Margaritifera falcata (Gould, 1850)
Western pearlshell
Bivalvia: Margaritiferidae

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SUMMARY

The western pearlshell (*Margaritifera falcata*) has been documented widely in western North America; it is the most common species in the Pacific Northwest. The range of *Margaritifera falcata* extends from Alaska and British Columbia south to California and east to Nevada, Wyoming, Utah and Montana. This species inhabits cold creeks and rivers with clean water and sea-run salmon or native trout. Documented host fishes for *M. falcata* include: cutthroat trout, rainbow/steelhead trout, Chinook salmon, and brown trout, and a number of other fish are considered potential hosts. The average life span of *M. falcata* is approximately 60-70 years, although some individuals are thought to have lived more than 100 years. Because this species is sedentary, sensitive to environmental changes, and long-lived, it can be an excellent biological indicator of water quality. Freshwater mussels that live in dense beds, including *M. falcata*, provide an important water purification service; they can filter suspended solids, nutrients and contaminants from the water column and collectively 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.

M. falcata has been extirpated from northern Nevada, from most areas in northern Utah, and numerous examples exist documenting the decline of this species in particular streams and rivers throughout its range. In addition, there are reports of populations of *M. falcata* that apparently have not reproduced for decades; populations of such a long lived species may appear stable, when in fact they are not reproducing. However, *M. falcata* is still abundant in many areas, and we lack the information on historical abundance that would be necessary to document the level of decline that has probably occurred over the past century. There is a need to document the current distribution and abundance of this species, so that if *M. falcata* populations decline in the future, those declines can be documented and protection for vulnerable populations can be provided.

CONSERVATION STATUS
Xerces Red List Status: Vulnerable
NatureServe Global Status (2008): G4G5 – Apparently Secure
NatureServe National Status: United States-N4, Canada (2006)-N4N5
NatureServe State Status: Alaska (SNR), California (SNR), Idaho (SNR), Montana (S2S4), Nevada (SNR), Oregon (S4), Utah (SH), Washington (S4), Wyoming (SNR)
NatureServe Provincial Status – Canada: S5 (BC)

IUCN Red List: N/A
USA – Endangered Species Act: N/A
Canada – Canadian Species At Risk Act: N/A
American Fisheries Society Status (Williams *et al.* 1993): Undetermined

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SPECIES PROFILE

DESCRIPTION

Figure 1. Photograph of *Margaritifera falcata* 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).

Margaritifera falcata has a black, elongate, and moderately thick shell (Henderson 1929) with a straight or slightly concave ventral margin (Clarke 1981). The shell reaches up to 125 mm in length, 55 mm in height, and 35 mm in width (Clarke 1981). The shell has closely spaced concentric lines on an otherwise smooth exterior surface (Clarke 1981). In juveniles, the periostracum is brown, whereas it is black and eroded at the umboes in adults (Clarke 1981). The lateral teeth are incomplete (Burch 1973) and not well developed; the pseudocardinal teeth are erect and serrated (Clarke 1981); there are two pseudocardinal teeth in the left valve and one in the right valve (Henderson 1929, Clarke 1981). The nacre color is generally dull purple, but can also be salmon-colored or pink (Clarke 1981, Henderson 1929, Nedeau *et al.* 2009). The beak sculpture consists of a few coarse ridges parallel to the lines of growth (Clarke 1981).

TAXONOMIC STATUS

Margaritifera falcata (Gould, 1850). *Margaritifera* in the Pacific drainage were considered *Margaritifera margaritifera* until 1970, when Heard and Guckert reevaluated the Unionacea and separated *M. falcata* in the Pacific drainage from *M. margaritifera* in the Atlantic drainage (Heard & Guckert 1970). The taxonomic status of this species is currently uncontested (Turgeon *et al*. 1998).

Type locality: "Puget Sound, Oregon" [sic now Washington]; holotype USNM 5893, according to Johnson (1964) (reported in Frest & Johannes 1995).

