ORNL/TM-2004/98/R1

August 2011

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Prepared for Oak Ridge National Laboratory
Managed by UT-Battelle, LLC, for the U.S. Department of Energy
under contract DE-AC05-00OR22725

Invasive Plant Management Plan

for the OAK RIDGE RESERVATION

Cover photo by Harry Quarles

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INVASIVE PLANT MANAGEMENT PLAN FOR THE OAK RIDGE RESERVATION

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Date Published: August 2011

Prepared for
U.S. Department of Energy
Office of Science

Prepared by
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Oak Ridge, Tennessee 37831-6283
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

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ACRONYMS AND ABBREVIATIONS

APHIS	Animal and Plant Health Inspection Service
ATU	all-terrain utility vehicle
CSC	Certified Services Company
CX	categorical exclusion
DOE	U.S. Department of Energy
EMS	Environmental Management System
E.O.	Executive Order
ESD	Environmental Sciences Division (ORNL)
EPA	U.S. Environmental Protection Agency
ETTP	East Tennessee Technology Park (formerly K-25 Gaseous Diffusion Plant)
FICMNEW	Federal Interagency Committee for the Management of Noxious and Exotic Weeds
FY	fiscal year
GPS	global positioning system
IPC	Invasive Plant Control, Inc.
IPM	integrated pest management
MOA	memorandum of agreement
MOU	memorandum of understanding
NA	Natural Area (in Research Park)
NEPA	National Environmental Policy Act
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PS	Progressive Solutions, LLC
PVC	polyvinyl chloride
RA	Reference Area (in Research Park)
ROW	right-of-way
RSS	Research Safety Summary
TCWP	Tennessee Citizens for Wilderness Planning
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment and Conservation
TN EPPC	Tennessee Exotic Pest Plant Council
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UTK	University of Tennessee–Knoxville
Y-12	Y-12 National Security Complex

GLOSSARY

Aggressive species: Aggressive species are those that spread rapidly, persist, and have the greatest tendency to exclude native plant species, thus, becoming pests.

Alien species: "'Alien species' means, with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem" [E.O. 13112, Section 1. Definitions (a)].

Biocontrol: Biological control, or biocontrol, involves reconnecting invasive plants with the specialized natural enemies that usually limit their density in their native ranges.

Integrated pest management: Integrated pest management (IPM) is the coordinated use of pest and environmental information with available pest control methods to prevent unacceptable levels of pest damage by the most economical means and with the least possible hazard to people, property, and the environment. "IPM is a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks" (FIFRA, 7 U.S.C. 136r-1).

Invasive plant species: "'Invasive species' means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" [E.O. 13112, Section 1. Definitions (f)].

Native: A native (or indigenous) species is one that was not introduced into a geographical area by human actions.

Nonnative: A nonnative (or alien, exotic, foreign, introduced, or nonindigenous) species is one that occurs artificially in locations beyond its known historical natural range. *Nonnative* can refer to species brought in from other continents, regions, ecosystems, and even other habitats.

Noxious weed: "A 'noxious weed' is a species that is, or is liable to be, troublesome, aggressive, intrusive, detrimental, or destructive to agriculture, silviculture, or important native species, public roads or other property; and is difficult to control or eradicate (WAPA 1999)." "The term 'noxious weed' means any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment" [Title IV—Plant Protection Act. Public Law 106–224. June 20, 2000. Sec. 403. Definitions (10)].

Pest plants: "Plant species, and parts thereof that might be used for propagation, which are injurious to the agricultural, horticultural, silvicultural, or other interests of the state [of Tennessee]" [Rules of the Tennessee Department of Agriculture, Division of Plant Industries. Chapter 0080-6-24, Pest Plant Regulations, 0080-6-24-.01 Definitions (1)].

Problematic species: Problematic species are those most likely to interfere with native species in natural areas.

Restoration: *Restoration* means return of an ecosystem to a close approximation of its presumed condition prior to disturbance.

Undesirable plant species: "The term 'undesirable plants' means plant species that are classified as undesirable, noxious, harmful, exotic, injurious, or poisonous, pursuant to State or Federal law. Species listed as endangered by the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.) shall not be designated as undesirable plants under this section and shall not include plants indigenous to an area where control measures are to be taken under this section" [Federal Noxious Weed Act Sec. 2814, "Management of undesirable plants on Federal lands (e)" Definitions (7)].

ACKNOWLEDGEMENTS

Many individuals contributed to the original version of this document and to this update/revision. Their input is much appreciated. Those who were involved include staff from Oak Ridge National Laboratory (ORNL); Y-12 National Security Complex; East Tennessee Technology Park; U. S. Department of Energy; Invasive Plant Control, Inc.; Certified Services Company; Tennessee Valley Authority; Tennessee Wildlife Resources Agency; University of Tennessee–Knoxville; and Tennessee Department of Environment and Conservation.

Thank you to Dan Druckenbrod (ORNL) for helpful technical review comments, and Greg Byrd (ORNL) for field reconnaissance locating invasive infestations. ORNL staff members Lana McDonald, Sherri Cotter, Sherry Wright, and Jeanne Dole (retired) provided invaluable work on the production of the report.

Finally, thanks to J. Warren Webb, retired ORNL staff member, who was a participant in the production of the 2004 version of this plan.

1. INTRODUCTION

Invasive plants pose a number of ecological threats to natural systems. At their worst invasive plants alter ecosystem operation and the services provided, decrease native biodiversity, increase risks to threatened and endangered species, and impose a high financial burden for control once they have spread. In addition, invasive plants can increase risks to natural areas from storm and fire damage; crowd out native habitats along rights-of-way (ROWs); invade a variety of native habitats; overtake and damage structures, open areas, power lines, shade trees, lawns, and gardens; and are responsible for a loss of local sense of place and aesthetics.

The need for actively battling pest plants is not a new issue for those with grounds, forestry, and facility maintenance responsibilities. For those managing other types of resources (such as natural areas, wetlands, and cultural resources), however, care that was once passive in nature (i.e., identify and protect the area from disturbance) now requires active management to maintain the integrity of the habitat or ecosystem. Because invasive species (both plants and wildlife) damage "typical" landscapes as well as natural areas, active management and education can serve to reduce the impact of invasives across the entire landscape.

Approaching invasive plant problems through a strategic process can help achieve management goals and objectives (FWS 2009), and developing a plan for managing invasive plants can be highly beneficial. A plan can serve as a reference while management progresses and can support decision making and problem solving needed to achieve desired vegetation conditions. Having a plan in place also ensures consistency in management efforts as personnel change, helps engage stakeholders and citizens, and is useful as supporting material for writing grants and soliciting partnerships.

The U.S. Department of Energy (DOE) takes its responsibility for addressing invasive plant and noxious weed issues seriously (DOE 2002b). DOE has programs at many of its sites to control problem plant species, often in cooperation with state and federal agencies (DOE 1999, 2000a, 2000b, 2001a, 2001b, 2001c, 2002a, 2002b, 2007, 2009a, 2009b, 2010a, 2010b, 2010c; WAPA 2007). These programs highlight DOE's continued commitment to, and proactive stance toward, control of invasive and noxious plant species. The regulatory requirements on which DOE sites base their programs for dealing with undesirable plants include federal laws, Executive Orders (E.O.s), Presidential memos, contracts, agreements, and other requirements described in more detail in Sect. 2.

1.1 THE OAK RIDGE RESERVATION

The 33,542 acre DOE Oak Ridge Reservation (ORR) is mostly composed of native eastern deciduous forest with large blocks of mature interior forest; extensive areas of undisturbed wetlands, open water, and riparian vegetation; and several hundred acres of grassy meadows (Parr and Hughes 2006). Three major developed facility complexes—Oak Ridge National Laboratory (ORNL), the Y-12 National Security Complex (Y-12), and the East Tennessee Technology Park (ETTP)—are surrounded by approximately 20,000 acres of fairly unfragmented, undeveloped land. Most of this undeveloped area lies within DOE's Oak Ridge National Environmental Research Park (http://www.esd.ornl.gov/facilities/nerp/index.html).

Meeting DOE's mission goals and objectives requires multiple land uses on the reservation (ORO 2007). Thus, the land on the ORR surrounding the developed sites includes areas used for safety and security; emergency planning; research and education; utility corridors; biosolids land application; access roads; grounds maintenance; protection of rare plants, animals, and special habitats; general wildlife management; preservation of cultural and historic resources; cleanup and remediation of contamination; new facility construction; environmental regulatory monitoring; and public use. Different DOE contractors have responsibility for land management on various parts of the ORR. This multiplicity of land uses and contractors introduces challenges for effectively preventing and managing invasive species.

The ORR was acquired by the federal government in 1942 as part of the Manhattan Project. Aerial photos indicate that about half of the land was cleared at that time. Since then it has been protected and relatively undisturbed and has escaped the development that has gone on around it (Fig. 1). This protection has allowed it to revert from primarily farm land to more natural habitats. The cleared and cultivated areas have returned to forest through planted seedlings and natural succession, with about 70% of the reservation now in mature or maturing native forest.

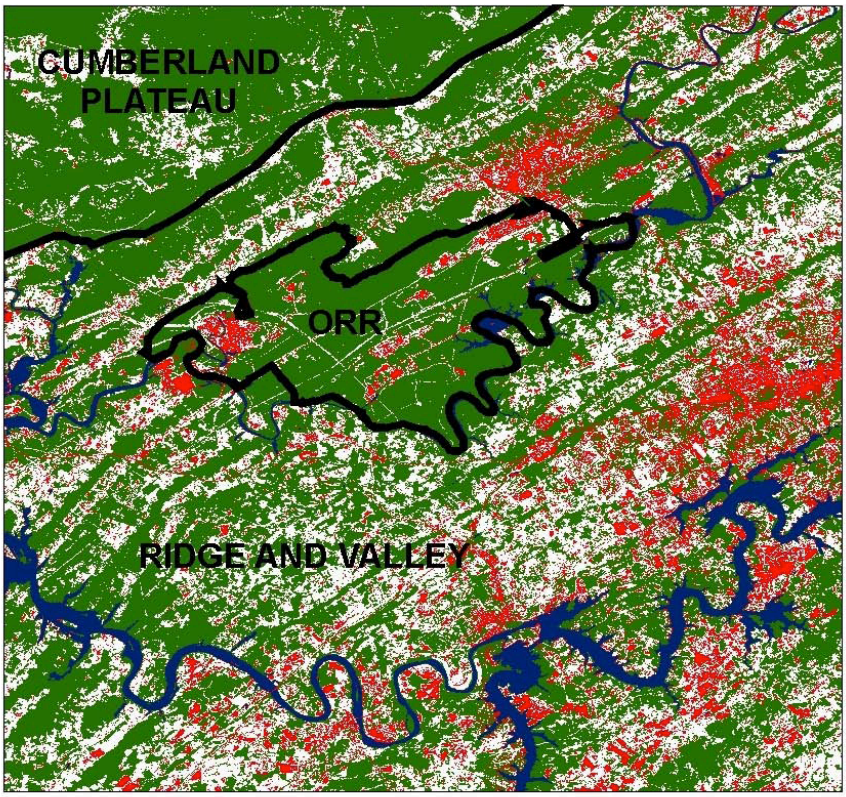

Fig. 1. The ORR stands out as an area protected from surrounding regional development.

Plant communities on the ORR are generally characteristic of the intermountain regions of Appalachia. Oak-hickory (*Quercus-Carya*) forest, which is most widely distributed on ridges and dry slopes, is the dominant plant association. Minor areas of other hardwood forest types include northern hardwoods, a few small natural stands of hemlock (*Tsuga canadensis*) or white pine (*Pinus strobus*), and floodplain forests (Mann et al. 1996). Other ecological communities found within the framework of mixed hardwood and pine forests on the reservation include cedar barrens, river bluffs, and wetlands. These plant communities include species and habitats now absent or uncommon in surrounding areas in which commercial and residential development has been extensive.

Invasive plants have spread out on the ORR from old home site plantings, well-intentioned erosion control efforts, and wildlife forage enhancement projects. Also, severe outbreaks of the southern pine beetle in the 1990s (http://www.esd.ornl.gov/facilities/nerp/forest_damage.html) (Fig. 2) opened up large areas (about 12,000 acres) of pine plantation to potential infestation by nonnative invasive plant species. Although a small portion of this damaged area was replanted with native grasses or woody plants, most of it was allowed to naturally regenerate, resulting in the growth of not only native plants, but also some invasive species.

Fig. 2. Some of the ORR areas damaged by southern pine bark beetles in the 1990s.

1.2 NATIONAL AND STATE PERSPECTIVE ON INVASIVE PLANTS

Government agencies (e.g., Department of Transportation, Bureau of Land Management) began to import nonnative invasive plants in the 1950s for various reasons, including erosion control along highways and public beaches. Many species were also introduced by individuals, either intentionally (e.g., gypsy moth for silk production) or accidentally (e.g., brought to this country by animals or with other imported goods). Initially there was no consideration of the potential negative effects of invasive exotic plants on ORR natural areas (e.g., ORR habitats with rare plants or wildlife), and seemingly harmless plants such as kudzu (*Pueraria montana*), spotted knotweed (*Centaurea maculosa*), and Amur bush honeysuckle (*Lonicera maackii*) began a silent biological invasion.

At least 4,200 species of introduced plants (about 8.4% of total introductions) have escaped from cultivation and established populations in the United States since the beginning of European colonization. Of that total at least 675 species (15%) are harmful, causing severe damage. In economic terms 79 species, or 12% of the total harmful species, caused documented losses of $97 billion from 1906 to 1991 according to Dr. Randy Westbrooks, Invasive Plant Coordinator for the U.S. Geological Survey. The

Weed Science Society of America's January 2010 revision of its Composite List of Weeds (http://www.wssa.net/Weeds/ID/WeedNames/namesearch.php) includes 3,488 plant species as weeds in the United States and Canada. These numbers do not include the hundreds of new species that have become established in the United States in recent decades (Westbrooks 1998).

The Tennessee Exotic Pest Plant Council (TN EPPC) has published a list (http://tneppc.org/invasive_plants) (with input from 21 field biologists and land managers across the state) that includes 86 species considered invasive exotic pest plants in Tennessee (TN EPPC 2009). Of these species 63 are considered severe or significant threats to natural communities. The alert list (species that are problems in surrounding states but not yet known to be a problem in Tennessee) includes an additional 49 species. Appendix A contains the TN EPPC invasive plants list and describes the criteria for each invasiveness category.

1.3 ORR INVASIVE PLANT MANAGEMENT PLAN DEVELOPMENT AND REVISION

Recognition of the potential impacts of invasive plants on facility operations and natural areas and the usefulness of a plan to manage them led to the development of the first Invasive Plant Management Plan for the ORR (Parr et al. 2004). That plan evaluated the situation on the ORR and discussed potential strategies to address the problem while meeting the intent of E.O. 13112 on invasive species (Sect. 2.3). The initial plan for the ORR included the following components:

- identifying mandates requiring management of invasive plants;
- ascertaining what invasive plants occur on the ORR;
- determining the extent of the problem on the ORR;
- preparing guidelines to prevent or minimize the spread of invasive species;
- prioritizing situations for invasive plant management;
- selecting appropriate treatments and timing;
- locating specific sites for initial treatments;
- leveraging resources for treatment;
- restoring treated areas, as needed;
- developing and maintaining an information database;
- sponsoring or facilitating research on invasive species;
- evaluating results and adapting the approach, as needed; and
- increasing awareness of ORR invasive plants through education of staff and the general public.

Details of these various components of invasive plant management are discussed in the following sections of this document. The results of the implementation of the initial plan are also presented, as is a revised plan based on an analysis of those results and the knowledge gained during the initial plan's implementation.

As part of the development of the initial plan, a National Environmental Policy Act (NEPA) review was conducted by ORNL staff in 2003. The areas in which treatment could be conducted and possible impacts were evaluated, and it was determined that the plan fell within two DOE categorical exclusions (CXs)— B1.20 and B 3.3 (DOE's NEPA implementing procedures, 10 Code of Federal Regulations 1021, Appendix B to Subpart D). This determination is reviewed every year during the update and revision of the Research Safety Summary (RSS) (see Sect. 4.5). Based on the most recent analysis, the CX is still valid.

1.4 PRIORITIES FOR INVASIVE PLANT MANAGEMENT

In developing the initial plan for the ORR, DOE and its contractors (including subcontractors) at ORNL, Y-12, and ETTP identified a number of priorities for managing invasive species. These priorities included

- detecting invasives early to facilitate their removal before they become a problem;

- integrating invasives treatment and removal with other tasks;
- considering the potential for contaminant transport during treatment;
- protecting
  - natural areas (e.g., rare species, special habitats),
  - research areas,
  - wildlife habitat,
  - cultural resources,
  - boundary areas,
  - wetlands, and
  - areas of potential hydrologic regime impacts;
- targeting treatment of
  - corridors that encourage movement of invasive species (e.g., roads, streams, fences),
  - ROW infrastructure,
  - restoration and remediation sites,
  - compliance and monitoring sites,
  - areas in which security is a concern,
  - areas of high visual impact, and
  - wildfire fuel accumulation areas;
- emphasizing safety and health considerations (e.g., breeding sites for mosquitoes, overgrowth in areas that could hide hazards, imminent safety hazards that should be addressed immediately); and
- implementing the philosophy and technology of integrated pest management (IPM) to increase the effectiveness of invasive plant control while minimizing any potential risks.

