Gonidea angulata (Lea, 1838)
Western ridged mussel
Bivalvia: Unionidae

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SUMMARY

The western ridged mussel (*Gonidea angulata*) is widely distributed from southern British Columbia to southern California, and can be found east to Idaho and Nevada. *G. angulata* inhabits cold creeks and streams from low to mid-elevations. Hardhead, Pit sculpin and Tule perch are documented fish hosts for *G. angulata* in northern California, although little is known about the fish species that serve as hosts for this mussel throughout other parts of its range.

G. angulata is sedentary as an adult and probably lives for 20-30 years, and thus can be an important indicator of habitat quality. *G. angulata* is a filter feeder that consumes plankton and other suspended solids, nutrients and contaminants from the water column. The large beds of *G. angulata* can improve water quality by reducing turbidity and controlling nutrient levels. Some Native American tribes historically harvested this animal and used it for food, tools and adornment.

Populations of *G. angulata* have likely been extirpated in central and southern California, and it has probably declined in abundance in numerous watersheds, including the Columbia and Snake River watersheds in Washington and Oregon. The western ridged mussel belongs to a monotypic genus and thus should be considered a high priority for conservation. Lack of information on the western ridged mussel's current and historical abundance and distribution, and a lack of understanding of which host fish species it uses will impede conservation efforts.

CONSERVATION STATUS

Rankings:
Xerces Red List Status: Vulnerable
NatureServe Global Status (2007): G3 – Vulnerable
NatureServe National Status: United States (2004)-N3, Canada (2006)-N1
NatureServe State Status (2009): S1S2 (CA), S2S3 (OR), SNR (ID), SNR (NV), S2 (WA)
NatureServe Provincial Status – Canada (2009): S1 (BC)
IUCN Red List: N/A
USA – Endangered Species Act: N/A
Canada – Canadian Species At Risk Act (2005): SC
Canada – Committee on the Status of Endangered Wildlife in Canada (2010): Endangered
American Fisheries Society Status (1993): Undetermined

SPECIES PROFILE

DESCRIPTION

Figure 1. Photograph of *Gonidea angulata* shell exterior (above left) and interior (above right) © Ethan Jay Nedeau, reproduced from the field guide *Freshwater Mussels of the Pacific Northwest* (Nedeau et al. 2009).

Gonidea angulata belongs to a monotypic genus. This species is obovate to trapezoidal in shape and generally does not exceed five inches in length. It is slightly laterally compressed. The shell has an angular ridge that runs from the beak to the basal part of the posterior margin. The ventral margin is generally straight. The shell is heavier than that of other native freshwater mussels that overlap in range with *G. angulata* (*Margaritifera falcata* and *Anodonta* spp.). The periostracum is yellowish-brown to brown or black. The shell does not have rays or sculpturing. Lateral teeth are absent. The right valve has one pseudocardinal tooth and the left valve has either one small tooth or no teeth. The pseudocardinal teeth are small, compressed, and can be difficult to distinguish. The nacre is generally white, but can be salmon-colored in fresh specimens and pale blue toward the posterior margin and beak cavity. (Burch 1973, Clarke 1981, and Nedeau *et al.* 2009).

TAXONOMIC STATUS

Gonidea angulata (Lea, 1838). The taxonomic status of this species is uncontested (Turgeon *et al.* 1998).

Type locality: "Lewis's River" (now interpreted as Snake River, Idaho, no specific locality) (reported in Taylor 1981).

Phylum: Mollusca
Class: Bivalvia
Family: Unionidae
Genus: *Gonidea*
Species: *Gonidea angulata*