Phylum: Mollusca
Class: Bivalvia

Family: Margaritiferidae
Genus: *Margaritifera*
Species: *Margaritifera falcata*

Life History

Freshwater mussels, including *M. falcata*, are filter feeders that consume plankton suspended in the water. As they feed, they filter large quantities of particulate matter and excrete those particles as 'pseudofaeces', which can be an important, nutrient rich food source for benthic macroinvertebrates (reviewed in Vaughn *et al.* 2008). *M. falcata* beds have been shown to increase the biomass of other benthic macroinvertebrates in the late summer (Howard & Cuffey 2006). *Margaritifera falcata* can occur in very high densities. Murphy reports a single bed in the Truckee River of California that contained 10,000 *M. falcata* individuals (Murphy 1942). *Margaritifera falcata* are very long-lived – with some individuals estimated to be 100 years in age (Hastie and Toy 2008).

Margaritifera falcata inhabit perennial rivers, streams and creeks at depths of 1.5 to 5 feet, and they tend to congregate in areas with boulders and gravel substrate, with some sand, silt and clay (summarized in Roscoe & Redelings 1964). This species prefers clear, cold water (Frest & Johannes 1995), and has been found at multiple elevations, including waterways above 5,000 feet (A. Smith, pers. comm. 2010). *Margaritifera falcata* occur in waterways with low velocities, low shear stress and stable substrates (Howard & Cuffey 2003, Vannote & Minshall 1982, Stone *et al.* 2004, Davis 2008). *Margaritifera falcata* is frequently found in eddies or pools (Howard & Cuffey 2003) and areas with stones or boulders that likely shelter mussel beds from scour during flood events (Vannote & Minshall 1982). This species appears to be intolerant of sedimentation; in the Salmon River of Idaho, *M. falcata* that were covered with sand and gravel were unable to uncover themselves and ultimately perished (Vannote & Minshall 1982).

<u>Reproduction and Host Fish Associations</u>

Hermaphrodism has been reported in *M. falcata* (Heard 1970). A recent genetic study by Chong *et al.* (2009) to isolate microsatellite loci and characterize populations of *M. falcata* from Washington and Montana showed significant heterozygote deficiencies at most loci, which is consistent with a hermaphroditic life history. Populations of *M. falcata* containing separate sexes are frequently reported (e.g. Spring Rivers 2007), although the extent of hermaphrodism in *M. falcata* is not well understood. In the closely related *M. margaritifera*, Bauer (1987) reports that mussels change from females to hermaphrodites when they are moved to new areas with few mussels upstream; this strategy would ensure successful reproduction even when males are scarce. If *M. falcata* exhibits a similar life history, one would expect to see a greater proportion of hermaphrodites in smaller populations.

Freshwater mussels, including *M. falcata*, 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).

The majority of documented and potential host fish for *M. falcata* are native salmonids (see Tables 1 and 2). The period during which adult *M. falcata* are gravid is not well understood, although in some reaches of the Pit River in California, gravid *M. falcata* have been found in April, June and July (Spring Rivers 2007). *M. falcata* conglutinates are released over a period of about 50 seconds as single masses that break up readily in the current (Murphy 1942). Glochidia release by *M. falcata* has been observed from mid-June to early July in the Truckee River of California (Murphy 1942), from mid-May to mid-June in the Siletz River of Oregon (Karna & Milleman 1978), and from mid-March to early May in the Willamette River of Oregon (Meyers & Milleman 1977). The precise timing of glochidia release may depend on the temperature of the water. *M. falcata* glochidia are hookless (Murphy 1942) and are approximately 71.5µm in length and 77.5µm in height (Araujo & Ramos 1998; reported in Barnhart 2008). Once they attach to a suitable host fish, *M. falcata* glochidia grow substantially – from 60 to 420µm – before dropping off of their host fish (Murphy 1942). Once glochidia have developed into juvenile mussels, they drop to the bottom of the stream or river and are thought to attach to the substrate by byssus threats (Murphy 1942).

