ecological types, but whose specific frequency of occurrence within these ecological types may be unknown. In contrast, *T. terrestris* may occur in juxtaposition to a variety of ecological types, but clear documentation is lacking that it actually occurs within the wildland occurrences of these types.

Question 1.1 Impact on abiotic ecosystem processes *Score:* **D** *Doc'n Level:* **Other pub.**
Identify ecosystem processes impacted: Negligible impacts to soil temperature and moisture.
Rationale: From Holm et al. (1991): water requirements of *T. terrestris* are low compared with other plants (assumed to be crops). In studies in Texas, Davis and Wiese (1964) found *T. terrestris* required 96 kg of water to produce 1 kg of dry matter as contrasted with sorghum or alfalfa that require about 300 to 840 kg of water to produces 1 kg of dry matter. Davis et al. (1965) found *T. terrestris* to be able to extract 14.1 kg of water per plant in excess of the rainfall received, this amount indicating an ability of the plant to remove water from soil at very high moisture tension (experiments were conducted in agricultural settings). *Tribulus terrestris* forms a taproot thus providing the mechanism for acquiring (requiring) more water. Holm et al. (1991) also suggest that problems and losses due to *T. terrestris* are of economic concern, predominately agriculture, because of the plant's ability to extract soil moisture from great depths. Roots can develop nitrogen-fixing nodules (CDFA 2003). Other reviews of the literature do not suggest there is an impact on natural abiotic processes.
Sources of information: See cited literature.

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **D** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: Negligible.
Rationale: From Guertin and Halvorson (2003): in Australia, sensitive to competition typically where perennial plants are maintained (Squires 1969). In India, it was noted that *T. terrestris* does not grow in continuous patches and is associated with sunny locations on a site (Pathak 1970). When it is observed in continuous patches on a site, the competition is low on the site (Pathak 1970). F. Northam (personal communication, 2003) commented that *T. terrestris* can be problematic for restoration projects.
Sources of information: See cited literature. Also considered personal communication with F. Northam (Noxious Weed Coordinator, Arizona Department of Agriculture, 2003).

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Negligible; human nuisance, injurious to grazing animals, foliage toxic to livestock.
Rationale: Impacts to grazing animals: foliage toxic (Schmutz et al. 1968 in Holm et al. 1991, CDFA 2003) and grazing animals [ungulates] eat burrs, which causes injuries to mouth, stomach, and intestines (WSNWCB 2001). No known studies on native fauna. Ants seem to congregate under plants and particularly near stem emergence (Working Group member observations). The species is out-competed by native forage, does not occur as continuous coverage, and is sensitive to competition. It is known predominantly from disturbed areas. The presumed impact on higher trophic levels is inferred to be negligible (Working Group inference).
Sources of information: See cited literature. Documentation level is observational based on inference by the Working Group, because impacts have not been directly observed on native fauna and the species rarely exists outside of agricultural and urban settings.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: No known hybridization.
Rationale: No known hybridization and no native *Tribulus* in Arizona. Native caltrop (*Kallstroemia)* looks similar but flowers at different times of year.
Sources of information: Kearney and Peebles (1960).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **C** *Doc'n Level:* **Other pub.**
Describe role of disturbance: *Tribulus terrestris* requires disturbance to establish and is most often associated with an anthropogenic disturbance.
Rationale: Habitat is disturbed places, along streets, roadsides, railways, cultivated fields and orchards, pastures, lawns and yards, waste places, walk ways, etc.
Sources of information: See CDFA (2003), Parker (1972) and Hickman (1993) in Guertin and Halvorson (2003).

Question 2.2 Local rate of spread with no management *Score:* **U** *Doc'n Level:* **Obs.**
Describe rate of spread: Unknown.
Rationale: Because *Microlarinus lareyneii* and *M. lypriformis* were introduced as a biocontrol agents in 1957 it is not known what the local spread would be with no management. As a result, because a biocontrol is currently in place, we do not known the rate of spread as of the last 20 to 30 years. From Gould and DeLoach (2002): these weevils became established in Arizona and California. The project has been considered a substantial success in non-irrigated areas, and a partial success overall. Fifteen years after the introduction of the weevils, the coverage and seed production of *T. terrestris* had declined more than 80% in twelve hundred field plots in California (Huffaker et al. 1983). The weevil was introduced into California and Nevada in 1961 and shortly thereafter in several other western states (does not mention which western states; Huffaker et al. 1961).
Sources of information: See cited literature. Score based on inference based on the literature by the Working Group.

Question 2.3 Recent trend in total area infested within state *Score:* **D** *Doc'n Level:* **Obs.**
Describe trend: Declining.

Rationale: Because of the success of the weevil, it is thought that the extent of infestation is declining overall. Where infestation is occurring in new areas, it is within areas of anthropogenic disturbance and not within wildlands.
Sources of information: Working Group inference based on literature cited in question 2.2.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Rev. sci. pub.**
Describe key reproductive characteristics: High viable seed output; viable after dormancy; can reproduce by both cross- and self-pollination; staggered germination; long-range dispersal; temperature and water limited; competition sensitive.
Rationale: Due to both cross pollination (CDFA 2003) and self pollination with seed set there is a potential of 100% reproduction capability (Reddi et al. 1981). Boydston (1990) reports that plants produced from 200 to 5600 burrs/plant and each burr contains up to 5 nutlets, and each nutlet can contain 2 to 5 seeds. Fruits only 10 days old potentially have viable seeds (Johnson 1932 in Squires 1979, as cited in Guertin and Halvorson 2003). Seeds remain viable for several years (CDFA 2003), staying dormant in the soil for 4 to 5 years (Whitson 1992). Seeds emerge at similar or increasing levels over several years from a given year's seed crop, which may enable *T. terrestris* to persist in spite of weed control programs (Boydston 1990). Seedlings emerge during early spring through summer, often in flushes following increased soil moisture (CDFA 2003).
Sources of information: See literature citations; original sources of information not available and therefore Guertin and Halvorson (2003) was used as a review of the literature.

Question 2.5 Potential for human-caused dispersal *Score:* **B** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Moderate potential based on fruit morphology and mechanism for dispersal.
Rationale: Spiny fruits are weed's primary means of dissemination-arrangement, length and angle of spines ensures placement on tires (vehicles, bikes, airplanes), shoes, clothing, pets, etc. Mountain bikes and off-road vehicles pose a potential threat to dispersing seeds into wildlands and at distances greater than 1 km. Due to the lack of studies or reports commenting on *T. terrestris* in wildlands and based on fruit morphology, it is inferred to have a moderate human caused dispersal rate. Can also be found in contaminated seed and feed (Johnson 1932 in Gould and Deloach 2002)
Sources of information: See cited literature; also see citations in Guertin and Halvorson (2003) and Holm et al. (1991).

Question 2.6 Potential for natural long-distance dispersal *Score:* **B** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Animals and possibly water.
Rationale: From Guertin and Halvorson (2003): fruits easily attach to animals fur thus facilitation long distance dispersal (it is not stated but the assumption is livestock fur). Sources of information in Guertin and Halvorson (2003): Ernst and Tolsma (1988), Squires (1979), and Whitson (1992). Fruits can also imbed themselves in hooves and feet a subsequently break off when animals try to rid themselves of the irritation (Ridley 1930). It was suggested by Working Group members that fruits of *T. terrestris* could float in water and be dispersed >1 km but no documentation was found to support this idea.
Sources of information: See cited literature.

Question 2.7 Other regions invaded	*Score:* **C** *Doc'n Level:* **Other pub.**
Identify other regions: Same ecological types invaded elsewhere.	
Rationale: Throughout California to Wyoming, eastern U.S., Central Mexico (Johnson 1932 In: CDFA 2003). Found most commonly in pastures, roadsides, orchards, vineyards, waste places, parks, railway yards and agricultural areas. In tropical regions *T. terrestris* develops woody roots and becomes perennial (CDFA 2003). Occurs in areas with mean annual minimum precipitation of 11 inches and maximum precipitation of 15 inches (Rice 2002). Requires relatively high temperatures for growth (WSNWCB 2001) and is intolerant of freezing temperatures (Squires 1979 in Guertin and Halvorson 2003, CDFA 2003). Can be killed by frost or drought (Squires 1979 in Guertin and Halvorson 2003). Adapted to warm and temperate regions (WSNWCB 2001). Prevalent in areas with hot summers on dry soils (CDFA 2003). Requires high temperatures and prefers dry, sandy soils but tolerates most soil types (WSNWCB 2001, CDFA 2003).	
Sources of information: See cited literature.	