LIFE HISTORY

Freshwater mussels, including *G. angulata*, are filter feeders that consume phytoplankton and zooplankton suspended in the water. *Gonidea angulata* is a relatively slow growing and long lived species – perhaps living 20 to 30 years (COSEWIC 2003, Vannote and Minshall 1982). Low shear stress (shear stress is caused by fast flowing water over substrate), substrate stability, and flow refuges are important determinants of freshwater mussel survival (Vannote and Minshall 1982). *G. angulata* occurs on the bottom of streams, rivers and lakes with substrates that vary from gravel to firm mud, and include at least some sand, silt or clay (COSEWIC 2003). This species is more common on the eastern side of Oregon and Washington than the western side (pers. comm. with A. Smith, mussel workgroup meeting, 2008). It is generally associated with constant flow, shallow water (<3 m in depth), and well oxygenated substrates (COSEWIC 2003). This species is often present in areas with seasonally turbid streams, but absent from areas with continuously turbid water (i.e. glacial melt water streams) (Frest and Johannes 1992). In Idaho, *G. angulata* is abundant in areas with sand and gravel bars, and less abundant in more stable, boulder dominated reaches, suggesting that it can tolerate soft, fine sediments (Vannote and Minshall 1982). *G. angulata* generally occurs at low to mid elevations (Nedeau et al. 2009) and it may be more common at downstream sites than headwater sites, as seen in an eastern Oregon study (Brim Box *et al.* 2006). Many sites where this species has been found lack dense macrophyte beds. Typically, individuals of this species are found buried to at least half their length in fine substrate, with the posterior end facing upstream (COSEWIC 2003). *G. angulata* can occur in dense beds, with densities of ~575/m^2 (Brim Box *et al*. 2006).

Reproduction and Host Fish Associations

Freshwater mussels, including *G. angulata*, require a host fish to reproduce and disperse. Because freshwater mussels are not able to move far on their own, their association with fish allows them to colonize new areas, or repopulate areas from which mussels have been extirpated. Fertilization occurs when female mussels inhale sperm through their incurrent siphon during the appropriate reproductive period. Eggs incubate and hatch into larvae, or glochidia, which are released into the water, either individually or in packets (called conglutinates). Glochidia will attach to fish and encyst in host fish tissues from 2-36 hours after they attach. Glochidia attach to host fish for a period of weeks to months. Once metamorphosed, juvenile mussels drop from their host fishes to the substrate. (McMahon and Bogan 2001).

Gravid *G. angulata* females have been found from late March through mid-July, and glochidia have been observed on fish from late March to early August (Spring Rivers 2007, COSEWIC 2003). *Gonidea angulata* glochidia are released in watery mucous and conglutinates are white, leaflike and joined in small groups at the dorsal end (Barnhart *et al.* 2008). Once glochidia are released, they attach to a fish host. In northern California, the release of glochidia apparently peaks in June, and the glochidia are probably excysted from fish primarily during the period from late June to late July (Spring Rivers 2007). The presence of glochidial host fish is necessary for the reproduction of mussel species. Although the entire suite of host fishes for *G. angulata* is not known, three native fish have been documented as hosts for *G. angulata* in northern California: hardhead (*Mylopharodon conocephalus*), Pit sculpin (*Cottus pitensis*), and tule perch (*Hysterocarpus traski*); these three species have been infested with *G. angulata* glochidia in the wild, and metamorphosis of the glochidia was observed (Spring Rivers 2007). The native Pit roach (*Lavinia symmetricus mitrulus*) and the non-native black crappie (*Pomoxis nigromaculatus*) may also serve as fish hosts for *G. angulata* in northern California – these fishes have been infested with *G. angulata* glochidia in the wild, but metamorphosis was not observed (Spring Rivers 2007).

Table 1. Documented fish hosts for *Gonidea angulata* from a study in the Pit River drainage of northern California (Spring Rivers 2007). In order to determine that a fish is a host for *G. angulata*, glochidial infestation of the fish must have been observed in the wild and metamorphosis of the glochidia must have been observed.

Fish species	Is fish species native to western U.S?	Glochidia infestation observed on *G. angulata* (natural or artificial)	Glochidia metamorphosis observed on *G. angulata*	Reference
hardhead, *Mylopharodon conocephalus*	Native	Natural	Yes	Spring Rivers 2007
Pit sculpin, *Cottus pitensis*	Native	Natural	Yes	Spring Rivers 2007
tule perch, *Hysterocarpus traski*	Native	Natural	Yes	Spring Rivers 2007

Table 2. Potential fish hosts for *Gonidea angulata*. The fish species listed below may be host fishes for *G. angulata*, but glochidial metamorphosis has not been observed on these fish.