These priorities formed the basis for specific treatment plans and schedules as described in this revised invasive plants management plan.

What is IPM?

- IPM is a decision-making process. Each plant, each year, and each habitat is slightly different, and programmed controls will not address those differences. Thus, monitoring must be performed and decisions must be made.
- IPM is a system of pest management decisions based on ecological, economic, and sociological values.
- IPM is a process of pest monitoring and sampling. Researchers must know the status of a pest and whether it really needs a control action.
- IPM is a process that considers all of the control options.

1.5 BENEFITS OF MANAGING INVASIVE PLANTS

In addition to meeting legal requirements, several benefits can be recognized for the ORR as a result of a comprehensive invasive plant management.

Treating invasive plants helps overcome the challenges involved in maintaining power-line corridors and other ROWs on the reservation. Dense stands of some invasive species can form an impenetrable barrier, presenting significant issues in accessing ROWs. Climbing species, such as kudzu, are particularly problematic for utility lines, causing arcing and increasing the fire potential. Both the difficulty and the time required to maintain these areas can be significantly increased by well-established thick stands of invasive woody plants. Eradicating these species followed by establishing native species (e.g., native grasses) makes maintenance more manageable.

Significant gains can be made by replacing invasive plants with native species that provide much higher quality wildlife habitat. The ORR supports a diversity of game and nongame wildlife species that

benefit from the diverse habitats currently found on the reservation. The Tennessee Wildlife Resources Agency (TWRA) is involved on the ORR and in statewide efforts to control and manage invasive plants impacting wildlife habitat.

Active management to keep invasive plants out of sensitive areas, such as wetlands and rare plant habitats, helps prevent disruptions of hydrologic regimes and displacement of native plants that cannot compete with the invasive species. Managing invasive plants can also help protect the significant, high-quality forest blocks on the ORR that are important to migratory songbird populations.

Managing invasive plants around field research sites can prevent impacts on environmental, energy, and remediation studies. Monitoring and remediation are likely to be more effective if sites are not compromised by overgrowth of invasive species.

Improvement in ORR aesthetics is an additional benefit. The growth pattern of many invasive plant species results in the establishment of monocultures of one species that can choke out more attractive native species. This results in vast areas that provide very little visual appeal. Proper management of these areas for more appealing native plant species results in more pleasing landscapes and can highlight species native to the region.

Restoration of rare plant communities can be an important outcome of invasive species management and control. On the ORR invasive species control, follow-up planting programs, and other management strategies can restore locally and regionally rare plant communities. A prime example is the reestablishment of historically common native grasslands. These native grasslands benefit wildlife, and their reestablishment can result in reduced maintenance requirements and consequent cost savings.

Invasive plant encroachment is a national issue that impacts vast areas of public and private lands, including other DOE facilities. The knowledge gained from implementation of the ORR invasive plant species program serves as an important model for application to other areas in need of management.

2. REQUIREMENTS FOR MANAGING INVASIVE PLANTS

2.1 MANAGEMENT OF UNDESIRABLE PLANT SPECIES ON DOE SITES

DOE has active programs at many of its sites to control problem plant species, often in cooperation with state and federal agencies (DOE 1999, 2000a, 2000b, 2001a, 2001b, 2001c, 2002a, 2002b, 2007, 2009a, 2009b, 2010a, 2010b, 2010c; WAPA 2007). These programs demonstrate DOE's commitment to the control of invasive and noxious plant species.

The regulatory requirements on which DOE sites base their programs for dealing with undesirable plants include the following:

- federal laws, E.O.s, and Presidential memos (see Sect. 2.3);
- land withdrawal orders;
- contracts for managing DOE sites;
- state weed-management laws;
- state noxious weed lists;
- county noxious weed-management legislation;
- county noxious weed lists; and
- compliance agreements and memorandums of understanding (MOUs).

2.2 TENNESSEE

Information on the most significant laws or other authorities related to undesirable plants that could be applicable to the ORR are discussed in this section.

Tennessee Plant Pest Act. The Tennessee Plant Pest Act (Tenn. Code Ann. §43-6-104 et seq.) is implemented by the Tennessee Department of Agriculture (TDA). Table 1 lists the species that have been named under that law as pest plants. TDA administers rules and regulations (Rules of TDA, Chapter 0800-06-24-.02) to prevent the introduction of pest plants into the state and eradicate and/or suppress and control them. The department is authorized to engage in investigation, inspection, treatment, eradication, and quarantine of plant materials, facilities, and equipment as may be necessary.

Table 1. Tennessee Pest Plants[a]

Scientific nomenclature	Common name
Commelina benghalensis	Tropical spiderwort
Elaeagnus pungens	Thorny olive
E. umbellate	Autumn olive
Imperata cylindrical	Cogongrass
Ligustrum sinense	Chinese privet
L. vulgare	Common privet, European privet
Lonicera x bella	Bell's honeysuckle
L. maackii	Shrub honeysuckle, Amur honeysuckle
L. morrowii	Morrow's bush honeysuckle, Morrow's honeysuckle
Lythrum salicaria, L. virgatum, and related cultivars	Purple loosestrife
Rosa multiflora	Multiflora rose
Salvinia molesta	Giant salvinia
Solanum viarum	Tropical soda apple

[a] Source: Rules of TDA, Chapter 0080-06-24-.02 (accessed March 28, 2011)

Roane and Anderson Counties. The ORR straddles two Tennessee counties, Roane and Anderson. Neither one has a county list of noxious weeds.

Tennessee Exotic Pest Plant Council. With input from experts across the state (e.g., botanists, land managers, others working with the state's natural resources), TN EPPC revised its list of introduced plant species that are invasive or may become invasive and cause damage to native plant communities (TN EPPC 2009) (Appendix A). The council acknowledges that most introduced species are harmless. It also realizes, however, that many species naturalize and thus have the potential to spread and become ecological disasters. This list has no regulatory authority but provides useful information to help guide agencies and private landowners in making responsible decisions about plant use and management decisions.

The TN EPPC website (http://www.tneppc.org/invasive_plants) provides information about each species on its list, including a full description, images, life history, similarity to other species, and various management recommendations.

2.3 FEDERAL ACTS AND OTHER AUTHORITIES

Information on the most significant laws or other authorities related to undesirable plants that could be applicable to DOE sites are discussed in this section.

Federal Noxious Weed Act (1974). Most of the content of the Federal Noxious Weed Act was repealed by the Plant Protection Act of 2000. Section 2814, *Management of Undesirable Plants on Federal Lands*, however, was amended and remains in effect. Subsection (a) of that section mandates that each federal agency

- designate an office or person to develop and coordinate an undesirable plants-management program for control of such plants on federal lands under the agency's jurisdiction,
- establish and adequately fund an undesirable plants-management program,
- complete and implement cooperative agreements with state agencies regarding the management of undesirable plant species on federal lands under the agency's jurisdiction, and
- establish IPM systems to control or contain undesirable plant species targeted under cooperative agreements.

Undesirable plants are defined to include, but are not limited to, noxious weeds (see glossary).

Subsection (c) allows federal agencies, as appropriate, to enter into cooperative agreements with state agencies to coordinate the management of undesirable plant species on federal lands.

Subsection (d), "Exception," states, "A Federal agency is not required under this section to carry out programs on Federal lands unless similar programs are being implemented generally on State or private lands in the same area."

Plant Protection Act (http://www.aphis.usda.gov/brs/pdf/PlantProtAct2000.pdf) (2000). This law, Title IV of the Agriculture Risk Protection Act of 2000, consolidates and modernizes all major statutes pertaining to plant protection and quarantine (e.g., Federal Noxious Weed Act, Plant Quarantine Act). (See Federal Noxious Weed Act, above, for information on parts of it that remain in effect.) The act permits the U.S. Department of Agriculture's (USDA's) Animal and Plant Health Inspection Service (APHIS) to address all types of weed issues, increases the maximum civil penalty for violations, and authorizes APHIS to take both emergency and extraordinary emergency actions to address incursions of noxious weeds.

Memorandum of Understanding for the Establishment of a Federal Interagency Committee for the Management of Noxious and Exotic Weeds (http://www.fs.fed.us/ficmnew/index.shtml) (1994). The Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW) was established through a MOU signed by agency leaders, including DOE's, in August 1994. FICMNEW represents an unprecedented formal partnership among 16 federal agencies with direct invasive plant management and regulatory responsibilities spanning the United States and its territories.

FICMNEW's charter directs the committee to coordinate, through the respective secretaries, assistant secretaries, and agency heads, information regarding the identification and extent of invasive plants in the United States as well as federal agency management of these species. FICMNEW accomplishes this coordination by developing and sharing scientific and technical information, fostering collaborative efforts among federal agencies, providing recommendations for national and regional-level management of invasive plants, and sponsoring technical/educational conferences and workshops concerning invasive plants.

During monthly open meetings, FICMNEW members interact on important national and regional invasive plant issues and share information with various public and private organizations participating with the federal sector to address invasive plant issues.

FICMNEW continues to bridge the gap between federal agency invasive plant management and scientific activities and has been a driving force behind the national emphasis against the broader invasive species threat.

Executive Order (E.O.) 13112, Invasive Species (1999). This E.O. directs all federal agencies to address invasive species concerns and refrain from actions likely to increase invasive species problems. It defines invasive species as "any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem."

The E.O. creates an interagency National Invasive Species Council to coordinate and improve the invasive species programs of 23 federal agencies and work closely with state and local governments and private organizations on this critical economic, environmental, and health issue. The council is cochaired by the departments of agriculture, commerce, and interior and includes seven other federal departments and agencies.

The E.O. also calls for development of a National Invasive Species Management Plan to better coordinate federal agency efforts. The plan, initially completed in January 2001 (NISC 2001), was updated in August 2008 to cover the period from 2008 through 2012 (NISC 2008).

One product of the management plan is the *National Early Warning and Rapid Response System for Invasive Plants in the United States* (FICMNEW 2001), which proposes a framework of public and private partners at all levels to address new invasive plants through

- early detection and reporting,
- identification and vouchering,
- verification,
- archiving of new records in databases,
- rapid assessment, and
- rapid implementation of control if plants are determined to be invasive.

The E.O. directs federal agencies to use all available tools in an IPM approach to manage undesirable plants on federal lands.

DOE Order 450.1A (2008).[*] The purpose of DOE's order entitled *Environmental Protection Program* [DOE Order 450.1 (https://www.directives.doe.gov/directives/archive-directives/450.1-BOrder-a/view)] is as follows:

> To implement sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources impacted by DOE operations, and by which DOE cost effectively meets or exceeds compliance with applicable environmental, public health, and resource protection requirements. The objectives are—
>
> a. To implement sustainable practices for enhancing environmental, energy, and transportation management performance, as stipulated in section 3(a) of Executive Order (E.O.) 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*, through environmental management systems that are part of Integrated Safety Management (ISM) systems established pursuant to DOE P 450.4, *Safety Management System Policy*, dated 10-15-96.
>
> b. To achieve the DOE Sustainable Environmental Stewardship goals ….

This order requires DOE facilities to prepare Environmental Management Systems (EMSs) to promote the long-term stewardship of a site's natural resources throughout its design, construction, operation, closure, and post-closure life cycle and provide for the protection of other natural resources, including biota. While there are no DOE orders or other DOE-wide requirements that specifically call for control and management of invasive plants and noxious weeds, the objectives of this DOE order cannot be fully met without invasive plant management to protect the land and other natural resources. A commitment to manage undesirable species would ensure that sound stewardship practices are developed and implemented to protect DOE land and natural resources. Thus, management of undesirable species could be incorporated into EMSs to achieve environmental goals.

The order assigns the Chief Health, Safety, and Security Officer (HS-1) the responsibility to develop new, or revise existing, DOE environmental protection directives, guidance, and procedures.

[*] As of April 2011, DOE was in the process of combining this order and DOE Order 432.B, *Departmental Energy, Renewable Energy and Transportation Management* (2/27/08), into a single sustainability order by which DOE can meet its greenhouse gas reduction goal as well as the goals set forth for federal agencies in E.O. 13514, *Federal Leadership in Environmental, Energy and Economic Leadership* (http://edocket.access.gpo.gov/2009/pdf/E9-24518.pdf).

Development of explicit guidance for dealing with undesirable plant and animal species would be a valuable way to meet this responsibility.

3. THE PROBLEM OF INVASIVE PLANTS ON THE ORR

The occurrence of invasive plants on the reservation has been recognized for years, especially in areas in which they have impacted management (e.g., forestry, maintenance). However, documentation of types and frequency of invasive plants in specific locations began in only the last 10 years.

Planning for invasive plant management on the ORR requires fundamental knowledge and key information to adequately assess and address the problems in the context of land management goals. This knowledge and information are derived from common elements and activities of invasive plant management and are essential for management planning.

3.1 INVASIVE PLANTS OCCURRING ON THE ORR

More than 1100 vascular plant species are found on the reservation. Of the 168 nonnative plant species, 54 are considered aggressive (Table 2). Based on a ranking system developed by the U.S. Geological Survey (USGS), 18 of those species were identified as the most problematic species for ORR natural areas (Tables 2 and 3) (Drake, Weltzin, and Parr 2002, 2003). The USGS ranking system uses species characterization information as well as attributes of the invaded site or community.

Ongoing field characterizations and data collections add to the list of nonnative invasive species on the ORR and may result in changes in priorities. For example, identification of a small population of spotted knapweed (*Centaurea maculosa*) in 2009 resulted in quick development and implementation of a plan to treat the plants at that location before they spread.

Table 2. Nonnative aggressive plant species on the ORR

Scientific nomenclature	Common name
Ailanthus altissima (Mill.) Swingle	Tree of heaven[a]
Albizia julibrissin Durz.	Mimosa
Allium vineale L.	Field garlic[a]
Amaranthus retroflexus L.	Green amaranthus
Ampelopsis brevipedunculata	Porcelainberry
Arthraxon hispidus	Hairy jointgrass
Arundo donax	Giant reed
Celastrus orbiculata	Oriental bittersweet
Cirsium vulgare (Savi) Ten.	Bull thistle[a]
Coronilla varia L.	Crown vetch[a]
Dioscorea batatas	Chinese yam[a]
Echinochioa crus-galli	Barnyard grass
Elaeagnus umbellata Thunb.	Autumn olive[a]
Elaeagnus pungens Thunb.	Thorny-olive[a]
Euonymus alata (Thumb) Sieb	Burning bush
Euonymus fortunei (Turcz.) Hand.-Mazz.	Winter creeper
Festuca arundinacea Schreb.	Tall fescue
Festuca pratensis Huds.	Meadow fescue
Glechoma hederacea L.	Gill-over-the-ground, ground ivy

Table 2 (continued)

Scientific nomenclature	Common name
Kummerowia striata (Thunb.) Schindl.	Japanese clover
Lespedeza bicolor Turcz.	Bicolor lespedeza, shrubby bushclover
Lespedeza cuneata (Dum.-Cours.) G. Don	Sericea lespedeza[a]
Ligustrum sinense Lour.	Chinese privet[a]
Ligustrum japonicum Thunb.	Japanese privet
Ligustrum vulgare L.	Common privet
Lonicera japonica Thunb.	Japanese honeysuckle[a]
Lonicera maackii (Rupr.) Maxim.	Amur bush honeysuckle[a]
Lonicera morrowii A. Gray	Morrow's bush honeysuckle
Lonicera tatarica L.	Tartarian honeysuckle, twinsisters
Lonicera x bella Zabel	Bush honeysuckle
Lysimachia nummularia L.	Moneywort, creeping Jenny
Lythrum salicaria L. [all varieties and cultivars]	Purple loosestrife
Mahonia bealei (Fortune) Carriere	Oregon grape
Mentha x piperita L.	Peppermint
Mentha spicata L.	Spearmint[a]
Microstegium vimineum (Trin.) A.	Camus Nepalgrass, Japanese grass[a]
Miscanthus sinensis	Zebragrass
Myriophyllum spicatum L.	Eurasian water milfoil
Nasturtium officinale	Watercress[a]
Paulownia tomentosa (Thunb.) Sieb. & Zucc. ex Steud	Princess tree[a]
Poa pratenss	Kentucky bluegrass
Plantago major	Common plantain
Polygonum cuspidatum Seib. & Zucc	Japanese knotweed, Japanese bamboo
Polygonum hydropiper L.	Smartweed
Poncirus trifoliata	Trifoliate orange
Potamogeton crispus L.	Curly pondweed
Pueraria montana (Lour.) Merr.	Kudzu[a]
Pyrus calleryana	Bradford pear
Rosa multiflora Thunb.	Multiflora rose[a]
Rumex conglomeratus Murray	Clustered dock
Sorghum halepense (L.) Pers.	Johnson grass[a]
Urtica dioica L.	Stinging nettle
Verbascum thapsus L.	Common mullein
Veronica arvensis	Corn speedwell
Veronica officinalis	Common speedwell
Veronica serpyllifolia L.	Thyme-leaved Speedwell
Vicia villosa	Hairy vetch
Vinca minor L.	Common periwinkle[a]

[a] Most problematic species on the ORR (Drake, Weltzin, and Parr 2002)

Table 3. Ranking of the 18 most problematic invasive plants for ORR Natural Areas[a]

Rank	Common name	Scientific name
1	Japanese grass	*Microstegium vimineum*
2	Japanese honeysuckle	*Lonicera japonica*
3	Chinese privet	*Ligustrum sinense*
4	Kudzu	*Pueraria Montana*
5	Multiflora rose	*Rosa multiflora*
6	Lespedeza	*Lespedeza cuneata*
7	Chinese yam	*Dioscorea batatas*
8	Tree of heaven	*Ailanthus altissima*
9	Field garlic	*Allium vineale*
10	Autumn olive	*Elaeagnus umbellata*
11	Oriental bittersweet	*Celastrus orbiculatus*
12	Princess tree	*Paulownia tomentosa*
13	Johnsongrass	*Sorghum halepense*
14	Periwinkle	*Vinca minor*
15	Spearmint	*Mentha spicata*
16	Watercress	*Nasturtium officinale*
17	Bull thistle	*Cirsium vulgare*
18	Crown vetch	*Coronilla varia*

[a] Source: Drake, Weltzin, and Parr 2002

3.2 SURVEYS OF THE ORR

Surveys are done with the goal of detecting new invasions early in order to begin eradication efforts as soon as possible. The location of invasive plants can also be correlated with places in which they are likely to spread. Potential dispersal routes include roadways and areas in which disturbance has occurred (e.g., pine plantations devastated by outbreaks of southern pine beetle). The primary areas on the ORR that were surveyed for invasive species as part of the development of the original invasive plant management plan are shown in Fig. 3.