Question 3.1 Ecological amplitude	*Score:* **U** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: In Arizona, *T. terrestris* is found below 7000 feet (Parker 1972). *Tribulus terrestris* habitat is disturbed places, along city streets and roadsides, railways, cultivated fields and orchards, pastures, lawns and yards, waste places, walkways (Parker 1972, Hickman 1993, CDFA 2003). Several herbarium records (SEINet 2003) exist from pine-oak woodlands; locales with elevations documented at 3500 feet at Coyote Mountain (present along with *Acacia* sp., *Prosopis* sp, and *Fouquieria splendens*) and at 6900 feet (Apache County), and at Havasu Canyon, lower Bonita Canyon in the Chiricahua National Monument, and Diamond Creek in Grand Canyon National Park. None of these records, however, specify whether the occurrence is independent of anthropogenic disturbance. Foy et al. (1983 in Guertin and Halvorson 2003) reports "presumably" [*Tribulus*] was unintentionally imported into U.S. on military planes from the Sahara Desert region and other reports suggest it was accidentally imported from the Mediterranean into the U.S. on livestock (Andres and Goeden 1995 in Gould and DeLoach 2002). First reported in California in 1903 (Davidson 1903 in Squires 1979 in Guertin and Halvorson 2003). First record noted in the University of Arizona herbarium was for 1905 (SEINet 2003).	
Rationale: Restricted to disturbed areas. Because the ecological amplitude of *T. terrestris* is so broad, it can invade most ecological types in Arizona when they are anthropogenically disturbed to a significant degree (that is, the species generally would not occur in natural areas). Because Working Group members could not identify an ecological type outside of urban or wildland-urban interface areas where *T. terrestris* was known to invade or exist, a score of **U** was assigned for each ecological type that an occurrence of *T. terrestris* was documented as occurring nearby (see Worksheet B).	
Sources of information: See cited literature. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2003). Score based on the literature, observations, and inference by Working Group members.	

Question 3.2 Distribution	*Score:* **U** *Doc'n Level:* **Obs.**
Describe distribution: Found throughout Arizona (Kearney and Peebles 1960, Parker 1972, McDougall 1973).	
Rationale: See comments under question 3.1.	

Sources of information: Score based on the literature, observations, and inference by Working Group members.

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**[No]**	**1 pt.**
	Total pts: 8	**Total unknowns: 0**	
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	**U**
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	**U**
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	**U**
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	**U**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Andres, L.A., and R.D. Goeden. 1995. Puncture vine. In J.R. Nechols and others (eds), Biological Control in the Western United States: Accomplishments and Benefits of Regional Research Project W-84, 1964−1989. University of California Publication 3361.

Boydston, R.A. 1990. Time of emergence and seed production of Longspine sandbur (*Cenchrus longispinus*) and Puncture vine (*Tribulus terrestris).* Weed Science 38:16−21.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

[CDFA] California Department of Food and Agriculture. 2003. *Tribulus*. In E.A. Healy, S. Enloe, J.M. DiTomaso, B. Roberson, N. Dechoretz, S. Schoenig, P. Akers, L. Butler, and J. Garvin (eds.), Encycloweedia. Non-Cropland Weed group, University of California Extension Service, Weed Science Program, Department of Vegetable Crops, The University of California, Davis, California. Available online at: http://pi.cdfa.ca.gov/weedinfo/TRIBULUS2.htm.

Davidson, A. 1903. New plant records for Los Angeles County, Part II. Southern California Academy of Science Bulletin 2:43.

Davis, R., and A. Wiese. 1964. Weed root growth patterns in the field. Pages 367−368 in H. Andrews (ed.), Proceedings of the 17th Southern Weed Conference. University of Tennessee, Knoxville.

Davis, R., A. Wiese, J. Pafford. 1965. Root moisture extraction profiles of various seeds. Weeds 13:98−100.

Ernst, W.H., and D.J. Tolsma. 1988. Dormancy and germination of semi-arid annual plan species, *Tragus berteronianus* and *Tribulus terrestris*. Flora 181(3/4):243−251.

Foy, C.L., D.R. Forney, and W.E. Cooley. 1983. History of weed introductions. In C.L. Wilson and C.L. Graham (eds.), Exotic Plant Pests and North American Agriculture. Academic Press, New York. 522 p.

Gould, J.R., and C.J. DeLoach. 2002. Biological control of invasive exotic plant species; protocol, history, and safeguards. Pages 284−306 in B. Tellman (ed.), Invasive Exotic Species in the Sonoran Region. The University of Arizona Press and the Arizona-Sonora Desert Museum, Tucson.

Guertin, P., and W.L. Halvorson. 2003. Status of Fifty Introduced Plants in Southern Arizona Parks. U.S. Geological Survey, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson. Available online at: http://sdrsnet.srnr.arizona.edu/index.php?page=datamenu&lib=2&sublib=13; accessed November 2004.

Hickman, J.C. (ed.). 1993. The Jepson Manual: Higher Plants of California. University of California Press, Berkeley. 1400 p.

Holm, L.G., D.L. Plucknett, J.V. Pancho, and J.P. Herberger. 1991. The World's Worst Weeds: Distribution and Biology. Krieger Publishing Company, Malabar, Florida. 609 p.

Huffacker, C.B, D.W. Ricker, and C.E. Kennett. 1961. Biological control of puncturevine with imported weevils. Calif. Agric. 15:11–12.

Huffacker, C.B., J. Hamai, R.M. Nowierski. 1983. Biological control of puncturevine, *Tribulus terrestris*, in California after twenty years of activity of introduced weevils. Entomophaga 28:387–400.

Johnson, E. 1932. The puncture vine in California. Agricultural Experiment Station Bulletin 528. University of California, College of Agriculture.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

McDougall, W.B. 1973. Seed Plants of Northern Arizona. The Museum of Northern Arizona. Flagstaff. 594 p.

Parker, K.F. 1972. An Illustrated Guide to Arizona Weeds. The University of Arizona Press, Tucson. 338 p. Available online at http://www.uapress.arizona.edu/online.bks/weeds/puncture.htm; accessed July 2003.

Pathak, P.S. 1970. Contributions to the ecology of *Tribulus terrestris* Linn. II. Habitat studies. Agra University Journal of Research Science 19:149–166.

Reddi, C.S., E.U. Reddi, and N.S. Reddi. 1981. Breeding structure and pollination ecology of *Tribulus terrestris*. Proceedings of the Indian National Science Academy, Part B 47:185–193.

Rice, P.M. 2002. INVADERS Database System, University of Montana, Division of Biological Sciences, Missoula, Montana. Available online at: http://invader.dbs.umt.edu.

Richardson, D.M., P. Pyšek, M. Rejmánek, M.G. Barbour, F.D. Panetta, and C.J. West. 2000. Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions 6:93–107.

Ridley, H.N. 1930. The Dispersal of Plants throughout the World. L. Reeve and Co., Ltd., Ashford, Kent. 744 p.

Schmutz, E., B. Freeman, and R. Reed. 1968. The Livestock Poisoning Plants of Arizona. University of Arizona Press, Tucson. 176 p.

Squires, V.R. 1969. Ecological factors contributing to the success of *Tribulus terrestris* L. as a weed in a winter rainfall environment in southern Australia. Proceedings of the Ecological Society of Australia 4:55–66.

Squires, V.R. 1979. The biology of Australian weeds. 1. *Tribulus terrestris* L. Journal of the Australian Institute of Agricultural Science 45:75–82.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

[WSNWCB] Washington State Noxious Weed Control Board. 2001. Puncture vine (*Tribulus terrestris* L.). Available online at: http://www.wa.gov/weed_info/puncturevine.html; accessed June 2003.

Whitson, T.D. (ed.). 1992. Weeds of the West. The Western Society of Weed Science in cooperation with the Western United States Land Grant Universities Cooperative Extension Services and the University of Wyoming. 630 p.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Ulmus pumila* L. (USDA 2005)
Synonyms:	None listed in USDA (2005).
Common names:	Siberian elm (sometimes erroneously identified as Chinese elm [*Ulmus parvifolia*])
Evaluation date (mm/dd/yy)**:**	08/06/04
Evaluator #1 Name/Title:	Jeff Schalau/Associate Agent, Agriculture and Natural Resources
Affiliation:	University of Arizona Cooperative Extension, Yavapai County
Phone numbers:	Phone: (928) 445−6590 ext. 251; Fax: (928) 445−6593
Email address:	jschalau@ag.arizona.edu
Address:	840 Rodeo Dr #C, Prescott, Arizona 86305
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	08/06/04: W. Albrecht, W. Austin, D. Backer, J. Hall, L. Moser, F. Northam, B. Phillips, J. Schalau, K. Watters 10/22/04: W. Albrecht, D. Backer, L. Moser, B. Phillips, J. Schalau
Committee review date:	08/06/04 and 10/22/04
List date:	10/22/04
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

Question		Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**C**	Observational	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **None**
1.2	Impact on plant community	**B**	Other published material		
1.3	Impact on higher trophic levels	**C**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Observational	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **11 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**U**	Observational		
2.4	Innate reproductive potential	**A**	Other published material		
2.5	Potential for human-caused dispersal	**B**	Other published material		
2.6	Potential for natural long-distance dispersal	**C**	Observational		
2.7	Other regions invaded	**C**	Other published material		 Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **B**	
3.2	Distribution	**C**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes *Score:* **C** *Doc'n Level:* **Obs.**
Identify ecosystem processes impacted: *Ulmus pumila* has the potential to utilize soil moisture, capture light, and utilize moisture that would otherwise be available to native species.
Rationale: Research and subsequent publications are focused on areas outside of Arizona. *Ulmus pumila* germinates and grows rapidly in disturbed areas with available soil moisture. It is a deciduous tree with a dense canopy that will capture available light between spring and fall. This could reduce temperatures in the understory and alter site microclimate. Although little information is available on this species, it is invading native plant communities in Arizona and New Mexico. *Ulmus pumila* also has the capacity to store quantities of water in its trunk. Significant amounts of xylem fluid was observed leaking from a cut stump in New Mexico (A. Fletcher, personal communication, 2004).
Sources of information: Personal observations by J. Schalau (Associate Agent, Agriculture and Natural Resources, University of Arizona Cooperative Extension, Yavapai County, Prescott, Arizona, 2004) and personal communication with A. Fletcher (Invasive Species Coordinator, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 2004).

