U.S. FISH AND WILDLIFE SERVICE SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

Scientific Name:

Quadrula petrina

Common Name:

Texas Pimpleback

Lead region:

Region 2 (Southwest Region)

Information current as of:

03/17/2015

Status/Action

___ Funding provided for a proposed rule. Assessment not updated.

___ Species Assessment - determined species did not meet the definition of the endangered or threatened under the Act and, therefore, was not elevated to the Candidate status.

___ New Candidate

_X_ Continuing Candidate

___ Candidate Removal

> ___ Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status
>
> ___ Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species
>
> ___ Range is no longer a U.S. territory
>
> ___ Taxon mistakenly included in past notice of review

___ Taxon does not meet the definition of "species"

___ Taxon believed to be extinct

___ Conservation efforts have removed or reduced threats

___ More abundant than believed, diminished threats, or threats eliminated.

___ Insufficient information exists on taxonomy, or biological vulnerability and threats, to support listing

Petition Information

___ Non-Petitioned

_X_ Petitioned - Date petition received: 10/15/2008

90-Day Positive:12/15/2009

12 Month Positive:10/06/2011

Did the Petition request a reclassification? **No**

For Petitioned Candidate species:

Is the listing warranted(if yes, see summary threats below) **Yes**

To Date, has publication of the proposal to list been precluded by other higher priority listing? **Yes**

Explanation of why precluded:

Higher priority listing actions, including court-approved settlements, court-ordered and statutory deadlines for petition findings and listing determinations, emergency listing determinations, and responses to litigation, continue to preclude the proposed and final listing rules for this species. We continue to monitor populations and will change its status or implement an emergency listing if necessary. The Progress on Revising the Lists section of the current CNOR (http://endangered.fws.gov/) provides information on listing actions taken during the last 12 months.

Historical States/Territories/Countries of Occurrence:

- **States/US Territories**: Texas
- **US Counties**: Bandera, TX, Bexar, TX, Blanco, TX, Brown, TX, Burnet, TX, Caldwell, TX, Coke, TX, Coleman, TX, Comal, TX, Concho, TX, DeWitt, TX, Fayette, TX, Gillespie, TX, Goliad, TX, Gonzales, TX, Guadalupe, TX, Hays, TX, Irion, TX, Karnes, TX, Kendall, TX,

Kerr, TX, Kimble, TX, Lampasas, TX, Llano, TX, Mason, TX, McCulloch, TX, Medina, TX, Menard, TX, Mills, TX, Runnels, TX, San Saba, TX, Sterling, TX, Tom Green, TX, Travis, TX, Victoria, TX, Wharton, TX, Williamson, TX, Wilson, TX
- **Countries**: United States

Current States/Counties/Territories/Countries of Occurrence:

- **States/US Territories**: Texas
- **US Counties**: Caldwell, TX, Colorado, TX, Concho, TX, DeWitt, TX, Fayette, TX, Goliad, TX, Gonzales, TX, Hays, TX, Karnes, TX, Matagorda, TX, Menard, TX, Runnels, TX, San Saba, TX, Victoria, TX, Wharton, TX, Wilson, TX
- **Countries**:Country information not available

Land Ownership:

Four of the known Texas pimpleback populations occur in State designated no-harvest sanctuaries including: sections of Concho River in Concho County, San Saba River in Menard County, and all of San Marcos River (Howells 2010e, p. 8). The remaining populations occur in the Colorado or Guadalupe-San Antonio River systems adjacent to private land.

Lead Region Contact:

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Biological Information

Species Description:

The Texas pimpleback is a large pimpleback species with a moderately inflated shell that generally reaches 60– 90 mm (2.4–3.5 in) (Howells 2002b, pp. 3–4). With the exception of growth lines, the shell of the Texas pimpleback is generally smooth and moderately thick (Howells 2002b, p. 4). Externally, coloration ranges from yellowish-tan to dark brown with some individuals mottled or with dark green rays. Internally, the nacre (inside of shell) is white and iridescent posteriorly (Howells 2002b, p. 4).

Taxonomy:

The Texas pimpleback was originally described as Unio petrinus by Gould in 1855. It was placed in the genus Margaron by Lea in 1870 and ultimately moved to Quadrula by Simpson in 1900

(Simpson 1900, p. 783). Graf and Cummings (2007, p. 18) have proposed moving it to the genus Amphinaias, but other freshwater mussel taxonomists recommend waiting for additional work to be completed on members of Quadrula before splitting the genus (Bogan 2011, pers. comm.). The Texas pimpleback is recognized by the Committee on Scientific and Vernacular Names of Mollusks of the Council of Systematic Malacologists, American Malacological Union (Turgeon et al. 1998, p. 37), and we recognize it as a valid species.

Habitat/Life History:

The Texas pimpleback typically occurs in moderately sized rivers, usually in mud, sand, gravel, and cobble, and occasionally in gravel-filled cracks in bedrock slab bottoms (Horne and McIntosh 1979, p. 122; Howells 2002b, p. 4). The species has not been found in water depths over 2 m (6.6 ft). Texas pimpleback have not been found in reservoirs, which indicates that this species is intolerant of deep, low velocity waters created by artificial impoundments (Howells 2002b, p. 4). In fact, Texas pimpleback appear to tolerate faster water more than many other mussel species (Horne and McIntosh 1979, p. 123).

There is very little specific information on age, or size of maturity for Texas pimpleback. However, new research conducted by USGS and the Service on host fish use for central Texas Candidate mussels revealed that Texas pimpleback use the channel catfish as a host fish (Johnson et al. 2014, p. 41). Gravid females (females with eggs inside) have been found from June through August, and the smallest documented gravid female was 45 mm (1.8 in) long (Howells 2000b, p. 38). Additionally, mussels in the genus Quadrula are typically short-term brooders (Gorden and Layzer 1989, p. 6; Garner et al. 1999, p. 277), and we expect the same of the Texas pimpleback. Glochidia are hookless and elliptical in shape (Howells et al. 1996, p. 120).. This species is a host fish specialist that freely broadcasts its glochidia by reflexive release in the form of mature conglutinates which are usually fragile and tend to disintegrate shortly after release (Johnson et al. 2014, p. 41).

Adult freshwater mussels are filter-feeders, siphoning algae, bacteria, detritus, microscopic animals, and dissolved organic matter (Fuller 1974, pp. 221–222, Silverman et al. 1997, p. 1862; Nichols and Garling 2000, p. 874–876; Christian et al. 2004, p. 109). For their first several months, juvenile mussels feed using cilia (fine hairs) on the foot to capture suspended as well as depositional material, such as algae and detritus (Yeager et al. 1994, pp. 253–259). Mussels tend to grow relatively rapidly for the first few years, and then slow appreciably at sexual maturity, when energy presumably is being diverted from growth to reproductive activities (Baird 2000, pp. 66–67). Mussels are extremely long lived, living from two to several decades (Rogers et al. 2001, p. 592), and possibly up to 200 years in extreme instances (Bauer 1992, p. 427).

Most mussel species, including Texas pimpleback, have distinct forms of male and female. During reproduction, males release sperm into the water column, which females draw in through their siphons. Fertilization takes place internally, and the resulting eggs develop into specialized larvae (called glochidia) within the female's modified gill pouch (called marsupia) for four to six weeks. The females will then release matured glochidia individually, in small groups, or embedded in larger mucus structures called conglutinates. Glochidia are obligate parasites (cannot live independently of their hosts) on fish and attach to the gills or fins of appropriate host species where they encyst (enclose in a cyst-like structure) and feed off of the host's body fluids (Vaughn and Taylor 1999, p. 913) and develop into juvenile mussels weeks or months after attachment (Arey 1932, pp. 214–215). The glochidia will die if they fail to find the appropriate host fish, attach to a fish that has developed immunity from prior infestations, or attach to the wrong location on a host fish (Neves 1991, p. 254; Bogan 1993, p. 299). Mussels experience their primary opportunity for dispersal and movement within the stream as glochidia attached to a host fish (Smith 1985, p. 105). Upon release from the host, newly transformed juveniles drop to the substrate on the bottom of the stream. Those juveniles that drop in unsuitable substrates die because their immobility prevents them from relocating to more favorable habitat. Juvenile freshwater mussels burrow into interstitial substrates and grow to a larger size that is less susceptible to predation and displacement from high flow events (Yeager et al. 1994, p. 220). Throughout the rest of their life cycle, mussels generally remain within the same small area where they released from the host fish.

Historical Range/Distribution:

The Texas pimpleback is endemic to the Colorado and Guadalupe-San Antonio River basins of central Texas (Howells 2002b, p. 3). In the Colorado River basin, Texas pimpleback occurred throughout nearly the entire mainstem, as well as numerous tributaries, including the Concho, North Concho, San Saba, Llano, and Pedernales Rivers, and Elm and Onion Creeks (Howells 2010e, p. 5; Randklev et al. 2010c, p. 4; OSUM 2011d, p. 1). Within the Guadalupe-San Antonio River basin, it occurred throughout most of the length of the Guadalupe River, as well as in the San Antonio, San Marcos, Blanco, and Medina Rivers (Horne and McIntosh 1979, p. 122; Howells 2010e, p. 5; OSUM 2011d, p. 1).

Current Range Distribution:

The Texas pimpleback has declined significantly rangewide, and only four streams—the lower Colorado River, San Saba River, Concho River, Guadalupe River, and San Marcos River—are known to harbor persisting Texas pimpleback populations. All but two of these populations are disjunct, small, and isolated. The species has been extirpated from the remainder of its historical range.

Colorado River System

In the Colorado River system, Texas pimpleback once occurred throughout the mainstem and in many major tributaries. Currently, the species has been extirpated from the Pedernales, North Concho, and Llano Rivers, as well as Onion Creek. It has also likely been extirpated from the mainstem Colorado River above Brown and McCulloch Counties and associated tributaries. The Concho River contains the most abundant population of Texas pimpleback and one of only two large populations of the species likely to be remaining in the Colorado River system, but most individuals are old and there has been very little evidence of recruitment.

In the mainstem Colorado River, Texas pimpleback historically occurred from Runnels County downstream to Colorado County (Howells 2010e, p. 5; Randklev et al. 2010c, pp. 3–4; OSUM 2011d, p. 1). Surveys between 1989 through 2010 in numerous locations along the river yielded no evidence of the species anywhere except in Runnels and San Saba Counties (Howells 1995, pp. 20, 29; 1997a, pp. 27, 31, 35; 2000a, p. 27; 2002a, p. 7). However, surveys in 2011 and 2012 found that Texas pimpleback persist in McCulloch, Brown, Mills, San Saba, Lampasas, Colorado, and Wharton Counties (Randklev 2012, pers. comm.; Service Files, 2012; Service Files, 2013).