In 2000 Sara Drake (a student at the University of Tennessee) characterized invasive plants within and adjacent to 16 ORR Research Park Natural Areas (Drake, Weltzin, and Parr 2002). In 2002 locations of kudzu that were visible from reservation roads were recorded using global positioning system (GPS) data. A project to predict the distribution and dominance of exotic species in the Southern Appalachians, funded by the U.S. Environmental Protection Agency (EPA) National Center for Environmental Research, included numerous permanent plots on the ORR that provided data on invasive plants within forested areas (Michael Huston personal communication with Pat Parr in 2003). In 2003 the Tennessee Department of Environment and Conservation (TDEC) established invasive plant monitoring plots within an area designated for conservation easement on Black Oak Ridge. A rigorous characterization of invasive species within Research Park Natural Areas was also begun in 2003 (Johnston 2003).

In 2004 when the initial invasive plant management plan was finalized, abundance data were available for 18 of the approximately 90 Research Park Natural or Reference Areas and a select number of species (e.g., kudzu, oriental bittersweet). The information was recorded on topographic map software for future reference.

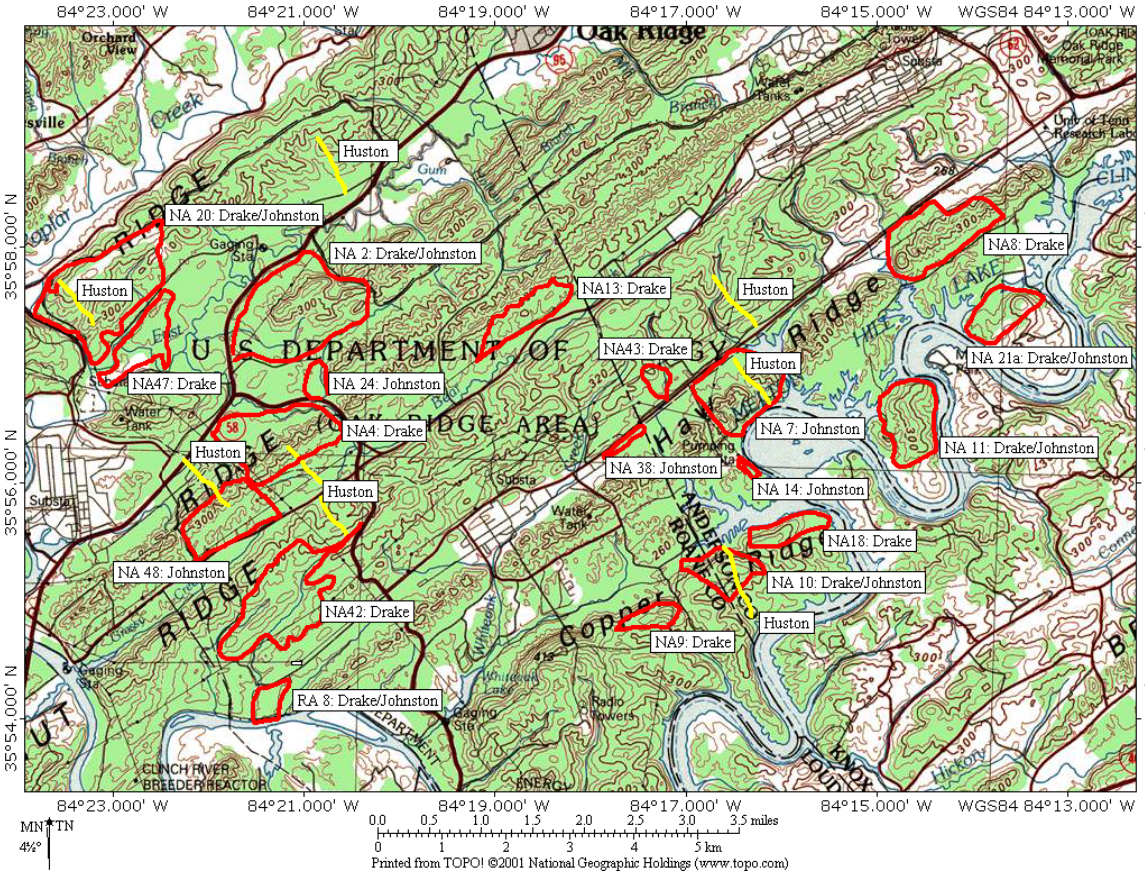

Fig. 3. Areas of the ORR that were surveyed for invasive plant species in 2004. Natural Areas (NAs) and Reference Areas (RAs) are outlined in red, research transects are depicted as yellow lines, and primary surveyors of each area are indicated by name labels.

3.3 DATABASES FOR INVASIVE PLANT MANAGEMENT

As described in the initial invasive species plan, a database has been developed to record location and abundance information gathered from surveys of invasive plants (as described above) combined with treatment efforts. This database attempts to capture all useful information, such as where a treatment has occurred, when it began, the target species, the treatment technique, who did the work, the GPS coordinates of the treatment if helpful, and when possible, a digital image history of before and after photos to indicate the degree of success. It also includes quantitative values of invasive plant density before and after treatment for those sites at which such data have been measured. The database was set up as an Excel spreadsheet and later moved to Access database software. This shift to a more advanced data management format will help link ORR information with national data sets, such as the Early Detection and Distribution Mapping System (http://www.eddmaps.org/), being created to help manage invasive species at a larger scale.

4. DEVELOPING THE INVASIVE PLANT SPECIES MANAGEMENT PLAN

Planning for invasive plant management requires fundamental knowledge and key information to adequately assess and address the problems in the context of land management goals. This knowledge and information are derived from common elements and activities of invasive plant management. Recently there has been a slow but obvious shift toward an ecological approach to managing plant invasions in

wildland ecosystems and away from simply removing unwanted plants (FWS 2009). To achieve desired vegetation conditions, land managers and scientists are referring to the ecological principles and processes operating within plant communities (e.g., species interactions) and larger scale of ecosystems (e.g., effects of natural disturbances). Knowledge of ecological principles and processes can be incorporated into management in many ways, from evaluating soil properties and plant life history strategies to directing desired changes in plant communities according to successional theory.

4.1 MANAGEMENT APPROACH OPTIONS

Three primary approaches to invasive plant treatments are implemented on the ORR. These approaches include targeting control to

- manage an individual species wherever it occurs,
- manage multiple species in specific areas, and
- cover the corridors or routes of dispersal and invasion.

Because of the size of the ORR and the variety of problems presented by invasive plants, the judicious application of all three techniques offers the best route for success. The approach used depends on the likelihood for success, cost, and priority for controlling the target species or protecting the specific area. In many situations treatment of specific invasive problems requires more than one treatment approach.

4.1.1 Target Invasive Plants by Species

Targeted species management focuses treatment on a single invasive plant species. This can be effectively implemented in areas in which one species has crowded out other species, is just getting started, or is the only invasive species interspersed with desirable plants. The goal is to implement treatment before the species population reaches a size at which it can reproduce faster than it can reasonably be controlled.

4.1.1.1 Most likely to be controlled

Some invasive species are easier to control than others and thus merit individual attention. Trees and shrub species take longer to mature and therefore have a somewhat slower rate of invasion than vines or forbs (i.e., herbaceous flowering plants other than grasses, sedges, and rushes) that usually produce seeds within the first few growing seasons. Attacking these comparatively slower-growing species before they reach reproductive age results in a better chance of controlling them.

On the ORR several species fall into this category. Tree species that can become significant problems include princess tree (*Paulownia tomentosa*), also known as royal paulownia or empress tree, mimosa (*Albizia julibrissin*), tree of heaven (*Ailanthus altissima*), and white poplar (*Populus alba*). Four shrubs—autumn olive (*Elaeagnus umbellata*), privet (*Ligustrum* spp.), thorny olive (*Eleagnus pungens*), and bush honeysuckle (*Lonicera* spp.)—also take a few years to reach fruit-bearing stages and are worth targeting. All of these species, however, were abundant and represented by fruit-bearing individuals on the ORR before invasive plant control efforts were initiated. Therefore, they now require extensive efforts to control.

4.1.1.2 New or recurrent invasive species

Targeting an individual species is particularly useful when the species occurs only singly or at limited locations. This is a function of the fact that the best time to control an invasive is when it first appears, a method that has had some success on the ORR.

Oriental bittersweet (*Celastrus orbiculatus*) was found in the 2003 Natural Areas survey in Natural Area (NA) 2 and was controlled by an intensive treatment approach over 3 years. Renewing the effort to control this species while its numbers were low was a successful strategy. Identification of a small population of spotted knapweed along Bethel Valley Road in 2009 resulted in quick development and implementation of a plan to treat the plants at that location before they spread. Other invasive species that have been observed on the ORR and treated whenever and wherever seen include giant reed (*Arundo donax*) and zebragrass (*Miscanthus sinensis*).

For this strategy to be useful, partial surveys of the ORR should be conducted on an annual basis so that the majority of the reservation is checked about every 5 years. Increased awareness of potential new invaders will make early treatment more likely. Follow-up monitoring of locations in which such species have been treated will also help prevent their becoming significant problems.

4.1.1.3 Species occurring at high densities

Targeting an individual species can be successful when it occurs at very high densities in a few locations. By their nature some invasive species spread slowly at first, becoming locally abundant before they become a more widespread problem. By targeting areas with high-density infestations, these species may be more efficiently controlled.

Control of two high-density species, kudzu and autumn olive, was initiated in 2003 on the ORR. Kudzu is a fast-growing vine that spreads locally by rhizomes and extended stems more often than through seed dispersal. Although quite tenacious, a control effort that is repeated for several years can produce significant reductions. In 2003 two small patches of kudzu (less than 1 acre each) were sprayed. Follow-up treatments and treatments in most of the major patches of kudzu on the ORR since then have reduced the amount of kudzu on the reservation. Continued vigilance is, however, needed as kudzu can grow back from any surviving portions of roots in future years.

Autumn olive also occurs at extremely high densities on the ORR, and a cooperative treatment program involving the Tennessee Valley Authority (TVA), TWRA, and ORNL was started in 2003. This treatment process has been a multiyear effort because autumn olive produces large quantities of berries that are widely spread on the ORR. Control efforts have continued since then with a notable reduction of autumn olive in the ORR areas of highest infestation.

Other species, such as Japanese grass (*Microstegium vimineum*), can also occur in very high densities. Control methods are, however, less successful on this annual species than on kudzu or autumn olive. Therefore, treatment efforts on this invasive are not a high priority on the ORR. Treatments of Japanese grass have been undertaken only where infestations threaten to interfere with DOE missions (ORNL field research plots).

4.1.2 Target Invasive Plants by Area

In many cases a variety of invasive plants grows in a particular area, allowing the potential for multispecies management. Such treatment can, however, be labor intensive, requiring careful selection of the plants to be treated to avoid treating desired native species. Also, the ability to identify the wide range of possible invasive species is necessary when targeting specific plants. Different species may require treatment at different times of the year and different types of treatment (see Chap. 6). Thus, multispecies management is not always easily implemented.

Targeting invasive species by area is also important in areas in which disturbance has occurred. For example, the ORR forests were overwhelmed by exploding populations of the southern pine beetle in the 1990s (Roy, Evans, and Ryon 2001). From 1993 to 2001 beetles impacted about 12,000 acres of the forested areas of the ORR that had a pine component. Impacts in some areas were obvious, while others were subtle or unremarkable (Fig. 2). The devastation of this primary cover opened many of these areas to invasive plants. By treating the invasive plants in these areas, negative impacts of the pine loss could be

reduced or minimized and native plants allowed to revegetate. Some of these areas have been cleared and reseeded to native grasses with control of invasives as necessary during establishment of the grasslands.

4.1.2.1 Environmentally sensitive areas and aesthetic resources

A multispecies approach is often necessary to protect sensitive or special-value areas. In these cases eliminating only the primary invasive species may not meet the goal of protecting rare species or unique habitats. Also, an effort to target multiple species at one time can be more cost efficient if the method of treatment is the same for all target species.

In 2003 a multispecies treatment effort was initiated in Raccoon Creek Barrens Reference Area. At this site the primary invasive plant was sericea lespedeza (*Lespedeza cuneata*), but other invasive plants were also present, including Johnsongrass (*Sorghum halepense*), fescue, privet, multiflora rose (*Rosa multiflora*), bull thistle (*Cirsium vulgare*), and Japanese honeysuckle (*Lonicera japonica*). All these species were treatable with glyphosate-based herbicide delivered by a variety of targeted methods, so a multispecies treatment was practical and efficient. Since then multispecies treatment of a variety of invasives has been carried out in 26 designated Natural Areas, and 4 designated Reference Areas across the ORR.

4.1.2.2 Target operational areas

In addition to treatment efforts concentrated on sensitive and unique areas, an area approach can be taken at specific reservation facilities. Because there are several major facilities within the ORR, the responsibility for some areas is divided among managing organizations. For example, TWRA manages wildlife habitat activities on the Three Bend Scenic and Wildlife Refuge, ORNL and TWRA treat invasive species, and DOE contractor ESH maintains most of the fire roads. Also, the invasive plant management team works with DOE, ORNL, Y-12, and ETTP maintenance and environmental organizations to integrate control of invasive plants into their normal activities.

One useful strategy for managing invasive plants is to work with the operational organizations of these facilities to treat problems in their areas. If regular grounds crews are scheduled to clear or trim in an area that also contains invasive plants, with a little guidance they can achieve multiple objectives with the same effort. Further, these efforts can provide leverage (e.g., labor, supplies, follow-up treatment) to gain even more treatment of invasive plants. For instance, when Y-12 wanted to clear the boundary around the facility, a contractor treated the invasive species and taught the Y-12 staff how to identify and treat them. This and similar efforts have raised awareness of invasive plant problems at Y-12, with the result that managers request and regularly schedule invasive plant treatment throughout the facility.

4.1.3 Target Routes of Dispersal and Invasion

The third major approach to treatment of invasive species is to attack their routes of dispersal or invasion. Most invasive plants become established first along corridors of disturbance and in areas that have open canopies exposed to full sunlight. These routes of dispersal/invasion (Fig. 4) include existing roads, road expansions and new roads, utility ROWs, streams and riparian buffers, and fenced perimeters. By managing invasive species in these corridors, not only are individual invasive plants eliminated, but their ability to spread further throughout the ORR is also limited.

For each type of dispersal corridor, implementation of slightly different control approaches is needed. For riparian areas a highly selective treatment is recommended to minimize loss of vegetative cover that helps control erosion and stabilize stream banks. The ROW treatments along streams pose no special difficulties except in cases in which steep slopes present a problem.

For roadsides the treatment can be broader in spectrum because the invasive plants often form a thick monoculture along the edges of a road. Treatment can also be more mechanical because roads provide easy access.