Table 1. Documented fish hosts for *M. falcata* are listed below. In order to determine that a fish is a host for *M. falcata*, 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 (natural or artificial)**	**Glochidia metamorphosis observed**	**Reference**
brown trout, *Salmo trutta*	Nonnative	Natural	Yes	Murphy 1942
Chinook salmon, *Oncorhynchus tshawytscha*	Native	Natural	Yes	Karna & Milleman 1978
cutthroat trout, reported as *Salmo clarki*; now *Oncorhynchus clarki*	Native	Natural	Yes	Karna & Milleman 1978
rainbow trout/steelhead trout, *Oncorhynchus mykiss*	Native	Natural	Yes	Murphy 1942, Karna & Milleman 1978

Table 2. Potential fish hosts for *Margaritifera falcata*. The fish species listed below may be suitable hosts for *M. falcata*, but either glochidia infestation has only been observed under artificial conditions, or glochidial metamorphosis has not been observed. Further studies should be conducted to determine whether or not the fish in this table serve as hosts for *M. falcata* under natural conditions.

Fish species	**Is fish species native to western U.S?**	**Glochidia infestation observed (natural or artificial)**	**Glochidia metamorphosis observed**	**Reference**
brook trout, *Salvelinus fontinalis*	Nonnative	Artificial	Yes	Murphy 1942
bull trout, *Salvelinus confluentus*	Native	Natural	No	M. Steg, unpublished observation
kokanee salmon, *Oncorhynchus nerka kennerlyi*	Native	Artificial	Yes	Meyers and Milleman 1977
lahontan redside, *Richardsonius egregious*	Native	Artificial	Yes	Murphy 1942
Prickly sculpin, *Cottus asper*	Native	Natural	No	Karna & Milleman 1978
speckled dace, *Rhinichthys osculus robustus*	Native	Artificial	Yes	Murphy 1942
tahoe sucker, *Catostomus tahoensis*	Native	Artificial	Yes	Murphy 1942
threespine stickleback, *Gasterosteus aculeatus*	Native	Natural	No	Karna & Milleman 1978

DISTRIBUTION

Margaritifera falcata is broadly distributed in western North America; its historic range extends from Alaska and British Columbia south to California and east to Nevada, Wyoming, Utah and Montana. It is apparently most abundant in Oregon, Washington, Idaho and British Columbia. The maps in Figures 2 and 3 illustrate watersheds (8 digit HUCs) that contain records of *M. falcata* prior to 1985 (red) and records of *M. falcata* observed or collected after 1985 (blue). Watersheds that contain records with no date associated are displayed with diagonal hash-marks. One may conclude that *M. falcata* 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 ‘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. For example, there is evidence that *M. falcata* have been extirpated from the Umatilla River in Oregon (Brim Box *et al.* 2006), but the watershed is still colored blue because *M. falcata* has been observed or collected in other rivers or streams in that same watershed since 1985.

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 *Margaritifera falcata* and more recent (post-1985, blue) records of *M. falcata*.