In Runnels County, Texas pimpleback shells were found in 1993 (Howells 1995, p. 20), but several subsequent surveys between 1996 and 2008 detected no further evidence of the species within the mainstem of Colorado River (Howells 1997a, p. 27; 1998, p. 10; 2002a, p. 7; 2004, p. 7; Burlakova and Karatayev 2010a, p. 10). Surveys conducted in 2011 found 10 live individuals in Brown and McCulloch Counties and three in Brown and San Saba Counites (Randklev 2012, pers. comm.). In San Saba County, a single shell was collected in 1989 (Howells 2002b, p. 6), and three recently dead individuals were found in 1999 (Howells 2000a, pp. 25–26). An additional shell was collected in 2001 (Howells 2002a, p. 6). In 2011, a total of 109 live Texas pimpleback were found in the same general area downstream from the confluence with the San Saba River in Mills and San Saba Counties (Randklev 2012, pers. comm.) In addition presence/absence surveys during 2012 and 2013 within the mainstem of the river in San Saba and Lampasas Counties located several spent valves of Texas pimpleback ranging from recent dead to long dead (Service Files, 2012; Service Files, 2013). It is likely Texas pimpleback persists in McCulloch, Brown, Mills, San Saba, and Lampasas Counties.

It was uncertain whether or not Texas pimpleback historically occurred in the mainstem of the lower Colorado River as far downstream as Wharton County, because there have been several unidentified Quadrula sp. records since the 1990s. However, surveys conducted by the Service and USGS, in 2012 and 2013, revealed that Texas pimpleback does occur in Colorado and Wharton Counties. During these survey efforts, 18 live and several recent dead to long dead shells were found (Service Files, 2012; Service Files, 2013). Based on these recent surveys, it is the Service’s opinion that a small to medium sized population may persist in this section of the river.

In Runnels County, Elm Creek once supported a Texas pimpleback population. Small numbers of Texas pimpleback were found in 1993 and 1995 (Howells 1995, p. 21; 1996, p. 20), but none were found in 1997, 2001, or 2003 (Howells 1998, p. 11; 2002a, p. 5; 2004, p. 7). In 2005 and 2008, only recently dead to long dead individuals were collected (Howells 2006, pp. 63–64; Burlakova and

Karatayev 2010a, p. 10). No known live individuals have been found in over a decade despite repeated sampling efforts, and it is likely the Texas pimpleback has been extirpated from this stream.

The Concho River in Concho County supports the largest Texas pimpleback population. Thirteen and 28 individuals were collected in 1993 and 1994, respectively (Howells 1995, pp. 24–25; 2006, p. 61). However, low water and high temperatures in 1997 killed large numbers of many freshwater mussel species in the area up and downstream of Paint Rock, and 63 recently dead Texas pimpleback were found (Howells 1998, pp. 14–15). A severe drought in 1999 resulted in this area of the Concho River being reduced to a series of small pools. Few live Texas pimpleback were collected during this drought, in addition to many recently dead individuals (Howells 2000a, p. 23). No evidence of the species was found in 2004 (Howells 2005, p. 9), but eight live individuals were found in 2005 (Howells 2006, p. 60), evidence that the species had survived the extreme dewatering of the river. In 2008, 61 live Texas pimpleback were collected in this area, and the population was estimated to contain approximately 4,000 individuals (Burlakova and Karatayev 2010a, p. 10; 2010b, p. 1). However, the average length of individuals collected at this site was over 90 mm (3.5 in), indicating that reproduction is limited in this population. Further, although no mussel surveys occurred in 2009 and 2010, the river was reported to be extremely low during this time (Howells 2010e, p. 6); the result of this additional dewatering on the population is unknown. In 2012, a live individual and recently dead shells were found upstream of this site (Blair 2012, pers. comm.).

The San Saba River historically contained Texas pimpleback (Randklev et al. 2010c, p. 2), but no live individuals had been collected in over a decade until shells were collected in 1992 and 1995 (Howells 1994, p. 7; 1996, p. 21), and five live individuals were collected in 1997 (Howells 1998, p. 16). However, subsequent surveys were conducted in 2000, 2004, and 2005, with only shell material being found in 2000 (Howells 2001, pp. 28–29), and no evidence of Texas pimpleback was found in 2004 and 2005 (Howells 2005, pp. 8–9; 2006, pp. 64–65). A single shell was collected in 2008 (Burlakova and Karatayev 2010b, p. 1). However, in 2011, 39 live individuals were found at two sites in the lower San Saba River in San Saba County (Burlakova and Karatayev 2011, p. 3). The individuals found were of various sizes and ages, indicating a reproducing population (Burlakova and Karatayev 2011, p. 4). Further surveys at this site confirmed a large population in the area, with 140 individuals, including many juveniles, found here (Randklev 2011b, p. 1). Later in 2011, a population estimate was conducted for the section of the river within San Saba County, and it was estimated to be approximately 9,000 individuals (Burlakova and Karatayev 2012a, p. 12; Burlakova and Karatayev 2012b, p. 9). These surveys of the lower San Saba River discovered a second large population of Texas pimpleback, which was successfully reproducing and recruiting (Burlakova and Karatayev 2012a, p. 13; Burlakova and Karatayev 2012b, p. 9). The Service and U.S. Geological Survey (USGS) conducted surveys within San Saba County at two sites and located several live and fresh dead to recently dead individuals in 2012 and 2013, which confirms the continued presence of this species in the San Saba River (Service Files, 2012; Service Files, 2013). However, this population continues to be threatened by low flow conditions due to droughts and water withdrawals (Burlakova and Karatayev 2012a, p. 13; Burlakova and Karatayev 2012b, p. 10). Further upstream in Menard County, the Service located fresh and recent dead shells of Texas pimpleback (Service Files 2013).

The Texas pimpleback also historically occurred in the North Concho, Pedernales, and Llano Rivers, as well as Onion Creek (Howells 2010e, p.5; Randklev et al. 2010c, p. 4; OSUM 2011d, p. 1); all are tributaries within the Colorado River system. In the North Concho River, all freshwater mussels are presumed extirpated from historically occupied areas (Howells 1995, pp. 22– 23). The Pedernales River historically harbored a Texas pimpleback population (OSUM 2011d, p. 1), but only old shells have been collected in this river in recent years (Howells 1994, p. 5). Since 1993, no evidence of Texas pimpleback has been found (Howells 1995, pp. 27–28; 1999, p. 16; Service Files, 2012); therefore, the species is presumed to be extirpated. Additionally, repeated surveys in the Llano River in Kimble and Mason Counties consistently failed to collect live Texas pimpleback, with shells found only in Llano County in 1997 (Howells 1996, pp. 21–22; 1998, p. 17; 2005, p. 8). In 2012 and 2013, the Service and USGS conducted several surveys throughout the Llano and Pedernales Rivers and found no evidence of this species (Service Files, 2012; Services Files, 201). The Texas pimpleback is likely extirpated from all of these streams.

Guadalupe River System

In the Guadalupe River system, the Texas pimpleback has been extirpated from nearly the entire reach of the mainstem Guadalupe, San Antonio, and Blanco Rivers. Small populations of a few to approximately 40 individuals remain in the lower Guadalupe and San Marcos Rivers In the mainstem Guadalupe River, the Texas pimpleback was historically known throughout the length of the river, from as long ago as 1905 (Randklev et al. 2010c, p. 1; OSUM 2011d, p. 1). Numerous surveys between 1992 and 2005 had not yielded any evidence of the species anywhere but in Victoria County (Howells 1994, pp. 7–9; 1995, pp. 30–32; 1996, pp. 25–27; 1997a, pp. 37–40; 1999, pp. 18–19; 2002a, p. 8; 2003, pp. 15, 17; 2006, pp. 71–72; Johnson 2009, p. 1), where two live individuals were collected in 2009. However, in 2011, seven live individuals were found in Comal County (Randklev 2012, pers. comm.) and a live individual and one very recently dead juvenile was found downstream just below the Upper Guadalupe River Authority Dam in Kerr County during presence/absence surveys, indicating that this species may still persist in area but in very low numbers (Service Files, 2013). Further downstream in Victoria County, several live and recently dead Texas pimpleback at various age classes were found during presence/absence surveys in 2012, indicating that successful reproduction and recruiting is taking place (Service Files, 2012). A small population may remain in the lower Guadalupe River.

In the San Marcos River near the confluence with the Blanco River in Hays County, repeated surveys between 1992 and 2000 yielded no evidence of Texas pimpleback (Howells 1994, pp. 9–10; 1995, pp. 33–34; 1996, p. 27; 1997a, p. 40; 2000a, p. 28; 2001, pp. 32–33). However, in

2003 two shells were collected (Howells 2004, p. 16), and in 2004, a single live individual was found (Howells 2005, p. 10). In 2011, 37 live individuals were observed in Caldwell/Gonzales Counties southwest of Lulling, Texas (Burlakova and Karatayev 2012a, p. 12; Burlakova and Karatayev 2012b, p. 12) and an additional 62 were collected, tagged, and released in 2013 (TPWD 2014, p. 174). The Texas pimpleback likely persists in this river in very low numbers.

The Texas pimpleback appears to be extirpated from the San Antonio River, with only shell fragments found near the City of San Antonio in Bexar County in 1993 (Howells 1995, p. 35). No evidence of the species was found downstream in Karnes County in 1996 (Howells 1997a, pp. 41–42). A relative mussel abundance, species richness, and habitat utilization analysis was conducted in 2011in a four mile section of the lower San Antonio River from Bexar County to Goliad County; no live or dead Texas pimpleback were found during these survey efforts (Larralde 2011, pp. 18), which confirms that this species has been extirpated from this system.

The Texas pimpleback was once described as abundant in the Blanco River just upstream of its confluence with the San Marcos River in Hays County (Horne and Mcintosh 1979, p. 126), but repeated surveys of this area between 1992 and 1995 yielded no recent evidence of the species (Howells 1994, p. 9; 1995, pp. 32–33; 1996, p. 27), with only a subfossil shell collected in 1993 (Howells 1995, p. 33). No shell material or live individuals were found in additional surveys in 2011 (Johnson 2011, p. 1).

Population Estimates/Status:

Based on historical and current data, the Texas pimpleback has been eliminated from long reaches of former habitat in hundreds of miles of the Colorado and Guadalupe River systems.
Only two populations appear large enough to be stable, but evidence of recruitment in the Concho River population is limited. The San Saba River population may be the only remaining recruiting population of Texas pimpleback. Two additional populations are represented by one or two individuals; all populations are highly disjunct.

Threats

A. The present or threatened destruction, modification, or curtailment of its habitat or range:

The decline of mussels in Texas and across the United States is primarily the result of habitat loss and degradation (Neves 1991, pp. 252, 265; Howells et al. 1996, pp. 21–22). Chief among the causes of mussel decline in Texas are the effects of impoundments, sedimentation, dewatering, sand and gravel mining, and chemical contaminants (Neck 1982a, pp. 33–35; Howells et al. 1996, pp. 21–22; Winemiller et al. pp. 17–18). These threats are discussed below.