Question 1.2 Impact on plant community composition, structure, and interactions *Score:* **B** *Doc'n Level:* **Other pub.**
Identify type of impact or alteration: *Ulmus pumila* has the potential to displace all native vegetation when density is high. Species displaced in riparian communities would primarily be cottonwoods and willows. Once established in riparian areas, seedlings can become established on adjacent uplands. *Ulmus pumila* can impact grasses and forbs when growing in very dense, multi-aged concentrations. It can virtually preclude other vegetation from growing, leading to increased erosion in some areas (A. Fletcher, personal communication, 2004). The effects on other plant communities (meadows and upland areas) are unknown.
Rationale: *Ulmus pumila* is an aggressive competitor once established. Densities of 2,100 seedlings on one-half acre have been documented in New Mexico (USDA 2004). Fast growing seedlings quickly overtake native vegetation, especially shade-intolerant species (Wieseler 2004). In Illinois *U. pumila* has invaded and, after a few years, dominated prairie areas particularly where disturbance has occurred (Illinois Natural History Survey 1990).
Sources of information: See cited literature. Also considered personal observations by J. Schalau (Associate Agent, Agriculture and Natural Resources, University of Arizona Cooperative Extension, Yavapai County, Prescott, Arizona, 2004) and personal communication with A. Fletcher (Invasive Species Coordinator, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 2004).

Question 1.3 Impact on higher trophic levels *Score:* **C** *Doc'n Level:* **Obs.**
Identify type of impact or alteration: Bird populations in riparian areas may be reduced after invasion by *U. pumila*. It has displaced cottonwoods and willow used for nesting sites by native birds (A. Fletcher, personal communication, 2004).
Rationale: *Ulmus pumila* may affect higher trophic levels indirectly through displacement of native vegetation. Birds seem avoid nesting in *U. pumila*, although they may eat the seeds. *Ulmus pumila* also has an associated insect: the elm leaf beetle (*Pyrrhalta luteola*). This insect is native to southern Europe and is widely established in North America. Adults and larvae feed on the leaves during the growing season and the insect has no known affect on other trophic levels.
Sources of information: Personal communication with A. Fletcher (Invasive Species Coordinator, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 2004).

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n Level:* **Other pub.**
Identify impacts: No known hybridization.
Rationale: No native species of *Ulmus* occur in Arizona (Kearny and Peebles 1960). No literature sources found related to the ability of *U. pumila* to hybridize. *Ulmus pumila* does not appear to hybridize with any other plants in Arizona.
Sources of information: See cited literature.

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score :* **B** *Doc'n Level:* **Obs.**
Describe role of disturbance: Disturbed soils due to construction impacts, land management activities, vehicles, and recreational impacts are primary anthropogenic disturbances that promote *U. pumila* establishment. Flooding, wind erosion, fire, and wildlife impacts are primary natural disturbance factors that promote *U. pumila* establishment.
Rationale: Motor vehicles, grazing animals, and recreational enthusiasts are all potential contributors to anthropogenic disturbance factors that lead to invasion by *U. pumila*. In riparian areas, periodic flooding and subsequent soil disturbance creates niches for *U. pumila* establishment. Thickets of seedlings can be found where *U. pumila* has been planted or naturalized individuals are well-established. A major means of movement and establishment is road construction and widening, and roadside maintenance at time trees are seeding. It has also been observed spreading into edges of undisturbed grasslands, uplands adjacent to riparian areas, forested lands, and along irrigation ditches (A. Fletcher, personal communication, 2004).
Sources of information: Personal observations by J. Schalau (Associate Agent, Agriculture and Natural Resources, University of Arizona Cooperative Extension, Yavapai County, Prescott, Arizona, 2004) and personal communication with A. Fletcher (Invasive Species Coordinator, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 2004).

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n Level:* **Obs.**
Describe rate of spread: *Ulmus pumila* increases rapidly spreads quickly once established in an area, but does not double in 10 years. Many mature trees grow in areas where they were not planted.
Rationale: *Ulmus pumila* has been and continues to be planted as a shade tree in Arizona and New Mexico. From these areas, it has spread into riparian areas, along roadsides, and into disturbed waste areas. Where this has occurred, trees of all ages are present indicating successful colonization and continuous spread. April Fletcher (personal communication, 2004) has observed that as soon as at least one tree matures and begins to produce seed, successive spread can be very rapid. Where establishment occurs, there may be 6 to 10 seedlings the first year, and every year subsequently. The seedlings and young trees frequently grow between three and five feet per year even when moisture levels are below normal.
Sources of information: Personal observations by J. Schalau (Associate Agent, Agriculture and Natural Resources, University of Arizona Cooperative Extension, Yavapai County, Prescott, Arizona, 2004) and personal communication with A. Fletcher (Invasive Species Coordinator, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 2004).

Question 2.3 Recent trend in total area infested within state *Score:* **U** *Doc'n Level:* **Obs.**
Describe trend: *Ulmus pumila* is increasing in several locations within Arizona. However, the author is unaware of any new regions being colonized. No extensive management efforts are underway in Arizona. However, some landowners (mostly home gardeners) are working to control it on their land because of its invasiveness.
Rationale: *Ulmus pumila* was widely introduced as a fast growing shade tree in many areas of Arizona in the late 1800s and early 1900s. It also happens to be drought-tolerant which increases its

chance of survival in rural plantings. It is the author's opinion that its range is not necessarily increasing.
Sources of information: Personal observations by J. Schalau (Associate Agent, Agriculture and Natural Resources, University of Arizona Cooperative Extension, Yavapai County, Prescott, Arizona, 2004).

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n Level:* **Other pub.**
Describe key reproductive characteristics: *Ulmus pumila* is a fast growing tree that produces abundant seed crops in the spring of the year, germinates rapidly, and is not easily killed unless entire root crown is removed or herbicides are applied.
Rationale: *Ulmus pumila* has a minimum seed-bearing age of eight years and produces many winged fruit, each of which contains a single seed. Where trees are abundant, hundreds of thousands of seeds blow in the wind and become piled in drifts. The seeds can remain viable for eight years and readily germinate and produce blankets of seedlings in areas void of other vegetation. The seedlings grow rapidly, putting down a deep taproot which allows it to successfully compete with native vegetation. Rapid and prolific resprouting can occur when the shoot is removed or disturbed.
Sources of information: See USDA (1974, 2004). Also considered personal observations by J. Schalau (Associate Agent, Agriculture and Natural Resources, University of Arizona Cooperative Extension, Yavapai County, Prescott, Arizona, 2004) and personal communication with A. Fletcher (Invasive Species Coordinator, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 2004).

Question 2.5 Potential for human-caused dispersal *Score:* **B** *Doc'n Level:* **Other pub.**
Identify dispersal mechanisms: Human caused dispersal of *U. pumila* is ongoing: it is still being promoted and sold in nurseries for landscape use. It is planted as a shade tree in areas where irrigation water is limited and new plants are often allowed to grow or locally transplanted by landowners to more desirable locations. Seeds can also be inadvertently transported by vehicles (windshields, truck beds, vents, etc.) and introduced to new areas. *Ulmus pumila* was also widely planted because it less severely affected by Dutch Elm Disease: a disease caused by the fungus *Ophiostoma ulmi* (= *Ceratocystis ulmi*) that is transmitted by bark beetles or through root grafts (Stack et. al. 1996).
Rationale: *Ulmus pumila* can be found in many public plantings (parks, landscapes, etc.). Sales of *Ulmus pumila* have decreased due to introductions of Dutch Elm Disease resistant cultivars of American elm (*Ulmus americana*).
Sources of information: See cited literature.