Fish species	Is fish species native to western U.S?	Glochidia infestation observed on *G. angulata* (natural or artificial)	Glochidia metamorphosis observed on *G. angulata*	Reference
Pit roach, *Lavinia symmetricus mitrulus*	Native	Natural	No	Spring Rivers 2007
black crappie, *Pomoxis nigromaculatus*	Non-native	Natural	No	Spring Rivers 2007

DISTRIBUTION

Gonidea angulata is broadly distributed in Washington, Oregon, California, Idaho, Nevada, possibly Montana (see Gangloff and Gustafson 2000), and southern British Columbia. The maps in Figures 2 and 3 illustrate watersheds that contain records of *Gonidea angulata* prior to 1985 (red) and records of *G. angulata* observed or collected after 1985 (blue). Watersheds that contain records with no date associated are displayed with diagonal hash-marks. One may conclude that *G. angulata* has been extirpated from watersheds with only historical records (red), but that assumption may be inaccurate if surveys have not been conducted in that watershed since 1985. To address this issue, we created a map of 'search effort' (Figure 3). Black dots represent locations where an individual searched for or collected any species of freshwater mussel. Of the thousands of mussel records and 'search effort' records that we received, we generally only had the capacity to map records that had geographic coordinates associated with them, which was a fraction of the total number of records. We also manuscripted some 'search effort' points in southern California and Arizona from geographic descriptions, since we considered those watersheds to be of high conservation priority for some species of freshwater mussels. The representation of search effort in Figure 3 represents an underestimate of the true search effort that has occurred since 1985.

Caution should be exercised in interpreting the maps below. It is problematic to conclude that a species is absent from an area that may have been searched only once. In addition, the 8-digit

HUC watershed scale of the maps in figures 2 and 3 is too coarse to show declines that may have occurred in individual streams or rivers.

The maps below were created from thousands of records from the published literature, museum collections, unpublished reports, and state, tribal, nonprofit, retired and amateur biologists. Please contact mussels@xerces.org for more information about the records used to create these maps.

Figure 2. Map of watersheds containing historical (pre-1985, red) records of *Gonidea angulata* and more recent (post-1985, blue) records of *G. angulata*.