Impoundments

A major factor in the decline of freshwater mussels across the United States has been the large-scale impoundment of rivers (Vaughn and Taylor 1999, p. 913). Dams are the source of numerous threats to freshwater mussels: They block upstream and downstream movement of species by blocking host fish movement; they eliminate or reduce river flow within impounded areas, thereby trapping silts and causing sediment deposition; and dams change downstream water flow timing and temperature, decrease habitat heterogeneity, and affect normal flood patterns (Layzer et al. 1993, pp. 68–69; Neves et al. 1997, pp. 63–64; Watters 2000, pp. 261–264; Watters 1996, p. 80). Within reservoirs (the impounded waters behind dams), the decline of freshwater mussels has been attributed to sedimentation, decreased dissolved oxygen, and alteration of resident fish populations (Neves et al. 1997, pp. 63– 64; Pringle et al. 2000, pp. 810–815; Watters 2000, pp. 261–264). Dams significantly alter downstream water quality and stream habitats (Allan and Flecker 1993, p. 36; Collier et al. 1996, pp. 1, 7) resulting in negative effects to tailwater (the area downstream of a dam) mussel populations (Layzer et al. 1993, p. 69; Neves et al. 1997, p. 63; Watters 2000, pp. 265–266). Below dams, mussel declines are associated with changes and fluctuation in flow regime, scouring and erosion of stream channels, reduced dissolved oxygen levels and water temperatures, and changes in resident fish assemblages (Williams et al. 1992, p. 7; Layzer et al. 1993, p. 69; Neves et al. 1997, pp. 63–64; Pringle et al. 2000, pp. 810–815; Watters 2000, pp. 265–266). Numerous dams have been constructed throughout the Colorado and Guadalupe-San Antonio River systems within the range of Texas pimpleback (Stanley et al. 1990, p. 61).

Population losses due to the effects of dams and impoundments have likely contributed more to the loss of diversity and abundance of freshwater mussels across Texas, including Texas pimpleback, than any other factor. Stream habitat throughout nearly all of the range of Texas pimpleback has been affected by numerous impoundments, leaving generally short, isolated patches of remnant habitat between dams. Impoundments have resulted in profound changes to the nature of the rivers, primarily replacing free-flowing river systems with a series of large reservoirs.

There are no natural lakes within the range of the Texas pimpleback, nor has it ever been found in reservoirs. Historically, the Texas pimpleback could be found in areas of the Guadalupe River in Comal County (Randklev et al. 2010c, p. 4), but it has not been found in the area since the construction of Canyon Reservoir (Burlakova and Karatayev 2009, p. 6). We presume the species is extirpated from this reach because of the effects of the reservoir. Surveys of the reservoirs on the Guadalupe and Colorado Rivers have been ongoing since at least 1992, and no evidence of live or dead Texas pimpleback has been found in any reservoir (Howells 1994, pp. 1–20; 1995, pp. 1–50; 1996, pp. 1–45; 1997a, pp. 1–58; 1998, pp. 1–30; 1999, pp. 1–34; 2000a, pp. 1–56; 2001, pp. 1–50; 2002a, pp. 1–28; 2003, pp. 1–42; 2004, pp. 1–48; 2005, pp. 1–23; 2006, pp. 1–106; Karatayev and Burlakova 2008, pp. 1–47; Burlakova and Karatayev 2010a, pp. 1–30; 2011, pp. 1–8), further indicating this species is not tolerant of impoundments.

Impoundments occur throughout the range of the Texas pimpleback. The majority of the Guadalupe, San Antonio, and Colorado, as well as many tributaries, are now impounded. There are 37 major reservoirs and numerous smaller impoundments within the historical and current range of the Texas pimpleback. There are 31 major reservoirs within the Colorado River basin, with another reservoir (Goldthwaite Reservoir) proposed for the Colorado River in San Saba County near a Texas pimpleback population; this reservoir was the number one recommendation in the water plan for the region (TWDB 2011, pp. 4–85). There are 29 reservoirs within the Guadalupe River basin and 34 within the San Antonio River basin, each with a storage capacity of 3,000 acre-feet or more, and many other smaller reservoirs (Exelon 2010, p. 2.3–4). The majority of the large dams were constructed for power generation, flood control, and water supply by the Lower Colorado River and Guadalupe-Blanco River Authorities beginning as early as 1935 (Guadalupe-Blanco River Authority 2011, p. 1; LCRA 2011a, p. 1). These and numerous smaller dams occur throughout the Colorado and Guadalupe River basins, fragmenting habitat and populations of Texas pimpleback.

Dams threaten freshwater mussels in several ways. First, they can prevent the movement of freshwater mussel host fish. The overall distribution of mussels is a function of the dispersal of their hosts (Watters 1996, p. 83). For example, Watters (1996, p. 80) found that the distributions of the fragile papershell (Leptodea fragilis) and pink heelsplitter (Potamilus alatus) in five midwestern rivers were determined by the presence of low-head dams. These dams were non-navigable (without locks), lacked fish ladders, and varied in height from 1 to 17.7 m (3 ft to 58 ft), and the host fish could not disperse through them. Although the distribution of mussels may depend on many ecological factors, the evidence presented in Watters (1996, pp. 79–85) illustrates that dams as small as 1 m (3 ft) high can limit the distribution of mussels. There are many dams that occur throughout the range of the Texas pimpleback that lack fish ladders and may be a barrier to the movement of fish hosts and, therefore, the distribution of mussels. Because the Texas pimpleback populations are all separated by dams of various sizes that are not passable by fish, the mussels are unable to disperse from its current occupied range through host fish migration.

Dams also alter aquatic habitat within the resulting impoundments. It is well documented that many mussel species that are adapted to flowing water stream environments do poorly in the altered aquatic conditions found within impoundments (Williams et al. 1992, p. 7; Vaughn and Taylor 1999, p. 913). Once a dam is constructed, the original river channel upstream remains intact but under much deeper water with much lower velocities. As water velocity decreases, water loses its ability to carry sediment; sediment falls to the substrate, eventually smothering mussels that cannot adapt to soft substrates (Watters 2000, p. 263). Over time, the original mussel species composition of the stream channel may be eliminated or changed in favor of silt tolerant species (Watters 2000, p. 264). The mussel community may be altered from one with many different species to a community dominated by one to several very common species (Neck 1982b, p. 174). Texas pimpleback does not occur in reservoirs, indicating it is not tolerant of lentic conditions, and it is now extirpated from impounded areas where it occurred prior to inundation. The inundation of stream habitat by impoundments is a likely cause of the reduction in the distribution of the Texas pimpleback. The presence of the impoundments has caused the permanent loss of Texas pimpleback habitat throughout its range.

The loss of seven freshwater mussel species native to Texas, including Texas pimpleback, due to impoundment construction was documented on the Medina River (Neck 1989, p. 323). The Medina River was impounded in 1913 by construction of Medina Dam, and now only three different species of mussels, all of which are tolerant of lentic habitats, occur in the impounded area. The bottom of Medina Lake now consists of moderate and steep limestone slopes and excessive silt deposits, whereas before it was most likely made up of a combination of silt, sand, and gravel substrates. Most mussels native to the Medina River were unable to adapt to the change in flowing water and substrate conditions (Neck 1989, p. 323), including the Texas pimpleback, which is no longer found in the river.

Mussels downstream of impoundments are often affected through changes in fish host availability, water quality (particularly lower water temperatures), habitat structure, and stream channel scouring (Vaughn and Taylor 1999, p. 916). The release of cold water from the hypolimnion (deeper and colder layer of water in reservoirs) can decrease the occurrence of fish species adapted to warm water and increase the occurrence of fish species adapted to colder water (Edwards 1978, pp. 73–75). This changes the species composition of suitable host fish and may prevent mussels from completing an essential part of their reproductive cycle. This has been demonstrated by the extirpation of mussel species from several rivers on the eastern seaboard of the United States, which has been linked to the disappearance of appropriate host fish; the reintroduction of the host fish to rivers has enabled mussel species to recolonize areas (Kat and Davis 1984, p. 174). In addition, because mussel reproduction is temperature dependent (Watters and O’Dee 1999, pp. 455–456), it is likely that individual mussels living in cold waters downstream of dam releases may reproduce less frequently, if at all (Layzer et al. 1993, p. 69). Low water temperatures can also significantly delay or prevent metamorphosis (Watters and O’Dee 1999, pp. 454–455) and glochidial release, which is often triggered by water temperature (Watters and O’Dee 2000, p. 136).

Similar changes in water temperatures downstream of dams may be responsible for the loss of some Texas pimpleback populations. For example, Canyon Reservoir on the Guadalupe River in Comal County is a deep impoundment built in 1964 that has hypolimnetic water releases. Temperature monitoring stations throughout the Guadalupe River basin show that maximum temperatures above Canyon Reservoir averaged 29.6 degrees Celsius (°C) (85.3 degrees Fahrenheit (°F)); the maximum stream temperatures below the reservoir averaged only 19.7 °C (67.5 °F) (Edwards 1978, p. 72). After impoundment, dissolved oxygen and water temperature dropped, with an accompanying drop in mussel numbers and species diversity (Young et al. 1976, p. 216). According to historical museum records analyzed by Randklev et al. (2010b, pp. 1–32), the Texas pimpleback once occurred in this area of the Guadalupe River prior to the construction of Canyon Reservoir. The Guadalupe River and Canyon Lake in Comal and Kendall Counties were surveyed in 2009, and no live or recently dead Texas pimpleback were found (Burlakova and Karatayev 2010a, pp. 12–13). We reasonably conclude that the loss of the Texas pimpleback from this area was caused by the changes to the aquatic habitat of the Guadalupe River from the effects of Canyon Reservoir. Many of the dams throughout the range of Texas pimpleback have hypolimnetic water releases, including Canyon Reservoir on the Guadalupe River (Magnelia 2001, p. 1), and Inks Lake, Lake LBJ (Schnoor and Fruh 1979, p. 506), and Lake Travis (Texas Natural Resource Conservation Commission 2001, p. 4) on the Colorado River, among others. We anticipate that changes in water temperatures from water released by these and other reservoirs also alter mussel habitats in streams, causing the elimination of mussel populations downstream.

In addition to the temperature of water released from dams, highly fluctuating, turbulent tailwaters devoid of sediment will scour the riverbed downstream of dams, rendering the area without mussel habitat (Layzer et al. 1993, p. 69). Depending on the use of the dam, water levels may fluctuate on a regular interval (for hydroelectric purposes) or at random (for flood control) (Watters 2000, p. 265). On the Colorado River, Inks Lake, Lake Marble Falls, Lake Buchanan, Lake Austin, Lake Travis, and Lady Bird Lake are each used for one or both of these purposes. Mortality of another rare mussel species in Texas, the Texas heelsplitter (Potamilus amphichaenus) was attributed to scheduled dewatering of the Neches River below B.A. Steinhagen Reservoir in east Texas (Neck and Howells 1994, p. 15).