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n Level:* **Obs.**
Identify dispersal mechanisms: Wind is the natural dispersal mechanism for Ulmus pumila. Birds may transport *Ulmus pumila* seeds considerable distances to start new populations.
Rationale: Although it is possible to transport *U. pumila* seed further than one kilometer, it is the author's opinion that this is a rare occurrence. It would certainly have a greater potential to be transported long distances where vegetative cover is reduced (grazed grasslands or fallowed farmland) or on smooth paved surfaces. Some *U. pumila* populations in New Mexico appear to have been started by birds because no other logical mechanisms were apparent (A. Fletcher, personal communication, 2004).
Sources of information: Personal observations by J. Schalau (Associate Agent, Agriculture and Natural Resources, University of Arizona Cooperative Extension, Yavapai County, Prescott, Arizona, 2004) and personal communication with A. Fletcher (Invasive Species Coordinator, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 2004).

Question 2.7 Other regions invaded *Score:* **C** *Doc'n Level:* **Other pub.**
Identify other regions: *Ulmus pumila* has invaded similar areas in New Mexico as it has in Arizona. However, in New Mexico, it has been identified as a riparian invader and efforts are underway to aggressively control it. In Illinois, it has invaded dry and mesic prairies, including sand prairies (Illinois Natural History Survey 1990).
Rationale: *Ulmus pumila* is listed as a noxious weed in New Mexico and is present in all other surrounding states. In New Mexico it is typically found in riparian areas, but has been observed to invade roadsides, meadows, pinyon/juniper woodlands, and upland areas. Infestations are present in the upper reaches of the Rio Grande, Pecos River, and other river systems, and are spreading into higher elevations (USDA 2004).
Sources of information: See cited literature.

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n Level:* **Obs.**
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: *Ulmus pumila* was introduced to the United States in the 1860s as a landscape tree (USDA 1974). The oldest verified herbarium specimen was collected on April 22, 1962 in west Tempe (SEINet 2005). *Ulmus pumila* has been observed in riparian areas, roadsides, and waste areas at 3,500 to 8,000 foot elevations in northern Arizona and New Mexico. Some evidence exists that indicates *U. pumila* may spread to elevations higher than 8,000 feet in New Mexico.
Rationale: Although riparian areas are the most prevalent ecosystem affected by *U. pumila*, it has observed it in grasslands, shrublands, and ponderosa pine forests of northern Arizona (J. Schalau, personal observations, 2004). It has also invaded pinyon-juniper woodlands in New Mexico (A. Fletcher, personal communication, 2004).
Sources of information: Personal observations by J. Schalau (Associate Agent, Agriculture and Natural Resources, University of Arizona Cooperative Extension, Yavapai County, Prescott, Arizona, 2004), personal communication with A. Fletcher (Invasive Species Coordinator, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, 2004),and information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed May 2005).

Question 3.2 Distribution *Score:* **C** *Doc'n Level:* **Obs.**
Describe distribution: Occurrence within ecological type is at the highest between 5 to 20% (see Worksheet B).
Rationale: See Worksheet B.
Sources of information: Personal observations by J. Schalau (Associate Agent, Agriculture and Natural Resources, University of Arizona Cooperative Extension, Yavapai County, Prescott, Arizona, 2004).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**Yes**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**Yes**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**No**	**1 pt.**
	Total pts: 7 Total unknowns: 0		
	Score : A		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	**D**
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	**C**
	montane riparian	
Woodlands	Great Basin conifer woodland	**D**
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	**D**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Illinois Natural History Survey. 1990. Vegetation Management Guideline Siberian Elm (*Ulmus pumila* L.). Vol 1, No. 21. 3 p. Available online at: http://www.inhs.uiuc.edu/chf/outreach/VMG/sibelm.html; accessed August 3, 2004.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Stack, R.W., D.K. McBride, and H.A. Lamey. 1996. Dutch Elm Disease. North Dakota Cooperative Extension Publication PP-324. Available online at: http://www.ext.nodak.edu/extpubs/plantsci/trees/pp324w.htm.

[USDA] U.S. Department of Agriculture, Forest Service. 1974. Seeds of Woody Plants in the United States. USDA Handbook 450. 883 p.

[USDA] U.S. Department of Agriculture, Forest Service. 2004. Strategy for Long-Term Management of Exotic Trees in Riparian Areas for New Mexico's Five River Systems. Draft Technical Report. U.S. Department of Agriculture, Forest Service, Southwestern Region. 26 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Wieseler, S. 2004. Siberian Elm. Plant Conservation Alliance, Alien Plant Working Group, 4 p. Available online at: http://www.nps.gov/plants/alien/fact/ulpu1.htm; accessed August 3, 2004.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Verbascum thapsus* L. (USDA 2005)
Synonyms:	None identified in USDA (2005).
Common names:	Common mullein, woolly mullein, velvet plant, flannel plant, big taper, velvet dock
Evaluation date (mm/dd/yy)**:**	05/11/03
Evaluator #1 Name/Title:	Dana Backer, Conservation Ecologist
Affiliation:	The Nature Conservancy
Phone numbers:	(520) 622–3761
Email address:	dbacker@tnc.org
Address:	1510 E. Fort Lowell Rd., Tucson, Arizona 85719
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	06/24/03: W. Austin, D. Backer, P. Guertin, J. Hall, R. Haughey, L. Moser, F. Northam, R. Paredes, B. Phillips, K. Thomas, L. Thomas, K. Watters 08/26/03: W. Albrecht, W. Austin, D. Backer, J. Busco, R. Hiebert, L. Makarick, L. Moser, T. Olson, B. Phillips, T. Robb, K. Thomas, K. Watters
Committee review date:	06/24/03 and 08/26/03
List date:	08/26/03
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

	Question	Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**D**	Observational	**"Impact"** **Section 1 Score:** **D**	**"Plant Score"** **Overall Score:** **Evaluated but not listed** **Alert Status:** **None**
1.2	Impact on plant community	**D**	Other published material		
1.3	Impact on higher trophic levels	**D**	Observational		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Reviewed scientific publication	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **10 pts** **Section 2 Score:** **C**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**A**	Reviewed scientific publication		
2.5	Potential for human-caused dispersal	**C**	Other published material		
2.6	Potential for natural long-distance dispersal	**D**	Reviewed scientific publication		
2.7	Other regions invaded	**C**	Other published material		 Something you should know.
3.1	Ecological amplitude	**A**	Observational	**"Distribution"** **Section 3 Score:** **A**	
3.2	Distribution	**A**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes	*Score:* **D** *Doc'n level:* **Obs.**
Identify ecosystem processes impacted: Not considered a threat to abiotic processes.	
Rationale: From the literature reviewed, no mention was made of abiotic ecosystem processes and system-wide parameters being significantly diminished. The assumption of Working Group members was that *V. thapsus* has been studied by several researchers and if there were impacts on ecosystem processes they would have been mentioned; therefore, the absence of such information suggests there are no known impacts.	
Sources of information: Score based on inference of the literature (or lack there of) by the Working Group members; no direct information available. Literature reviewed: Gross (1980), Gross and Werner (1982), Hoshovsky (1986),and Pitcairn (2000).	

Question 1.2 Impact on plant community composition, structure, and interactions	*Score:* **D** *Doc'n level:* **Other pub.**
Identify type of impact or alteration: A visual alteration of the community structure does occur but impacts in the long-term have not been documented. *Verbascum thapsus* is easily out competed in areas with a densely vegetated ground cover but readily grows in disturbed sites. Some observed impact on displacing native herbs and grasses in Sierra Nevada during early succession.	
Rationale: From research conducted on *V. thapsus* and summarized below, *V. thapsus* requires disturbance to establish, preferring bare ground. It is an early successional plant and will be out competed during the course of the successional process. Therefore, the long-term impacts may not be significant but definitive information on this question was not available in the literature or from interviews of knowledgeable individuals. Observations do suggest an impact to the horizontal structural component during the early successional phase. From Pitcairn (2000; an observational account of change in plant composition and interaction is described in Sierra Nevada): "Not considered a weed of most wildlands and natural areas; however, in the sparsely vegetated soils of the eastern Sierra Nevada it is abundant and has invaded pristine meadows with undisturbed soils, displacing native herbs and grasses. Appears to be an early colonizer after forest fire in western Sierra Nevada preventing the establishment of native herbs and grasses but eventually these give way to a developing shrub canopy. In this situation, mullein appears to disrupt the normal sequence of ecological succession." Other observations from ponderosa pine forest in northern Arizona suggest mullein may out compete native seedlings during early years of restoration (thinning, burning) when seedlings are germinating from the original seed bank (J. Springer, personal communication, 2003). In Michigan, Gross (1984) compared seedling emergence on bare and vegetated sites. On bare soil 50% of the total emergence occurred within nine days of sowing. This took 30 days on vegetated soils. Seedling growth rates were four to seven times faster on bare soils, producing 2000 times more biomass within the same time period (Gross 1984). Seedlings did not establish in small experimentally created openings (15 x 15 cm), but they did colonize larger openings (0.5 m^2or more) such as those created by animal digging. The necessity of bare ground for seedling emergence and establishment means that only a narrow "window in time" is available during which mullein colonization may occur (Gross and Werner 1982). In an ecological system undergoing succession, the proportion of open ground will decrease with time, and the probability of an individual mullein seedling becoming established will also decrease (Gross 1980). In experiments conducted in Michigan and Ohio, *V. thapsus* establishes only in patches of bare ground (Gross and Werner 1982). Gross (unpublished data) showed mullein did not become established in small experimentally-created openings (15 x 15cm) in a 15-year old-fields but did colonize larger openings (≥0.5	