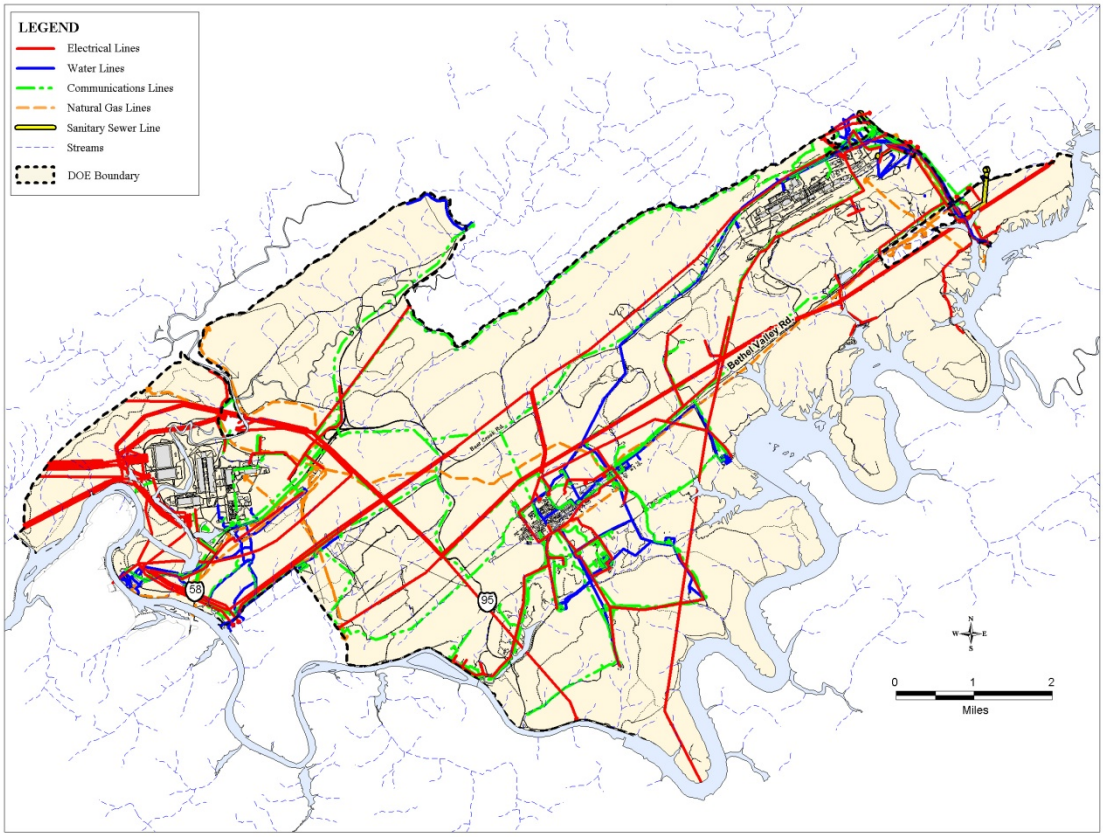

Fig. 4. Location of major routes of dispersal for invasive plants on the ORR. Routes include roadways, streams, and utility rights-of-way.

Areas damaged by pine beetles have been particularly vulnerable to invasion by nonnative species, but they are difficult to treat because of their large size on the ORR and rough ground surface. A small fraction of the pine beetle areas ravaged in the 1990s was cleared by raking up the debris into piles, burning it, and then planting native grasses or woody plants. Those areas with pine beetle damage are monitored and treated, as necessary, to help control the invasive plant problem on the ORR.

4.2 PRIORITIZING OPTIONS

The ORR is so large that available labor and funding do not allow all existing invasive species problems to be addressed at the same time. Priorities must thus be set when selecting locations for management of invasive plants and the specific approach to use. Prioritization involves examining the impact of specific invasives, selecting among the possible treatment approaches discussed above, determining applicable treatment techniques (see Chap. 5), and identifying resources available to implement the possible treatments.

The initial invasive plants management plan included a procedure that blended all three major treatment approaches and other relevant data to provide a numerical ranking scheme to prioritize areas and species for initial treatment. As the program has been implemented, experience gained in prioritizing treatment areas has replaced the formal quantitative ranking procedure. Priority targets for treatment are now identified by implementing an adaptive management scheme that is based on past experiences—knowing what has been done and what areas need quick follow up. For example, there has been good success in controlling kudzu at several places on the ORR. Thus, patches of kudzu that have been treated and are considered to be under control are scheduled to be checked each year to determine their status.

Re-treating areas in which kudzu has again become a concern is given a higher priority than attempting to control kudzu in areas that have never been treated. Use of such an adaptive management scheme allows priorities to be adjusted, even on a weekly basis, as conditions change and new information becomes available. Priority rankings vary from year to year depending on progress made in controlling some species, discovery of new species on the ORR, funding changes, and availability of personnel.

4.3 IMPLEMENTATION AND SCHEDULE

Invasive plant management on the ORR informally began in 2002 and 2003 in selected demonstration areas (see Sect. 6.1). These demonstration projects involved treating selected areas and laid the foundation for current efforts. Based on those initial efforts, implementation is based on an adaptive management scheme that incorporates past experiences—knowing what has been treated where and what areas need quick follow up.

Implementation, within available funding constraints, uses contractor and subcontractor staff who specialize in treatment of invasive plants. Funds from the site-wide reservation management budget are leveraged with resources from the three ORR facilities and interested agencies such as TVA and TWRA. Treatment locations for which costs or labor can be shared with other groups are favored in implementation. The schedule each year is based on the assessment of priorities, treatment options, and available funds.

4.4 LONG-TERM PLANNING

An overall long-term goal of reducing invasive plants as much as possible on the ORR was set during the development of the initial management plan. Implementing efforts to meet this goal has helped focus invasive plant management on the ORR. Maximum benefits have resulted from prioritizing invasive species control in areas identified as important—natural areas, research areas, security areas, wildlife management areas, and remediation sites—and in areas in which treatments are most likely to make a difference.

Several strategies help to reach the overall long-term goal. First, a standard approach is used each year, including revisiting treated areas for evaluation and necessary follow-up control. Secondly, management of invasive plants is coordinated with other reservation management. For example, if not controlled, autumn olive would overgrow the access roads on ROWs, and there is a need to maintain low-growing plants on ROWs to prevent interference with power lines. Thus, maintenance of ROWs has been modified to include treatment of invasive species because the goals of the two programs complement each other. In addition, work undertaken with TWRA to convert nonnative fescue areas to native grasses as part of the improvement of wildlife habitat (Ryon, Parr, and Cohen 2007) promotes the long-term invasive plant management goals.

To be successful these long-term efforts must span more than one fiscal year. Thus, consistent budget levels need to be maintained for many years.

4.5 SAFETY CONSIDERATIONS

An integrated safety assessment, documented in an RSS that considers all likely hazards and controls for invasives, is an important part of the invasive plant management program. This assessment also includes documentation of a NEPA consistency review. All activities conducted under this plan are described in RSS #583 (https://portal.ornl.gov/sites/psd/wpc/rhacs/Lists/Main/AllItems.aspx?mode=List), the Environmental Sciences Division (ESD) guide to field-removal or control of exotic invasive plants on the ORR. The RSS addresses issues such as

- potential hazards of a wide variety of activities (e.g., use of chemical and mechanical tools) that may be encountered when treating invasive plants;

- contamination, steep or uneven terrain, and poisonous plants or animals that may be found at sites to be treated; and
- environmental stresses (e.g., extreme heat or cold) that may occur while implementing treatments.

The RSS is required reading for all ORNL participants in the invasive plant management program. The RSS is updated at least annually to summarize actions planned for the next year. Each revision is reviewed by appropriate experts before it is reauthorized. In addition, all ORNL subcontracts include a safety checklist review, and contractors must demonstrate that a health and safety plan is in place.

4.6 GUIDELINES TO PREVENT OR MINIMIZE THE SPREAD OF INVASIVES

Preventive measures to avoid or minimize introduction and spread of invasive plants can reduce impacts to ORR resources. The following guidelines have been incorporated into routine operating activities:

- prohibit purchases or acquisition of plants identified as invasive in Tennessee (see Appendix A) for use on the ORR, including around facilities, for remediation, or for wildlife management. Special exceptions must be approved by the ORNL Natural Resources Manager;
- select from a list of native plants or noninvasive species approved by DOE for use in landscaping on the ORR;
- require nurseries or agencies providing plant material to inspect and certify that their shipments do not accidentally contain plants identified as invasive in Tennessee;
- include an assessment of the potential of spread of invasive plants during project NEPA reviews;
- purchase or acquire seed only from dealers who ensure a high degree of seed purity;
- educate individuals who work in the field so they can identify invasive plants, spot new ones, and map locations;
- report invasives sighted in the field to the ORNL Natural Resources Manager;
- conduct annual spring and fall surveillance and monitoring to spot new invasive plants or detect new hot spots;
- perform road maintenance when invasives are less likely to be spread (i.e., before germination or prior to seed set);
- clean tires, vehicles, and equipment carefully after they have been in an area in which invasive plants occur and seeds are likely to be carried out on the equipment;
- require a follow-up plan to deal with invasive plants after completion of field projects that may open areas or result in areas vulnerable to spread of invasive species; and
- continue to educate employees, reservation users, and the public (especially boundary neighbors) about invasive plants.

5. TREATMENT TYPES AND TIMING

IPM, the treatment strategy used on the ORR, is an effective and environmentally sensitive approach to invasive species management that relies on a combination of commonsense practices (see Sect. 5.6.). IPM programs use current, comprehensive information on the life cycles of invasive species and their interaction with the environment. This information, in combination with appropriate control methods, is

used to manage invasive species by the most economical means and with the least possible hazard to people, property, and the environment.

Managing exotic species does not, however, necessarily result in complete eradication and may accomplish control of the species for only a limited time. Not only does soil often retain viable invasive plant seeds that will germinate for many years after removal, but sites beyond the immediate management zone may also contain seeds and other dispersal propagules that can reinvade a treated area. Thus, managing problem areas on the ORR requires a long-term commitment and implementation of a plan that incorporates a monitoring program to detect recolonization, including of surrounding sites that may provide seeds and other dispersal propagules. Such a plan incorporates the need for and enables subsequent appropriate retreatment.

The increase in the number of species of invasive plants in the region necessitates a regular review of the frequency and types of treatments needed for ORR infrastructure maintenance, the most effective schedule for compliance monitoring, and the best methods to use for wildland fire prevention. The types and timing of treatments make a difference in the effectiveness of the results and the efficiency of the effort. Not all invasive species will respond to the same types of treatments, and a single type of treatment may not be appropriate for a site with multiple invasive species, especially if they are interspersed with desirable plants.

To enhance the effectiveness of invasive species control, IPM takes advantage of all appropriate management options and treatment techniques including

- mechanical and manual,
- biocontrol,
- chemical,
- prescribed burning, and
- other approaches.

The techniques selected for treatment of invasive plants on the ORR consider issues such as the existence of desirable species in the area, proximity to water, stage of the plant in the growing season, density of the population, and available manpower. Land managers and researchers on the ORR continue to experiment with combinations of treatments, doses, and timing to meet site-specific needs as described in this updated invasive plants management plan.

5.1 MECHANICAL AND MANUAL TREATMENTS

Mechanical and manual treatments include hand pulling, weed wrenching, cutting, and mowing. Mechanical treatments (e.g., mowing) have been extensively used on the ORR, usually to meet management goals other than control of invasive vegetation (e.g., to ensure visibility along roads, to control growth of woody vegetation that could interfere with power lines). These techniques can also be specifically targeted to invasive plants. Thickets of species such as privet and autumn olive can be mowed to remove surface growth. Roots are, however, typically not killed, and mowing results in additional sprouts that require repeated mowing or chemical treatment for ultimate control. Mowing invasive species can be part of an effective control strategy for heavy infestations if cut surfaces are also chemically treated to control root masses. Similarly, invasive trees can be individually cut, and effectiveness can be enhanced through the use of chemical treatment to prevent root sprouts. Other mechanical methods, such as hand pulling and digging out roots, are also effective for control of certain species in selected settings but are labor and time intensive for large infestations. Some species (e.g., tree of heaven) are stimulated by mechanical cutting and come back unless additional treatments are used.

5.2 BIOCONTROLS

Biological control (or biocontrol) is the science of reconnecting invasive plants with the specialized natural enemies that often limit their density in their native ranges. This process consists of surveys in the

plant's area of origin to discover candidate natural enemies, studies on their biology and host specificity, and release and evaluation of their impacts on the target plant. In the eastern United States, projects have targeted aquatic, pasture, and forest weeds (Van Driesche et al. 2002). Results to date have been varied, with biocontrol showing promise for economic control of aquatic species such as Eurasian watermilfoil (*Myriophyllum spicatum*) (Johnson and Blossey 2002) and pasture species such as multiflora rose (Amrine 2002). Because these methods are not yet as widespread as more conventional control methods, the cost is often high. In addition, the application of biocontrol agents can be time and labor intensive. No biocontrols have been introduced on the ORR, but when an appropriate setting for their use is found, they will be evaluated as a management option.

5.3 PRESCRIBED BURNING

Careful, controlled use of fire (i.e., prescribed burns) can be an effective tool for management of native warm-season grasses and understory vegetation in forests. The potential to use fire to control invasive species is dependent on the invasive species and whether the native vegetation is fire adapted (D'Antonio 2000; Wittenberg and Cook 2001). In some cases fire may suppress invasive plant species, whereas in other cases fire may promote plant invasion and plant population expansion (FWS 2009).

The use of prescribed burns has been beneficial in controlling large infestations of invasive plants (Tu, Hurd, and Randall 2001). In most cases the burns are not sufficient on their own to eliminate the plants, but when they are combined with follow-up chemical treatment, they can be very effective. The Nature Conservancy has experimented with the use of prescribed burns and published a Fire Management Manual for the use of its staff and volunteers involved in fire management operations on its behalf (TNC 2010).

Fire has been used on the ORR to treat invasive plants, for cleanup of areas with pine beetle damage in preparation for restoration activities, and to encourage the reestablishment and growth of native warm-season grasses**.** Currently an active fire management program for native grass communities on the ORR is followed. Controlled burns on an as-needed basis maintain the grasslands and other special habitats by controlling a variety of woody species including invasives.

5.4 CHEMICAL TREATMENTS

A primary goal of any invasive plant management program is selectivity—that is, control of the invasive species without harming desirable, native vegetation that is often present in close proximity. Chemical treatments can offer such selectivity through use of appropriate application technique, timing, and chemical modes.

Chemical use is usually considered when other efforts are ineffective or when infestations must be reduced to attain manageable levels by other means. The chemicals used for treatment are applied as recommended in conformance with product labels. These chemicals are considered to be safe when used according to the label recommendations. All precautions are made to minimize the impact on nontarget species.

5.4.1 Herbicide Selection

Herbicides used for chemical treatment on the ORR include those that can be applied without certification and those that require special licensing for application. Selection of the appropriate herbicide depends on the chemical mode of action that kills a particular plant group and the likelihood of not harming desirable groups of plants in the area. Table 4 describes the major herbicides used on the ORR and includes information on their selectivity and application techniques.

Table 4. Herbicides used for control of invasive species on the ORR and information on their use

Product name[a]	Chemical and formulaton	Selectivity	Technique: Typical rate (% in water, unless otherwise stated)
Accord	54% glyphosate	Nonselective	Foliage spray: 5%; cut surface: 50–100%; specifically approved for use near and in standing water
Arsenal	28.7% imazapyr	Nonselective; has soil activity	Foliage spray: 1%
Garlon 3A	44% triclopyr (amine)	Woody plants and broadleaf weeds; grasses unaffected	Foliage spray: 1–5%; cut surface: 25–100%
Garlon 4; Remedy	62 % triclopyr (ester)	Woody plants and broadleaf weeds; grasses unaffected	Basal: 1–30% solution of product with oil; cut surface: 20–30% solution of product with oil
Pathfinder II	62 % triclopyr (ester)	Woody plants and broadleaf weeds; grasses unaffected	Basal: premixed, used undiluted
Pathway	5.4 % picloram and 20.9% 2,4-D	Woody plants and broadleaf weeds; grasses unaffected; has soil activity	Cut surface: premixed, used undiluted
Roundup Glypro SP	41% glyphosate	Nonselective	Foliage spray: 5%; cut surface: 50–100%
Spike 20P	20% tebuthiuron	Nonselective	Applied as pellets to soil surface at rate of 0.38 to 1.13 oz. per 100 ft^2
Tordon K	24% picloram	Woody plants and broadleaf weeds; grasses unaffected; has soil activity	Foliage spray: 0.5–1% solution
Transline	41% clopyralid	Broadleaf weed and legumes; grasses unaffected; has soil activity	Foliage spray: 0.25–0.75%

[a] All chemicals manufactured by Dow Chemical except for Roundup, which is manufactured by Monsanto, and Arsenal, which is manufactured by BASF Corporation.

5.4.2 Application Techniques

Techniques for applying herbicides include dabbing, handheld spraying, backpack spraying, high-volume truck container spraying with hoses, wicking, and basal bark treatments. Each of these techniques can be preferentially directed at a particular invasive species while minimizing harm to any desirable neighbors. Table 5 describes the primary herbicide application techniques used on the ORR and includes notes about timing and selectivity.