Fluctuating water levels below dams also result in dramatic changes in water velocity. Downstream of Lake Livingston on the Trinity River in east Texas, for example, high-volume water discharges and abrupt stoppages of flow resulted in a river bed composed of large rocks and shifting sand (Neck and Howells 1994, p. 14); these kinds of habitat changes would be inhospitable to Texas pimpleback below the dams within its range. In some rivers this unstable zone may be extensive. For example, the Brazos River downstream of Possum Kingdom Reservoir in Texas exhibited unstable substrate for 150 km (240 mi) below the dam (Yeager 1993, p. 68).

In one study of the downstream effects of dams, Vaughn and Taylor (1999, p. 915) found a strong, gradual, linear increase in mussel species richness and abundance at sites on the Little River in Oklahoma downstream from Pine Creek Reservoir. Their research revealed that mussel species richness and total abundance did not begin to rebound until 20 km (12 mi) downstream of the impoundment and did not peak until 53 km (33 mi) downstream. They noted the most obvious difference since reservoir construction has been the alteration of the flow and temperature regimes, which gradually return to preimpoundment levels with downstream distance from the dam. These alterations appear to have produced an extinction gradient of mussels that is most severe near the dam (Vaughn and Taylor 1999, p. 915). We expect similar effects on the Texas pimpleback and other Texas mussels downstream of dams.

Dam construction also fragments the range of Texas pimpleback, leaving remaining habitats and populations isolated by the structures as well as by extensive areas of deep uninhabitable, impounded waters. These isolated populations are unable to naturally recolonize suitable habitat that may be impacted by temporary but devastating events, such as severe drought, floods, or pollution. Dams impound river habitats throughout almost the entire range of the species, and these impoundments have left short and isolated patches of remnant habitat, typically between impounded reaches.

In summary, the widespread construction of dams has affected the Texas pimpleback throughout its range by significantly altering stream habitat both upstream and downstream of the dams by changing fish assemblages, water depths and velocities, water temperature, dissolved oxygen, substrate, and stream channels. The effects of dams are ongoing and continue to negatively impact the Texas pimpleback rangewide. Because of this loss of habitat and its effects on the populations, we find that the effects of impoundments are a threat to the Texas pimpleback.

Sedimentation

Siltation and general sediment runoff is a pervasive problem in streams and has been implicated in the decline of stream mussel populations (Ellis 1936, pp. 39–40; Vannote and Minshall 1982, p. 4105; Dennis 1984, p. ii; Brim Box and Mossa 1999, p. 99; Fraley and Ahlstedt 2000, pp. 193–194). Specific biological effects on mussels from excessive sediment include reduced feeding and respiratory efficiency from clogged gills (Ellis 1936, p. 40), disrupted metabolic processes, reduced growth rates, increased substrate instability, limited burrowing activity (Marking and Bills 1979, pp. 208–209; Vannote and Minshall 1982, p. 4106), physical smothering, and disrupted host fish attractant mechanisms (Hartfield and Hartfield 1996, p. 373). The primary effects of excess sediment on mussels are sublethal, with detrimental effects not immediately apparent (Brim Box and Mossa 1999, p. 101).

The physical effects of sediment on mussel habitats are multifold and include changes in suspended material load; changes in streambed sediment composition from increased sediment production and runoff in the watershed; changes in the form, position, and stability of stream channels; changes in water depth or the width-to-depth ratio, which affects light penetration and flow regime; actively aggrading (filling) or degrading (scouring) channels; and changes in channel position that may leave mussels stranded (Brim Box and Mossa 1999, pp. 109–112).

Increased sedimentation and siltation may explain, in part, why Texas pimpleback appear to be experiencing recruitment failure in some streams. Interstitial spaces (small openings between rocks and gravels) in the substrate provide essential habitat for juvenile mussels. When clogged with sand or silt, interstitial flow rates and spaces may become reduced (Brim Box and Mossa 1999, p. 100), thus reducing juvenile habitat availability. Juvenile freshwater mussels, including Texas pimpleback juveniles, burrow into interstitial substrates, making it particularly susceptible to degradation of this habitat.

Even in 1959, Colorado River was noted as having high sedimentation rates from agricultural activities (Soil Conservation Service 1959, pp. 56, 59). Approximately 40 percent of U.S. river miles do not meet Clean Water Act standards due to excessive sediment loads (Environmental Protection Agency (EPA) 2000, p. 1), with agricultural activities being the primary source of sediment in streams (Waters 1995, p. 170). In general, sedimentation, resulting from unrestricted access by livestock, has been shown to be a significant threat to many streams and their mussel populations (Fraley and Ahlstedt 2000, p. 193). A primary land use throughout the range of the Texas pimpleback is grazing by cattle, sheep, and goats (Hersh 2007, p. 11). Soil compaction, which reduces vegetative growth, from intensive grazing, may reduce infiltration rates and increase runoff and erosion, and trampling of riparian vegetation increases the probability of erosion (Armour et al. 1994, p.10; Brim Box and Mossa 1999, p. 103).

Sedimentation may become an increasing threat to the Texas pimpleback in the Colorado and Guadalupe River basins as the Austin and San Antonio metro areas continue to expand.

Activities associated with urbanization, such as road construction and increased impervious surfaces (surfaces that do not allow infiltration of rain water), can be detrimental to stream habitats (Couch and Hamilton 2002, p. 1). Runoff from increased impervious surfaces increases sediment loads in streams and destabilizes stream channels (Pappas et al. 2008, p. 151). Impervious surfaces also result in channel instability by accelerating stormwater runoff, which increases bank erosion and bed scouring, thereby further increasing downstream sedimentation (Brim Box and Mossa 1999, p. 103). While erosion and sedimentation associated with road construction may be temporary, the existence of road crossings is shown to have ongoing impacts to mussel habitat. For example, in the Guadalupe River, road crossings were found to cause a long-term increase in sedimentation both upstream and downstream, as channel constriction reduced flow upstream, causing sediment deposition, and runoff from the road increased sedimentation downstream (Keen- Zebert and Curran 2009, p. 301). Urban development activities may also affect streams and their mussel fauna where adequate streamside buffers are not maintained and erosion from adjacent land is allowed to enter streams
(Brainwood et al. 2006, p. 511).

Large projects that reduce vegetative cover within the watersheds supporting Texas pimpleback populations can also increase sedimentation flowing into streams. For example, the Lower Colorado River Authority Transmission Services Corporation (LCRA TSC) is proposing to construct two new 345- kilovolt (kV) electric transmission line facilities between Tom Green (in the Colorado River basin near San Angelo) and Kendall Counties (in the Guadalupe River basin north of San Antonio) to provide electrical power to accommodate increased human populations (Clary 2010, p.

1). One of the proposed project routes occur within the range of the Texas pimpleback. This route proposes to cross through the San Saba River, which contains the only known reproducing population of the Texas pimpleback. The proposed project could negatively affect Texas pimpleback habitat if construction or maintenance of the transmission line requires removal of vegetation within the riparian zone and that removal results in an increase in sediment runoff into San Saba River (Clary 2010, pp. 7, 9, 15). Similar infrastructure development activities to accommodate Texas population growth are expected to be undertaken across the species' range and will likely lead to additional sources of sediment in the streams inhabited by the Texas pimpleback.

Streams occupied by Texas pimpleback are subject to increasing levels of sedimentation from agriculture, urbanization, and sand and gravel mining (discussed in section titled Sand and Gravel Mining). Agriculture is a common land use in the Guadalupe and San Antonio River basins, and the city of San Antonio, the second largest city in Texas, continues to grow (City of San Antonio 2010, p. 5). Sedimentation from agriculture, urbanization, and sand and gravel mining will continue to threaten the Texas pimpleback in the foreseeable future.

Dewatering

River dewatering can occur in several ways: Anthropogenic activities such as surface water diversions and groundwater pumping, and natural events, such as drought. Surface water diversions and groundwater pumping can lower water tables, reducing river flows and reservoir levels. When water levels in streams and reservoirs are lowered dramatically, it can result in mussels being stranded and dying in previously wetted areas. This is a particular concern within and below reservoirs where water levels are managed for purposes that result in water levels in the reservoir or downstream to rise or fall in very short periods of time, such as when hydropower facilities release water during peak energy demand periods.

Drought can also severely impact Texas pimpleback populations. Central Texas, including the Colorado and Guadalupe River basins, experienced a major drought in the late 1970s (Lewis and Oliveria 1979, p. 243). Near record dry conditions in 2008 followed by a pattern of below-normal rainfall during the winter and spring of 2009 led to one of the worst droughts in recorded history for most of central Texas, including the range of the Texas pimpleback (Nielsen-Gammon and McRoberts 2009, p. 2). This drought's severity was exacerbated by abnormally high air temperatures, a likely effect of climate change, which has already increased average air temperatures in Texas by at least 1 °C (1.8 °F) (Nielsen- Gammon and McRoberts 2009, p. 22). Instream flows throughout the Colorado River basin during this drought were significantly reduced (USGS 2011c, p. 1), and Texas pimpleback populations in areas with reduced water levels may have been negatively affected.

Central Texas is currently experiencing another extreme drought, with rainfall between October 2010 and July 2011 being the lowest on record during those months (LCRA 2011c, p. 1); the effects of this drought are being observed but are not yet fully known. Due to severe drought in 2011, many gravel bars surveyed in March and July were barely covered with water (Photo 3, 5), large areas of the San Saba River were completely dry (Photo 4), and the situation got even worse at the end of summer (Burlakova and Karatayev 2012b, p. 10). It has also been noted by Burlakova and Karatayev (2012b, p. 14) that sections of the Pedernales River in early 2011 had stopped flowing and only pools of water were left behind; 11 recently dead Texas pimpleback and several other mussels were found as a result of the river drying up (Burlakova and Karatayev 2012b, p. 14). As the drought continued in the fall of 2011, many of the populations in San Saba River may no longer exist; 2012 was dry as well, which may have further stressed any remaining populations. In 2015, TPWD was sent out to San Saba River to investigate over pumping issues in middle San Saba River where conditions were characterized as very long distances of dry river with few isoloated pools (TPWD 2015, p. 2). This ongoing threat continues to kill several candidate mussel species, including the Texas pimpleback (TPWD 2015, p. 3). These conditions were also reported by (Burlakova and Karatayev 2012b, p. 10).

According to the National Weather Service records for 2011, more than 77 percent of Texas is experiencing moderate to extreme drought (Burlakova and Karatayev 2012b, p. 16). Current climate model simulations suggest that the American southwest could experience a 60-year stretch of heat and drought unseen since the 12th century and that the region is likely to become drier and experience more frequent droughts, with changes accelerating toward the end of the century (Woodhouse et al. 2010, pp. 21283-21288). Droughts result in a decrease in water depth and flow velocity, which reduces food and oxygen delivery. As droughts persist, mussels face hypoxia, elevated water temperature and, ultimately, stranding (Golladay et al. 2004, p. 501).

We do not know the extent of the impacts of stream dewatering on the Texas pimpleback; however, because several populations are small and isolated, the loss of numerous individuals at a site can have dramatic consequences to the population. Hydropower facilities, diversions associated with construction, and drought are occurring throughout the range of the Texas pimpleback; therefore, the effects of dewatering are ongoing and unlikely to decrease, resulting in significant threats to the Texas pimpleback.