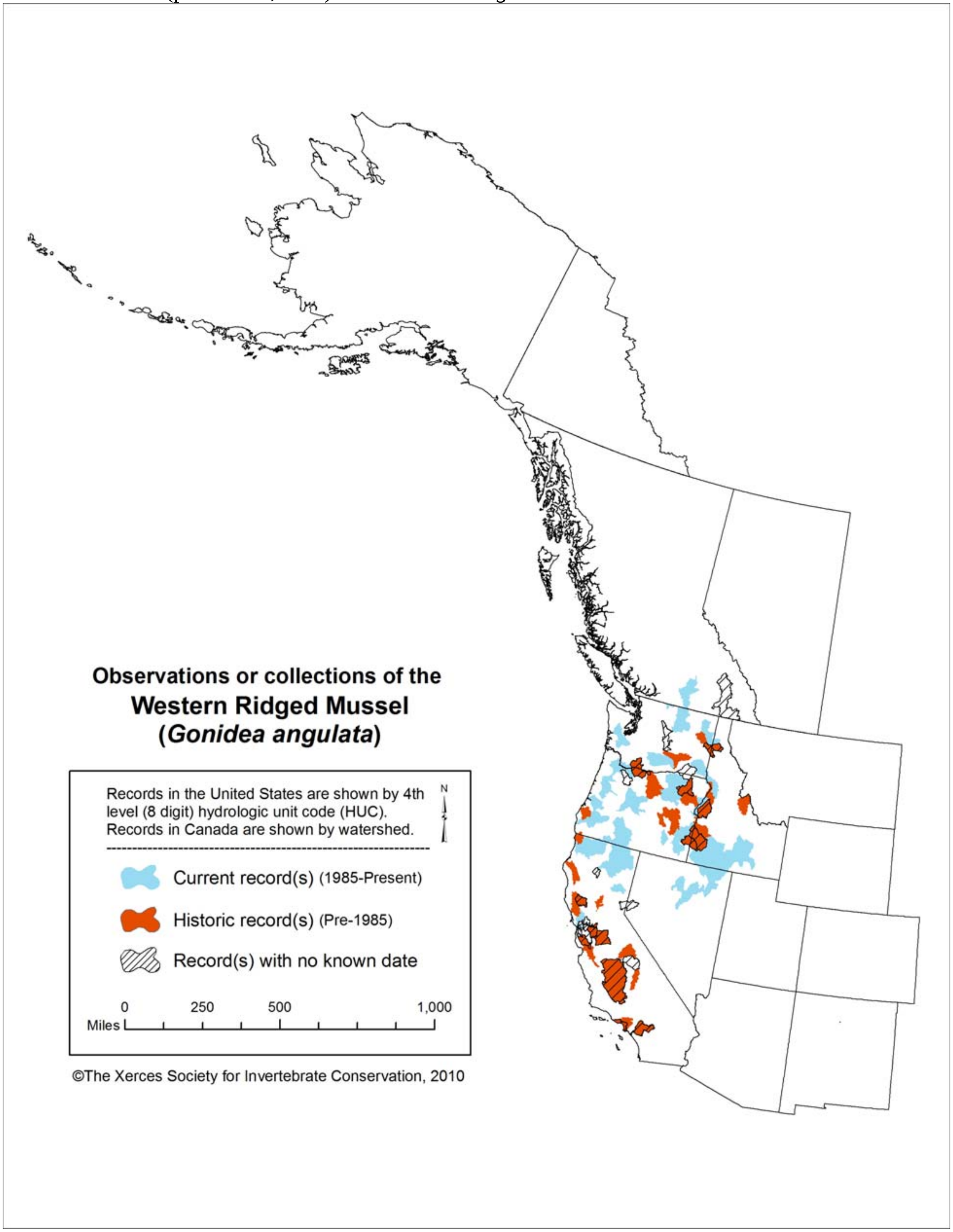
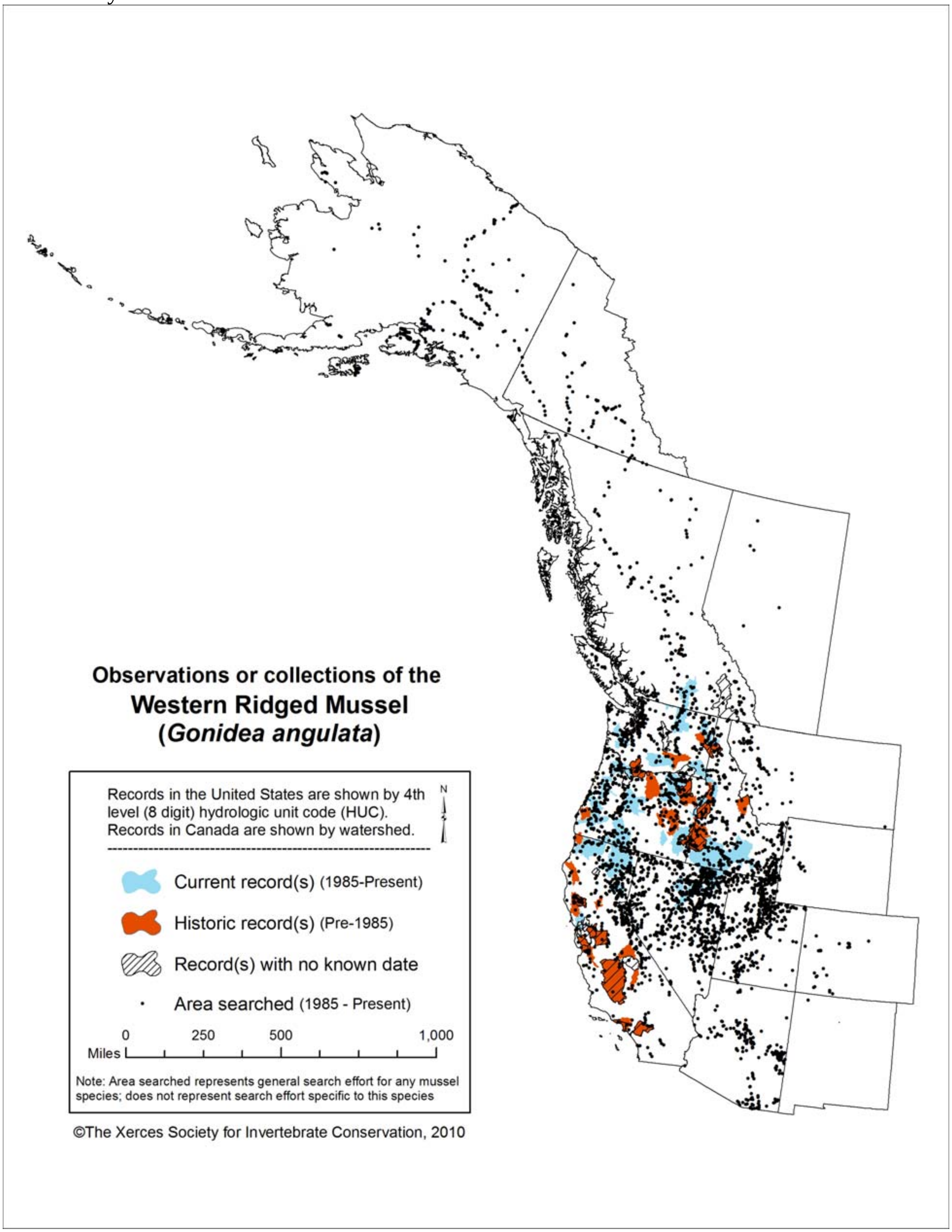