Table 5. General application techniques for using chemicals to control invasive plants on the ORR

Technique	Description	Timing	Selectivity
Foliage spray	Herbicide mixture is sprayed on plant foliage until wet	Whenever foliage is present	Spray can be directed to avoid desirable vegetation; selective herbicides can be used; application can be made to evergreen foliage when deciduous foliage is not present
Cut surface	Herbicide mixture is sprayed, painted, or dabbed onto cut stumps or "frill" cuts made into stems of plants to be killed	Year-round except when freezing	Only target species are treated
Basal	Herbicide mixture in oil base is sprayed around stem wetting the lower 12 in. (the "base," hence "basal")	Year-round except when bark is frozen or wet	Spray can be directed to avoid desirable vegetation when present
Soil surface	Herbicide in pellet form is applied around the base of the plant to be treated	Year-round	Only target plants are treated

Handheld wick application of herbicide was tested on lespedeza at the Raccoon Creek Barrens. It proved, however, to be difficult to do as the plants' tall stems would fall over when the wick contacted them. Therefore, handheld wick application is not normally used as a treatment method on the ORR. Truck-mounted wicking is, however, an efficient treatment (Fig. 5). Polyvinyl chloride (PVC) pipe with a wick attached below it is mounted on the front of a truck that is then driven slowly along a road where lespedeza is to be treated. The wick drips the appropriate herbicide and efficiently treats the lespedeza.

Fig. 5. Truck-mounted wick-type herbicide application device being used to apply glyphosate-based herbicide to lespedeza and Johnsongrass at the Raccoon Creek Barrens.

5.4.3 Treatment Timing

Susceptibility of particular plant species to chemical control depends on biological characteristics that are most often keyed to the annual growth cycle. For example, control of deciduous species with foliage-active herbicides is possible only when foliage is present and typically works best when leaves are fully developed in summer. By contrast, evergreen species offer a wider foliage treatment window. Cut surface treatments can be performed year-round on all woody species, as can basal treatments, although effectiveness varies with the season. Basal applications work best in late winter and early spring as the plant mobilizes energy to break winter dormancy.

The choice of an application technique for a particular species or group of species is limited by the period of the year when the technique can be used for that species. Next, the choice among potential techniques can be optimized based on considerations such as ease of application, opportunity for greater selectivity of application, and availability of labor and time. For example, foliage applications to evergreen species can be made when nearby, desirable deciduous species are without leaves, thereby giving an extra margin of selectivity. Basal applications can be made in winter when foot travel through a forest is easier than in summer, thereby increasing the number of stems that can be treated per unit of time. Cut surface treatments can be made for woody species whenever labor is available, regardless of the season of the year.

For purposes of facilitating choice of application techniques and optimization of timing of treatments, the most problematic ORR invasive species have been grouped into eight categories based on relevant biological characteristics. These plant groups are deciduous trees, deciduous shrubs, deciduous vines, evergreen shrubs, evergreen vines, legumes, monocots, and herbaceous dicots (forbs). For each of these plant groups or species, a determination has been made of which application techniques are possible during each month of the year (Table 6). Table 6 can be used as an invasive plant control planning tool by noting seasonal overlaps of optimal treatment times. In addition, when locations of plant groups to be treated are determined and transportation to them is organized by cluster, further optimization of resources is possible.

Table 6. Timing of herbicide application techniques for invasive plants on the ORR

Plant group	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deciduous trees	CB	CB	CB	CB	CB	***F***CB	***F***CB	***F***CB	***F***CB	***F***CB	CB	CB
Deciduous shrubs												
Multiflora rose	CB	CB	***B***C	***B***C	***BF***C	FCB	FCB	FCB	FCB	CB	CB	CB
Autumn olive	CB	***B***C	***B***C	BC	CB	***F***CB	***F***CB	***F***CB	***F***CB	CB	CB	CB
Bush honeysuckle	CB	***B***C	CB	CB	CB	***F***CB	***F***CB	***F***CB	***F***CB	CB	CB	CB
Deciduous vines												
Chinese yam	CB	CB	CB	CB	CB	***F***BC	***F***BC	***F***BC	FBC	CB	CB	CB
Oriental bittersweet	***C***B	***C***B	***C***B	CB	***C***B	FCB	FCB	FCB	FCB	CB	***C***B	***C***B
Evergreen shrub	FCB	FCB	***F***CB	FCB	***F***CB	FCB	FCB	FCB	FCB	FCB	***F***CB	***F***CB
Evergreen vine	FCB	FCB	***F***CB	FCB	***F***CB	FCB	FCB	FCB	FCB	FCB	***F***CB	***F***CB
Legumes												
Crown vetch						***F***	***F***	***F***	***F***			
Lespedeza					F	F	F	*F*	F			
Kudzu	C	C	C	C	C	***F***	***F***	***F***	***F***	C	C	C
Monocots												
Field garlic				***F***	***F***	***F***						
Microstegium								***F***	***F***			
Johnsongrass						***F***	***F***	***F***	***F***			
Herbaceous dicots				F	F	F	F	F	F			

Treatment types: F= foliar spray; C = cut surface (frill or cut stump); B = basal bark treatment.
Abbreviations in a month indicate treatment is possible at that time with that technique; ***italic, bold*** letters indicate treatment is optimal for that type of treatment during that month with respect to ease of application, enhanced selectivity, or efficacy.

While many invasive species can be effectively controlled throughout much of the year, others, such as the annual grass *Microstegium* (Japanese grass), have a much narrower window for effective control. For this species mowing, burning, or herbicide applications early in the season do not control the plant; new seeds in the soil can germinate following such measures, and the resultant plants can still have time to set seed by the end of the season. Therefore, the most effective time to kill or otherwise remove the foliage of *Microstegium* is late in the season, but before seed has set, to avoid a new crop. This procedure must be followed for several years to give lasting control as seeds remain viable for 3 to 5 years.

5.5 OTHER APPROACHES

Creative approaches to treatment can be implemented if they are cost effective. For example, a few large princess trees occur on the ORR. Removal of these specific trees through a contract with specialty wood cutters might be a doubly positive approach because the wood is used in special products. There are, however, a number of such trees on the ORR, so eliminating the largest ones would not remove the source of a problem plant species. Also, it is unclear if such removal would be cost effective. Another creative approach would be to use goats as an alternative to herbicides to eliminate kudzu. Keep Knoxville Beautiful, with the aid of a grant from the UPS Foundation, fenced several areas in Knoxville in which goats fed on the kudzu that was destroying the native vegetation (Chung 2010). Goats have not, however, been tried to date on the ORR as a measure to control kudzu due to cost-effective control achieved through contract selective herbicide applications and the potential for goats to nonselectively consume all vegetation present. In addition, hoof damage to soil and deposition of invasive seed to soil from goat wastes are other potential drawbacks of their use for invasive control.

5.6 INTEGRATED PEST MANAGEMENT

The philosophy and technology of IPM, which has a long history in agriculture, are being applied to invasive plant problems on the ORR. Pest management as opposed to eradication implies that some pests will always be around. It is the goal of pest management to keep the pest populations down to a level at which damage is not overly evident. The IPM approach emphasizes coordinated use of information about invasive species and the local environment with available pest control methods. This will prevent unacceptable levels of pest damage by the most economical means and with the least possible hazard to people, property, and the environment. Using the IPM approach, three important concepts must be accepted:

- No single pest control method is always used. All of the control options — biological, chemical, mechanical, and cultural — must be considered. Chemical control is, however, used only when needed or most cost effective.
- Monitoring (sampling) of the pest is constantly needed to evaluate the status (e.g., not present, present but not causing aesthetic damage, present and causing aesthetic damage) of a pest population.
- Therefore, mere presence of a pest may not be a reason to justify implementation of control actions.

Thus, IPM integrates treatment methods with available information to increase the effectiveness of invasive plant control and minimize any potential risks.

5.7 LEVERAGING RESOURCES FOR TREATMENT

Because invasive plants are a nationwide problem, working (formally and informally) with other agencies within the region provides a mechanism to share and obtain regional resources. Agencies and organizations who have worked together on the ORR both formally and informally include

- Appalachian Regional Commission;
- Bechtel Jacobs Corporation;

- B&W Y-12[†];
- Certified Services Company;
- Community Reuse Organization of East Tennessee;
- DOE;
- Environmental Landscape Design Associates;
- GroWild (native plant nursery);
- Invasive Plant Control, Inc. (IPC);
- National Park Service (Great Smoky Mountains National Park);
- Progressive Solutions, LLC;
- Southeast Exotic Pest Plant Council;
- Southern Appalachian Man and the Biosphere Cooperative;
- Tennessee Citizens for Wilderness Planning (TCWP);
- TDEC;
- TN EPPC;
- TVA;
- TWRA;
- The Nature Conservancy;
- University of Tennessee–Knoxville (UTK); and
- U.S. Forest Service.

A 2003 memorandum of agreement (MOA) among UT-Battelle, TVA, TWRA, and DOE enabled the initiation of treatment of several acres of autumn olive, privet, bush honeysuckle, and other invasive plants within power-line ROW and adjacent areas where they had spread. The MOA is no longer in effect, but it was instrumental in the initiation of the invasive plants management program.

TWRA is responsible, through an agreement with DOE, for managing wildlife on the entire ORR. Its goals to benefit wildlife include control of invasive species (plant and wildlife) and restoration using native grasses. TWRA and ORNL have cooperated in the treatment of invasive species in areas on Solway, Gallaher, and Freels Bends and in the area of the deer checking station on Bethel Valley Road.

Research has been conducted by university faculty and students on invasive plants using study sites on the Research Park. Research projects have included analyzing moisture and shading on *Microstegium,* evaluating the impact of invasive plants on a small population of a state-listed orchid, determining factors that may inhibit invasive plant growth, and studying impacts of changes in climate and carbon dioxide on invasive plant growth. Results of these research projects are shared through presentations at conferences and in other forums.

6. TREATMENT RESULTS

Implementing this IPM plan for invasive plants on the ORR ensures that the selection of a particular management treatment (or combination of treatments) considers the likelihood for success, cost, and priority for controlling the target species or protecting the specific area. Because of the size of the ORR and the variety of problems presented by invasive plants, the judicious application of all the techniques described in Chap. 5 offers the best route for success. In many situations treatment requires more than one approach.

Since the initial invasive plants management plan was prepared, much experience has been gained with treatment techniques and timing on the ORR. That experience has resulted in treatment strategies and timing being refined for maximum effectiveness as discussed below.

[†] B&W Y-12 currently operates and manages the Y-12 National Security Complex. When this management plan was first developed, BWXT Y-12 operated and managed Y-12.

Figure 3 shows the areas of the ORR that had been surveyed for invasive plant species as of 2004. That information was used to develop the initial invasive species management plan and prioritize the areas for initial treatment. Since then numerous additional areas with invasive species have been discovered and treated. The discussion below describes the initial demonstration projects and also more recent efforts. It also discusses how this program will continue in the future.

6.1 DEMONSTRATION PROJECTS

To highlight the need for management of invasive plants on the ORR and to develop experience in controlling them, a series of small demonstration projects were initiated in 2002 through 2004. These projects spanned the varying types of possible treatments that could be implemented on the ORR. They were generally located where they would be visible to DOE and contractor staff. These projects provided an important part of the knowledge base from which the full-scale ORR treatment program has grown, as described later in this chapter.

6.1.1 First Creek Project

First Creek is a small tributary that flows through the west end of ORNL. It served as a site for a DOE Environmental Management program wetland enhancement project as mitigation for disturbance of a wetland in cleanup actions elsewhere on the ORR. Thus, in the 1990s many native wetland plants had been planted in its riparian area. Several years following planting, however, the site had become severely compromised by invasive plants such as fescue (*Festuca spp*.), Japanese honeysuckle, crown vetch (*Coronilla varia*), and privet.

During the summer of 2003, IPC treated most of the privet using cut and spray techniques and treated the crown vetch and some fescue using a foliar spray. Because the area was sensitive to erosion, plugs of native grasses and wildflowers were added to the site after treatment. Follow-up in 2004 and thereafter has dealt with treatment of the remaining honeysuckle, privet, fescue, and crown vetch.

6.1.2 Fifth Creek Project

Fifth Creek is a small tributary that flows through the center of ORNL. Problem species include privet, autumn olive, thorny olive, Johnsongrass (*Sorghum halepense*), mimosa, princess tree, honeysuckle, creeping euonymus (aka winter creeper) (*Euonymus fortunei*), and porcelainberry (*Ampelopsis brevipedunculata*). High seed production and flowing water increase distribution of invasives along the stream (Fig. 6). Riparian areas were treated by IPC in the summer of 2003 using a variety of techniques (e.g., backpack and truck tank sprayers and cut-surface treatments. Follow-up treatments in 2004 focused on removing the euonymus and implementing some limited restoration. Annual monitoring and spot treatment have continued to the present.

Fig. 6. Autumn olive seeds spread by Fifth Creek are visible beneath the water's surface and easily gathered.

6.1.3 Raccoon Creek Cedar Barrens, Reference Area 8, Project

Raccoon Creek Cedar Barrens, Reference Area (RA) 8, borders the Clinch River west of ORNL. The vegetation in the barren represents a valuable resource for the ORR. In the summer of 2003, roadside areas were treated to remove sericea lespedeza (Fig. 5), and some interior areas were treated for privet, fescue, and Johnsongrass (*Sorghum halepense*). As part of the demonstration project, boom applicators and weed wands were used and were determined to be very effective techniques for controlling invasive species over large areas.

6.1.4 Bethel Valley Road Kudzu Project

Several areas along Bethel Valley Road were infested with kudzu. During the summer of 2003, a small patch of kudzu just east of the west ORNL portal was treated by Certified Services Company (CSC) using a power sprayer. This is a highly visible area, and the resulting control of this well-known invasive has been useful in educating employees and guests about the impacts of invasive plant management. Follow-up treatments were conducted by CSC in 2004 and, as needed, since then.

6.2 AREA TREATED 2003 THROUGH 2010

Follow-up on some of the demonstration areas has continued since the original management plan was developed and implemented, and extensive additional areas have been treated. Through the end of the 2010 treatment season in October, 2,686 acres had been treated. Due to retreatment required in many places, this acreage includes some areas treated more than once. Table 7 shows the areas treated by year for major treatment categories (i.e., within kudzu patches, within native grass community restoration areas, along road and forest edges, in riparian zones, and within contiguous tracts. Descriptions of much of this treatment appear below, followed by a narrative summary by year.

Table 7. Acreages treated for invasive plants on the ORR from 2003 through 2010 in various treatment categories

Year	Total acres treated	Kudzu	Native grass communities	Roads/edges	Riparian	ROW	Contiguous tract
2003	98	12	12	47	2	23	2
2004	136	48	14	19	6	20	29
2005	125	56	15	38	11	0	5
2006	254	62	63	26	87	16	0
2007	236	58	70	96	12	0	0
2008	427	27	85	173	4	138	0
2009	526	35	30	14	5	0	442
2010	884	44	32	5	26	87	690

6.3 KUDZU

Kudzu, known as the weed that ate the South, is a native of Asia that has been widely planted throughout the eastern United States in an attempt to control erosion. Successful long-term control of kudzu requires the extensive root system to be destroyed (PCA 2009), any root crowns remaining can lead to reinfestation of an area. Mechanical methods involve cutting vines just above ground level and destroying all cut material. Late-season cutting should be followed by immediate application of a systemic herbicide (e.g., glyphosate) to cut stems to encourage transport of the herbicide into the root system. The USDA is searching for biological control agents for kudzu that will not impact native species (Britton, Orr, and Sun 2002; Weaver and Lyn 2007).

When the initial invasive plants management plan for the ORR was being developed, kudzu was found in many areas—some of them very large patches. With the success of the demonstration treatment along Bethel Valley Road (see Sect. 6.1.4), treatment was initiated at other kudzu patches on the ORR. Areas in which kudzu has been treated include those below. (Unless otherwise mentioned, treatment consisted of spraying with a low rate of Tordon 101 in a high volume of water.)

- **Freels Bend:** Trees at the Freels Bend entrance that were being overtaken by kudzu were treated in 2004. By 2007 only a few straggling vines needed follow-up treatment (Fig. 7).
- **Scarboro Road:** In the summer of 2005, kudzu covered a slope at the boundary of Y-12. In August that year the entire area was sprayed, and results were seen in September. By April 2006 grasses had replaced the vanishing kudzu. In August 2007 the vegetation community was more diverse. In 2010 additional treatment was necessary as some kudzu had returned.
- **Gallaher Bend:** A 42-acre patch of kudzu on Gallaher Bend (Fig. 8), was contained in 2009 to prevent it from invading the forests surrounding it while additional treatments were planned. Initial plans to treat the remainder in 2010 were derailed by the need to retreat kudzu elsewhere on the ORR. Thus, in 2010 the corridor around the patch was retreated and expanded, and plans were made to treat more of the patch in the future.
- **ETTP railroad:** Kudzu encroachment on the ETTP railroad spur and patrol road was a long-standing problem. Spraying just the railroad track area did not address the greater problem. When kudzu growing on trees was also sprayed, results were obvious after a little more than 2 weeks. This application was followed by spot treatments in subsequent seasons.

Before treatment in summer 2004

After treatment in August 2007

Fig. 7. Trees treated for kudzu at Freels Bend entrance before and after treatment.

Fig. 8. Picture taken from within the 42-acre kudzu patch at Gallaher Bend in 2009.
Photograph courtesy of Ernest Ryan.