Sand and Gravel Mining

Sand and gravel mining (removing bed materials from streams) has been implicated in the destruction of mussel populations across the United States (Hartfield 1993, pp. 136–138). Sand and gravel mining causes stream instability by increasing erosion and turbidity (a measure of water clarity) and causing subsequent sediment deposition downstream (Meador and Layher 1998, pp.

8–9). These changes to the stream can result in large-scale changes to aquatic fauna, by altering habitat and affecting spawning of fish, mussels, and other aquatic species (Kanehl and Lyons 1992, pp. 4–11).

Sedimentation and increased turbidity can accrue from instream mining activities. In the Brazos River, a gravel dredging operation was documented as depositing sediment as far as 1.6 km (1 mi) downstream (Forshage and Carter 1973, p. 697). Accelerated streambank erosion and downcutting of streambeds are common effects of instream sand and gravel mining, as is the mobilization of fine sediments during sand and gravel extraction (Roell 1999, p. 7).

Mining activities may threaten some local Texas pimpleback populations. In 1995, the reach of the Guadalupe River near Victoria, which contains a Texas pimpleback population, was described as having numerous current and abandoned sand and gravel mining areas (USACE 1995, p. 7). Currently, TPWD has permitted one sand mining activity within the current range of Texas pimpleback, in the Guadalupe River basin in Comal County (TPWD 2009b, p. 1); a small Texas pimpleback population occurs downstream of this area in the Guadalupe River. The permit allows for the repeated removal of sand and gravel at various locations within the stream.

In areas where repeated mining occurs, an upstream progression of channel degradation and erosion (called headcutting) can occur (Meador and Layher 1998, p. 8). Headcutting may move miles upstream in a zipper-like fashion as the upper boundary of the modified area collapses. Headcutting can be found within the majority of rivers and streams in Texas, including within the Texas pimpleback's current and historical range (Kennon et al. 1967, p. 22). Headcuts induced by sand and gravel mining operations can cause dramatic changes in streambank and channel shape that may affect instream flow, water chemistry and temperature, bank stability, and siltation (Meador and Layher 1998, p. 8), all of which are harmful to freshwater mussels. Mussels are particularly vulnerable to channel degradation and sedimentation processes associated with headcutting due to their immobility (Pringle 1997, p. 429).

Headcuts from sand and gravel mining operations have been documented in the San Antonio River basin in Karnes County from as early as 1967, with downstream channels having steep, eroded banks (Kennon et al. 1967, p. 22). There has been no evidence of Texas pimpleback in Karnes County in recent years (Howells 1997a, pp. 41–42), and the effects of sand mining may have been a factor in the species' extirpation.

In addition to headcutting, mines that are located near stream channels are subject to the gravel pit being captured by the stream during flood events or due to gradual channel migration (Simmang and Curran 2006, p. 1). For example, two gravel mines along the Colorado River downstream of Austin were inundated; one by stream channel migration in 1984, one by stream capture in 1991

(Simmang and Curran 2006, p. 1). Once captured by the mainstem river, gravel mines contribute large amounts of suspended sediment to the river, causing additional turbidity and sedimentation and further degrading mussel habitat.

The Texas pimpleback population in` the Guadalupe River may be currently` threatened by sand and gravel mining. These activities occur over a long period of time, destabilizing habitat both` upstream and downstream, which decreases the likelihood of recolonization after the activity has been completed. Therefore, the effects of sand and gravel mining are an ongoing threat to the Texas pimpleback.

Chemical Contaminants

Chemical contaminants are ubiquitous throughout the environment and are a major reason for the decline of freshwater mussel species nationwide (Richter et. al. 1997, p. 1081; Strayer et al. 2004, p. 436; Wang et al. 2007a, p. 2029). Chemicals enter the environment through both point and nonpoint discharges, including spills, industrial sources, municipal effluents, and agriculture runoff. These sources contribute organic compounds, heavy metals, pesticides, herbicides, and a wide variety of newly emerging contaminants to the aquatic environment. As a result, water quality can be degraded to the extent that mussel populations are adversely affected.

Chemical and oil spills can be especially devastating to mussels because they may result in exposure of a relatively immobile species to elevated concentrations that far exceed toxic levels. Acute and chronic exposure to oil spills in freshwater systems is largely understudied; therefore, little information is available on effects of oil spills on freshwater ecosystems (Harrel 1985, p. 223; Bhattacharyya et al. 2002, p. 205). Oil is retained much longer in marshes and other low-energy environments, such as slow-moving streams and rivers, than on wave-swept coasts (Bhattacharyya et al. 2002, p. 205). Oils have been found in sediments at low energy sites as much as 5 years after the occurrence of spills, and they may be released into the water column long after the initial spill. Oil may have various chronic effects on water-column and benthic (bottom-dwelling) species. These effects include sensory disruption, behavioral and developmental abnormalities, and reduced fertility (Bhattacharyya et al. 2002, p. 205). Oil spilled on the water surface may also limit oxygen exchange, coat the gills of aquatic organisms, and cause pathological lesions on respiratory surfaces, thereby affecting respiration in aquatic organisms. Effects of oil on freshwater mussels may result from oil settling on the sediment surfaces and accumulating in the sediment. This can prevent invertebrate colonization (Bhattacharyya et al. 2002, p. 205). Complete recovery of benthic communities may be a matter of years, with communities in the meantime consisting solely of pollutant-tolerant organisms (Bhattacharyya et al. 2002, p. 205). Oil spills can occur from on-site accidents (tank, pipeline spills) or from tanker truck accidents within watersheds occupied by Texas pimpleback.

Exposure of mussels to persistent low concentrations of contaminants likely to be found in aquatic environments can also adversely affect mussels and their populations. Such concentrations may not be immediately lethal, but over time can result in mortality, reduced filtration efficiency, reduced growth, decreased reproduction, changes in enzyme activity, and behavioral changes to all mussel life stages (Naimo 1995, pp. 351–352; Baun et al. 2008, p. 392). Frequently, procedures that evaluate the ‘‘safe’’ concentration of an environmental contaminant (for example, national water quality criteria) do not have data for freshwater mussel species or do not consider data that are available for freshwater mussels (March et al. 2007, pp. 2066–2067, 2073). One chemical that is particularly toxic to early life stages of mussels is ammonia. Sources of ammonia include agricultural activities (animal feedlots and nitrogenous fertilizers), municipal wastewater treatment plants, and industrial waste (Augspurger et al. 2007, p. 2026), as well as precipitation and natural processes (decomposition of organic nitrogen) (Goudreau et al. 1993, p. 212; Hickey and Martin 1999, p. 44; Augspurger et al. 2003, p. 2569; Newton 2003, p. 2543). Therefore, ammonia is considered a limiting factor for survival and recovery of some mussel species due to its ubiquity in aquatic environments, high level of toxicity, and because the highest concentrations typically occur in mussel microhabitats (Augspurger et al. 2003, p. 2574). In addition, studies have shown that ammonia concentrations increase with increasing temperature and low-flow conditions (Cherry et al. 2005, p. 378; Cooper et al. 2005, p. 381), which may be exacerbated during low-flow events in streams. Within the range of Texas pimpleback, high ammonia levels are common, either chronically, such as in Elm Creek, which is listed as impaired due to high ammonia concentrations (Texas Commission on Environmental Quality (TCEQ) 2010a, p. 294), or due to spills. A wastewater leak in August 2010 spilled approximately 380,000 liters (L) (100,000 gallons (gal)) of sewage into Elm Creek (Bramlette and Cosel 2010, p. 1); ammonia is present in high concentrations in sewage, among other pollutants. Additionally, a sewage spill in 2008 in Onion Creek discharged nearly 380,000 L (100,000 gal), and another sewage spill occurred in April 2011 in Quinlan Creek, a tributary to the Guadalupe River near the Kerr County population (MacCormack 2011, p. 1). High ammonia levels from chronic sources as well as from spills may be affecting Texas pimpleback populations.

In addition to ammonia, agricultural sources of chemical contaminants include two broad categories that have the potential to adversely affect mussel species: Nutrients and pesticides. High amounts of nutrients, such as nitrogen and phosphorus, in streams can stimulate excessive plant growth (algae and periphyton, among others), which in turn can reduce dissolved oxygen levels when dead plant material decomposes. Nutrient over-enrichment in streams is primarily a result of runoff of fertlizer and animal manure from livestock farms, feedlots, and heavily fertilized row crops (Peterjohn and Correll 1984, p. 1471). Over-enriched conditions are exacerbated by low-flow stream conditions, such as those experienced during typical summer season flows. Bauer (1988, p. 244) found that excessive nitrogen concentrations can be detrimental to the adult freshwater pearl mussel (Margaritifera margaritifera), as was evident by the positive linear relationship between mortality and nitrate concentrations. Also, a study of mussel life span and size (Bauer 1992, p. 425) showed a negative correlation between growth rate and high nutrient concentrations, and longevity was reduced as the concentration of nitrates increased. Juvenile mussels in interstitial habitats are particularly affected by depleted dissolved oxygen levels resulting from nutrient over-enrichment (Sparks and Strayer 1998, p. 133). The Texas pimple occurs within the Concho River watershed, which has been documented as having particularly high nitrates for nearly 20 years, likely due to intensive agriculture in the area (Texas Clean Rivers Program 2008, p. 2), which may be affecting the Texas pimpleback population.

Mussels are also affected by metals (Keller and Zam 1991, p. 543) such as cadmium, chromium, copper, mercury, and zinc, which can negatively affect biological processes such as growth, filtration efficiency, enzyme activity, valve closure, and behavior (Keller and Zam 1991, p. 543; Naimo 1995, pp. 351–355; Jacobson et al. 1997, p. 2390; Valenti et al. 2005, p. 1244). Metals occur in industrial and wastewater effluents and are often a result of atmospheric deposition from industrial processes and incinerators. Studies have shown that copper can have toxic effects on glochidia and juvenile freshwater mussels (Wang et al. 2007a, pp. 2036–2047; Wang et al. 2007b, pp. 2048–2056). In the range of Texas pimpleback, high copper concentrations have been recorded in the lower Guadalupe and San Antonio Rivers (Lee and Schultz 1994, p. 8). While these high levels of copper in fish are not directly informative of the level of copper within the habitat of the Texas pimpleback, these observations demonstrate that copper levels are likely high in the lower Guadalupe and San Antonio Rivers. Because we know that copper contamination in water can lead to death of mussels, we conclude that the copper may be adversely affecting Texas pimpleback.