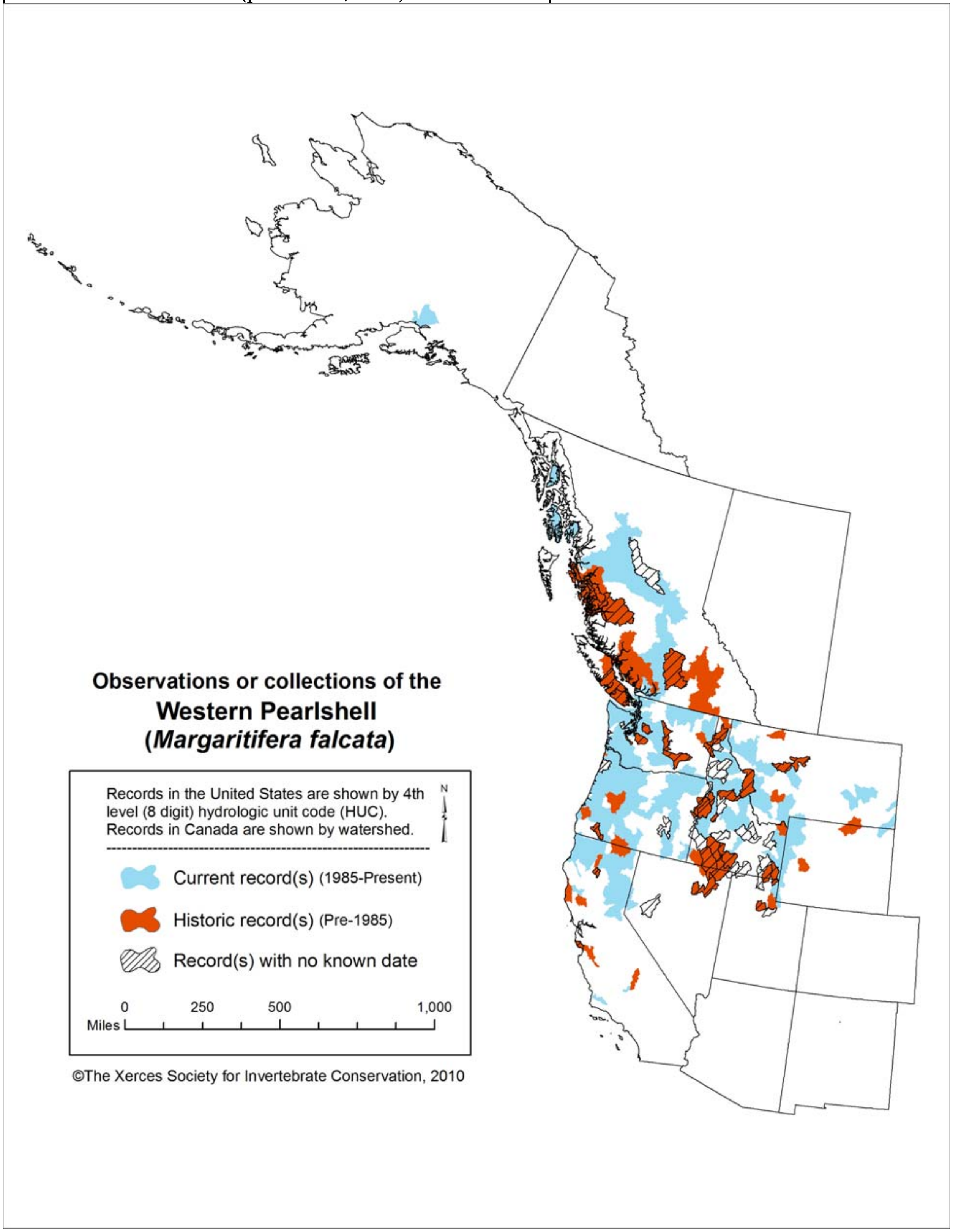