- **Blair Road and Highway 58 intersection:** Kudzu was among the problem invasive species at this location that had aesthetic impacts. In 2004 it was treated with a foliar spray of Garlon 3a and Tordon by CSC. Spot treatments in 2005 and 2006 removed straggler kudzu. Native vegetation then reestablished itself from the existing seed bank.
- **Bear Creek Road and Highway 95 intersection:** Kudzu was among the problem invasive species at this location that had aesthetic impacts. It also threatened a plantation of walnut trees. Kudzu was treated from 2004 to 2006, and warm-season grasses were planted in 2005. By 2007 most kudzu had been removed without damaging the trees on which it was growing, and native grasses were growing. Follow-up treatment was needed to remove the large kudzu root nodes.
- **McKinney Ridge:** Kudzu growing in this area was removed to protect nearby hemlock trees.

Experience on the ORR has shown that a high-volume spray of a low concentration of Tordon can successfully reduce the level of kudzu infestations. In sensitive areas where there could be root uptake of herbicide from the soil by nontarget broadleaf plant species (e.g., the walnut plantation), Roundup or Transline is used instead of Tordon. Monitoring is, however, necessary once initial treatment has been completed, as kudzu can grow back even after not being observed at treated areas for several years. For example, in the summer of 2010, visits to several treated areas on the ORR (e.g., the ETTP railroad site) revealed resurgent kudzu populations that required additional treatment.

Thus, all areas treated for kudzu will be checked at least once each growing season and additional treatment provided, as necessary.

6.4 TREATMENTS TARGETING OTHER SINGLE SPECIES

In addition to kudzu, several other invasive plants are persistent problems on the ORR and have, therefore, been individually targeted. The species and locations at which they have been treated include those below.

- **Autumn olive:** Autumn olive is a persistent problem on the ORR, with a particularly heavy infestation at Freels Bend. Removal of this invasive requires a combination of mechanical and herbicide control techniques.
- **Chinese yam and thorny olive:** Chinese yam (aka air potato) (*Dioscorea batatas*) and thorny olive tend to grow along the edge of woods on the ORR. They have been treated with targeted spraying. These treatment methods include hacking the bark and spraying herbicide into the cut surfaces, spraying around the base of the plants, and for Chinese yam, spraying the leaves.
- **Princess tree:** Princess tree is a particular problem at Y-12 where the seeds lodge next to buildings, germinate, and quickly grow into large-size trees. It can also damage pavement when the seeds fall into cracks and then germinate. Treatment is primarily application at cut surfaces near the base of the trees.
- **Purple loosestrife:** Purple loosestrife (*Lythrum salicaria*) has become a problem invasive species on the ORR along Scarboro Creek where it was replacing native vegetation (Fig. 9). The invasive

plant management team treated that area with a foliar spray of Accord (glyphosphate) in 2007. In an act that will prevent purple loosestrife from reinvading that area, spot spraying of upstream plants was organized in 2010 by TCWP with the approval of the city of Oak Ridge. Additional spot spraying was conducted by the invasive plant management team and TVA staff with assistance from TCWP volunteers.

- **Spotted knapweed:** Spotted knapweed, a plant native to eastern Europe, is a pioneer species that grows in recently disturbed sites or openings. Unfortunately, once it has been established at a site, it continues to spread into the surrounding habitat. Spotted knapweed was first found growing on the ORR in 2009 along a power-line ROW. Treatment of those plants consisted of spot spraying with a 5% solution of Garlon 3a. When the site was checked a week later, sprayed plants were dead. Because most of the plants had not yet set seed, treatment should help limit the spread of the infestation. Monitoring of the site takes place annually, and treatment will continue as needed. Knapweed will also be included as a target species in invasive plant surveys of the ORR.
- ***Microstegium*:** Although microstegium is too widespread throughout the ORR to be effectively controlled with current resources, research plots within the Carbon Sequestration Research Area have been specifically targeted to prevent interference with long-term projects.

Thus, all areas that have been treated for these species continue to be checked at least once each growing season to determine whether additional retreatment is necessary.

Fig. 9. Purple loosestrife being treated in Scarboro Marsh.

6.5 TREATMENTS TARGETING MULTIPLE SPECIES

Some areas are first treated for the species that is causing the major problems, with follow-up treatments targeting a number of invasives. Targeting multiple species is more efficient and cost-effective than treating invasive species individually. Such management is the preferred method of dealing with invasive plants on the ORR whenever possible. Some examples of situations in which this approach has been implemented (in addition to those described in Sect. 6.1) include those below.

- **Freels Bend:** On Freels Bend 442 acres have been spot treated to control a number of species including tree of heaven, autumn olive, bush honeysuckle, mimosa, multiflora rose, princess tree,

privet, and thorny olive. The area was initially treated in 2009. Monitoring of that area in 2010 showed good control of all those species. Additional acres were spot treated in 2010, with similar good results anticipated.

- **White Oak Creek Watershed:** The riparian area of the White Oak Creek Watershed (Fig. 10) was covered by a number of invasive plants, including autumn olive, privet, thorny olive, winter creeper, Johnsongrass, mimosa, princess tree, and porcelainberry. Their high seed production and the flowing water in the creek increased the distribution of these invasives. Treatments began in 2003 using a variety of techniques, including backpack sprayer, truck tank sprayer, and cut-surface treatments. In summer 2006 1,160 gallons of spray were applied and 13.6 miles of the stream bank and 15.9 miles of roadside in the watershed were treated. Seven staff members worked for an aggregate of 1,000 hours. Selected portions of the watershed have been retreated since 2006. Targets include privet, autumn olive, Johnsongrass, crown vetch, Japanese honeysuckle, and creeping euonymus.

Fig. 10. Invasive plants along White Oak Creek.

- **Y-12 security boundary:** The Y-12 security boundary (Fig. 11) was treated to remove invasive plants, including tree of heaven, which is stimulated by cutting and so needs herbicide application. Other invasives that were treated included autumn and thorny olive, and privet.
- **Fifth Creek:** Fifth Creek, a small tributary that flows through the center of ORNL, was the site of one of the early demonstration projects (Sect. 6.1.2). Problem species in the riparian areas have been treated several times, and results have been good. Annual monitoring and spot treatment will continue.
- **Wheat Community African burial ground:** The graveyard was overgrown with multiple invasive species. The area was treated and has been monitored since to catch invasives before they again become a problem. (Fig. 12).
- **Wheat Church (aka Jones Church) vista:** After dead pines were cleared from the area between Wheat Church and the highway, brush grew up and eventually again obscured the view of the church from the road. That area then became a native grass demonstration area. Treatment

included removing invasive species and burning to encourage grass growth. The forests nearby were also treated as invasive plants had been expanding from the area in front of the church and invading them. A GPS unit was used during herbicide treatments to make sure that the entire area was covered without spraying areas more than once.

Fig. 11. A tree of heaven awaits treatment inside the Y-12 boundary.

Fig. 12. Treatment of invasive species at the Wheat Community African burial ground.

6.6 ANNUAL TREATMENT SUMMARIES AND HIGHLIGHTS FOR ALL MANAGEMENT APPROACHES

Narrative summaries of work done to control invasive plants on the ORR are given by year below. Table 7 shows the number of acres of invasives treated each year for major treatment types.

2003

The invasive plant control program for the ORR was initiated using both commercial contractors and ORNL ESD employees. Two contractors were hired with different specialties. One, CSC, is an industrial vegetation control contractor. CSC treated roadside invasive vegetation concentrations of autumn olive around ORNL, in some ROW areas, and in open fields around the deer check station. CSC also began treatment with a picloram-based restricted-use herbicide of the kudzu infestation at the ESD communications tower area and obtained good initial brownout results.

The other contractor employed, IPC, specializes in control of invasive plants in environmentally protected areas. They treated kudzu in RA8 with herbicides selected to minimize the possibility of collateral damage to nearby desirable vegetation and also treated kudzu along East Fork Poplar Creek in front of Y-12. Kill of desirable nontarget vegetation was not observed. IPC also treated a variety of invasives along creeks within ORNL, along woods and roadside edges, along the Y-12 boundary fence, and within the African burial ground near ETTP.

The invasive plant management team treated invasives around and in Hembee Marsh, Bethel Valley Road and Old Bethel Valley Road, RA8, and native grass demonstration areas.

Equipment and Techniques

CSC used truck-mounted high-pressure and high-volume spraying equipment to deliver picloram, triclopyr, and glyphosate herbicides in relatively low concentrations. Good penetration of the applied solutions was obtained with the high pressure and high volumes.

- Use of picloram herbicide (Tordon) is restricted in high-concentration formulations because it can remain active in soil and be taken up by roots of desirable vegetation as well as move from the site if soil is moved as by erosion. Because it was used only where there was no desirable vegetation and soil movement was unlikely, such as in the middle of large kudzu patches, kill of nontarget vegetation was not a problem.
- Triclopyr-based herbicide (Garlon) is effective only on broad-leaved plants and does not harm grasses. Triclopyr herbicides were used by CSC and IPC along grassy roadsides to remove broad-leaved invasives to good advantage.
- Glyphosate-based herbicide (Roundup) is effective on both broad-leaved plants and grasses but is not active in soil. This herbicide was used by CSC at the edges of kudzu patches where roots of desirable trees were present. Just the kudzu was sprayed, and any spray reaching the soil was of no importance to nearby trees; consequently, the trees were not killed by the treatment.

IPC and ESD used glyphosate- and triclopyr-based herbicides applied to foliage. The selectivity of triclopyr made it a good choice for invasive broad-leaved plants in grasslands. Glyphosate was used for isolated invasive plants or broad expanses of homogeneous invasive plants, both broad-leaved ones like privet and autumn olive and invasive grasses such as Johnsongrass. IPC and ESD used lower volumes and higher concentrations of these herbicides than did CSC, and they were applied from lighter equipment such as backpack-type sprayers (Fig. 12) and small vehicle-mounted units. The smaller scale of the equipment allowed access to deep woods and other hard-to-reach areas in which invasives often proliferate.

Another technique used was to deliver concentrated herbicides (glyphosate, triclopyr, and picloram) to cut surfaces of invasive plants that were too tall to spray (Fig. 13). For tall invasive trees (e.g., tree of heaven, mimosa, princess tree), the bark was cut at intervals around the trunk, and herbicides were squirted into the cuts from handheld spray bottles. For privet and other species too tall to spray but with small stem diameters, the stem was completely severed and herbicide squirted into the cut stump. Because only small amounts of herbicide were used and were applied on only the cut surface, the operation was highly targeted, and collateral damage was not observed.

Fig. 13. A cut-surface treatment to a mimosa tree too tall to foliage spray.

For treatment within RA8, a special technique using wick applicators to dispense glyphosate herbicide allowed highly targeted application to protect the unique desirable vegetation. Within the RA the invasive plant management team treated individual invasive plants by rubbing them with a "wickwand" consisting of a hollow handle containing the herbicide attached to an application head consisting of a herbicide-saturated sponge. Using this technique the herbicide was applied to only the actual leaf surface of the invasive. For control of Johnsongrass and lespedeza along the roadside of RA8, a larger version of the apparatus was used consisting of a truck-mounted wick applicator (Fig. 5). The herbicide was delivered through saturated lengths of rope protruding from a plastic pipe forming a reservoir for the glyphosate herbicide. The apparatus was mounted high enough to contact the Johnsongrass as the truck was driven along the RA8 boundary, but higher than any desirable vegetation. Only the Johnsongrass was killed (Fig. 14).

2004

Once again the invasive plant management team and contractors IPC and CSC treated invasives at various locations on the ORR using a variety of targeted herbicides and techniques. A new technique used by ESD was to treat thorny olive along woods' edges on Bethel Valley Road and within the ORNL plant area using a basal application during the winter. In this method a triclopyr ester formulation is mixed with oil and applied to the lower portion of stems to a height of about 12 inches. The herbicide penetrates through the bark and kills the invasive plant as it starts to break dormancy and grow in the spring. Use of this method made it possible to treat during the winter when foot travel in the woods was easy. Because small amounts of herbicide were used and it could be directed precisely to the stem to be controlled, thorny olive could be removed without harming nearby desirable vegetation (Fig. 15).

Fig. 14. Lespedeza and Johnsongrass (at left of frame) controlled by truck-mounted wick applicator.

Fig. 15. Thorny olive selectively controlled by a basal herbicide application.

Treatment of kudzu was initiated by CSC on a larger scale based on the earlier success at the ESD tower area. Several large patches were treated with good results. The technique developed by CSC was to first treat the patch perimeter to a depth of about 50 ft and then allow about 2 weeks for the herbicide to produce brownout (Fig. 16). Once this treatment took effect, it revealed obstacles previously hidden by the kudzu that the contractor could avoid during subsequent treatments. Large patches could then be completely treated in what was usually one or two more applications. A particularly large patch was treated at the intersection of Oak Ridge Turnpike and Bear Creek Road. The kudzu had partially blocked sight distance on the intersection (Fig. 17). The Oak Ridge Police Department provided traffic control while CSC treated the patch. Results were good, and visibility on the steep curves was improved.

The invasive plant management team treated a variety of road, woods, and ROW edges for the invasives that had spread along these areas, including privet, mimosa, and tree of heaven. Both sides of the north boundary trail in NA20 from Oak Hills Estates to East Fork Poplar Creek were sprayed to remove primarily privet and Japanese honeysuckle. CSC initiated control of autumn olive, a species that had previously been planted to provide wildlife food and cover and had succeeded too well, on the TVA power-line ROW in the Mount Vernon Road area.

2005

During 2005 treatment techniques used in previous seasons were again employed to treat new kudzu patches, various invasives along roadsides and in natural areas, and in areas in which native grass communities had been previously established. Kudzu patches treated in prior seasons were retreated as necessary, and reclaimed kudzu areas were seeded with native grass species such as Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), and little bluestem (*Schizachyrium scoparium*). Experience gained with treating kudzu to this point showed that in treated areas vegetation spontaneously regenerated from seed stock in the soil. It was decided, however, to enhance this effect in several areas with native grass seeding to supplement the existing seed bank.

Fig. 16. Brownout of kudzu is visible in foreground as contractor walks through area to be treated in next application.

Fig. 17. Treatment of kudzu interfering with sight distance near intersection of Highway 95 and Bear Creek Road.

It was also found that if a kudzu patch was treated completely in one year (Fig. 18), follow-on treatment would be necessary in the second year to control new growth from existing kudzu rootstock that had not been completely killed. About 50% of the spray volume used the first season would be required in the second season. Retreatment would again be required in the third year, but at only about 20% of that used in the first year. After the third year the patch would usually be largely under control, with treatment in subsequent years performed on an as-needed basis, usually requiring relatively small amounts of herbicide.

During this season treatment of autumn olive in the Mount Vernon Road/Bethel Valley Road area continued. This area was recognized as the approximate epicenter of autumn olive spread throughout the ORR. Special attention was given by contractor IPC to control of this species and other brushy invasives growing along the entire boundary fence surrounding Y-12. TVA controlled all brushy species on its 500 kv power-line ROW in the Mount Vernon Road/Bethel Valley Road area with aerial spraying from a helicopter. Selective herbicides were used at the request of ORNL to control brush without killing grasses so that erosion problems could be prevented.

2006

During 2006 treatment more acres were treated than in previous years, with much of the effort devoted to ridding ORR stream riparian areas of invasives that often spread along the watercourses. This campaign was referred to as the Watershed Blitz. In all, 13.6 miles of riparian area were selectively treated for invasive species consisting of autumn olive, privet, multiflora rose, and several others (Fig. 19). Other areas treated under the riparian invasive control theme included the East Campus Pond (formerly known as the Swan Pond). Invasive plants were removed from the shore in advance of native landscape plantings. Invasives, primarily sericea lespedeza, were treated at North Tributary 3 in the Bear Creek

Kudzu treatment in progress; note applicator in center of frame in distance

Results apparent later that season

Fig. 18. Before and after kudzu treatment in the same season.

Fig. 19. Privet controlled (in center of picture) along an ORNL watercourse during the Watershed Blitz.

Valley as part of the establishment and maintenance of a native grass community in an area in which the tributary was relocated during a DOE environmental restoration project. Treatment of kudzu patches continued by contractor CSC, with major large new patches being undertaken in the ORNL 7000 area and in the location of the ORNL West End Treatment Facility.

2007

A new invasive species was encountered and treated in 2007: purple loosestrife. The invasive plant management team treated this invasive wetland species in the Scarboro Marsh area on the shore and in standing water with a glyphosate herbicide specifically approved by EPA for use in aquatic areas (Fig. 9). Other new invasive species were treated as well, including two grasses: giant reed and zebragrass. Kudzu spraying continued, including at major new sites along the ETTP railroad siding on Blair Road and a large patch within the Black Oak Ridge Conservation Easement. Maintenance spraying of kudzu patches sprayed in prior years was performed as necessary. Power-line ROWs in the Tower Shielding area, which are maintained by ORNL, were treated with herbicide to control tree of heaven (Fig. 20) by ORNL grounds maintenance personnel trained by the invasive plant management team . More than 52 miles of roadside were treated for invasives, including autumn olive, privet, honeysuckle, princess tree, multiflora rose, bush honeysuckle, and mimosa, in a campaign termed the Roadside Blitz.

Fig. 20. Tree of heaven in an ORNL power-line ROW before control by the Facilities and Operations Directorate.