m^2) created by animal digging (Gross 1980). Competition will reduce the numbers of successfully germinating seeds (Gross 1980). *Verbascum thapsus* is an earlier colonizer; local populations become established, reproduce and become locally extinct within two to three years after disturbance (Salisbury 1942, Gross and Werner 1978). If seeds are not present in the soil when a disturbance occurs then the limited spatial dispersal ability is probably insufficient to ensure the arrival of propagules rapidly enough for a population to become established while bare ground is still abundant (Gross and Werner 1982).
Sources of information: See cited literature; also see Hoshovsky (1986). Also considered personal communication with J. Springer (Senior Research Specialist, Ecological Restoration Institute, Northern Arizona University, Flagstaff, Arizona, observations of work conducted by W. Chancellor [Northern Arizona University] and J. Crawford [National Park Service], 2003).

Question 1.3 Impact on higher trophic levels *Score:* **D** *Doc'n level:* **Obs.**
Identify type of impact or alteration: No known impact or alteration.
Rationale: No mention was made in the literature reviewed of the impacts of *V. thapsus* on higher trophic levels. The Working Group made the assumption that because *V. thapsus* has been studied by several researchers, if impacts occurred to other species they would have been mentioned; therefore, the absence of such information suggests a lack of impacts. Other comments: thought to serve as a host for insects that are themselves economic pests (Maw 1980). Unpalatable to cattle (Fogg 1945 in Gross and Werner 1978) and some phytophagous insects (P. Harris, personal communication in Gross and Werner 1978). Julie Crawford (personal communication, 2003) reports having seen mice nesting in the rosette.
Sources of information: See cited literature. Also considered personal communication with J. Crawford (Botanist, National Park Service, Grand Canyon National Park, Flagstaff, Arizona, 2003). Score based on inference drawn from the literature and observations.

Question 1.4 Impact on genetic integrity *Score:* **D** *Doc'n level:* **Other pub.**
Identify impacts: No known hybridization.
Rationale: Although *Verbascum* does hybridize with *V. lychnitus* and *V. nigrum* (Clapham et al. 1952), it is not common nor do these species exist in Arizona.
Sources of information: See cited literature; also see Kearney and Peebles (1960).

Question 2.1 Role of anthropogenic and natural disturbance in establishment *Score:* **B** *Doc'n level:* **Rev. sci. pub.**
Describe role of disturbance: Bare ground needed to establish (human or natural).
Rationale: *Verbascum thapsus* tends to be an initial colonist in newly disturbed sites. Local populations become established, reproduce and become locally extinct within two to three years after disturbance (Salisbury 1942, Gross and Werner 1978).The necessity of bare ground for seedling emergence and establishment means only a narrow "window in time" is available during which mullein may colonize (Gross and Werner 1982). If seeds are not present in the soil when a disturbance occurs, then the limited spatial dispersal ability is probably insufficient to ensure the arrival of propagules rapidly enough for a population to become established while bare ground is still abundant (Gross and Werner 1982). *Verbascum thapsus* can colonize larger openings (0.5 m^2or more), such as those created by animals (Gross 1984). *Verbascum thapsus* is perpetuated by the disturbances created by elk, cattle, and fire (J. Crawford, personal communication, 2003)
Sources of information: See cited literature. Also considered personal communication with J. Crawford (Botanist, National Park Service, Grand Canyon National Park, Flagstaff, Arizona, 2003). Score based on inference drawn from the literature and observations.

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n level:* **Obs.**
Describe rate of spread: Increasing but less rapidly than doubling in <10 years.
Rationale: Rate of spread would depend on the rate of disturbance. *Verbascum thapsus* is limited to a type of microhabitat—bare ground of newly disturbed areas, by its lack of dispersal mechanisms, and by its inability to compete with other plants. The preceding suggests that plant spread is stable. However, in ephemeral riparian systems, it has been observed to spread (e.g., in Tuckup Canyon, Grand Canyon National Park [K. Watters, personal communication, 2003] and tributaries to Oak Creek Canyon: Munds and Kelly Canyons [K. Thomas, personal communication, 2003]). Seeds need to be present in the soil when the disturbance occurs. The limited dispersal ability of *Verbascum thapsus* is probably insufficient to ensure the arrival of propagules rapidly enough for a population to become established while bare ground is still abundant (Gross and Werner 1982). *Verbascum thapsus* rapidly establishes following forest fire in western Sierra Nevada. High densities of rosettes appear to prevent the reinvasion of native herbs and grasses in burned areas but eventually these give way to a developing shrub canopy (Pitcairn 2000). Similar observations were made in ponderosa pine by J. Crawford (personal communication, 2003).
Sources of information: See cited literature. Also considered personal communications with K. Watters (Research Technician, National Park Service, Southern Colorado Plateau Network, Flagstaff, Arizona, 2003), K. Thomas (Vegetation Ecologist, U.S. Geological Survey, Southwest Biological Science Center, Colorado Plateau, Flagstaff, Arizona, 2003), and J. Crawford (Botanist, National Park Service, Grand Canyon National Park, Flagstaff, Arizona, 2003). Score based on inference drawn from the literature and observations.

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n level:* **Obs.**
Describe trend: Stable.
Rationale: Does not seem to be increasing or decreasing. *Verbascum thapsus* currently occurs within all 50 states (USDA 2005) and is believed to have been brought to the U.S. in the mid-1700s. In Arizona it is identified as occurring in Coconino, Yavapai, Apache, Mohave, Gila, and Cochise counties (Kearney and Peebles 1960, McDougall 1973). A curculinoid weevil (*Gymnaetron tetrum* Fab.) specific to *V. thapsus* was introduced to North America (Burcham 1937) and ends up destroying up to 50% of the seeds (Gross and Werner 1978). Several micro-organisms (USDA 1960) and leaf -inhibit parasitic fungi (USDA 1953) exist that potentially affect *V. thapsus*, but their specific impacts or effects were not reported by Gross and Werner (1978).
Sources of information: See cited literature. Specific information to address trend was not available. Score is based on inference drawn from the literature cited above.

Question 2.4 Innate reproductive potential *Score:* **A** *Doc'n level:* **Rev. sci. pub.**
Describe key reproductive characteristics: Greater than 100,000 seeds per plant; biennial; seed viability 35 years, self- and cross-pollination.
Rationale: See documentation in Worksheet A.
Sources of information: See Worksheet A.

Question 2.5 Potential for human-caused dispersal *Score:* **C** *Doc'n level:* **Other pub.**
Identify dispersal mechanisms: Used as medicinal plant; tobacco use by Navajo Nation individuals.
Rationale: Not known to be a popular ornamental. Used as remedy for coughs and diarrhea.
Sources of information: See Hoshovsky (1986).

Question 2.6 Potential for natural long-distance dispersal *Score:* **D** *Doc'n level:* **Rev. sci. pub.**

Identify dispersal mechanisms: Seeds dispersed as far as 11 m, though 93% fall within 5 m and 75% fall within 1 m of parent plant (Gross and Werner 1978).

Rationale: Requires movement of stalk by wind or large animal to release seeds from plant (McLean and Ivimey-Cook 1956 in Gross and Werner 1978). Seeds posses no specialized morphological adaptations for dispersal by wind or animals (Gross and Werner 1978). Seeds are small and lie on surface or sift below surface relatively rapidly (Harper 1977).

Sources of information: See cited literature.

Question 2.7 Other regions invaded *Score:* **C** *Doc'n level:* **Other pub.**

Identify other regions: Only those where it is known to exist in Arizona.

Rationale: The literature was limited in identifying the ecological types in which *V. thapsus* occurs except those in which it is already known to occur. *Verbascum thapsus* is currently occurs within all 50 states (USDA 2005)

From Pitcairn (2000): occurs throughout California but is particularly abundant in dry valleys on the eastern side of Sierra Nevada. High population densities have been observed in moist meadows and creek drainages new Mono Lake and Owens Valley. Found from sea level to 8000 feet (2440 m) elevation.

In Canada *V. thapsus* is reported to grow abundantly in soils with a pH range of 6.5 to 7.8 (Gross and Werner 1978).

Sources of information: See cited literature.