Figure 3. Map of watersheds containing historical (pre-1985, red) records of *Gonidea angulata* and more recent (post-1985, blue) records of *G. angulata*. Black dots indicate areas that have been surveyed for freshwater mussels since 1985.



THREATS

Threats to *G. angulata* and other species of freshwater mussels in North America include: impoundments and loss of host fish, channel modification from channelization, dredging and mining, restoration activities, contamination, sedimentation, nutrient enrichment, water withdrawal and diversion, thermal pollution, livestock grazing in riparian areas, and the introduction of non-native fish and invertebrate species. Many of these impacts, especially a reduction in stream flow and thermal pollution in arid areas, are being exacerbated by climate change.

Impoundments and loss of host fish

Numerous freshwater mussel species in eastern North America have gone extinct as a direct result of dams (Vaughn and Taylor 1999, Watters 1996, Williams *et al.* 1992), which can change a water body's fish fauna, substrate composition, benthic community, water chemistry, dissolved oxygen levels and temperature (Bogan 1993). The elimination of a host fish species is likely the most harmful effect that dams have on freshwater mussels; Williams *et al.* (1992) report instances of 30-60 percent of a region's mussel fauna being extirpated as a result of dam construction. The most fragile part of a mussel's life cycle is its obligatory association with a host fish; in some cases, damming has extirpated a mussel species' obligate host fish and that, in conjunction with increased siltation and pollution, has led to a rapid decline in many species of freshwater mussels (Bogan 1993). Since the beginning of the 20th century, 5% of native North American fish fauna have gone extinct, and an additional 364 fish species are considered endangered, threatened, or of special concern (Williams *et al.* 1989). The host fishes utilized by *G. angulata* across its range are not well understood; this lack of information will certainly be an impediment to conserving this species.

In addition, the flow regime of a river is frequently altered by dams; researchers in northern California suggest that the unnatural pulses in stream discharge from dams (pulsed flows) have the ability to interfere with the reproductive success of freshwater mussels by reducing contact between glochidia and host fish and preventing settlement of juveniles after excystment, if pulsed flows occur during key periods of *G. angulata*'s reproductive cycle (Spring Rivers 2007).

Hardhead, which has been identified as a host fish for *G. angulata* in northern California, is on the 'watchlist' for Species of Special Concern within the state of California because it is not as widespread or abundant as it once was (CA DFG 1995, Spring Rivers 2007).

Channel modification

Dredging and channelization

River channels are regularly dredged and modified for navigation, flood control, and drainage, which has led to the local extirpation of freshwater mussel populations in the southeastern U.S. (Bogan 1993). Sedentary mussels are directly displaced by dredging operations, and frequently killed in dredge spoils (Neves *et al.* 1997). Dredging and channelization increases erosion and sedimentation and destabilizes the substrate, which decreases habitat suitability for freshwater mussels (Neves *et al.* 1997). Dredging and channelization leads to headcutting, which also causes erosion and sedimentation (Hartfield 1993).