2008

During this season the Roadside Blitz concept was continued, and most of the fire roads maintained on the ORR by DOE were treated for invasives. This network of roads is kept clear to allow control equipment into the areas in case of forest fire. However, the necessary clearing of the road surface and roadsides increases the edge area within the ORR's interior forests and allows spread and penetration of invasive plants into these areas. Many of these fire roads had been upgraded in recent years, and it was desirable to control a variety of invasive species along them before major infestations developed in new locations. Spraying of these roadsides was facilitated with a new piece of equipment, an all-terrain utility vehicle (ATUV) (Fig. 21). Another technique was employed to control invasive species and general brush in native grass communities: fire (Fig. 22). Controlled burns were conducted at the Wheat Church overlook vista and in native grass communities previously established in pine-bark-beetle-damaged areas. Kudzu treatments continued, and a major new area was treated at McKinney Ridge atop a quarry overlooking ETTP. This kudzu control was undertaken to protect a stand of hemlock trees, which are uncommon on the ORR, from encroachment by kudzu.

2009

In 2009 two major initiatives were undertaken: beginning treatment of an approximately 42 acre patch of kudzu on Gallaher Bend (Fig. 8) and treating a 442 acre portion of Freels Bend for autumn olive and other brushy invasive species.

The Gallaher Bend kudzu was treated by contractor CSC, who also did follow-up work on other kudzu patches treated in previous seasons. The strategy at Gallaher Bend for the season was to treat the perimeter of the plot first, to halt its spread (Fig. 23), and then treat into the patch far enough to assess whether surface erosion of treated areas would become a problem (Fig. 24). Evaluation of treated areas at the end of the season and through the winter showed that the treated areas naturally regenerated from existing native seed stock, and erosion was not noted. To facilitate access to the large patch, trails were

prepared into the area with the assistance of TWRA. About a quarter of the patch was treated by the season's end, with the remainder to be treated in subsequent seasons.

Fig. 21. Roadside control of invasive vegetation (princess tree) using an ATUV-mounted sprayer.

Fig. 22. Control of invasive plants within a native grass community is aided by controlled burning.

Fig. 23. By the end of the spraying season, treatment effect along the perimeter of the Gallaher Bend kudzu patch was readily visible.

Fig. 24. Erosion of the soil surface in treated areas did not prove to be a problem.

The second initiative was to try to gain control of a large contiguous land area, the southern portion of Freels Bend, which had a particularly high density of autumn olive, privet, and several other woody invasive species. A contract was signed with Progressive Solutions, LLC (PS), which uses large numbers of on-the-ground workers with backpack sprayers and cut-surface application equipment to sweep through areas, locating and controlling all invasive species present. They treated a contiguous area of 442 acres identified on aerial photographs (Fig. 25) for eight particularly troublesome species: autumn olive, privet, multiflora rose, bush honeysuckle, thorny olive, tree of heaven, mimosa, and princess tree. The results were guaranteed; any invasives not controlled would be treated the following spraying season.

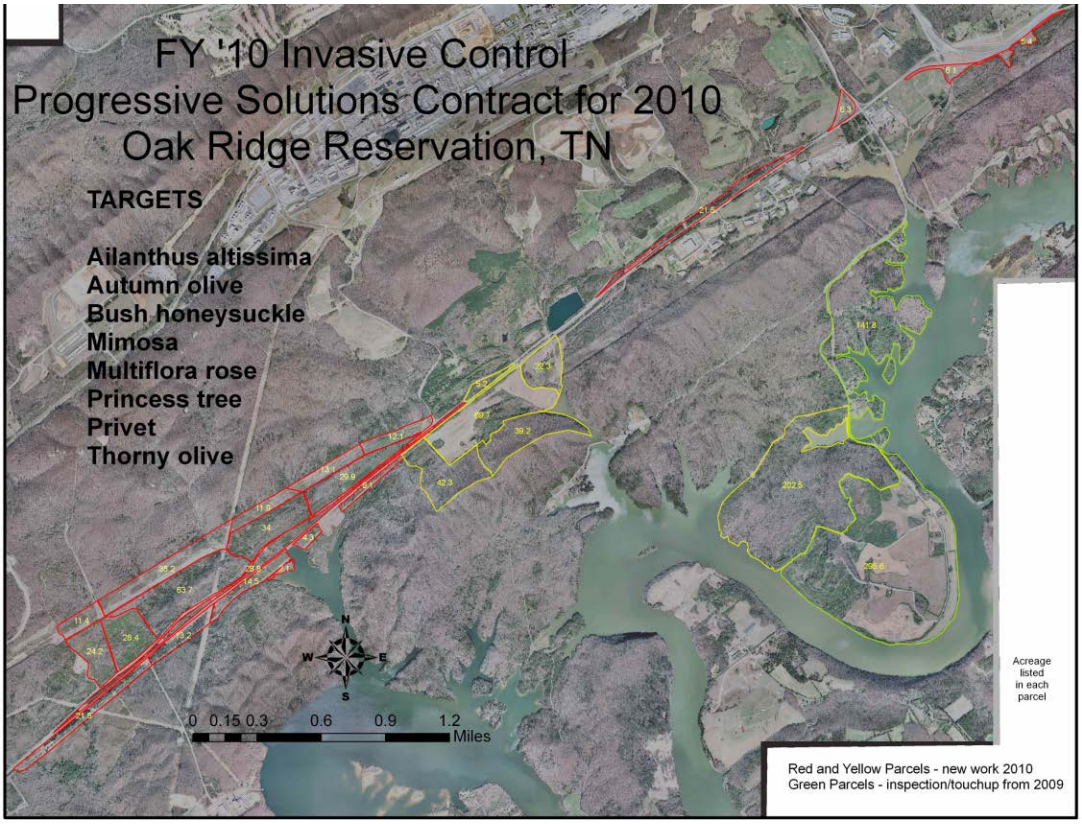

Fig. 25. Aerial photograph overlay map showing tracts treated for invasive plants by contractor Progressive Solutions in 2009 and 2010.

Also in 2009 the invasive plant management team controlled invasives around the East Campus Pond and the P-1 Pond at ETTP as well as in several riparian areas at ORNL. CSC, in addition to kudzu work, sprayed autumn olive along Bethel Valley and Old Bethel Valley Roads and concentrated on the high density in an area designated as the Autumn Olive Focus Area. CSC also performed cut-surface treatment of princess trees throughout the Y-12 complex. ESD personnel also used a granular herbicide, Spike 40-P, to selectively control multiflora rose and other species along White Wing Road.

2010

During 2010 the kudzu work at Gallaher Bend continued. The perimeter was retreated as necessary, and about half of the remaining parcel was treated, working down the slope and closer to the Melton Lake shoreline. Contractor CSC also touched up other areas previously treated for kudzu, including the patrol road at ETTP and the ETTP railroad siding. In addition, CSC controlled invasives along East Fork Poplar Creek within Y-12.

In 2010 the results for contractor PS's 2009 spraying were evident (Fig. 26), revealing systematic and selective control of the eight species targeted. They were again employed to treat large land areas with heavy infestations of woody invasive species (Fig. 25). They first retreated missed stems within the areas treated at Freels Bend in 2009, in accordance with their guarantee. They then treated parcels identified along Bethel Valley Road and at the epicenter of the autumn olive focus area near the TWRA deer check station. In all, PS treated 777 new acres.

Fig. 26. In 2010 selective control of autumn olive and other brushy species at Freels Bend from 2009 treatment was visible.

ESD personnel continued maintenance of the area around the P-1 Pond at ETTP by selectively treating Johnsongrass with a vehicle-mounted wick applicator dispensing glyphosate and selectively removed invasives from various native grass restoration areas.

7. FOLLOW-UP IN TREATED AREAS

Managing exotics does not always result in their complete eradication but may only keep them under control. The ultimate goal in controlling invasive plants is the restoration of native species in an area formerly invaded by invasive species (Miller 2003). Thus, success consists of removal (i.e., killing the invasive plant with no reestablishment from existing seed stocks or nearby root stocks) followed by rehabilitation or restoration of native species (i.e., establishment and/or release of fast-growing native plants that can outcompete and outlast any surviving nonnative plants while stabilizing and protecting the soil). The rehabilitation phase, the most important final phase of an integrated invasive plant eradication and reclamation program, can occur either naturally or with assistance (Miller 2003).

After eradication of nonnative plants, native plant communities often naturally reinitiate succession from the seeds in the soil or from existing native vegetation surrounding the treated area. Native species with light seeds are usually present in the seed bank, while heavier seeds will gradually be deposited on a site by birds and other animals. When succession is naturally reinitiated, only regular monitoring and

occasional spot treatments are needed as follow-up in a treated area. Thus, to ensure that this natural restoration is taking place, treated areas on the ORR are monitored for success and retreated for invasive species as needed.

In many cases, however, especially where extensive monocultures of a particular invasive species have become established, more extensive efforts are required to restore native vegetation. Successful treatment of invasive species such as kudzu, which can completely occupy extensive areas, may result in open areas so large that surface erosion can become a problem before native species have time to become reestablished. Where this is the case, surface preparation, if necessary, and revegetation with native species are initiated to assist in meeting management goals.

Valuable experience has been gained in reestablishing native species on the ORR in areas in which invasive species have been controlled. For example, slopes from which kudzu has been removed have occasionally been planted with native grasses to prevent further erosion problems. Power-line ROWs act as dispersal corridors for invasive species such as autumn olive, privet, and bush honeysuckle. During the demonstration phase of the invasive plants management plan development, treatment was initiated on several acres with invasive plants within power-line ROWs and adjacent areas. The follow-up recommended was revegetation with native grasses and shrubs. After initial treatment it was determined that revegetation was not necessary as the soil was very fertile, and grasses, daylilies, and other plants grew without being planted. Some retreatment has since been needed, for example for privet, which is not always killed by the initial treatment, and the power-line ROWs have been reseeded with native grasses and low-growing shrubs after herbicide treatments removed some autumn olive patches.

Some native grasslands are also being established on the ORR to replace higher-maintenance lawn areas and to restore areas affected by other stressors (e.g., the Southern pine beetle). Where such active restoration is employed, areas are monitored and maintained as necessary until native communities have become established. After native species are restored, these functional plant communities help prevent the establishment of invasive plants in what would otherwise be disturbed areas.

The initial invasive plants management plan acknowledged a concern that if plants were removed from large areas, erosion might subsequently become a problem, and revegetation might be needed to control it. Erosion has not, however, been a problem even in places n which large areas have been treated (e.g., for kudzu control). Thus, very little revegetation has been necessary in areas treated for invasive species on the ORR. Erosion is still a potential concern, and areas that have been treated are checked to make sure it has not occurred. Where it happens, efforts will be implemented to control it.

8. AWARENESS AND EDUCATION

Engagement includes reaching out to employees; local, national and international partners in the public and private sectors; key constituencies and stakeholders; and the broader citizenry to join forces and seek solutions to the challenges posed by invasive species. Managing invasive species is a long-term activity that requires continuing education and awareness. Constant challenges include maintaining the skills among ORNL staff to identify current and watch-list invaders, sharing methods of effective treatment with others in the region, and finding funding sources.

8.1 PUBLIC AND EMPLOYEE OUTREACH

Many people are unaware that common plants, such as privet and honeysuckle, are not native species and pose a problem to natural ecosystems. Educating neighbors and adjacent property owners about invasive species and how they spread increases their awareness of the issue. If invasive species are controlled, or at least minimized, on private property, they are less likely to spread to the ORR. Thus, outreach to employees at the DOE facilities and to the general public is and will continue to be an important part of the invasive plant management program.

Outreach is accomplished in varying ways, including sharing information with employees at the DOE facilities (e.g., short notices in onsite communications such as *ORNL Today*), contributing articles to local newspapers, appearing on local television programs, speaking to community organizations (e.g., TCWP, local Rotary clubs), and escorting the public on walks so they can observe first hand some of the invasive plant problems on the ORR. Such outreach increases general public awareness and highlights the value of invasive plant control, both on the ORR and in the surrounding community.

A major avenue of outreach to employees and the general public is the Research Park website (http://www.esd.ornl.gov/facilities/nerp/index.html). The website provides much information about invasive species, including a section (http://www.esd.ornl.gov/facilities/nerp/invasive_species.html#PLANTS) specifically on invasive plants, Research Park briefs (http://www.esd.ornl.gov/facilities/nerp/invasive_plants.pdf) about invasive plant species on the ORR, and a list (http://www.esd.ornl.gov/facilities/nerp/links_invasives.html) of links to sites with additional information on invasive plants and their management.

8.2 WORKSHOPS AND TRAINING

In April 2003 ORNL held a workshop that provided information on invasive plants to individuals who make land management decisions or oversee such activities on the ORR. Approximately 50 individuals from 11 different agencies and organizations involved with or interested in ORR land management participated. The workshop featured a number of speakers, including Steve Manning and Lee Patrick from IPC (http://www.invasiveplantcontrol.com/), a company that deals with nationwide management of invasive species; Sam Rogers, a professor from UTK with expertise in invasive plants; and Mike Berkley, a nursery owner from middle Tennessee with expertise in using native plants in landscaping. Presentations at the workshop covered identification of invasive species and various treatment approaches. Site visits to several ORR field projects showcased ORNL's demonstration program on managing invasive species.

Shortly after the workshop, follow-up small group meetings were held at ETTP, Y-12, and ORNL to discuss needs specific to each of the facilities. In addition, invasive plant experts presented training sessions to reservation users and caretakers (e.g., maintenance staff at each site). These sessions described potential threats from invasive plants, provided information on how to identify invasive species, discussed treatment options, and generally increased awareness of the issue of invasive plants.

Since then ORNL staff have regularly interacted with individuals at each facility to discuss specific issues they are aware of at their site and to find out what areas they would like to have treated. Such interaction will continue in the future and may be expanded to include other facility staff members and contractor staff who are actively involved in ORR invasive plant treatment.

In addition, ORNL staff have made presentations to various community organizations for on the importance of controlling invasive plants in the local environment. ORNL staff have also provided assistance to TCWP with community invasive removal projects along Oak Ridge streams. Assistance by ORNL staff to the city of Oak Ridge as it plans invasive plant control along Oak Ridge Greenways is in progress.

9. PLANNED INVASIVE PLANT MANAGEMENT ACTIVITIES FISCAL YEARS 2011 TO 2016

In fiscal years 2011 to 2016, the following activities will be undertaken:

- kudzu spraying and reclamation as necessary;
- autumn olive treatment in areas of densest infestation;
- control of invasives in native grass restoration areas;
- control of thorny olive, privet, and other invasives in ORR edge areas;

- monitoring of natural areas and reference areas, with invasive treatment as necessary;
- public invasive plants awareness walks and other educational/recreational activities;
- cooperation with the city of Oak Ridge on invasives prioritization and treatment on ORR boundaries;
- promoting greater interaction with TVA in managing its ROWs to control invasive plant species and limit their dispersal;
- monitoring for invasives not yet sighted on the ORR but known to be spreading to the area (e.g., cogongrass);
- treatment of invasives throughout ORR based on prioritization; and
- exploring ways to leverage resources and share our experience.

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APPENDIX A: TENNESSEE INVASIVE PLANT SPECIES LIST

APPENDIX A: TENNESSEE INVASIVE PLANT SPECIES LIST

This appendix contains a reprint of "Invasive Exotic Pest Plants in Tennessee—2009" published by the Tennessee Exotic Pest Plant Council, http://www.tneppc.org/invasive_plants [has html list with pdf options] December 2009, second edition (printed with permission).

RANK DEFINITIONS

- **Severe Threat:** Exotic plant species that possess characteristics of invasive species and spread easily into native plant communities and displace native vegetation
- **Significant Threat:** Exotic plant species that possess invasive species but are not presently considered communities as those species listed as Rank 1
- **Lesser Threat:** Exotic plant species that spread in or near disturbed areas and are not presently considered a threat to native plant communities
- **Alert:** Exotic plant species that are known to be invasive in similar habitats to those found in Tennessee, are listed as a severe threat in adjacent states, or pose substantial management difficulties where they occur but for which more information is needed to determine their invasiveness in the state of Tennessee

Invasive Exotic Pest Plants in Tennessee – 2009

Updated in December 2009 with the help of 21 field biologists and land managers and using listing criteria developed from a variety of existing protocols (TNC/NPS, MA, CA, CT, VI).

Tennessee Exotic Pest Plant Council Criteria for Evaluating Plant Species for Invasiveness in Tennessee

Criteria that must be met for plants to fall into the following categories: Severe Threat, Significant Threat, Lesser Threat, Alert.

Invasiveness Category	Criteria that must be met for each invasive category
Base criteria	1-4
Severe threat	5 or 6
Significant threat	7 and 8 or 9
Lesser threat	10 and 11
Alert	12 or 13 or 14

BASE CRITERIA:

1) The plant species, sub-species or variety is established outside of cultivation and is non-native to some portion of the region of North America within which it occurs.
2) The species has the potential for rapid growth, high seed or propagule production and dispersal, and establishment in natural communities of North America or in managed areas where it is not desired or the species persists in free living infestations (outside of cultivation) within Tennessee.
3) The species occurs in the state of Tennessee.
4) The species is known to out-compete other species in native plant communities within the state of Tennessee.