Question 3.1 Ecological amplitude *Score:* **A** *Doc'n level:* **Obs.**

Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: From Hoshovsky (1986): probably introduced into North America (from Europe) as a medicinal herb. Introduced into Virginia in mid-1700s as piscicide. Became so well established that in a 1818 flora of the East Coast it was described as native. It became naturalized (i.e., self-sustaining populations occur without direct intervention by humans, but the species does not necessarily invade natural, semi-natural, human-made ecosystems [Richardson et al. 2000]) along the West Coast by 1876 (Brewer et al. 1876).

First recorded in California in 1880 as being widely naturalized in old fields in Siskyou County (Watson 1880 in Pitcairn 2000). First dated record for Arizona at the University of Arizona herbarium is 1905 (SEINet 2003).

From Gross and Werner (1978): Habitat: climatic conditions of cool summers (mean temperature of warmest month <22°C but with at least 4 months over 10°C. Mean annual precipitation is 500 to 1500 mm and 140-day minimum growing season. Found mainly on dry, sandy soils; in England common in chalk and limestone districts (Furneaux 1909, Good 1948).

Rationale: Found in open sites, along roadsides, neglected meadows, waste areas, river bottoms, and industrial areas (Spencer 1957 and Semenza et al. 1978, both in Hoshovsky 1986) and moist meadows and drainages (in California; Pitcarin 2000). Requires light and moisture to germinate and germination inhibited bellow 50°F and constant temps over 104°F; requires 50 to 150 cm precipitation annually.

In Arizona *V. thapsus* occurs in Coconino, Yavapai, Apache, Mohave, Gila and Cochise Counties (Kearney and Peebles 1960, McDougall 1973).

Sources of information: See cited literature. Also considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at:

http://seinet.asu.edu/collections; accessed 2003) and personal communications with L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center, Flagstaff, Arizona, 2003), L. Moser (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2003), J. Springer (Senior Research Specialist, Ecological Restoration Institute, Northern Arizona University, Flagstaff, Arizona, 2003), and J. Crawford (Botanist, National Park Service, Grand Canyon National Park, Flagstaff, Arizona, 2003).

Question 3.2 Distribution *Score:* **A** *Doc'n level:* **Obs.**
Describe distribution: See question 3.1 and Worksheet B.
Rationale: Based on observations of those listed below and Working Group consensus.
Sources of information: Personal communications with L. Makarick (Below the Rim Vegetation Program Manager, National Park Service, Grand Canyon National Park Science Center, Flagstaff, Arizona, 2003), L. Moser (Botanist, U.S. Department of Agriculture, Forest Service, Coconino National Forest, Flagstaff, Arizona, 2003), F. Northam (Weed Biologist [former Arizona Department of Agriculture Noxious Weed Coordinator], Tempe, Arizona, 2003), J. Springer (Senior Research Specialist, Ecological Restoration Institute, Northern Arizona University, Flagstaff, Arizona, 2003), and J. Crawford (Botanist, National Park Service, Grand Canyon National Park, Flagstaff, Arizona, 2003).

Research Needs (from Hoshovsky 1986)

Detailed observations focused on the vegetational change of the affected area over time will help to determine what method of control would be most efficient.

No quantitative monitoring studies of mullein were discovered in this research. Because it is not considered a major agricultural weed in California, apparently little interest or funding is available for detailed sampling programs. Whatever monitoring may be done is probably qualitative: has it invaded a site? Does it re-establish itself following control treatment?

Does mullein significantly outcompete native plant species? Does the establishment of mullein alter the local natural plant succession? Casual observation suggests the persistence of mullein in open, sunny areas. Does mullein truly persist in the same area for many years? What factors contribute to its persistence?

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**[Yes]**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**[Yes]**	**No**	**2 pt.**
Populations of this species produce seeds every year.	**[Yes]**	**No**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**[Yes]**	**No**	**1 pt.**
Seeds remain viable in soil for three or more years	**[Yes]**	**No**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**[Yes]**	**No**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**Yes**	**[No]**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**Yes**	**[No]**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**Yes**	**[No]**	**1 pt.**
	Total pts: 8	**Total unknowns: 0**	
	Score : A		

Note any related traits: Only seeds that lie at or near the surface (0.5 cm or less) will germinate (Gross 1980). Seeds viable for over 100 years (Kivilaan and Bandurski 1981). Produces 100,000 to 180,000 seeds per plant (Gross 1980, Gross and Werner 1982), average of 223,200 (Stevens 1932). Only short- and long-tongued bees are effective vectors for cross pollination; flowers are also self-pollinating (Gross and Werner 1978). After single reproductive event entire plant dies (Baskin and Baskin 1981). Seeds remain viable up to 35 years (Darlington and Steinbauer) 1961). Mullein is monocarpic and has no means of vegetative reproduction (Gross 1980). Flowering begins in late June of second year and peaks in early August; rarely do plants remain a third year (Gross 1981). The length of flowering period appears to be a function of stalk height and taller stalks continue to flower into late September and early October (Gross and Werner 1978).

Cutting the rosette below the crown will prevent species from flowering (Darlington et al. 1940). Repeated mowing prevents the flower stalk from bolting but the basal rosette will increase in size. If moving is discontinued, the plant will then bolt and produce flowers (Gross and Werner 1978).
From Gross (1980): seeds can germinate over a wide range of environmental conditions (Semenza et al. 1978), requiring only moisture and exposure to light to germinate (Gardner 1921, Semenza et al. 1978).

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	**U**
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	**C**
	montane wetlands	**A**
	playas	
Riparian	Sonoran riparian	
	southwestern interior riparian	**C**
	montane riparian	**A**
Woodlands	Great Basin conifer woodland	**B**
	Madrean evergreen woodland	**A**
Forests	Rocky Mountain and Great Basin subalpine conifer forest	**C**
	montane conifer forest	**A**
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Baskin, J.M., and C.C. Baskin. 1981. Seasonal changes in germination responses of buried seeds of *Verbascum thapsus* and *V. blattaria* and ecological implications. Canadian Journal of Botany 59:1769−1775.

Brewer, W.H., S. Watson, and A. Gray. 1876. Botany of California. Welch Bigelow and Co., University Press, Cambridge.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Burcham, E.L. 1937. Notes on Curculionidae (Coleoptera). J. Wash. Acad. Sci. 27:312−316.

Clapham, A.R., T.G. Tutin, and E.F. Burg. 1952. Flora of the British Isles. University Press, Cambridge. 1591 p.

Darlington, H.T., E.A. Bessey, and C.R. Megee. 1940. Some important Michigan weeds. Mich. State Coll. Agric. Exp. Sta. Spec. Bull. 304.

Darlington, H.T., and G.P. Steinbauer. 1961. The eighty-year period for Dr. Beal's seed viability experiment. Amer. J. Botany 48:321−325.

Fogg, J.M. 1945. Weeds of Lawn and Garden. University of Pennsylvania Press, Philadelphia. 215 p.

Furneaux, W.S. 1909. Field and Woodland Plants. Longmans, Green and Co., London. 383 p.

Gardner, W.A. 1921. Effect of light on germination of light sensitive seeds. Bot. Gax. 71:249−288.

Good, R.D. 1948. A geographical handbook of the Dorset flora. Dorset Nat. Hist. Arch. Soc., Dorchester. 255 p.

Gross, K.L. 1980. Colonization by *Verbascum thapsus* (mullein) of an old-field in Michigan: experiments on the effects of vegetation. J. of Ecology 68:919−927.

Gross, K.L. 1981. Predictions of fate from rosette size in four "biennial" plant species: *Verbascum thapsus*, *Oenothera biennis*, *Daucus carota*, and *Tragopogon dubius*. Oecologia 48:209−213.

Gross, K.L. 1984. Effects of seed size and growth form on seedling establishment of six monocarpic perennial plants. J. of Ecology 72:369−387.

Gross, K.L., and P.A. Werner. 1978. The biology of Canadian weeds. 28. *Verbascum thapsus* L. and *V. blatteria* L. Canadian Journal of Plant Science 58:401−413.

Gross, K.L., and P.A. Werner. 1982. Colonizing abilities of "biennial" plant species in relation to ground cover: implications for their distributions in a successional sere. Ecology 63:921−931.

Harper, J.L. 1977. Population Biology of Plants. Academic Press, London.

Hoshovsky, M.C. 1986. *Verbascum thapsus.* Element Stewardship Abstract. The Nature Conservancy. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu/esadocs/documents/verbtha.html.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

Kivilaan, A., and R.S. Bandurski. 1981. The one hundred-year period for Dr.Beal's seed viability experiment. American Journal of Botany 68:1290−1292.

McDougall, W.B. 1973. Seed Plants of Northern Arizona. The Museum of Northern Arizona, Flagstaff. 594 p.

McLean, R.C., and W.R. Ivimey-Cook. 1956. Textbook of Theoretical Botany. Volume II. Longmans, Greene, and Co., London. 1130 p.