Mining

Instream mining of gravel and suction dredge mining for gold and other metals are common practices in the western U.S. Instream gravel mining removes substrate and leads to siltation downstream (Bogan 1993), which can directly and indirectly harm freshwater mussels. In a study investigating the impact of suction dredge mining on freshwater mussels in the Similkameen River in Washington state, Krueger *et al.* (2007) found that *G. angulata* died when covered with tailings from a suction dredge. However, another study by Vannote & Minshall (1982) reported that while large mussels of a different species (*Margaritifera falcata*) were unable to uncover themselves and perished when they were covered with sediment, *G. angulata* and small *M. falcata* were able to uncover themselves and migrate vertically.

Restoration Activities

Activities such as culvert removal, dam removal, and stream reconfiguration to restore aquatic habitat for salmonids have become very common, especially in the Pacific Northwest. Frequently, these activities are undertaken without considering the distribution or conservation needs of freshwater mussels occurring in those streams. These operations can involve temporary stream dewatering, movement of personnel and equipment in streams, and flushing of sediments – all of which could have a negative impact on the survival of mussel populations.

Contaminants

Flourishing populations of freshwater mussels are generally associated with high levels of dissolved oxygen and other conditions that are typical of unpolluted water bodies. Contaminants can destroy populations of freshwater mussels directly (by exerting toxic effects) and indirectly (by harming host fishes and/or food sources). (Havlik and Marking 1987). Many contaminants occur regularly in aquatic environments; for example, a study in the Columbia River documented that freshwater mussels belonging to another genus (*Anodonta* sp.) had a concentration of DDT (dichlorodiphenyltrichloroethane) from 14.9 ppb in spring to 2 ppb in fall and a concentration of PCBs (polychlorinated biphenyls) of 35-160 µg/kg wet weight (Claeys *et al.* 1975). Pollution from papermills, chemical factories, steel mills, and tanneries has been implicated in the extirpation of freshwater mussel populations in the eastern U.S. in the first half of the 20^{th} Century (Bogan 1993). A review by Havlik and Marking (1987) reported that the following aquatic contaminants are lethal to freshwater mussels at various concentrations: cadmium, copper sulfate, ammonia, potassium, chromium, arsenic trioxide, copper, and zinc. Cadmium was the most toxic at only 2 ppm (parts per million) and copper sulfate was found to be toxic at levels of 2-18.7 ppm. Long term exposure to copper sulfate was lethal to mussels at concentrations as low as 25 ppb (parts per billion). Ammonia, which is a common pollutant from agricultural fertilizers and municipal sewage, was found to be toxic to mussels at only 5 ppm. (Havlik and Marking 1987). In an Illinois river, no mussels were found in an area with ammonia concentrations that exceeded 6 ppm, and mussels began to appear downstream where ammonia concentrations were progressively lower (Starrett 1971).

Freshwater mussels can be valuable indicators of pollutants, since they are sedentary, occupy a low position on the food chain, frequently bioaccumulate heavy metals, pesticides, and other contaminants, and can be long-lived. Toxins in the shell are indicative of past exposure, whereas toxins in the soft tissues indicate more recent exposure. Because freshwater mussels frequently bioaccumulate contaminants, substances can be detected in their tissues that are too low in concentration to be detected in the surrounding water body.

Sedimentation and nutrient enrichment

Because freshwater mussels are filter feeders, they generally cannot handle high levels of siltation that come from agricultural runoff, silvicultural operations and headcutting (Bogan 1993). The EPA considers fifty percent of U.S. rivers and streams that were assessed to be impaired, primarily due to sedimentation, nutrient enrichment, contamination with pathogens and habitat alterations (U.S. EPA 2010).

Water withdrawal and diversion

Numerous streams in North America have been modified by water flow diversion and groundwater use (Dudley and Larson 1976). A review of the effects of artificially reduced stream flow on invertebrates and instream habitat revealed that these activities lead to increased sedimentation, decreased velocity, wetted width and depth, and can alter water temperature and chemistry (Dewson *et al.* 2007). These impacts generally reduce habitat diversity and alter invertebrate community composition (Dewson *et al.* 2007). Climate change is projected to exacerbate the impact of low stream flow on freshwater mussels. For example, stream flows have decreased at a rate of approximately 2% per decade for the past century in the Rocky Mountain region of the western U.S. as a result of climate change (Rood *et al.* 2005).