Mercury is another heavy metal that has the potential to negatively affect mussel populations, and it is widely distributed in the environment. Mercury has been detected throughout aquatic environments as a product of municipal and industrial waste and atmospheric deposition from coal burning plants. Rainbow mussel (Villosa iris) glochidia have been demonstrated to be more sensitive to mercury than juvenile mussels, with the median lethal concentration value of 14 parts per billion (ppb) for glochidia, compared to 114 ppb for the juvenile life stages (Valenti 2005, p. 1242). The chronic toxicity tests conducted determined that juveniles exposed to mercury greater than or equal to 8 ppb exhibited reduced growth. Acute mercury toxicity was determined to be the cause of extirpation of a diverse mussel community for a 112 km (70 mi) portion of the North Fork Holston River in Virginia (Brown et al. 2005, pp. 1455– 1457). Mercury has been documented throughout the Guadalupe and San Antonio Rivers, with particularly high concentrations in fish in the upper reaches of both rivers (Lee and Schultz 1994, p. 8). As with copper, we do not have information on the concentration of mercury that Texas pimpleback is being exposed to in these streams, but the higher than expected levels in fish indicate high mercury levels in the area, which may be adversely affecting Texas pimpleback.

Pesticides are another source of contaminants in streams. Elevated concentrations of pesticides frequently occur in streams due to pesticide runoff, overspray application to row crops, and lack of adequate riparian buffers. The timing of agricultural pesticide applications in the spring often coincides with the reproductive and early life stages of mussels, which may increase the vulnerability of mussels to pesticides (Bringolf et al. 2007a, p. 2094). Little is known regarding the effect of currently used pesticides to freshwater mussels even though some pesticides, such as glyphosate (active ingredient in Roundup®), are used globally. Recent studies tested the toxicity of glyphosate, its formulations, and a surfactant (MON 0810) used in several glyphosate formulations, to early life stages of the fatmucket (Lampsilis siliquoidea) (Bringolf et al. 2007a, p. 2094). Studies conducted with fatmucket juveniles and glochidia determined that the surfactant was the most toxic of the compounds tested and that fatmucket glochidia were the most sensitive organisms tested to date (Bringolf et al. 2007a, p. 2094). Roundup®, technical grade glyphosate isopropylamine salt, and isopropylamine were also acutely toxic to juveniles and glochidia (Bringolf et al. 2007a, p. 2097). These commonly applied pesticides may be adversely affecting Texas pimpleback populations.

The effects of other widely used pesticides, including atrazine, chlorpyrifos, and permethrin, on glochidia and juvenile life stages have also recently been studied (Bringolf et al. 2007b, p. 2101). Environmentally relevant concentrations (concentrations that may be found in streams) of permethrin and chlorpyrifos were found to be toxic to glochidia and juvenile fatmucket (Bringolf et al. 2007b, pp. 2104–2106). Commonly applied pesticides are a threat to mussels as a result of their widespread use. All of these pesticides are commonly used on agricultural lands throughout the range of the Texas pimpleback, which may be adversely affecting the species.

A potential, but undocumented, threat to freshwater mussels, including Texas pimpleback, are compounds referred to as ‘‘emerging contaminants’’ that are being detected in aquatic ecosystems at an increasing rate. These include pharmaceuticals, hormones, and other organic contaminants that have been detected downstream from urban areas and livestock production (Kolpin et al. 2002, p. 1202) and have been shown to affect fish behavior (TCEQ 2010b, p. 3). In samples of the Trinity River, for example, compounds such as antidepressants, antihistamines, blood pressure lowering medication, antiseizure medication, and antimicrobial compounds were all detected during a 2006 study (TCEQ 2010b, pp. 27–28). A large potential source of these emerging contaminants is wastewater being discharged through both permitted (National Pollutant Discharge Elimination System (NPDES)) and nonpermitted sites within the Colorado and Guadalupe River systems. Although streams within the range of Texas pimpleback have not been tested for these emerging contaminants, permitted discharge sites are ubiquitous in watersheds with Texas pimpleback populations, providing many opportunities for contaminants to impact the species.

A study in the Blanco River found that mussels may be adversely affected by sewage effluent (Horne and McIntosh 1979, p. 132). Ammonia levels below the outfall were three times higher than the levels above the outfall and were higher than recently determined toxicity values of ammonia for mussels (Augsperger et al. 2003, p. 2572). The river was nutrient-enriched for miles downstream, and mussels were less abundant below the outfall than above (Horne and McIntosh 1979, pp. 124–125, 132). Texas pimpleback have not been found alive in the Blanco River since 1978.

Texas Commission on Environmental Quality (TCEQ) data for 2010 indicated that 26 of the 98 assessed water bodies within the historical and current range of the Texas pimpleback did not meet surface water quality standards and were classified as impaired water bodies under the Clean Water Act (Texas Clean Rivers Program 2010a, p. 5). These water bodies were impaired with dissolved solids, nitrates, bacteria, low dissolved oxygen, aluminum, sulfates, selenium, chloride, and low pH associated with agricultural, urban, municipal, and industrial runoff. Additionally, the Concho River near Paint Rock has been repeatedly documented as having high nitrates (Texas Clean Rivers Program 2008, p. 2); a significant Texas pimpleback population occurs just upstream of this site. Of these, nitrates and low dissolved oxygen pose the greatest threat to Texas pimpleback, as discussed above.

Chemical contaminants, such as ammonia, copper, mercury, nutrients, pesticides, and other compounds are currently a threat to the Texas pimpleback. The species is vulnerable to acute contamination from spills as well as chronic contaminant exposure, which is occurring rangewide.

Summary of Factor A

The reduction in numbers and range of the Texas pimpleback is primarily the result of the long-lasting effects of habitat alterations such as the effects of impoundments, sedimentation, sand and gravel mining, and chemical contaminants. Impoundments occur throughout the range of the species and have far-reaching effects both up and downstream. Both the Colorado and Guadalupe River systems have experienced a large amount of sedimentation from agriculture, instream mining, and urban development. Sand and gravel mining affects Texas pimpleback habitat by increasing sedimentation and channel instability downstream and causing headcutting upstream. Chemical contaminants have been documented throughout the range of the species and may represent a significant threat to the Texas pimpleback. Based upon our review of the best commercial and scientific data available, we conclude that the present or threatened destruction, modification, or curtailment of its habitat or range is an immediate threat of high magnitude to the Texas pimpleback.

B. Overutilization for commercial, recreational, scientific, or educational purposes:

The Texas pimpleback was historically harvested occasionally but never experienced high levels of collecting pressure (Howells 2010e, p.10). Although levels were light enough that commercial harvest was likely not a threat to populations, all commercial collecting became illegal when Texas pimpleback was listed as threatened by TPWD; therefore, commercial harvest is not a current threat to Texas pimpleback. Some scientific collecting occurs but is not likely to be a significant threat to the species because it occurs only rarely. However, handling mussels can disturb gravid females and result in glochidial loss and subsequent reproductive failure. Additionally, handling has been shown to reduce shell growth across mussel species, including several species of Lampsilis (Haag and Commens-Carson 2008, pp. 505–506). Repeated handling by researchers may adversely affect Texas pimpleback individuals, but these activities are occurring rarely and are not likely to be a threat to populations. Handling for scientific purposes contributes to the long-term conservation of the species.

We do not have any evidence of risks to the Texas pimpleback from overutilization for commercial, recreational, scientific, or educational purposes, and we have no reason to believe this factor will become a threat to the species in the future. Based upon the best scientific and commercial information available, we conclude that overutilization for commercial, recreational, scientific, or educational purposes does not pose a significant threat to the Texas pimpleback rangewide.

C. Disease or predation:

Disease

Little is known about disease in freshwater mussels. However, disease is believed to be a contributing factor in documented mussel die-offs in other parts of the United States (Neves 1987, pp. 11–12). Diseases have not been documented or observed during any studies of Texas pimpleback.

Predation

Raccoons will prey on freshwater mussels stranded by low waters or deposited in shallow water or on bars following flooding or low water periods (Howells 2010c, p. 12). Predation of Texas pimpleback by raccoons may be occurring occasionally, but there is no indication it is a significant threat to the status of the species.
Some species of fish feed on mussels, such as common carp, freshwater drum, and redear sunfish, all of which are common throughout the range of Texas pimpleback (Hubbs et al. 2008, pp. 19, 45, 53). Common species of flatworms are voracious predators of newly metamorphosed juvenile mussels of many species (Zimmerman et al. 2003, p. 30). Predation is a normal factor influencing the population dynamics of a healthy mussel population; however, predation may amplify declines in small populations primarily caused by other factors.

Summary of Factor C

Disease in freshwater mussels is poorly known, and we do not have any information indicating it is a threat to the Texas pimpleback. Additionally, while predation is likely occurring within Texas pimpleback populations, it is a natural ecological interaction and we have no information indicating the extent of such predation is large enough to be a threat to populations of Texas pimpleback. Based upon the best scientific and commercial information available, we conclude that disease or predation is not a threat to the Texas pimpleback.

D. The inadequacy of existing regulatory mechanisms:

The Act requires us to examine the adequacy of existing regulatory mechanisms with respect to threats that may place the Texas pimpleback in danger of extinction or increase its likelihood of becoming so in the future. Existing regulatory mechanisms that could affect threats to the Texas pimpleback include State and Federal laws such as the Texas Threatened and Endangered Species regulations, Texas freshwater mussel sanctuaries, State and Federal sand and gravel mining regulations, and regulation of point and non-point source pollution.

Texas Threatened and Endangered Species Regulations

On January 8, 2010, the Texas Parks and Wildlife Commission placed 15 species of freshwater mussels, including the Texas pimpleback, on the State threatened list (Texas Register 2010, pp. 6–10). Section 68.002 of the Texas Parks and Wildlife (TPW) Code and Section 65.171 of the Texas Administrative Code (TAC) prohibit the direct take of a threatened species, except under issuance of a scientific collecting permit. ‘‘Take’’ is defined in Section 1.101(5) of the TPW Code as collect, hook, hunt, net, shoot, or snare, by any means or device, and includes an attempt to take or to pursue in order to take. While this law protects individuals from take, it is difficult to enforce and does not provide any protection for Texas pimpleback habitat. Moreover, our assessment finds that the species is not threatened by take (see Factor B above). There are no State provisions under the Texas Threatened and Endangered Species Regulations for reducing or eliminating the threats (see Factor A above) that may adversely affect Texas pimpleback or its habitat. In addition, these State regulations do not call for development of a recovery plan that will restore and protect existing habitat for the species. For these reasons, we find that existing Texas regulatory mechanisms for State-listed threatened species are currently inadequate to protect Texas pimpleback and its habitat or to prevent further decline of the species.

Freshwater Mussel Sanctuaries
The TPWD has designated specific areas of streams and reservoirs as no harvest mussel sanctuaries (31 TAC, part 2, chapter 57, subpart B, Rule 57.157). The locations of the designated mussel sanctuaries were selected because they support populations of rare and endemic mussel species or are important for maintaining, repopulating, or allowing recovery of mussels in watersheds where they have been depleted. As a result of the designation of mussel sanctuaries, four of the Texas pimpleback populations are protected from harvesting disturbance of other species (Howells 2010f, p. 12). Unfortunately, mussel sanctuaries only restrict the harvest of

mussels and do not address other activities that may affect mussels or their habitats. Therefore, these designations provide no regulatory mechanisms to protect Texas pimpleback from habitat alteration.