RON McCONATHY

Chinese privet (*Ligustrum sinense*)

SEVERE THREAT:

5) The species meets criteria 1-2 and is listed as a noxious weed in Tennessee or by the federal government, – OR – 6) The species meets criteria 1-4 and occurs in at least 30 counties (ca. 30% of Tennessee counties), presents substantial management difficulties (for example, *Lespedeza cuneata* at a high density and narrow distribution poses less of a threat to native populations and is easier to manage than *Lespedeza cuneata* at lower density dispersed over large areas and growing among off-target native species potentially affected by herbicide use, while *Microstegium vimineum* occurs in dense populations, creates substantial seed banks that are unmanageable over the short-term, and requires long-term efforts).

SIGNIFICANT THREAT:

7) The species meets criteria 1-4 and meets either 8 or 9 below, – AND – 8) The species occurs within at least 30 counties in Tennessee and management does not present substantial difficulties, – OR – 9) The species occurs in 10 to 29 counties within Tennessee and presents substantial management difficulties.

LESSER THREAT:

10) The species meets criteria 1 through 4, – AND – 11) The species occurs in 10 to 29 counties within Tennessee and does not present substantial management difficulties.

ALERT:

12) The species meets criteria 1 through 2 and shows invasiveness in similar habitats to those found in Tennessee, – OR – 13) 1 through 3 and shows invasiveness in similar habitats to those found in Tennessee, – OR – 14) The species meets criteria 1-4, occurs in fewer than 10 counties, and is considered a severe threat in adjacent states or poses substantial management difficulties.

Severe Threat: Exotic plant species that possess characteristics of invasive species and spread easily into native plant communities and displace native vegetation.

Species ITIS Nomenclature	Common Name	Habit
Ailanthus altissima (P. Mill.) Swingle	tree of Heaven	tree
Albizia julibrissin Durazz.	mimosa	tree
Alternanthera sessilis (L.) R. Br. ex DC.	sessile joyweed	forb/herb
Bromus tectorum L.	cheat grass, downy brome	grass
Celastrus orbiculatus Thunb., *Celastrus orbiculata* Thunb.	Asian bittersweet	woody vine
Dioscorea oppositifolia L., *D. batatas* Dcne., *Dioscorea polystachya* Turcz.	Chinese yam	deciduous vine
Elaeagnus umbellata var. *parviflora* (Royle) Schneid.	autumn olive	shrub
Hydrilla verticillata (L.f.) Royle	Hydrilla, water thyme	aquatic
Hypericum perforatum L.	goatweed, St. John's-wort	shrub, subshrub
Imperata cylindrica (L.) Beauv. (all varieties and cultivars)	cogongrass, Japanese bloodgrass	grass
Kummerowia stipulacea (Maxim.) Makino, *Lespedeza stipulacea* Maxim.	Korean clover	forb
Lespedeza bicolor Turcz.	bicolor lespedeza, shrubby bushclover	shrub, subshrub
Lespedeza cuneata (Dum.-Cours.) G. Don	sericea lespedeza	forb
Ligustrum sinense Lour.	Chinese privet	shrub
Ligustrum vulgare L.	common privet	shrub
Lonicera japonica Thunb.	Japanese honeysuckle	vine
Lythrum salicaria L. [all varieties and cultivars]	purple loosestrife	wetland forb
Microstegium vimineum (Trin.) A. Camus, *Eulalia viminea* (Trin.) Kuntze	Nepalgrass, Japanese grass	grass
Paulownia tomentosa (Thunb.) Sieb.& Zucc. ex Steud.	princess tree	tree
Polygonum cuspidatum Seib. & Zucc., *Fallopia japonica* (Houttt.) Dcne.	Japanese knotweed, Mexican bamboo, fleeceflower	subshrub
Pueraria montana var. *lobata* (willd.) Maesen & S. Almeida, *Pueraria lobata* (Willd.) Ohwi	Kudzu	vine
Rosa multiflora Thunb. ex Murr.	multiflora rose	shrub
Rottboellia cochinchinensis (Lour.) W.D. Clayton	Itchgrass	grass
Salvinia molesta Mitchell	aquarium water-moss	aquatic
Solanum viarum Dunal	tropical soda apple	subshrub
Sorghum halepense (L.) Pers.	Johnson grass	grass

CHUCK BARGERON, UNIVERSITY OF GEORGIA

Japanese honeysuckle (*Lonicera japonica*)

TENNESSEE EXOTIC PEST PLANT COUNCIL, WWW.TNEPPC.ORG

Significant Threat: Exotic plant species that possess characteristics of invasive species but are not presently considered to spread as easily into native plant communities as those species listed as **Rank 1**.

Species ITIS Nomenclature	Common Name	Habit
Alliaria petiolata (Bieb.) Cavara & Grande, *Alliaria officinalis* Andrz. *ex* Bieb	garlic-mustard	forb
Allium vineale L.	field Garlic	forb/herb
Alternanthera philoxeroides (Mart.) Griseb., *Achyranthes philoxeroides* (Mart.) Standl.	alligatorweed	forb/herb
Arthraxon hispidus (Thunb.) Makino, *Arthraxon hispidus* var. *cryptatherus* (Hack.) Honda	hairy jointgrass	grass
Arundo donax L., *Arundo donax* var. *versicolor* (P. Mill.) Stokes	giant reed, elephant grass	grass
Berberis thunbergii DC	Japanese barberry	shrub
Broussonetia papyrifera (L.) L'Her. *ex* Vent.	paper mulberry	tree
Carduus nutans L.	musk thistle, nodding thistle	forb
Centaurea biebersteinii DC, *Centaurea stoebe L. ssp. micranthos* (Gugler) Hayek	spotted knapweed	forb/herb
Cirsium vulgare (Savi) Ten., *Carduus vulgaris* Savi	bull thistle	forb
Elaeagnus pungens Thunb.	thorny-olive	shrub
Eragrostis curvula (Schrad.) Nees	weeping love grass	grass
Glechoma hederacea L.	gill-over-the-ground, ground ivy	deciduous vine
Iris pseudacorus L.	pale-yellow iris	wetland forb
Lolium arundinaceum (Schreb.) S.J. Darbyshire, *Festuca arundinacea* Schreb., *Schedonorus phoenix* (Scop.) Holub	tall fescue	grass
Lonicera maackii (Rupr.) Herder.	Amur bush honeysuckle	shrub
Lysimachia nummularia L.	moneywort, creeping Jenny	forb/herb
Maclura pomifera (Raf.) Schneid.	Osage Orange	tree
Melia azedarach L.	Chinaberry	tree
Mentha x piperita L.	peppermint	forb/herb
Miscanthus sinensis Anderss., *Miscanthus sinensis* var. *gracillimus* A.S. Hitchc., *M. sinensis* var. *variegatus* Beal, *M. sinensis* var. *zebrinus* Beal	zebra grass, Chinese silver grass	grass
Murdannia keisak (Hassk.) Hand.-Maz., *Aneilema keisak* Hassk.	Asian spiderwort	forb/herb
Myriophyllum aquaticum (Vell.) Verdc., *Myriophyllum brasiliense* Camb.	parrot feather, Brazilian water-milfoil	aquatic
Myriophyllum spicatum L.	Eurasion water-milfoil	aquatic
Polygonum caespitosum var. *longisetum* (deBruyn) A.N. Steward, *Persicaria longiseta* (de Bruyn) Moldenke	bunchy knotweed, oriental ladysthumb, bristly lady's-thumb	forb/herb
Polygonum persicaria L.	lady's thumb	forb/herb
Populus alba L.	white poplar	tree
Potamogeton crispus L.	curly pondweed	aquatic
Rorippa nasturtium-aquaticum (L.) Hayek, *Nasturtium officinale* Ait. f.	watercress	aquatic
Setaria faberi R.A.W. Herrm.	nodding foxtail-grass	grass
Setaria italica (L.) P. Beauv.	foxtail-millet	grass
Setaria viridis (L.) P. Beauv.	green millet, giant green foxtail	grass
Spiraea japonica L.f.	Japanese spiraea	shrub
Tussilago farfara L.	coltsfoot	forb/herb
Verbascum thapsus L.	common mullein	forb/herb
Vinca major L.	Greater periwinkle	vine
Vinca minor L.	common periwinkle	vine

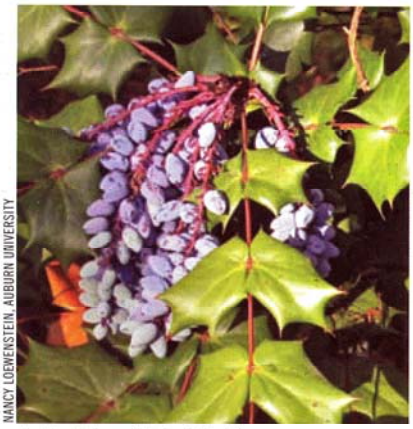
Lesser Threat: Exotic plant species that spread in or near disturbed areas, and are not presently considered a threat to native plant communities.

Species ITIS Nomenclature	Common Name	Habit
Bromus secalinus L.	rye brome	grass
Bromus sterilis L.	poverty brome	grass
Buglossoides arvensis (L.) I.M. Johnston, *Lithospermum arvense* L.	corn gromwell	forb/herb
Bupleurum rotundifolium L.	hound's-ear, hare's-ear	forb/herb
Cardiospermum halicacabum L.	balloonvine, love-in-a-puff	deciduous vine
Centaurea cyanus L.	bachelor's button, cornflower	forb/herb
Cichorium intybus L.	chicory	forb
Clematis terniflora DC, *Clematis maximowicziana* Franch. & Savigny, *Clematis paniculata* Thunb.	leatherleaf clematis, sweet autumn clematis	vine
Conium maculatum L.	poison hemlock	forb
Dipsacus fullonum L.	Fuller's teasle, common teasle	forb/herb
Egeria densa Planch., *Elodea densa* (Planch) Casburg	Brazilian elodea, Brazilian water-weed	aquatic
Euonymus alatus (Thunb.) Siebold, *Euonymus alata* (Thunb.) Sieb.	burning bush	shrub
Euonymus fortunei (Turcz.) Hand.-Mazz., *Euonymus hederaceus* Champ. & Benth.	winter creeper	woody vine
Hedera helix L.	English ivy	woody vine
Hibiscus syriacus L.	Rose of Sharon	shrub, tree
Mentha spicata L.	spearmint	wetland forb
Muscari neglectum Guss. ex Ten., *Muscari atlanticum* Boiss. & Reut.	grape hyacinth	forb/herb
Ornithogalum umbellatum L.	Star of Bethlehem	forb/herb
Pastinaca sativa L.	wild parsnip	forb/herb
Ranunculus bulbosus L.	St. Anthony's turnip	forb/herb
Rubus phoenicolasius Maxim.	wineberry	subshrub
Tragopogon dubius Scop.	yellow goat's-beard	forb
Wisteria floribunda (Willd.) DC, *Rehsonia floribunda* (Willd.) Stritch	Japanese wisteria	vine

CHRIS EVANS, RIVER TO RIVER CWMA, COURTESY OF BUGWOOD.ORG

Greater periwinkle (*Vinca major*)

Alert: Exotic plant species that are known to be invasive in similar habitats to those found in Tennessee, are listed as a severe threat in adjacent states, or pose substantial management difficulties where they occur but for which more information is needed to determine their invasiveness in the state of Tennessee.



NANCY LOEWENSTEIN, AUBURN UNIVERSITY

Beale's barberry (*Mahonia bealei*)

JAMES H. MILLER, USDA FOREST SERVICE

Chinese wisteria (*Wisteria sinensis*)

Species ITIS Nomenclature	Common Name	Habit
Achyranthes japonica var. *hachijoensis* Honda	Japanese chaff flower	forb
Acroptilon repens (L.) DC., *Centaurea repens* L.	Russian knapweed	forb/herb
Agrostis stolonifera L.	creeping bentgrass	grass
Bromus japonicus Thunb. ex Murr., *Bromus arvensis* L.	Japanese bromegrass	grass
Buddleja davidii Franch.	butterfly bush	shrub subshrub
Carduus acanthoides L.	plumeless thistle	forb/herb
Cirsium arvense (L.) Scop., *Carduus arvensis* (L.) Robson	Canada thistle	forb/herb
Coronilla varia L., *Securigera varia* (L.) Lassen	crown vetch	vine
Daucus carota L.	wild carrot, Queen Anne's-lace	forb
Dioscorea bulbifera L.	air-potato	deciduous vine
Eichhornia crassipes (Mart.) Solms	floating water hyacinth	aquatic
Elaeagnus angustifolia L.	Russian olive	tree
Firmiana simplex (L.) W. Wight	Chinese parasoltree	tree/shrub
Gaillardia pulchella Foug.	firewheel	forb
Helianthus ciliaris DC.	Texas blueweed	forb/herb
Hesperis matronalis L.	dame's rocket	forb/herb
Ilex crenata Thunb.	Japanese holly	shrub/small tree
Koelreuteria paniculata Laxm.	goldenrain tree	tree
Kummerowia striata (Thunb.) Schindl., *Lespedeza striata* (Thunb.) Hook. & Arn.	Japanese clover	forb/herb
Lepidium campestre (L.) Ait. F.	field pepperweed	forb/herb
Leucanthemum vulgare Lam., *Chrysanthemum leucanthemum* L., *Chrysanthemum vulgare* Lam.	ox-eye daisy	forb/herb
Ligustrum japonicum Thunb.	Japanese privet	shrub
Ligustrum obtusifolium Sieb. & Zucc.	border privet	shrub
Lonicera fragrantissima Lindl. & Paxton	January jasmine	shrub
Lonicera morrowii Gray	Morrow's bush honeysuckle	shrub
Lonicera tatarica L.	Tartarian honeysuckle, twinsisters	shrub
Lonicera x bella Zabel	Bell's bush honeysuckle	shrub
Lotus corniculatus L.	birdfoot trefoil	forb/herb
Ludwigia uruguayensis (Camb.) Hara, *Ludwigia grandflora* (M. Micheli) Greuter & Burdet	Uraguay waterprimrose	forb/herb to subshrub
Lygodium japonicum (Thunb. ex Murr.) Sw.	Japanese climbing fern	forb/herb/vine
Mahonia bealei (Fortune) Carr., *Berberis bealei* Fortune	Oregon grape	shrub
Melilotus alba Medikus	white sweet clover	forb/herb
Melilotus officinalis (L.) Lam., *Melilotus albus* var. *annuus* Coe; *Melilotus albus* Medik.	yellow sweet clover	forb/herb
Myosotis scorpioides L.	true forget-me-not	forb/herb
Najas minor All.	water nymph	aquatic
Nandina domestica Thunb.	Nandina, sacred-bamboo	shrub
Phalaris canariensis L.	canary grass	grass
Phragmites australis (Cav.) Trin. ex Steud.	common reed	grass, aquatic
Polygonum perfoliatum L.	mile-a-minute	forb/herb
Pyrus calleryana Dcne.	Bradford pear, callery pear	tree
Rubus bifrons Vest ex Tratt	Himalayan berry	subshrub
Salsola tragus L., *S. kali* spp. *tragus* (L.) Celak.	prickly Russian thistle	forb
Senna obtusifolia (L.) H.S. Irwin & Barneby, *Cassia obtusifolia* L.	sicklepod senna	forb/herb
Setaria pumila (Poir.) Roem. & Schult.	yellow foxtail, smooth millet	grass
Sonchus arvensis L.	perennial sowthistle, sowthistle	forb/herb
Trapa natans L.	water chestnut	aquatic
Triadica sebifera (L.) Small, *Sapium sebiferum* (L.) Roxb., *Triadica sebiferum* (L.) Roxb.	Chinese tallowtree	tree
Tribulus terrestris L.	puncturevine	forb/herb
Wisteria sinensis (Sims) DC, *Rehsonia sinensis* (Sims) Stritch	Chinese wisteria	vine

TENNESSEE EXOTIC PEST PLANT COUNCIL, WWW.TNEPPC.ORG

APPENDIX B: SELECTED PORTIONS OF EXECUTIVE ORDER 13112

APPENDIX B: SELECTED PORTIONS OF EXECUTIVE ORDER 13112

E.O. 13112 Invasive Species

Sec. 2. *Federal Agency Duties*.

(a) Each Federal agency whose actions may affect the status of invasive species shall, to the extent practicable and permitted by law,

(1) identify such actions;

(2) subject to the availability of appropriations, and within Administration budgetary limits, use relevant programs and authorities to:

(i) prevent the introduction of invasive species;

(ii) detect and respond rapidly to and control populations of such species in a cost-effective and environmentally sound manner;

(iii) monitor invasive species populations accurately and reliably;

(iv) provide for restoration of native species and habitat conditions in ecosystems that have been invaded;

(v) conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally sound control of invasive species; and

(vi) promote public education on invasive species and the means to address them; and

(3) not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere unless, pursuant to guidelines that it has prescribed, the agency has determined and made public its determination that the benefits of such actions clearly outweigh the potential harm caused by invasive species; and that all feasible and prudent measures to minimize risk of harm will be taken in conjunction with the actions.

(b) Federal agencies shall pursue the duties set forth in this section in consultation with the Invasive Species Council, consistent with the Invasive Species Management Plan and in cooperation with stakeholders, as appropriate, and, as approved by the Department of State, when Federal agencies are working with international organizations and foreign nations.