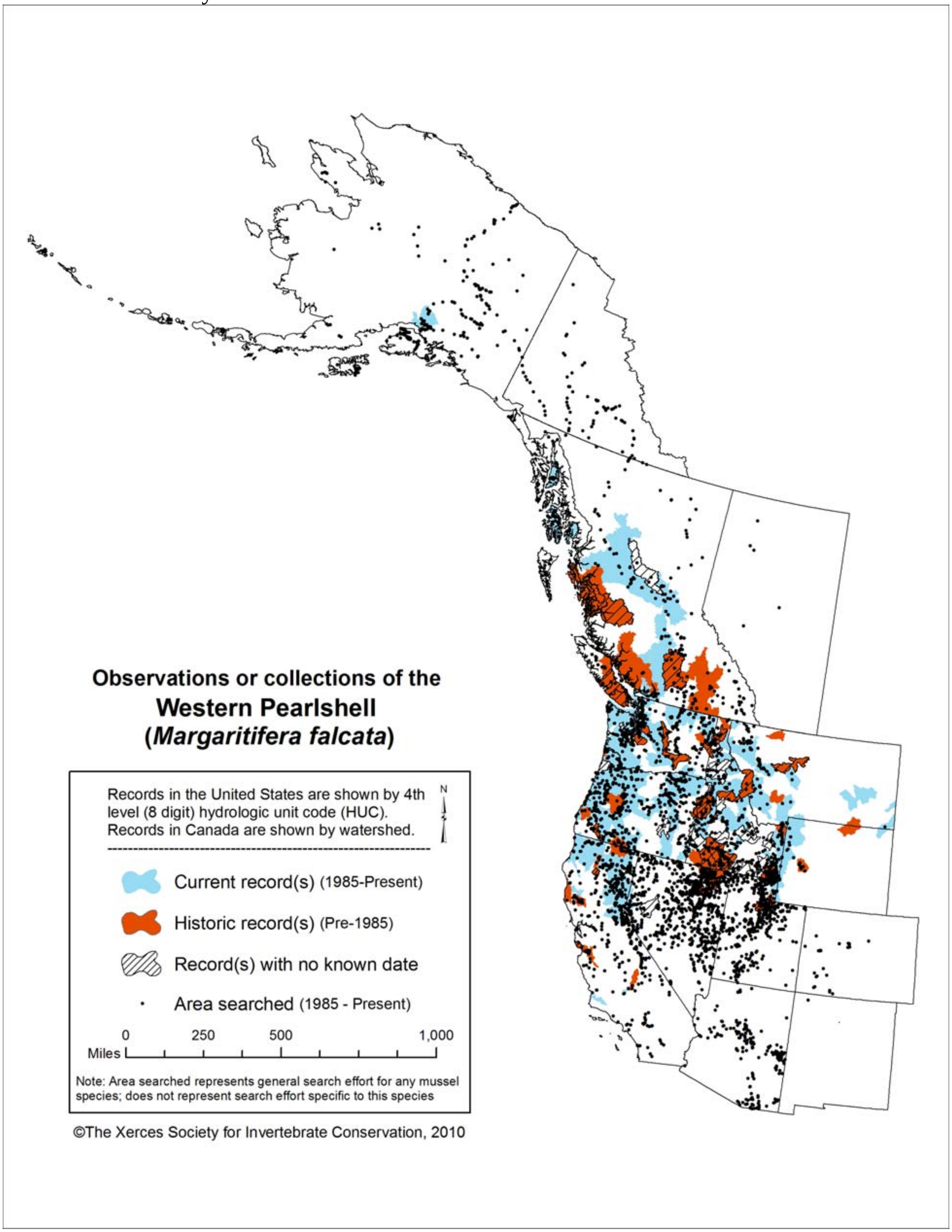