State Sand and Gravel Mining Regulations

The TPWD has been responsible for regulating the ‘‘disturbance of taking’’ streambed materials since 1911 (Meador and Layher 1998, p. 11) and has issued several permits for ongoing activities within the Texas pimpleback range (for more information on the effects of sand and gravel mining on Texas pimpleback, please refer to ‘‘Sand and Gravel Mining’’ under Factor A in Five-Factor Evaluation). In addition to authorized activities, there are ongoing unauthorized sand and gravel mining activities within the range of Texas pimpleback. For example, the LCRA, which monitors water quality permit applications submitted through other agencies (LCRA 2011b, p. 1), found unpermitted sand removal from the Llano River in Llano County during a site visit in 2010 (Lehman 2010, p. 1). This site is located upstream from a known population of the Texas pimpleback and other rare mussels (Howells 1994, p. 6), and the sand removal may have increased turbidity and sedimentation downstream within Texas pimpleback habitat. Sand and gravel mining may be one of the least regulated of all mining activities (Meador and Layher 1998, p. 10).

Clean Water Act

The U.S. Army Corps of Engineers (USACE) retains oversight authority and requires a permit for gravel and sand mining activities that deposit fill into streams under section 404 of the Clean Water Act (33 U.S.C. 1251 et seq.). Additionally, a permit is required under section 10 of the Rivers and Harbors Act (33 U.S.C. 401 et seq.) for navigable waterways. However, many mining operations do not fall under these two categories. For example, nationwide permits are issued by the USACE for types of projects that are presumed to have minimal environmental impacts. However, projects permitted by nationwide permits, such as small mining operations, may have cumulative effects on aquatic species like the Texas pimpleback through increased sedimentation and channel instability.

Point source discharges of potential contaminants within the range of the Texas pimpleback have been reduced since the inception of the Clean Water Act, but this reduction may not provide adequate protection for filter-feeding organisms that can be affected by extremely low levels of contaminants (see ‘‘Chemical Contaminants’’ under Factor A). The EPA’s established water quality criteria may not be protective of mussels. Current water quality standards applied by EPA were established to be protective of aquatic life; however, freshwater mussels were not used to develop these standards (EPA 2005, p. 5), and current research reveals mussels to be more sensitive to many aquatic pollutants than the tested organisms (Augsperger et al. 2007, p. 2025). For example, Augspurger et al. (2003, p. 2572) and Sharpe (2005, p. 28) suggested that the criteria for ammonia may not be sufficient to prevent impacts to mussels under current and future climate conditions. In addition, chronic copper concentrations lethal to juvenile freshwater mussels have been shown to be less than the EPA's 1996 chronic water quality criterion for copper (Wang et al. 2007b, pp. 2052–2055). Based on this information, the existing EPA water quality criteria may not be sufficient to prevent negative effects to the Texas pimpleback.

Nonpoint source pollution such as sedimentation and chemical contamination is considered a significant threat to Texas pimpleback habitat; however, the Clean Water Act does not adequately protect Texas pimpleback habitat from nonpoint source pollution, because most activities that cause nonpoint source pollution are not regulated under the Clean Water Act.

Summary of Factor D

Despite some State and Federal laws protecting the species and water quality, the Texas pimpleback continues to decline due to the effects of habitat destruction, poor water quality, contaminants, and other factors. The regulatory measures described above are not sufficient to significantly reduce or remove the threats to the Texas pimpleback.

E. Other natural or manmade factors affecting its continued existence:

Natural and manmade factors that threaten the Texas pimpleback include climate change, population fragmentation and isolation, and nonnative species.

Climate Change

It is widely accepted that changes in climate are occurring worldwide (International Panel on Climate Change (IPCC) 2007, p. 30). Understanding the effects of climate change on the Texas pimpleback is important because the disjunct nature of their remaining populations, coupled with the limited ability of mussels to migrate, makes it unlikely that the Texas pimpleback can adjust its range in response to changes in climate (Strayer 2008, p. 30). For example, changes in temperature and precipitation can increase the likelihood of flooding or increase drought duration and intensity, resulting in direct effects to freshwater mussels like the Texas pimpleback (Hastie et al. 2003, pp. 40–43; Golloday et al. 2004, p. 503). Because the range of the Texas pimpleback has been reduced to isolated locations with low population numbers in small rivers and streams, it is vulnerable to climatic changes that could decrease the availability of water or produce more frequent scouring flood events. Indirect effects of climate change may include declines in host fish populations, habitat reduction, and changes in human activity in response to climate change (Hastie et al. 2003, pp. 43–44).

For the next two decades, a warming of about 0.2 °C (0.4 °F) per decade is projected across the United States (IPCC 2007, p. 12), and hot extremes, heat waves, and heavy precipitation and flooding are expected to increase in frequency (IPCC 2007, p. 18). As with many areas of North America, central Texas is projected to experience an overall warming trend in the range of 2.5 to 3.3 °C (4.5 to 6 °F) over the next 50 to 200 years (Mace and Wade 2008, p. 656). Even under lower greenhouse gas emission scenarios, recent projections forecast a 2.8 °C (5 °F) increase in temperature and a 10 percent decline in precipitation in central Texas by 2080 to 2099 (Karl et al. 2009, pp. 123–124). Based on our current understanding of climate change, air temperatures are expected to rise and precipitation patterns are expected to change in areas occupied by the Texas pimpleback. Karl et al. (2009, p. 12) also suggests that climate change impacts on water resources in the southern Great Plains (including central Texas) are expected as rising temperatures and decreasing precipitation exacerbate an area already plagued by low rainfall, high temperatures, and unsustainable water use practices.

One preliminary study forecasting the possible hydrological impacts of climate change on the annual runoff and its seasonality in the upper Colorado River watershed was conducted by CH2M HILL (2008). In this initial evaluation, four modeling scenarios (chosen to represent a range of possible future climatic conditions) were each run under a 2050 and 2080 time scenario, producing annual surface water runoff estimates at multiple sites with stream gages in the Colorado River basin. For the 2050 scenarios, the results from all four climate change scenarios predicted significant decreases in annual runoff totals compared to historic averages (CH2M HILL 2008, pp. 7–30—7–32). For the 2080 scenarios, one model predicted increases in annual runoff; the other three 2080 scenarios predicted decreases in annual runoff (CH2M HILL 2008, pp. 7–30—7–33). The modeling efforts from this study focus on annual averages and cannot necessarily account for the seasonal variations in flooding events or long periods of drought. However, the study demonstrates the potential effects of climate change on surface water availability, which is forecasted to result in an overall decline in stream flows in the region where the Texas pimpleback occurs.

In summary, the disjunct nature of the remaining Texas pimpleback populations, coupled with the limited ability of mussels to migrate, makes it unlikely that Texas pimpleback can adjust their range in response to changes in climate (Strayer 2008, p. 30). Climate change could affect the Texas pimpleback through the combined effects of global and regional climate change, along with the increased probability of long-term drought. Climate change exacerbates threats such as habitat degradation from prolonged periods of drought, increased water temperature, and the increased allocation of water for municipal, agricultural, and industrial use. Climate change may be a significant stressor that exacerbates existing threats by increasing the likelihood of prolonged drought. As such, climate change, in and of itself, may affect the Texas pimpleback, but the magnitude and imminence of the effects remain uncertain. Based upon our review of the best commercial and scientific data available, we conclude that the effects of climate change in the future will likely exacerbate the current and ongoing threats of habitat loss and degradation caused by other factors, as discussed above.

Population Fragmentation and Isolation

Most of the remaining populations of the Texas pimpleback are small and geographically isolated and thus are susceptible to genetic drift (change of gene frequencies in a population over time), inbreeding depression, and random or chance changes to the environment, such as toxic chemical spills (Watters and Dunn 1995, pp. 257–258) or dewatering. Inbreeding depression can result in death, decreased fertility, smaller body size, loss of vigor, reduced fitness, and various chromosomal abnormalities (Smith 1974, pp. 350). Despite any evolutionary adaptations for rarity, habitat loss and degradation increase a species' vulnerability to extinction (Noss and Cooperrider 1994, pp. 58–62). Numerous authors (including Noss and Cooperrider 1994, pp. 58–62; Thomas 1994, p. 373) have indicated that the probability of extinction increases with decreasing habitat availability. Although changes in the environment may cause populations to fluctuate naturally, small and low-density populations are more likely to fluctuate below a minimum viable population (the minimum or threshold number of individuals needed in a population to persist in a viable state for a given interval) (Gilpin and Soule 1986, pp. 25–33; Shaffer 1981, p. 131; Shaffer and Samson 1985, pp. 148– 150).

Historically, the Texas pimpleback was once widespread throughout much of the Colorado and Guadalupe River systems when few natural barriers existed to prevent migration (via host species) among suitable habitats. The extensive impoundment of the Colorado and Guadalupe River basins has fragmented Texas pimpleback populations throughout these river systems. For fertilization, Texas pimpleback females need an upstream male to release sperm; populations with few individuals reduce the likelihood that females will be exposed to sperm while siphoning. Therefore, recruitment failure is a potential problem for many small populations rangewide, a potential condition exacerbated by its reduced range and increasingly isolated populations. If downward population trends continue, further significant declines in total Texas pimpleback population size and consequent reduction in long-term survivability may soon become apparent.

Small Texas pimpleback populations, including those in the lower Guadalupe River, mainstem Colorado River, and San Marcos River, may be below the minimum population size required to maintain population viability into the future. These populations are more vulnerable to extirpation since they are less likely to be able to recover through recruitment from events that reduce but do not extirpate populations. Additionally, these small populations are more vulnerable to extirpation from stochastic events, as the lack of connectivity among populations does not permit nearby populations to recolonize areas affected by intense droughts, toxic spills, or other isolated events that result in significant mussel die-offs. While the small, isolated populations do not represent an independent threat to the species, the situation does substantially increase the risk of extirpation from the effects of all other threats, including those addressed in this analysis, and those that could occur in the future from unknown sources.

Based upon our review of the best commercial and scientific data available, we conclude that fragmentation and isolation of small remaining populations of the Texas pimpleback of the Texas pimpleback are occurring and are ongoing threats to the species throughout all of its range.

Further, stochastic events may play a magnified role in extirpation of small, isolated populations.
Nonnative Species

Various nonnative aquatic species pose a threat to the Texas pimpleback, including golden algae, zebra mussels, and black carp. Golden algae is a microscopic algae considered to be one of the most harmful algal species to fish and other gill-breathing organisms (Lutz-Carrillo et al. 2010, p. 24) and was first discovered in Texas in 1985. It is presumed to have been introduced from western Europe (Lutz- Carrillo et al. 2010, p. 30). Since its introduction, golden algae has been found in Texas rivers and lakes, including two lakes in central Texas (Baylor University 2009, p. 1). Under certain environmental conditions, this algae can produce toxins that can cause massive fish and mussel kills (Barkoh and Fries 2010, p. 1; Lutz-Carrillo et al. 2010, p. 24). Evidence shows that golden algae probably caused fish kills in Texas as early as the 1960s, but the first documented fish kill due to golden algae in inland waters of Texas occurred in 1985 on the Pecos River in the Rio Grande basin (TPWD 2002, p. 1). The range of golden algae has increased to include portions of the Brazos and Colorado River basins, among others, and it has been responsible for killing more than 8 million fish in the Brazos River since 1981 and more than 2 million fish in the Colorado River since 1989 (TPWD 2010a, p. 1). Although actual mussel kills in Texas due to golden algae have not been recorded in the past, we expect golden algae to negatively affect mussel populations through direct loss of host fish and toxicity. Therefore, making future golden algae blooms a threat to the Texas pimpleback.