Pitcairn, M. 2000. *Verbascum thapsus* L. Pages 321−326 in C.C. Bossard, J.M. Randall, and M.C. Hoshovsky (eds.), Invasive Plants of California's Wildlands. University of California Press, Berkeley.

Richardson, D.M., P. Pyšek, M. Rejmánek, M.G. Barbour, F.D. Panetta, and C.J. West. 2000. Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions 6:93−107.

Salisbury, E.J. 1942. The reproductive capacity of plants. G. Bell & Sons, Ltd., London.

Semenza, R.J., J.A. Young, and R.A. Evans. 1978. Influence of light and temperature on the germination and seedbed ecology of common mullein (*Verbascum thapsus*). Weed Science 26:577−581.

Spencer, E.R. 1957. Just Weeds. Scribner & Sons, New York.

Stevens, O.A. 1932. The number and weight of seeds produced by weeds. Amer. J. of Bot. 19:784−794.

[USDA] U.S. Department of Agriculture. 1953. Plant Diseases. Yearbook of Agriculture. Washington, DC. 940 p.

[USDA] U.S. Department of Agriculture. 1960. Index of Plant Diseases. USA. Agric. Handbook 165. U.S. Government Printing Office, Washington, DC. 531 p.

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.

Watson, S. 1880. Geological Survey of California: Botany, Volume II. Welch Bigelow, Cambridge, Massachusetts.

Plant Assessment Form

For use with the "Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands" by the California Exotic Pest Plant Council and the Southwest Vegetation Management Association (Warner et al. 2003)

Printable version, February 28, 2003
(Modified for use in Arizona, 07/02/04)

Table 1. Species and Evaluator Information

Species name (Latin binomial)**:**	*Vinca major* L. (USDA 2005)
Synonyms:	*Vinca major* L. var. *variegata* Loud. (USDA 2005)
Common names:	Bigleaf periwinkle, periwinkle, large periwinkle, blue periwinkle, greater periwinkle
Evaluation date (mm/dd/yy)**:**	04/22/05
Evaluator #1 Name/Title:	Elizabeth Makings/ Botanist -Terrestrial Ecosystems Survey, Tonto National Forest; Collections Manager – Arizona State University Herbarium
Affiliation:	See above
Phone numbers:	(480) 767–7299
Email address:	emakings@cox.net
Address:	10063 E. San Bernardo, Scottsdale, Arizona 85258
Evaluator #2 Name/Title:	
Affiliation:	
Phone numbers:	
Email address:	
Address:	

List committee members:	J. Hall, E. Makings. F. Northam, T. Olson, P. Fenner, G. Russell
Committee review date:	04/22/05
List date:	04/22/05
Re-evaluation date(s):	

Table 2. Scores, Designations, and Documentation Levels

Question		Score	Documentation Level	Section Scores	Overall Score & Designations
1.1	Impact on abiotic ecosystem processes	**B**	Other published material	**"Impact"** **Section 1 Score:** **B**	**"Plant Score"** **Overall Score:** **Medium** **Alert Status:** **Alert**
1.2	Impact on plant community	**B**	Other published material		
1.3	Impact on higher trophic levels	**U**	Other published material		
1.4	Impact on genetic integrity	**D**	Other published material		
2.1	Role of anthropogenic and natural disturbance	**B**	Observational	**"Invasiveness"** *For questions at left, an A gets 3 points, a B gets 2, a C gets 1, and a D or U gets=0. Sum total of all points for Q2.1-2.7:* **11 pts** **Section 2 Score:** **B**	
2.2	Local rate of spread with no management	**B**	Observational		
2.3	Recent trend in total area infested within state	**C**	Observational		
2.4	Innate reproductive potential	**B**	Other published material		
2.5	Potential for human-caused dispersal	**B**	Other published material		
2.6	Potential for natural long-distance dispersal	**C**	Observational		
2.7	Other regions invaded	**C**	Other published material		RED FLAG **NO** Something you should know.
3.1	Ecological amplitude	**C**	Other published material	**"Distribution"** **Section 3 Score:** **C**	
3.2	Distribution	**C**	Observational		

Table 3. Documentation

Question 1.1 Impact on abiotic ecosystem processes	*Score:* **B** *Doc'n level:* **Other pub**.
Identify ecosystem processes impacted: Light availability, erosion.	
Rationale: Once established, *Vinca major* can form dense carpets. Patches of *V. major* can reach 100% cover along stream banks. Dense mats may smother all native groundcover vegetation and prevent regeneration of trees and shrubs. This can have important long term consequences on streambanks, where the eventual loss of native trees and shrub cover could lead to erosion.	
Sources of information: See Bailey (1914), Bean and Russo (1988), McLaughlin (1994), and Gilbert (2003). Also considered personal field observations of E. Makings (Terrestrial Ecosystems Botanist, U.S. Department of Agriculture, Forest Service, Tonto National Forest, 2005).	

Question 1.2 Impact on plant community composition, structure, and interactions	*Score:* **B** *Doc'n level:* **Other pub**.
Identify type of impact or alteration: Forms patches dominated by *V. major*.	
Rationale: *Vinca major* forms dense patches which exclude other plants. This creates a problem in areas where it competes with natives and reduces the level of diversity.	
Sources of information: See McClintock (1985 in Bean Russo 1988) and Pilversack (1999). Also considered information from two online databases: (1) Conservation Council of the South East Region (CCSER Undated) *Vinca major.* Weeds. Australian Capital Territory Government (available online at: http://www.ecoaction.net) and (2) Eurobodalla Shire Council (ESC Undated) *Vinca major.* South Coast Weeds (available online at: http://www.esc.nsw.gov).	

Question 1.3 Impact on higher trophic levels	*Score:* **U** *Doc'n level:* **Other pub**.
Identify type of impact or alteration: Extirpation of existing native or endangered species and reduction in native forage site/habitat are possible, though no published evidence or observations of higher trophic level impacts were identified.	
Rationale: Once established *V. major* competes with native vegetation by smothering all native groundcover vegetation and preventing the regeneration of trees and shrubs which in turn potentially reduces habitat and forage for animals utilizing the riparian corridor. *Vinca major* is able to grow in deep shade and poor soil, giving it a competitive advantage over other vegetation. Because no published evidence or observations of impacts were identified, the level of impact was determined to be unknown.	
Sources of information: See Bailey (1914 in Bean and Russo 1988) and Pilversack (1999). Also considered information from the Global Invasive Species Database (ISSG Undated) *Vinca major* (available online at: http://www.issg.org/database).	

Question 1.4 Impact on genetic integrity	*Score:* **D** *Doc'n level:* **Other pub**.
Identify impacts: No none hybridization.	
Rationale: No native *Vinca* in Arizona (Kearney and Peebles 1960)	
Sources of information: See cited literature; also see Salisbury (1961 in Bean and Russo 1988) and McLaughlin (1994).	

Question 2.1 Role of anthropogenic and natural disturbance in establishment	*Score:* **B** *Doc'n level:* **Obs**.
Describe role of disturbance: Cultivation, floods.	
Rationale: *Vinca major* is introduced to new locations usually as ornamental groundcover. This species appears to be dependent on human intervention for establishment. In Arizona it is mostly associated with historical and currently occupied homesites. *Vinca major* may be a threat to the understory of riverine vegetation as it can spread from plant fragments carried by high flows. In Arizona downstream establishment in most rivers is less likely because of the flashy nature of our rivers and flow regulation	

situation (dams). Fragments may break and be carried by high flows, but would require a shady, moist microclimate to become established.
Sources of information: See Muenscher (1955 in Bean and Russo 1988). Also considered information from the Global Invasive Species Database (ISSG Undated) *Vinca major* (available online at: http://www.issg.org/database) and personal field observations of E. Makings (Terrestrial Ecosystems Botanist, U.S. Department of Agriculture, Forest Service, Tonto National Forest, 2005). Score based on inference in part.

Question 2.2 Local rate of spread with no management *Score:* **B** *Doc'n level:* **Obs**.
Describe rate of spread: Increases, but less rapidly than doubling in <10 years.
Rationale: By most accounts, *V. major* is spreading slowly and locally only where it has been intentionally introduced.
Sources of information: See Pilversack (1999). Also considered information from the Conservation Council of the South East Region (CCSER Undated) *Vinca major.* Weeds. Australian Capital Territory Government (available online at: http://www.ecoaction.net), personal field observations of E. Makings (Terrestrial Ecosystems Botanist, U.S. Department of Agriculture, Forest Service, Tonto National Forest, 2005), and personal communications with E. Gilbert (observations while conducting floristic inventory of the West Fork of Oak Creek Canyon, Coconino County, Arizona as an Arizona State University graduate student, Tempe, Arizona, 2003) and M. Killeen (Assistant Manager Southeast Arizona Preserves, The Nature Conservancy, Ramsey Canyon Preserve, 2005).