Figure 3. Map of watersheds containing historical (pre-1985, red) records of *Margaritifera falcata* and more recent (post-1985, blue) records of *M. falcata*. Black dots indicate locations that have been surveyed for freshwater mussels since 1985.



THREATS

Like other freshwater mussels in North America, threats to *M. falcata* 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. *M. falcata* may be threatened by low genetic diversity as a result of recent population reductions, although it is difficult to detect the molecular signature of a genetic bottleneck for species with hermaphroditic life histories.

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). Salmonids in the Pacific Northwest – many of which are used as hosts by *M. falcata* – have been severely impacted by dams, water withdrawals and other factors; many distinct population segments of Chinook, chum, coho, sockeye and steelhead are listed as Threatened or Endangered under the U.S. Endangered Species Act (US Fish and Wildlife Service 2010). 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 *M. falcata*'s reproductive cycle (Spring Rivers 2007). In stream culverts also likely pose a significant obstacle to the dispersal of *M. falcata,* since they frequently inhibit fish passage (Vaughan 2002).

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 *M. falcata* died when covered with tailings from a suction dredge. Similarly, Vannotte & Minshall (1982) reported that large *M. falcata* were unable to uncover themselves and perished when they were covered with sediment.

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 20th 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, especially in the case of *M. falcata,* are 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). *M. falcata*, in particular, appear to require fast-flowing, clean water for survival. 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).

In the Umatilla River of Oregon, where native Chinook and coho salmon have been extirpated and steelhead are much less abundant than they once were as a result of extensive water withdrawals (Phillips *et al.* 2000), *M. falcata* no longer exists (Brim Box *et al.* 2006).

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, *M. falcata*, which appears to require cold water for survival. 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 mussel 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). The displacement of native salmonids by other species of fish poses a threat to *M. falcata*, since they have evolved using native salmonids as hosts.

CONSERVATION STATUS

Margaritifera falcata is a vulnerable species, but probably does not face an immediate risk of extinction. Numerous examples exist of *M. falcata*'s decline or extirpation from streams and rivers across its range, especially in the more arid areas of Utah and Nevada, although it is still widespread and abundant in other locations. In general, there is a lack of historic abundance data for freshwater mussels in western North America. Without historic abundance data, it is difficult to assess decline across this species' range. Numerous reports also exist of an apparent lack of reproduction in *M. falcata* populations, which could lead to population extirpation when the older individuals die. Populations of long lived species, such as *M. falcata*, may appear stable, when in fact they risk extinction due to lack of reproduction. NatureServe has assigned *M. falcata* a rounded global status of G4 – Apparently Secure. NatureServe also notes that *M. falcata* is declining in terms of area occupied and number of sites and individuals, and that populations showing repeated reproduction, evidenced by multiple age classes, are now rare. (NatureServe Explorer 2008).

Below is a summary of status information for *M. falcata* in each U.S. state and Canadian province where it occurs.

United States

Alaska

Little information is available on the status of *M. falcata* in Alaska. This species has been documented from numerous locations in southeastern Alaska (Smith *et al.* 2005), and Carol

Gelvin-Reymiller recently photographed a *M. falcata* shell collected from the Deshka River, which is significantly north and west of its previously known distribution (pers. comm. C. Gelvin-Reymiller, February 2009).

California

In a distributional study, Taylor (1981) speculated that *M. falcata* had probably been eradicated from the much of its original range in California. Howard found *M. falcata* at 4 of 5 historical localities and at 15 of 115 total localities in the Plumas, Tahoe and Eldorado forests and the Lake Tahoe Basin Management Unit in northern California (Western Mollusk Sciences 2008). One historical site on Truckee River contained approximately 20,000 *M. falcata* in a 0.8 km stretch (Murphy 1942); when Howard revisited this site in 2007, only ~120 *M. falcata* were counted, most of which appeared to be ~30 years or older (Western Mollusk Sciences 2008). Howard's study suggests that *M. falcata* has dramatically declined from the Truckee River and has not been reproducing in that area for three decades. A study in the Navarro and South Fork Eel Rivers found that recruitment of *M. falcata* in the Navarro River was lower than in the South Fork Eel River, perhaps due to greater loss of host fish, timbering and agricultural intensification in the Navarro River (Howard & Cuffey 2006). In another study, researchers found little evidence of reproduction by *M. falcata* in the Pit River drainage of northeastern California (Spring Rivers 2007), suggesting that this species may be especially vulnerable to altered flow regimes. In a large scale distributional study, Hovingh (2004) did not find *M. falcata* at any of the 155 sites surveyed in eastern California, Utah and Nevada.

Idaho

Margaritifera falcata has apparently been eliminated from the Middle Snake River, where it historically occurred in abundance in Native American middens (Frest & Bowler 1993, U.S. EPA 2002). Historically, the western pearlshell was found in the Snake, Coeur d'Alene, Lost, and Salmon River drainages. It is thought to still be extant in the: Clearwater, Selway, Lochsa, Lost, Coeur d'Alene, Little Salmon, Salmon, Pahsimeroi, and Blackfoot rivers. (Frest & Johannes 1997, Frest 1999; summarized in Stagliano *et al*. 2007).