Thermal pollution

Increased water temperatures as a result of decreased streamflow, loss of riparian vegetation, and global climate change are likely to stress, and perhaps eradicate, *G. angulata*. In a study in Fall River Lake in northern California, Spring Rivers (2007) found that high water temperatures (27.3°C or 81.1°F) and low water levels (<1 meter) may have caused the abortion of egg masses and premature onset of a non-gravid period that they observed in another genus of freshwater mussel (*Anodonta*), and note that thermal stress has caused abortion in other freshwater mussel species (Aldridge and McIvor 2003).

Livestock grazing in riparian areas

Livestock grazing in and near streams degrades the high water quality that freshwater mussels require for survival. Freshwater mussels generally require high levels of dissolved oxygen (Voshell 2002), yet the presence of livestock has been shown to increase eutrophication in water bodies (Mathews *et al.* 1994), which in turn can reduce levels of dissolved oxygen in water. Livestock tend to remain near streams because water, shade and forage abound (Strand & Merritt 1999), which exacerbates the impact of cattle on aquatic communities. Cattle grazing in riparian areas frequently leads to headcutting, which can increase sedimentation in the water body – a condition that freshwater mussels generally cannot handle (Bogan 1993). Grazing and trampling of riparian vegetation also increases water temperatures; high water temperatures may impede the ability of freshwater mussels to survive.

Introduction of non-native species

Invertebrates

The nonnative asian clam (*Corbicula fluminea*) is widespread in water bodies in western North America and may compete with native mussels (Clarke 1988), directly consume glochidia and impact nutrient cycling (Leff *et al.* 1990, Strayer 1999, Vaughn and Spooner 2006).

The zebra mussel (*Dreissena polymorpha*) and quagga mussel (*Dreissena rostriformis bugensis*) aggressively compete with native mussels, although they are less widespread in western North America than the asian clam. West of the Continental Divide, zebra and/or quagga mussels currently occur in waterbodies in Nevada, Arizona, California, Colorado and Utah. Zebra and quagga mussels can attach directly to the shells of native freshwater mussels and impede their ability to feed (Mackie 1991, Schloesser *et al*. 1996, Strayer 1999, Strayer and Malcolm 2007). They have free-swimming larvae that do not require a host fish to reproduce, and thus have a high reproductive advantage over native freshwater mussels.

Fish

Many species of non-native fish have been introduced into western North America, primarily for sport fishing, which has led to the reduction or elimination of native fish species (Moyle *et al.* 1986, Rinne and Turner 1991, Andersen and Deacon 1996). In the Great Basin alone, fifty non-native fish species have been intentionally introduced (Sada & Vinyard 2002). Although the full suite of host fishes used by *G. angulata* is unknown, it is possible that host fish species that *G. angulata* relies upon are being displaced by nonnative, less suitable host fish.

CONSERVATION STATUS

NatureServe indicates that *G. angulata* has both a global short term trend of declining (10-30%) and a global long term trend of declining (25% change to 50% decline) (NatureServe 2009). Species that are long-lived, such *G. angulata*, which likely lives for 20-30 years, can appear to have healthy populations, when in reality only the older adults may be withstanding environmental changes and the population may no longer be reproducing. This species has been extirpated from many sites in the Snake and Columbia River basins due to environmental degradation (Brim Box *et al.* 2006, COSEWIC 2003, Frest and Johannes 1995), although the extent of the decline in those areas is not well understood, as historical abundance data is generally lacking.

United States

California

California ranks *G. angulata* as S1S2, or critically imperiled/imperiled within the state. Taylor (1981) suggested that *G. angulata* has likely been extirpated from southern California and most of the Central Valley. Coney (1993) reports that *G. angulata* historically occurred in Ballona Creek and the Santa Ana River in the Los Angeles River Basin, but was unable to find any living specimens in surveys. J. Howard conducted extensive field surveys throughout California in 2008 and 2009, including visits to historic sites, and confirmed that *G. angulata* has been extirpated from southern California (Western Mollusk Sciences 2008, Howard 2010). *G. angulata* still persists in northern California; J. Howard notes that most sites do not have dense beds with the exception of one site on the upper Pit River in the Modoc National Forest and some sites on the Klamath River (Howard 2010).

Idaho
The state of Idaho has assigned a conservation status rank of S2, or imperiled, to *G. angulata*. *G. angulata* were found in low abundance (1-10/m^2) on the Snake River downstream of the Hells Canyon Dam (Richards *et al.* 2005). Frest and Johannes (2000) note that *G. angulata* is locally common in the Snake River plain, but decreasing in abundance, and should be monitored carefully in Idaho. The species is known historically (pre-1985) from the Boise, Little Salmon, Malad, Salmon, Snake, Spokane, and Weiser Rivers. Since 1985, it has been found in the Bruneau, Jarbridge, Malad, Snake, and Salmon Rivers. (Xerces freshwater mussel database 2010). Historic sites in Idaho should be revisited to assess the conservation status of *G. angulata* in the state.

Montana
The state of Montana has not assigned a conservation status rank to *G. angulata*. It is unknown whether *G. angulata* historically occurred in Montana. There is an historic record from the Columbia River in western Montana, although the Columbia River is not in Montana. Some have suggested that this record may have been from the Clark Fork River or Kootenai River in the Columbia River headwaters, although *G. angulata* does not currently occur in either of those locations. There are two possibilities: 1) that this record was mistaken and *G. angulata* never occurred in Montana, or 2) that *G. angulata* historically occurred in western Montana, but has been extirpated. (Gangloff and Gustafson 2000).

Nevada
The state of Nevada has not assigned a conservation status rank to *G. angulata*. This species occurs in the northeastern part of the state, in the Owyhee, Salmon and Humboldt Rivers. Few historic records exist from the state and little is known about this species' status where it occurs.

Oregon
The state of Oregon has assigned a conservation status rank of S2S3, or imperiled/vulnerable, to *G. angulata*. Numerous historic and more recent records exist for this species throughout Oregon, although there has not been a systematic effort to resurvey historic sites for this species across the state. Brim Box *et al.* (2006) report that freshwater mussels – including *G. angulata* – have been extirpated from most of the main stem of the Umatilla River, and currently only occur in the lower reaches. J. Brim Box (pers. comm. 2010) reports observing a mussel kill in entire beds of *G. angulata* in the John Day River, where the mussels occur at a density of ~500/m^2 and appear to be dying in place and remaining upright.

Washington
The state of Washington has assigned a conservation status rank of S2, or imperiled, to *G. angulata*. An extensive decline of *G. angulata* has been observed in the Little Spokane River over four decades; a healthy population existed at one site on the river in 1968 and throughout the 1970s, but by 2000, only a single mussel remained in that location (WDFW database and B. Lang, pers. comm. with S. Jepsen, 8 November 2009). Terry Frest noted that *G. angulata* was apparently extirpated from the Wenatchee and Yakima Rivers (reported in person by J. Fleckenstein, WA DNR, in Mussel workgroup meeting, 2008). There are numerous historic and more recent records of *G. angulata* in Washington.

Canada

British Columbia

The province of British Columbia has assigned a conservation status rank of S1, or critically imperiled, to *G. angulata*. The species only occurs in the southernmost part of the province. According to a Canadian national status report for *G. angulata*, in many locations only large individuals of this species are found, suggesting that it is not reproducing in certain areas (COSEWIC 2003).

CONSERVATION NEEDS

Since *G. angulata* belongs to a monotypic genus and is in serious decline, it is a high priority for conservation action. The glochidial host-fish species, once identified, should be protected. Populations of *G. angulata* should be protected and threats (listed above) should be addressed in areas where *G. angulata* beds occur.

RESEARCH NEEDS

Much more information is needed to understand the current distribution of *G. angulata*. Sites that historically contained *G. angulata* should be revisited to determine if the species is still extant at those sites (similar to the California study detailed in Howard 2010). Populations of *G. angulata* should be censused to provide abundance data and enable biologists to monitor population statuses over time. The age class structure of existing *G. angulata* populations should be examined to determine whether or not populations are reproducing. Biologists should investigate which fish species serve as glochidial hosts for *G. angulata*.

RESOURCES

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ADDITIONAL RESOURCES

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