Question 2.3 Recent trend in total area infested within state *Score:* **C** *Doc'n level:* **Obs**.
Describe trend: Species seems to be filling in through density increases at its known infestation sites.
Rationale: Patches of *V. major* exist in riparian areas throughout the state. Rate of spread is not known from the literature. Arizona populations appear to be slowly increasing at the local level.
Sources of information: Bean and Russo (1988). Also considered personal field observations of E. Makings (Terrestrial Ecosystems Botanist, U.S. Department of Agriculture, Forest Service, Tonto National Forest, 2005) and personal communication with M. Killeen (Assistant Manager Southeast Arizona Preserves, The Nature Conservancy, Ramsey Canyon Preserve, 2005).

Question 2.4 Innate reproductive potential *Score:* **B** *Doc'n level:* **Other pub**.
Describe key reproductive characteristics: *Vinca major* does not reproduce by seed in the wild (Salisbury 1961 in Bean and Russo 1988). Established plants spread by stolons rooting at the nodes and broken off sections of stem will take root.
Rationale: See Worksheet A.
Sources of information: See cited literature. Also considered information from the Conservation Council of the South East Region (CCSER Undated) *Vinca major.* Weeds. Australian Capital Territory Government (available online at: http://www.ecoaction.net).

Question 2.5 Potential for human-caused dispersal *Score:* **B** *Doc'n level:* **Other pub**.
Identify dispersal mechanisms: *Vinca major* is available commercially as an ornamental groundcover. It is cultivated in areas of the U.S. with mild temperatures where it has also spread outside of cultivation.
Rationale: The potential for human caused dispersal is moderate to low since it requires active intervention to be introduced to a new site (i.e., planting).
Sources of information: See McClintock (1985 in Bean and Russo 1988).

Question 2.6 Potential for natural long-distance dispersal *Score:* **C** *Doc'n level:* **Obs**.
Identify dispersal mechanisms: *Vinca major* is a riparian species that thrives along shady stream banks in Arizona (SEINet 2005). Detached stems from *V. major* have the ability to resprout after being carried downstream.
Rationale: Opportunities for dispersal of *V. major* are limited. The potential for long distance dispersal as a result of flooding events is probably rare.
Sources of information: Considered information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2005) and the Conservation Council of the South East Region (CCSER Undated) *Vinca major.* Weeds. Australian Capital Territory Government (available online at: http://www.ecoaction.net).

Question 2.7 Other regions invaded *Score:* **C** *Doc'n level:* **Other pub**.
Identify other regions: Natural forests, riparian zones, disturbed sites such as campgrounds and homesteads.
Rationale: Worldwide, *V. major* occurs in a variety of habitats associated with shady, moist grounds. It commonly occurs along riverbanks, ephemeral or permanent creek margins, and around lawns, cemeteries, and drainages where dense cover is available. These ecological types do not differ from those it occupies within the state.
Sources of information: See Bean and Russo (1988) and Hickman (1993). Also considered information from the Global Invasive Species Database (ISSG Undated) *Vinca major* (available online at: http://www.issg.org/database).

Question 3.1 Ecological amplitude *Score:* **C** *Doc'n level:* **Other pub**.
Describe ecological amplitude, identifying date of source information and approximate date of introduction to the state, if known: Natural and anthropogenic disturbed sites within Sonoran riparian (cottonwood-willow) and southwestern interior riparian (mixed deciduous broadleaf) ecological types.
Rationale: In Arizona *V. major* is documented along riparian corridors in the above ecological types. There are 27 vouchered collections held at the three main herbaria in Arizona (SEINet 2005). Thirteen different localities appear to be represented by those collections since many may be site duplications. For example, "West Fork of Oak Creek" or "Oak Creek Canyon" are cited in several collections but represent only two localities.
Sources of information: Information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2005).

Question 3.2 Distribution *Score:* **C** *Doc'n level:* **Obs**.
Describe distribution: See question 3.1. Occurrence frequency within the two ecological types invaded is limited.
Rationale: See Worksheet B and information in question 3.1.
Sources of information: Information from SEINet (Southwest Environmental Information Network), Arizona herbaria specimen database (available online at: http://seinet.asu.edu/collections; accessed 2005).

Worksheet A. Reproductive Characteristics

Complete this worksheet to answer Question 2.4.

Reaches reproductive maturity in 2 years or less	**Yes**	**No**	**1 pt.**
Dense infestations produce >1,000 viable seed per square meter	**Yes**	**[No]**	**2 pt.**
Populations of this species produce seeds every year.	**Yes**	**[No]**	**1 pt.**
Seed production sustained for 3 or more months within a population annually	**Yes**	**[No]**	**1 pt.**
Seeds remain viable in soil for three or more years	**Yes**	**[No]**	**2 pt.**
Viable seed produced with *both* self-pollination and cross-pollination	**Yes**	**[No]**	**1 pt.**
Has quickly spreading vegetative structures (rhizomes, roots, etc.) that may root at nodes	**[Yes]**	**No**	**1 pt.**
Fragments easily and fragments can become established elsewhere	**[Yes]**	**No**	**2 pt.**
Resprouts readily when cut, grazed, or burned	**[Yes]**	**No**	**1 pt.**
	Total pts: 4 Total unknowns: 1		
	Score : B		

Note any related traits:

Worksheet B. Arizona Ecological Types
(*sensu* Brown 1994 and Brown et al. 1998)

Major Ecological Types	Minor Ecological Types	Code*
Dunes	dunes	
Scrublands	Great Basin montane scrub	
	southwestern interior chaparral scrub	
Desertlands	Great Basin desertscrub	
	Mohave desertscrub	
	Chihuahuan desertscrub	
	Sonoran desertscrub	
Grasslands	alpine and subalpine grassland	
	plains and Great Basin shrub-grassland	
	semi-desert grassland	
Freshwater Systems	lakes, ponds, reservoirs	
	rivers, streams	
Non-Riparian Wetlands	Sonoran wetlands	
	southwestern interior wetlands	
	montane wetlands	
	playas	
Riparian	Sonoran riparian	**C**
	southwestern interior riparian	**C**
	montane riparian	
Woodlands	Great Basin conifer woodland	
	Madrean evergreen woodland	
Forests	Rocky Mountain and Great Basin subalpine conifer forest	
	montane conifer forest	
Tundra (alpine)	tundra (alpine)	

*A means >50% of type occurrences are invaded; B means >20% to 50%; C means >5% to 20%; D means present but ≤5%; U means unknown (unable to estimate percentage of occurrences invaded).

Literature Cited

Bailey L.H. 1914. The Standard Encyclopedia of Horticulture Vol. 6. Pages 3470–3471. MacMillan, New York.

Bean, C., and M.J. Russo 1988. *Vinca major.* Element Stewardship Abstract. The Nature Conservancy. Available online at: http://tncweeds.ucdavis.edu.

Brown, D.E. (ed.). 1994. Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City. 342 p. [Plus companion 60-inch by 48-inch map, Biotic Communities of the Southwest].

Brown, D., F. Reichenbacher, and S. Franson, S. 1998. A Classification of North American Biotic Communities. University of Utah Press, Salt Lake City. 141 p.

Gilbert, E. 2003. Flora of the West Fork of Oak Creek Canyon, Coconino County, Arizona. Master's thesis. Arizona State University, Tempe.

Hickman, J.C. (ed.). 1993. The Jepson Manual: Higher Plants of California. University of California Press, Berkeley.

Kearney, T.H., and R.H. Peebles (and collaborators). 1960. Arizona Flora. 2nd edition with supplement by J.T. Howell and E. McClintock and collaborators. University of California Press, Berkeley. 1085 p.

McClintock, E. 1985. Escaped exotic weeds in California. Fremontia 12:3–6.

McLaughlin, S.P. 1994. Apocynaceae. Journal of the Arizona-Nevada Academy of Science 27:164–168.

Muenscher, W. 1955.Weeds. 2nd editon. MacMillan, New York.

Pilversack, S. 1999. Flora of Ramsey Canyon Cochise County, Arizona. Master's thesis. Arizona State University, Tempe.

Salisbury, E.J. 1961. The fruiting of periwinkles. Journal of Royal Horticultural Society 86 (part II).

[USDA] U.S. Department of Agriculture, Natural Resources Conservation Service. 2005. The PLANTS Database, Version 3.5. Available online at: http://plants.usda.gov. Data compiled from various sources by Mark W. Skinner. National Plant Data Center, Baton Rouge, Louisiana.

Warner, P.J., C. Bossard, M.L. Brooks, J.M. DiTomaso, J.A. Hall, A. M. Howald, D.W. Johnson, J.M. Randall, C.L. Roye, M.M. Ryan, and A.E. Staton. 2003. Criteria for Categorizing Invasive Non-Native Plants that Threaten Wildlands. Available online at: www.caleppc.org and www.swvma.org. California Exotic Pest Plant Council and Southwest Vegetation Management Association. 24 p.