Montana

Margaritifera falcata has likely been extirpated from historical localities in the Bitterroot and Clark Fork Rivers (Stagliano *et al*. 2007), and populations in the Blackfoot and Big Hole Rivers are also reportedly declining, perhaps due to decreased stream flow, warming and degradation (Montana Field Guide 2008). In an unpublished thesis, Munday reports that the population of *M. falcata* in Clam Creek lacks small sized mussels, suggesting that this population is not reproducing (Munday no date).

Nevada

In a large scale distributional study, Hovingh (2004) did not find *M. falcata* at any of the 155 sites surveyed in eastern California, Utah and Nevada and concluded that the species had been extirpated from Nevada. Historical records of *M. falcata* from Nevada exist from the Truckee, Humboldt, and Owyhee Rivers (P. Hovingh, pers. comm., Aug. 2009).

Oregon
Margaritifera falcata is still relatively common and widespread in western Oregon, although there is evidence that this species has declined from a number of locations, including the: Owyhee River, Umatilla River, Middle Fork John Day River, Siuslaw River watershed, Siletz River, middle fork of the Snake River and the main stem of the Columbia River.

In a study in the Owyhee River Basin that compared the species composition of freshwater mussels in archeological Native American middens to the current mussel species composition in the same areas, Tait found that *M. falcata* has disappeared from some of the streams where it historically occurred, perhaps due to sedimentation or loss of native salmonid host fish species such as Chinook salmon and redband trout (C. Tait, pers. comm., 2009).

In a 2002-2003 study, Brim Box of the Confederated Tribes of the Umatilla Indian Reservation found that *M. falcata* has recently been extirpated from the Umatilla River; interviews with tribal elders confirmed that *M. falcata* historically occurred in the Umatilla River. Some native salmonid fish hosts, such as Chinook salmon, have also been extirpated from this system. In the Middle Fork John Day River, Brim Box found that fewer *M. falcata* occurred in areas of the river that had been channelized and/or mined than in areas of the river that had not been modified (Brim Box *et al.* 2003, Brim Box *et al.* 2006).

In the Siuslaw River watershed, Kinney has been studying *M. falcata* for 13 years. In Lake Creek, he estimated that one bed (called 'the Indiola colony') of *M. falcata* had approximately 10-12,000 individuals in 1996. In 2008, he estimated only 2-3 thousand individuals in this same colony. Kinney has observed an excessive degree of shell erosion and high acidity in these waters, and he speculates that the acidification from abandoned lead sinkers may be causing the elevated *M. falcata* mortality. (R. Kinney, pers. comm., 2009).

In the Siletz River on the Oregon Coast, Karna & Milleman (1978) reported a colony of approximately 100,000 *M. falcata* near River mile 21, with densities exceeding 400 mussels per meter squared. To the best of the authors' knowledge, no one has revisited that location to assess current *M. falcata* density or abundance, but an Oregon Department of Fish and Wildlife Memorandum from Bob Buckman dated August 15, 2001 states: "At both meetings anglers questioned us on what happened to the freshwater mussels in the Siletz. These folks reported abundant mussels or clams decades ago, but very few, if any currently. We did not have a good explanation and were reminded that we need to keep track of all native species." River mile 21 on the Siletz River should be revisited to assess the current density and abundance of *M. falcata*.

An ecological assessment of the Middle Snake River (forming the border between Oregon and Idaho) states: "The large freshwater clam *Margaritifera falcata*, once a food staple for Native Americans along the river, is now virtually eliminated from the Middle Snake" (U.S. EPA 2002). Frest (1999) notes that much of the Middle Snake River is becoming eutropified from agricultural runoff, urbanization and trout farms.

Utah
Margaritifera falcata was formerly known from 11 localities in the northern third of Utah state (summarized in Oliver & Bosworth 1999). After surveys of the known historical localities for

this species in Utah, Clarke (1993) concluded that it had been extirpated from the state, perhaps due to anthropogenic over-utilization of water resources. After surveying 155 sites in Utah, Nevada and eastern California, Hovingh (2004) suggested that *M. falcata* had been extirpated from Utah. The loss of cutthroat trout native to Hot Springs Lake and Utah Lake may have caused the extirpation of *M. falcata* from the Jordan River drainage (Hovingh 2004). However, in September of 2010, Cynthia Tait reported finding live *M. falcata* in Beaver Creek, a tributary of the Weber River, where they were formerly thought to have been extirpated (C. Tait, pers. comm. Sept. 2010; note that this new record is not reflected in the maps in Figures 2 and 3).

Washington

In Washington, substantial die offs of *M. falcata* have been observed in Bear Creek (Hastie & Toy 2008). In Nason Creek (Chelan County), Washington, no *M. falcata* were found that were younger than 45 years old, suggesting that the species has not been reproducing in that creek for decades. In one location in the Little Spokane River, *M. falcata* were observed in 1968, 1972, and 1992, but none in 2000. High numbers of dead *M. falcata* shells and few live individuals were observed in 2003 in Stearns Creek, in 2003 in the Snohomish River and in 1996 in Muck Creek. In a survey of one area of the SanPoil River in 1991, Frest reported only empty *M. falcata* shells and pollution from an old lumber mill nearby. (WDFW database of freshwater mussel records, 2009). Roscoe and Redelings (1964) note that a few thousand *M. falcata* were observed per 140 meters squared in the Kettle River (Stevens Co.) of Washington; Hovingh (2004) suggested that the current numbers of *M. falcata* in Washington represent depleted populations. As reported in the Oregon section above, *M. falcata* was formerly dominant in the Columbia River (summarized in Helmstetler & Cowles 2008), although recent surveys of 118 km of the mid-Columbia River did not reveal any *M. falcata*. High levels of arsenic and organochlorine pesticides were found in the tissues of other mussel species collected from the mid-Columbia during that survey. (Helmstetler & Cowles 2008).

Wyoming

Margaritifera falcata may have declined in the Bear River of Wyoming – one hundred specimens were observed in one location in the Bear River in 1956; when that same site was revisited in 1998, only 5 live specimens and 8 empty shells were observed (Hovingh 2004). However, *M. falcata* has been observed in numerous locations in its historic range of western Wyoming since 1985, including creeks and rivers in Teton, Lincoln, Sublette and Uinta counties (G. Edwards, pers. comm. April 2009, P. Hovingh, pers. comm. Aug 2009).

<u>Canada</u>

British Columbia

Margaritifera falcata is apparently secure in British Columbia. Healthy populations reportedly occur in northern British Columbia and on southern Vancouver Island (Metcalfe-Smith & Cudmore-Vokey 2004, NatureServe Explorer 2008). Lee (2000) reported that *M. falcata* was rare in the Pacific drainage of northern British Columbia.

CONSERVATION NEEDS
Populations of *M. falcata* and their salmonid host fishes should be monitored and protected. Threats to water quality and quantity, mentioned above, should be addressed to minimize impacts to all native freshwater mussels, including *M. falcata*. Basic research needs, discussed below, should be addressed.

RESEARCH NEEDS
Much more information is needed to understand the current distribution of *M. falcata*. Sites that historically contained *M. falcata* should be revisited to determine if the species is still extant at those sites, and a high priority should be given to sites with historical abundance data, such as the Siletz River (at River Mile 21) in Oregon. This species appears to be highly vulnerable in arid areas; historical sites in these areas should be prioritized for revisitation, such as those in Nevada, eastern Oregon, eastern Washington, and eastern California. Populations of *M. falcata* should be censused to provide abundance data and enable biologists to monitor population statuses over time. The age structure of existing *M. falcata* populations should be examined to determine whether or not populations are reproducing. Biologists should investigate more thoroughly which fish species serve as glochidial hosts for *M. falcata*.

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Gordon Edwards, Wyoming Game and Fish Department, April 2009
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ADDITIONAL RESOURCES

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