An additional nonnative species, the zebra mussel (Dreissena polymorpha), poses a potential threat to the Texas pimpleback. This invasive species has been responsible for the extirpation of freshwater mussels in other regions of the United States, including the Higgin’s eye (Lampsilis higginsii) in Wisconsin and Iowa (Service 2006, pp. 9–10). Zebra mussels attach in large numbers to the shells of live native mussels and are implicated in the loss of entire native mussel beds (Ricciardi et al. 1998, p. 615). This fouling impedes locomotion (both laterally and vertically), interferes with normal valve movements, deforms valve margins, and essentially suffocates and starves the native mussels by depleting the surrounding water of oxygen and food (Strayer 1999, pp. 77–80). Heavy infestations of zebra mussels on native mussels may overly stress the animals by reducing their energy reserves. Zebra mussels may also filter the sperm and possibly glochidia of native mussels from the water column, thus reducing reproductive potential. Habitat for native mussels may also be degraded by large deposits of zebra mussel pseudofeces (undigested waste material passed out of the incurrent siphon) (Vaughan 1997, p. 11).

Zebra mussels are currently found within the range of the Texas pimpleback. However, a live adult zebra mussel was first documented in Lake Texoma on the Red River (on the north Texas border with Oklahoma) in 2009 (TPWD 2009a, p. 1). Since that time, additional zebra mussels have been reported from Lake Texoma, where they are now believed to be well established (TPWD 2009c, p. 1). In spring and summer of 2013, Texas Parks and Wildlife Department (TPWD) monitored 23 other Texas reservoirs and found that zebra mussels may be present in two additional reservoirs: Lake Worth and Joe Pool. No adult zebra mussels or veligers have been found in either of the aforementioned water bodies (TPWD 2013, p. 1). To date, Lake Texoma, Lake Ray Roberts, Lake Lewisville, Lake Bridgeport, Lake Lavon, Lake Belton, and Lake Waco reservoirs and Elm Fork of the Trinity River are known to harbor zebra mussels TPWD 2014, p. 1). Zebra mussels are likely to spread to many other Texas reservoirs through accidental human transport (Schneider et al. 1998, p. 789). Although zebra mussels tend to proliferate in reservoirs or large pools, released zebra mussel veligers float downstream and attach to any hard surface available, rendering downstream Texas pimpleback populations extremely vulnerable to attachment and fouling. Because zebra mussels are so easily introduced to new locations, the potential for zebra mussels to continue to expand in Texas and invade the range of the Texas pimpleback is high. If this occurs, the Texas pimpleback is vulnerable to zebra mussel attachment and subsequent deprivation of oxygen, food, and mobility.

A molluscivore (mollusk eater), the black carp (Mylopharyngodon piceus) is a potential threat to the Texas pimpleback. The species has been commonly used by aquaculturists to control snails or for research in fish production in several States, including Texas (72 FR 59019, October 18, 2007). Black carp can reach more than 1.3 m (4 ft) in length and 150 pounds (68 kilograms (kg)) (Nico and Williams 1996, p. 6). Foraging rates for a 4-year old fish average 3 to 4 pounds (1.4 to1.8 kg) a day, indicating that a single individual could consume 10 tons (9,072 kg) of native mollusks over its lifetime (Mississippi Interstate Cooperative Resource Association (MICRA) 2005, p. 1). Black carp can escape from aquaculture facilities. For example, in 1994 30 black carp escaped from an aquaculture facility in Missouri during a flood. Other escapes into the wild by non-sterile carp are likely to occur. Because of the high risk to freshwater mussels and other native mollusks, the Service recently listed black carp as an injurious species under the Lacey Act (72 FR 59019, October 18, 2007), which prevents importations and interstate transfer of this harmful species, but does not prevent its release into the wild once it is in the State. If the black carp were to escape within the range of the Texas pimpleback, it would likely negatively affect native mussels, including the Texas pimpleback.

Based upon our review of the best commercial and scientific data available, we conclude that golden algae is an ongoing threat to the Texas pimpleback. Other nonnative species, such as zebra mussels and black carp, are a potential future threat to the Texas pimpleback that is likely to increase as these exotic species expand their occupancy within the range of the Texas pimpleback.

Summary of Factor E

The effects of climate change, while difficult to quantify at this time, are likely to exacerbate the current and ongoing threat of habitat loss caused by other factors, and the small sizes and fragmented nature of the remaining populations render them more vulnerable to extirpation. In addition, nonnative species, such as golden algae, currently threaten the Texas pimpleback, and the introduction of zebra mussels and black carp are potential future threats. Based upon our review of the best commercial and scientific data available, we conclude that other natural or manmade factors are immediate threats of moderate magnitude to the Texas pimpleback.

Conservation Measures Planned or Implemented :

The Texas pimpleback is listed as threatened in Texas and is a high priority species in the Texas Wildlife Action Plan 2005-2010 (TPWD 2005, p. 756).

The Service, TPWD, academia, and other resource agencies have proposed and ongoing studies in Texas' river systems for Texas freshwater mussels, including the Texas pimpleback, observing life history parameters (including determination of ecological fish hosts), survivability of juveniles, monitoring habitat, and analyzing population dynamics. In addition, TPWD has established a Mussel Watch group.

The Service is currently working on forming and implementing the use of a Strategic Conservation Plan for Texas Freshwater Mussels that will result in additional conservation measures such as, best management practices, survey protocols, relocation protocols, and monitoring guidelines. The Service will be collaborating with other Federal, State, and non-governmental agencies during the formation and implementation of the Strategic Conservation Plan.

Summary of Threats :

This status review identifies threats to the Texas pimpleback attributable to Factors A, D, and E. The primary threat to the species is from habitat destruction and modification (Factor A) from impoundments, which scour riverbeds, thereby removing mussel habitat, decrease water quality, modify stream flows, and restrict fish host migration and distribution of freshwater mussels. Additional threats under Factor A include sedimentation, dewatering, sand and gravel mining, and chemical contaminants. Also, most of these threats may be exacerbated by the current and projected effects of climate change (discussed under Factor E). Threats to the Texas pimpleback are not being adequately addressed through existing regulatory mechanisms (Factor D). Because of the limited distribution of this endemic species and its lack of mobility, these threats are likely to lead to the extinction of the Texas pimpleback in the foreseeable future.

The Texas pimpleback has been added as a candidate because it was found to warrant listing; however, it has been precluded by higher priority listing actions, and progress is being made to add or remove qualified species from the Lists of Endangered and Threatened Wildlife and Plants.

For species that are being removed from candidate status:

_____ Is the removal based in whole or in part on one or more individual conservation efforts that you determined met the standards in the Policy for Evaluation of Conservation Efforts When Making Listing Decisions(PECE)?

Recommended Conservation Measures :

Continued survey and monitoring efforts are needed throughout former and occupied sites to better define the species’ distribution and status in the Colorado and Guadalupe-San Antonio River systems.
Continued biological and ecological research efforts are needed to identify host fish, spawning and brooding seasons, glochidia, and habitat and physiochemical parameters for Texas pimpleback.
The Service will continue to work with TPWD, United States Geological Surveys (USGS), and others needed research in order to facilitate the conservation and preservation of the Texas pimpleback.

Long-term conservation measures need to be developed to facilitate and accomplish cooperative efforts between resource management agencies and private landowners. The development of candidate conservation agreements (with assurances) with interested parties would initiate conservation for the Texas pimpleback.

The Service will continue working with resource management agencies and the Texas Department of Transportation (TXDOT) on developing best management practices for proposed adjacent and instream impacts specific to Texas water systems.

The Service will continue working with resource management agencies and academia on developing a drought contingency plan that will facilitate the management and monitoring of mussel populations that harbor species of concern (i.e. the Texas pimpleback) during times of drought.

The Service will continue working with resource management agencies, TXDOT, and academia on the development of standard mussel survey, relocation, and monitoring protocols, which would establish a commonality among the wide variety of methods currently being used in Texas and would establish a baseline of what kind of data needs to be collected while conducting surveys.

Priority Table

Magnitude	Immediacy	Taxonomy	Priority
High	**Imminent**	Monotypic genus	1
		Species	**2**
		Subspecies/Population	3
	Non-imminent	Monotypic genus	4
		Species	5
		Subspecies/Population	6
Moderate to Low	Imminent	Monotype genus	7
		Species	8
		Subspecies/Population	9
	Non-Imminent	Monotype genus	10
		Species	11
		Subspecies/Population	12

Rationale for Change in Listing Priority Number:

No change in listing priority number.

Magnitude:

We consider the threats that the Texas pimpleback faces to be high in magnitude. Habitat loss and degradation from impoundments, sedimentation, sand and gravel mining, and chemical contaminants are widespread throughout the range of the Texas pimpleback and profoundly affect its habitat, and remaining populations are small, isolated, and highly vulnerable to stochastic events.

Imminence :

We consider the threats to the Texas pimpleback as described under Factors A, D, and E in the Five-Factor Evaluation for Texas Pimpleback section to be imminent because these threats are ongoing and will continue in the foreseeable future. Habitat loss and destruction has already occurred and will continue as the human population continues to grow in central Texas. The Texas pimpleback populations may already be below the minimum viable population requirement, which would cause a reduction in the number of populations and an increase in the species’ vulnerability to extinction. These threats are exacerbated by climate change, which will increase the frequency and magnitude of droughts. Therefore, we consider these threats to be imminent.

__Yes__ Have you promptly reviewed all of the information received regarding the species for the purpose of determination whether emergency listing is needed?

Emergency Listing Review

__No__ Is Emergency Listing Warranted?

Description of Monitoring:

The TPWD Mussel Watch group has been conducting surveys throughout Texas and found several fresh dead Texas pimpleback in the Colorado and Guadalupe-San Antonio River systems. The groups continued efforts along with historic data has sparked the interest of academia to further survey efforts in the Colorado and Guadalupe-San Antonio River systems where a couple of large, stable, reproducing populations were discovered and are now being closely monitored. These recent discoveries will likely lead to increased survey and monitoring efforts throughout Texas.

Indicate which State(s) (within the range of the species) provided information or comments on the species or latest species assessment:

none

Indicate which State(s) did not provide any information or comment:

none

State Coordination:

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Approval/Concurrence:

Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve: Jay E. Nicholopoulos 06/03/2016
Date

Concur: 11/14/2016
Date

Did not concur: ____________________ ________
Date

Director's Remarks: