Freshwater Mussels *of the* Pacific Northwest

Ethan Nedeau, Allan K. Smith, and Jen Stone

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Contents

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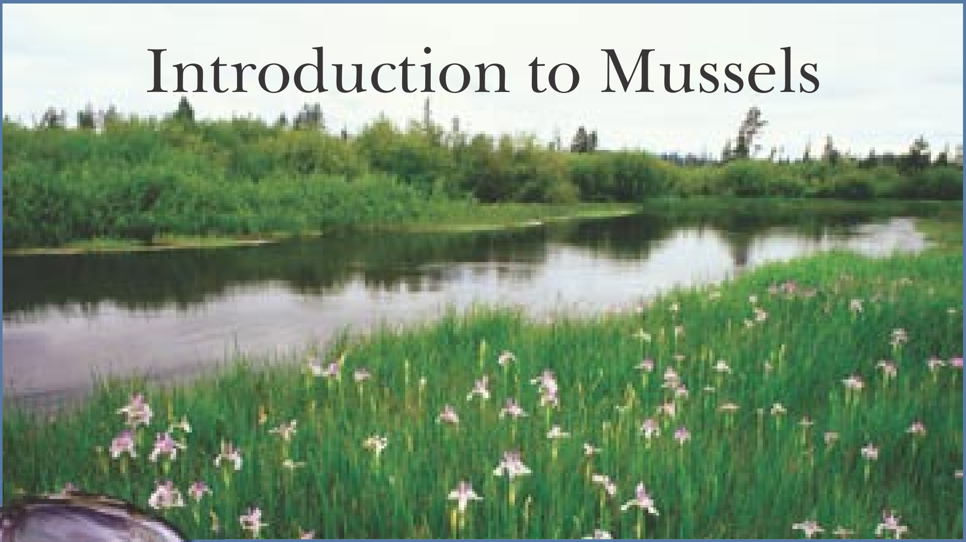
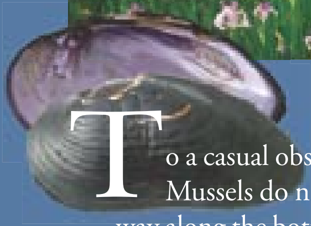
Front cover photos: Columbia River, Dennis Frates (top); bed of western pearlshells, CTUIR Freshwater Mussel Project (bottom)

Introduction to Mussels



Deschutes River, photo: Dennis Frates



To a casual observer, a freshwater mussel may look no different than a stone. Mussels do not move very far during their adult lives; they may inch their way along the bottom or slowly bury themselves if the need arises, the unobtrusive animals tend not to do anything that some might consider…dramatic. But these humble creatures can ascend waterfalls! Their young attach to unwitting fish that carry them to new places in a watershed—over waterfalls, across lakes, up and down rivers from headwaters to tidewaters, and even across the Continental Divide. This is one of the many wonders of freshwater mussels, and sadly, we are losing many species without ever learning their amazing secrets.

Normally, freshwater mussels can outlive most animal species on Earth; one species in the West can live longer than a century. But their longevity depends on stability—they are finicky about where they live, in what environmental conditions they thrive, and with which fish species they share their environment. Mussels are very sensitive to environmental changes and may indicate long-term degradation—or recovery—of aquatic ecosystems.

Nearly three-quarters of all 297 native freshwater mussel species in North America are imperiled and nearly 35 went extinct in the last century. They are one of the most endangered groups of animals on Earth, yet surprisingly little is known about their life history, habitat needs, or even how to distinguish different species—especially in western North America. This book summarizes the current knowledge of freshwater mussels in this region, focusing primarily on the Pacific Northwest. Research is ongoing and future editions may provide new information. In the meantime, this book will help raise awareness about freshwater mussels and help spotlight the importance of freshwater mussels in protection and restoration of our freshwater ecosystems.

What are Freshwater Mussels?

Freshwater mussels are mollusks that produce a bivalved shell. The two valves are mirror images of each other and are connected by an elastic-like ligament along the dorsal hinge. The outside of the valves is covered with material called periostracum that gives the shell its color, and the inside is lined with a smooth mother-of-pearl material called nacre. The raised rounded area along the dorsal margin is called the beak; shells grow outward from the beak in a concentric pattern. Mussels may possess “teeth” on the hinge that create a strong and sturdy connection between the valves. There are two types of teeth—lateral teeth are thin elongate structures parallel to the hinge, and pseudocardinal teeth are short stout structures below and slightly in front of the beak.

The living mussel occupies the cavity between the two valves. The only body parts that are visible outside of the shell are the foot that is used for locomotion and feeding, and the mantle edges that are modified into inhalent and exhalent apertures. The mantle is a thin sheet of tissue that lines the shell and envelops the body of the mussel. A mussel will pull the mantle edges and foot into the shell when disturbed. Mussels draw water (along with food and sperm) into the body through the inhalent aperture and expel filtered water, waste, and larvae out the exhalent aperture.

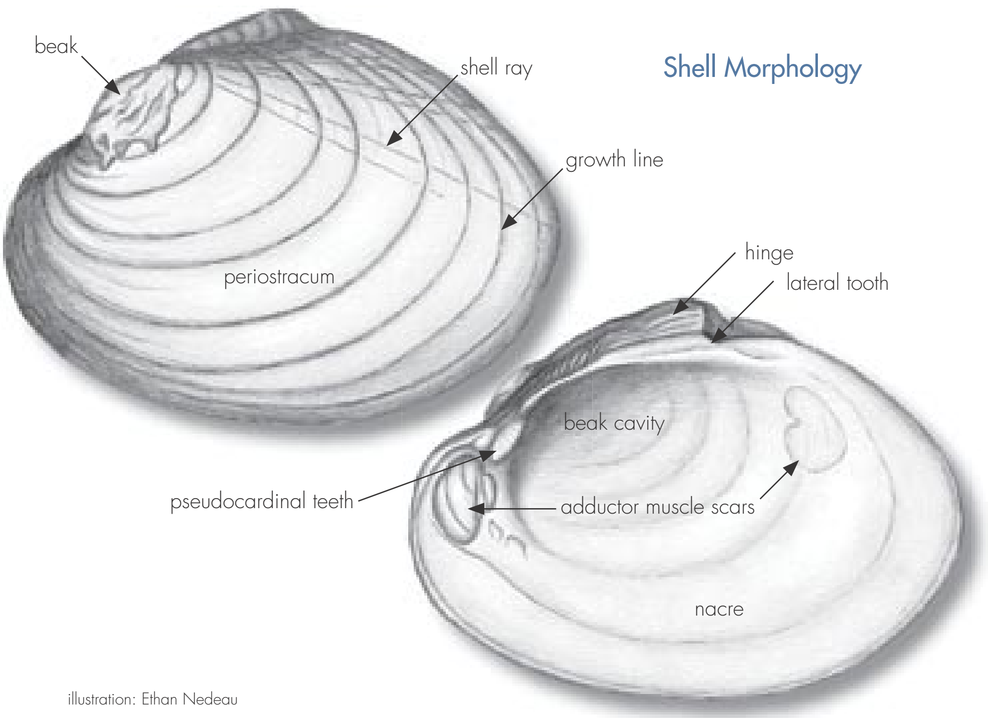
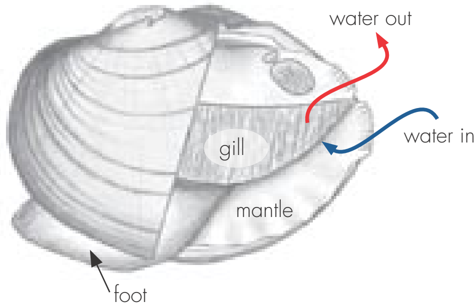


illustration: Ethan Nedeau



Filter-feeding

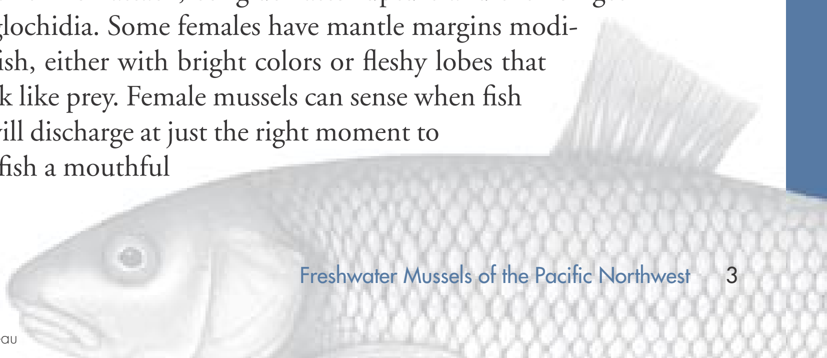
Mussels pump water and food in through the inhalent aperture, use their gills to filter food and other materials from the water, and then expel filtered water and waste out the exhalent aperture. **Left:** A bed of western pearlshells.

photo: CTUIR Freshwater Mussel Project; illustration: Ethan Nedeau

Life History

People who take the time to learn about freshwater mussels are amazed at the complex life cycle and reproductive traits that freshwater mussels possess. Some species of freshwater mussels can live longer than 150 years, making them one of the longest-lived animals on Earth. The larvae of native freshwater mussels are external parasites of fish. They display fascinating behavior—especially considering that they spend most of their lives partially buried in the sediment and do not seem to move very far.

During breeding, males release sperm into the water and females must "inhale" it for fertilization to occur. Embryos develop into larvae called glochidia, which are released by the female. The release of glochidia varies by species and environmental conditions. Some species will simply expel thousands of glochidia singly and hope that some will encounter a host. Some species bind glochidia to stringy mucous webs that may ensnare a fish's fins. Some species bind glochidia in packets called conglutinates, with shapes or colors that mimic the natural prey of their host fish, such as worms, insect larvae, or small fish. When fish attack, conglutinates rupture and the fish get a mouthful of glochidia. Some females have mantle margins modified to attract fish, either with bright colors or fleshy lobes that undulate to look like prey. Female mussels can sense when fish approach and will discharge at just the right moment to give the fooled fish a mouthful of glochidia.



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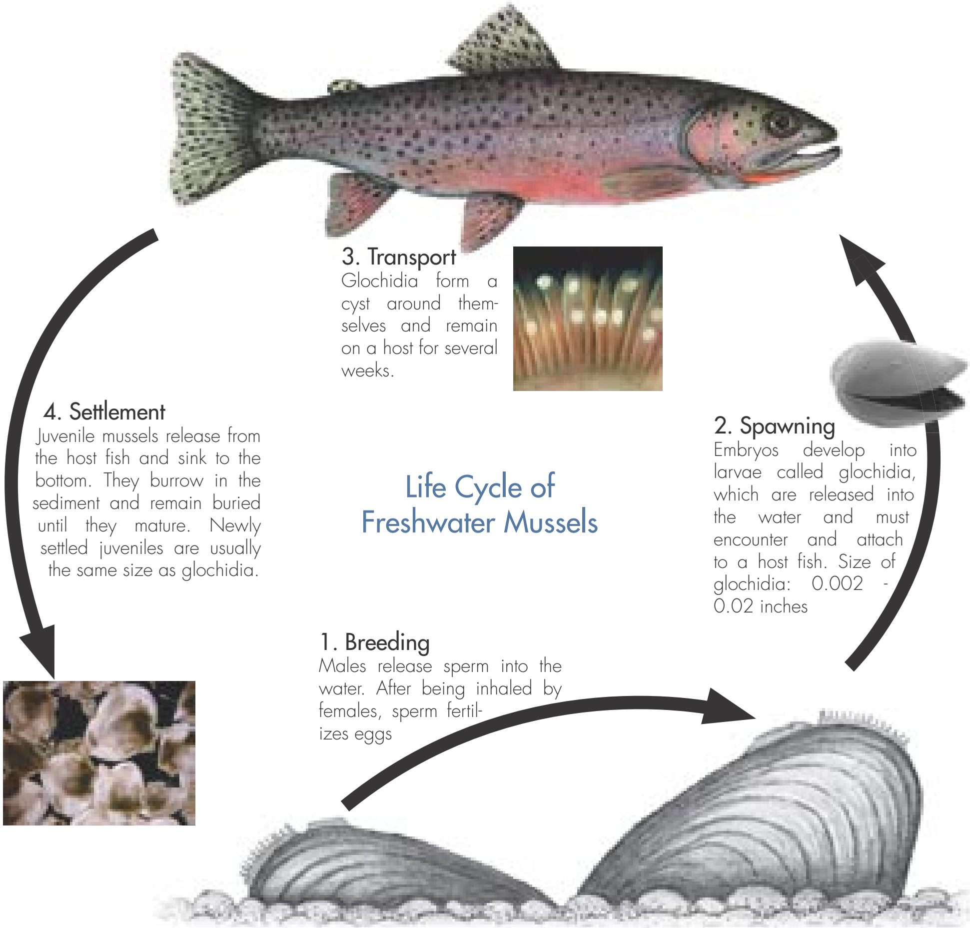


illustrations: Ethan Nedeau; glochidia image: U.S. Geological Survey; encysted glochidia and juveniles: Chris Barnhart

Once released, glochidia must encounter and attach to a host fish. They attach to gills or fins, and some mussels are specific to the fish species they parasitize. Glochidia may remain for several days or months, depending on the water temperature and mussel species. During this period, fish may swim many miles from where they were infected (particularly migratory fish) and thereby help mussels disperse within a waterbody. When ready, the juvenile mussels will release from the fish, fall to the bottom, burrow into the sediment, and begin their free-living existence. The chances of glochidia finding a host, attaching, landing in a suitable environment, and reaching adulthood are incredibly slim.

The small light specks on this trout's gills are mussel glochidia.
photo: Michelle Steg, Oregon Nature Conservancy

Underwater view of western ridged mussels situated in a gravel bed. photo: Allan Smith

Mussels spend their first few years buried in the sediment. During this time, they grow fast to protect against predators and the crushing and erosive force of rocks and water. Once mature, they spend most of their lives partially buried, with their posterior end sticking above the surface of the sediment.

The western pearlshell (*Margaritifera falcata*), and the closely-related eastern pearlshell (*M. margaritifera*) may live for over 100 years, making them two of the longest-lived animal species on Earth. During that time, they may move less than a few yards from the spot where they first landed after dropping from their host fish. Other species in western North America, such as the floaters, may live only ten to fifteen years.

Habitat

Freshwater mussels are confined to permanent water bodies, including creeks, rivers, ponds, and lakes. They are often absent or sparse in high-gradient, rocky rivers where the erosive forces of rocks and water may be too strong for juveniles to become established. The species that inhabit lakes and ponds are usually more tolerant of muddy substrates, low dissolved oxygen, and warm water temperatures. Mussels can also be found in freshwater tidal habitats such as the lower Columbia River and Kalama River. Brief exposure during low tides does not seem to affect their populations.

Creeks and rivers usually support the greatest diversity of mussels, perhaps because they provide a variety of habitat conditions, reliable flow, good

Mussels can inhabit both pristine and urban rivers and lakes, provided that water and habitat quality are suitable. photos: Allan Smith

water quality, and diverse fish communities. Species that live in flowing water usually prefer mud, sand, gravel, and cobble; flow velocities adequate to keep the water and sediment well oxygenated; and depths that are not prone to dewatering during dry periods. Recent research has shown that mussels may concentrate in areas with stable flow and substrate conditions.

Although many mussel species are sensitive to pollution and habitat disturbance, some can tolerate moderate human disturbance and exist near densely populated areas such as Seattle and Portland. Urban streams and ponds may support tolerant species if habitat is suitable, even if water quality is poor at times. Urban populations may suffer from poor recruitment, growth, or survival, but more studies are needed to document this.

Role in Ecosystems

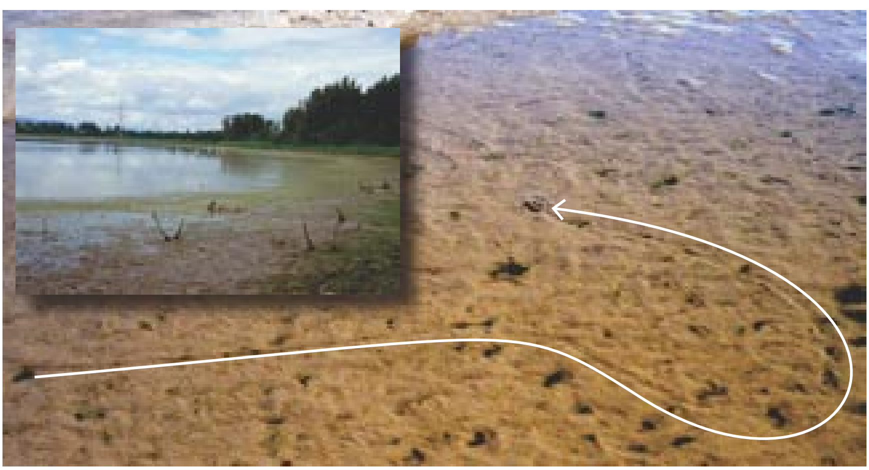
Mussels are important to food webs, water quality, nutrient cycling, and habitat quality in freshwater ecosystems. They greatly influence food webs by filtering tiny suspended materials—such as algae, bacteria, zooplankton, and sediment—from the water. They release much of the ingested material as feces or pseudofeces that sinks to the bottom, where it is more available for consumption by other benthic (bottom-dwelling) animals, especially aquatic macroinvertebrates. Collectively, mussels can filter a substantial volume of water each year and may help reduce turbidity. Mussels often comprise the greatest proportion of animal biomass (the sum total of living tissue, including shells) in a waterbody. Because mussels are so long-lived, they retain nutrients and minerals for a very long time.

Mussels are an important source of food for predators such as river otters and muskrats. However, muskrats were introduced outside of their native range in the West and may affect native mussel communities in some areas. Non-aquatic mammals such as raccoons and skunks may eat mussels that

Muskrats (right) and many other animals eat freshwater mussels. Muskrats leave shells in piles called middens (left). photo: Christine Humphreys, Painet Inc. (right), Ethan Nedeau (left)

they can reach in shallow water, or when water levels drop during droughts or reservoir drawdowns. Raccoon tracks are common in the mud and silt of the lowland waters of western Oregon and Washington; raccoons are on a ceaseless patrol for mussel meals. Waterbirds such as gulls and shorebirds also scavenge dead mussels when water levels are low. Some fishes eat juvenile mussels, including native sturgeon and suckers and nonnative sunfish and catfish.

Mussels may also influence habitat quality and diversity of benthic macroinvertebrates. Their movements help stir sediments and increase the exchange of oxygen and nutrients between the sediment and water. They serve a similar function as earthworms in your garden by allowing sediment to retain more organic matter and increasing sediment porosity. Mussel shells provide a surface for algae and animals (such as sponges and insect larvae) to attach.

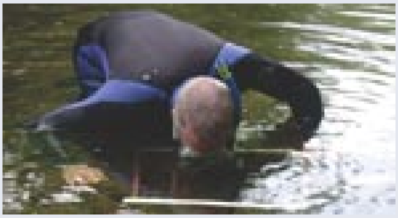


Mussels that sense receding water levels will often move to avoid exposure, but they are vulnerable to predators during these events (line drawn for emphasis). photos: Allan Smith

Mussels as Biomonitors

Freshwater mussels have several traits that make them excellent indicators of the long-term health of aquatic ecosystems, including the following:

- Since individuals live from ten to over one hundred years, their populations reflect the cumulative effects of environmental conditions and extreme events over time. The age and growth of mussels provides insight into population health and reproductive success.
- Adult mussels may only move a few yards during their lives. Mussels cannot respond quickly to escape adverse conditions (as a fish can), and if they disappear from an area, they are slow to recolonize. If conditions become unsuitable for mussels, they either stop reproducing, stop growing, or die. Careful studies can detect these responses.
- Mussels are sensitive to changing water quality, habitat, and fish communities. Low dissolved oxygen, chemical contamination, and sedimentation are just three of myriad stressors that affect mussels. Loss of host fish will eventually eliminate mussel communities even if other physical and chemical conditions are ideal.
- Because mussels are long-lived, filter-feeding animals, they accumulate chemical contaminants in their bodies and shells. Tissue concentrations of contaminants—such as mercury, lead, dioxin, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons—will indicate exposure risk of the entire aquatic community and provide insight into ecosystem health.
- Mussels are easy to collect, identify (at least to genus), and measure. Shells can be tagged so that growth, movement, or survival of animals can be tracked over time. Methods exist for estimating population sizes and studying long-term trends in abundance.



A researcher counts mussels within a $0.25m^2$ quadrat frame as part of a quantitative study of population size and trends.

A numbered tag cemented to a live animal using dental cement can stay attached for many years.

photos: Ethan Nedeau

The Blitzen River hosts four species of freshwater mussels. photo: Dennis Frates

Diversity and Distribution

Seven native freshwater mussel species occur west of the Continental Divide. The West has a very low diversity compared to the 290 species that occur in the eastern two-thirds of North America. Some locations in the southeastern United States historically supported more then seventy species! It is a treat to find more than two species of mussels living together in a single waterbody in the West. The Blitzen River in southeast Oregon's Malheur National Wildlife Refuge has exceptional diversity for the West—four species!

The low diversity of mussels west of the Continental Divide is the result of glaciers, dispersal barriers, climate, and geology. The Cordilleran Ice Sheet covered northern parts of the landscape up to about 18,000 years ago, destroying aquatic habitats and pushing mussels into southern refugia. The Continental Divide was an insurmountable dispersal barrier for most aquatic animals, keeping the rich diversity of eastern species from colonizing western rivers. The arid climate throughout parts of the West made conditions difficult for mussels to disperse and proliferate. Many streams and rivers were rocky, high-gradient environments with tremendous erosive force that inhibited long-lived, fragile, and sedentary animals from becoming established.

Species composition in Native American shell middens provides information on mussel communities and perhaps environmental conditions before

Use by Humans

Humans have exploited freshwater mussels for millennia, beginning with Native Americans that fashioned tools and implements from shells and ate mussels when there was a scarcity of more palatable food. Large, heavy-shelled species of the central United States were commercially harvested for buttons throughout the 1800s and early 1900s until the advent of plastic ended the shell button industry. The economic value of mussel shells grew when it was discovered that mussel shells could be used in the cultured pearl industry. When shell nuclei cut from thick-shelled North American species were slipped under the mantle of marine oysters, the oysters would create a pearl around it. Supplying Asia's cultured pearl industry became a multi-million dollar fishery in the United States. However, none of the seven species occurring west of the Continental Divide were commercially exploited for the cultured pearl industry because their shells were too thin. Freshwater mussels were harvested in Oregon in the early 1990s to provide specimens for biological supply companies. Yet, besides their value as environmental indicators and their role in healthy ecosystems, most people derive little direct economic benefit from western freshwater mussels.

European settlement, and when compared to current species composition, may reveal how the environment has changed. Excavations from prehistoric archeological sites in the Owyhee River basin of eastern Oregon found shells of western pearlshells and western ridged mussels (*Gonidea angulata*), indicating that Native Americans harvested these species 1000-9500 years ago. However, only western ridged mussels are encountered in the basin today. Absence of western pearlshells could be the result of water quality changes, or may be related to historic extirpation[1] of fish host species such as anadromous salmon and subsequent introduction of nonnative fish such as bass. In the Puget Sound region, there are mussel middens dating back over 2000 years.

Native American shell midden excavated from the Chief Joseph Dam Project. photo: Chief Joseph Dam Project

1. **extirpation** is often used to describe the localized loss of population(s) when other populations persist elsewhere in a species range. Loss of a species throughout its range is called **extinction**.

Freshwater mussels have been greatly affected by river management and the Grand Coulee Dam is a symbol of man's effort to tame the West's rivers.

Conservation and Management

Freshwater mussels are one of the most endangered groups of animals on Earth, and have become a symbol of the diversity and conservation of North America's rivers. Of the nearly 300 North American species, 35 have gone extinct in the last 100 years. Nearly 25% are listed as endangered or threatened under the United States Endangered Species Act and 75% are listed as endangered, threatened, or special concern at the state level. The conservation crisis of mussels is a result of continent-wide degradation of aquatic ecosystems and is a symbol of the loss of our native freshwater fauna.

Freshwater ecosystems of the West have suffered increased levels of alteration and exploitation since settlers first arrived over 150 years ago. Mussels have been eliminated from portions of rivers and even entire watersheds through the combined effects of habitat loss, pollution, blockage of anadromous fish, and introduced species. The factors that have had the greatest effect on freshwater mussels of the West include water availability, dams, introduced species, and the chronic effects of urbanization, agriculture, and logging on habitat quality.

Freshwater mussels have come into the spotlight in recent years because of the environmental movement, a growing awareness of aquatic ecosystem health, and a public desire to protect and restore native ecosystems and wildlife. Pacific salmon have been the symbol of this movement in the Northwest, but people are learning that the fate of mussels and salmon are intertwined.

Healthy rivers and healthy salmon runs are vital to freshwater mussels, and in turn, mussels contribute to riverine ecosystems for the benefit of all species, including these spawning sockeye salmon. photos: Thomas P. Quinn

Some of the West's mussels need native salmon to complete their life cycle, and all species benefit from the increased productivity (from nutrient-rich salmon carcasses) and diversity that healthy salmon runs provide. In turn, salmon and other aquatic species benefit from the ecosystem services provided by freshwater mussels. Effective conservation and management of freshwater mussels requires a holistic view of the entire watershed—from the nearby wastewater effluent, to the feedlot on the hill, to the allocation of water to humans or wildlife, to dams and flow management, and to fisheries in the watershed and adjacent waters.

This scientist is looking for mussels in the Middle Fork John Day River. photo: CTUIR Freshwater Mussel Project

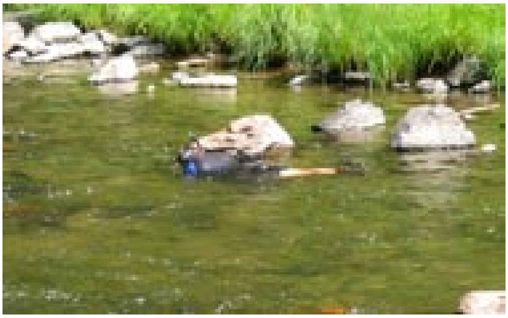
Searching For Mussels

Searching for freshwater mussels can be an enjoyable experience. Just spending time by a river or lake, looking carefully and moving deliberately, will foster a strong appreciation for aquatic environments. Information you collect can be important for conservation and management. The discovery of rare mussels in new places, or in places where people thought mussels had been eliminated, will help scientists and managers protect them.

Training the people who spend a lot of time near the water—boaters, fishermen, landowners, naturalists—to identify mussels may ultimately create an army of "mussel watchers." The three basic methods for surveying mussels are described below. When using these methods, please be aware of potential hazards, such as slippery banks and rocks, stinging or biting insects, snakes, deep mud, broken glass, pollution, dangerous flow conditions, underwater hazards such as drowned trees or debris, and boat traffic.

Shoreline Searches: Walk along the shoreline and look for shells discarded by predators or from mussels that died when water levels dropped. This is a safe and easy way to look for mussels, without having to get wet. Shoreline searches can be particularly effective when water levels are low, and they provide information on mortality that the low-flow event may have caused. Lowland freshwater tidal areas are good places to look for mussels during low tide. Sometimes it is possible to save mussels from predators or desiccation by carefully placing them in deeper water. Shoreline searches may be suitable for determining species richness. Unfortunately, shells found near the shore may not always represent the mussel community in the water. Predators may target certain species (especially large common species) and some species may be more abundant in deep water.

Bucket Surveys: Surveyors commonly use buckets fitted with a clear plastic bottom. This method enables you to search for live mussels in shallow water



Shoreline searches (top), clear-bottom buckets (left), and snorkeling (right) are common survey methods. photos: Allan Smith (top), CTUIR Freshwater Mussel Project (right)

while staying on your feet. This may be an important consideration if water quality is questionable, or if other factors do not permit you to swim. It is a better method than shoreline searches because you can find live animals in the water, but you are limited to shallow areas less than two or three feet deep and having sufficient water clarity to see the mussels.

Snorkeling: Searching for mussels while swimming, using a mask and snorkel, can be an enjoyable experience as long as conditions are suitable. Snorkeling allows you to survey a large area, search in deeper water, and see live animals better up-close. This method usually requires warm water temperatures, good water quality, and a safe working environment free of hazards. Wetsuits—and weights to counter the buoyant effect of wetsuits—are often required in cold water.

Warning about collecting mussels!

Scientists and managers want new information on mussel distribution, but they discourage people from killing and collecting live animals to prove that they found them. State or federal law protects some species, and it is a punishable crime to kill them or possess their shells. People are encouraged to submit observations of mussels and habitat conditions to local watershed groups or state and federal fish and wildlife offices, including photographs of shells and habitat. Experts can then verify the information.

Field Guide

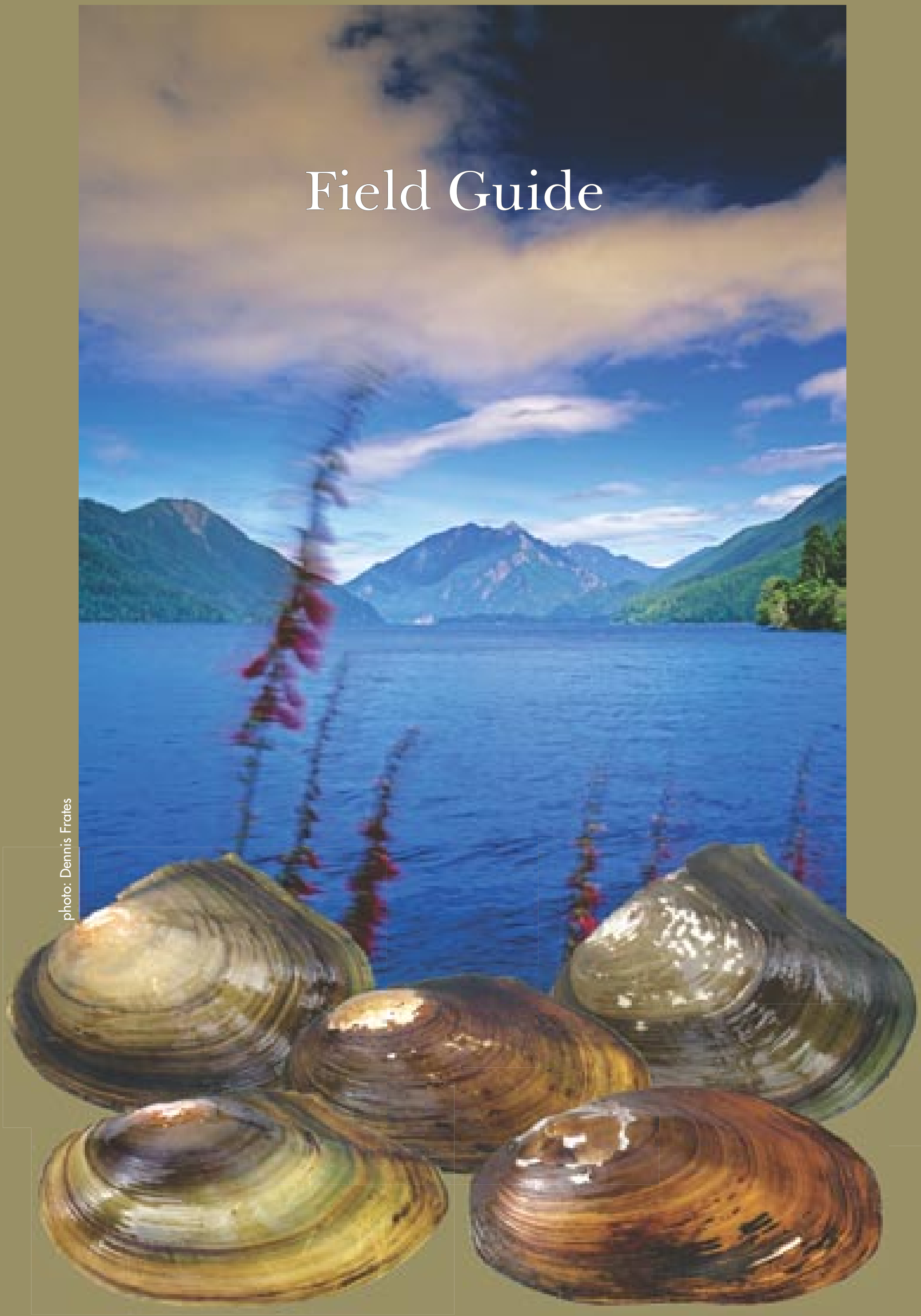
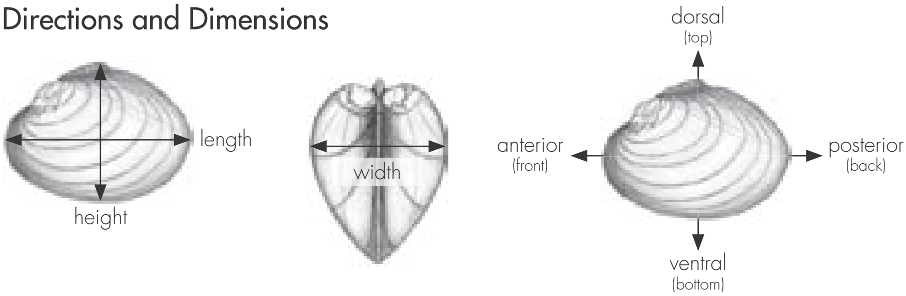


photo: Dennis Frates

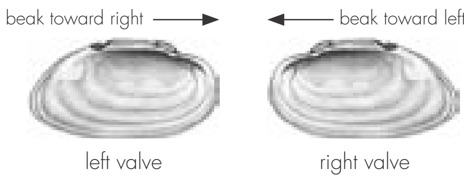
Key Terms

It can be daunting to learn all of the words used to describe the shape and appearance of mussels. Species identification is a visual process, so we try to minimize the technical words and illustrate the ones that we use. Please also refer to the general morphology diagrams on pages two and three.

Directions and Dimensions

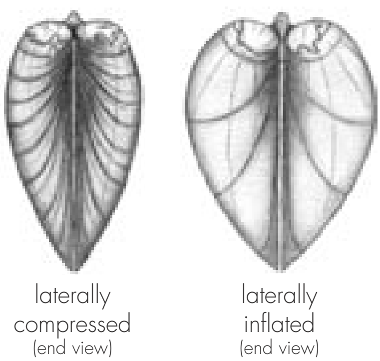


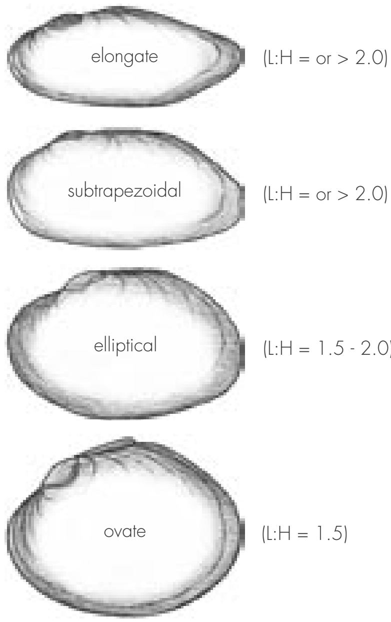
Left versus right valve: Place the shell in your palm with the nacre toward you and the beak up. If the beak is toward the right, it is the left valve. If the beak is toward the left, it is the right valve.



Shell Shape

L:H = ratio of length to height





Identification Key

This key was developed to enable the user to identify adult mussel shells or live animals. Descriptions, photographs, and illustrations are provided in the species accounts. Species in the genus *Anodonta* are difficult to separate; see page 19 for an explanation. This key can be used to make a best guess about species of *Anodonta*, but experts should confirm the identification.

Key to Genus

Outline of shell triangular or round. Beak inflated and centrally located along dorsal edge. Well-developed concentric sculpture lines, absent on other genera (introduced)…Asian clam, *Corbicula* (page 41)

Well-developed pseudocardinal teeth. Ventral margin slightly concave. Nacre purple on fresh specimens. Arborescent papillae surrounding the incurrent opening…western pearlshell, *Margaritifera* (page 34)

Distinct heavy ridge running at an angle from beak to posterior ventral surface. Shell thick, heavy, sturdy. Divided, purplish incurrent aperture papillae…western ridged mussel, *Gonidea* (page 38)

Pseudocardinal and lateral teeth and heavy ridge absent. Shell thin, light, and fragile. Single, whitish incurrent aperture papillae…Floaters, *Anodonta* (page 19)

Key to Species

1a. Outline of shell triangular or round. Well-developed concentric sculpture lines. Lateral teeth serrated. Adults are small (to about 2.25 in, though rarely more than one inch)… Asian clam, *Corbicula fluminea* (page 41)

1b. Outline of shell elongate or ovate. Adults larger than 2.25 in…2

2a. Shell thick, heavy, sturdy…3

2b. Shell thin, light, fragile. Hinge teeth absent…4 (genus *Anodonta*)

3a. Pseudocardinal teeth greatly reduced or inconspicuous and lateral teeth absent. Distinct, heavy ridge running at an angle from beak to posterior ventral surface. Ventral margin of shell straight or broadly curved…western ridged mussel, *Gonidea angulata* (page 38)

3b. Hinge with well developed pseudocardinal teeth. Shell with even surface; no distinct ridge. Ventral margin of shell slightly concave. Nacre purple or white on fresh specimens…western pearlshell, *Margaritifera falcata* (page 34)

4a. Shell L:H (length to height) ratio usually 1.5 or less. Height of posterior half of shell greater than height of anterior half. Shell broadly ovate in outline…5

4b. Shell L:H ratio close to or exceeding 2. Height of posterior half of shell nearly equal to height of anterior half…6

5a. Shell with high, conspicuous wing. Shell outline compressed. Shell thinner than other *Anodonta* species…winged floater, *Anodonta nuttalliana* (page 26)

5b. Shell with a wing of moderate height. Shell outline less compressed, especially in standing water. Shell comparable in thickness to other Anodonta species…California floater, *Anodonta californiensis* (page 24)

6a. Shell inflated only over anterior half of shell. Beak clearly projects above hinge line…Yukon floater, *Anodonta beringiana* (page 32)

6b. Shell inflated primarily along posterior ridge of shell. Beak does not or barely projects above hinge line…western floater, *Anodonta kennerlyi* (page 30)

6c. Shell primarily inflated over median portion of shell. Beak does not project above hinge line…Oregon floater, *Anodonta oregonensis* (page 28)

Floaters

Genus: *Anodonta*

Taxonomic Confusion

It would be misleading to publish a field guide to western mussels without explaining how little we know about the genus *Anodonta*. This genus has challenged taxonomists since 1838 when Isaac Lea first described three similar-looking shells from one location in the lower Willamette River as three different species: *nuttalliana* (winged floater), *oregonensis* (Oregon floater), and *wahlametensis* (Willamette floater). Subsequently, taxonomists described four more species: *beringiana* (Yukon floater), *californiensis* (California floater), *kennerlyi* (western floater), and *dejecta* (woebegone floater). These "species" were described according to the shape of the shells.

In most mussel genera, hinge teeth are used to distinguish species. However, as a rule, *Anodonta* species have no teeth (the Latin word *anodonta* means "without teeth"). Identification relies almost solely on shell shape, which unfortunately is quite variable. Age, sex, environmental conditions, and individual variation influences shell shape. Animals that live in lakes will often appear different than the same species that live in rivers. Color is influenced by water chemistry and age of the animal. Shell erosion—the intensity of which depends on water chemistry, sediment types, and flow conditions—will often obscure shell features such as shape, beak sculpture, and rays.

Recent advances in genetic research may help resolve the *Anodonta* problem in the West. Species with a broad geographic range and poor dispersal abilities, such as freshwater mussels, often exhibit a high degree of genetic variation across their range. Differences in the genetic make-up of isolated populations might be great enough to affect their appearance, but not enough to affect their ability to breed with each other. In other words, they might look different, but they may still be the same species. Scientists are trying to understand if the current "species" are genetically distinct throughout their range. The next step will be to find better sets of anatomical characters and life history information to distinguish species. Someday, it may be possible to identify species of *Anodonta* using soft tissue anatomy and genetic analysis, but this research is ongoing and beyond the scope of this publication.

This field guide generally follows the classification of Turgeon *et al.* (1998), which considers six species of *Anodonta* west of the Continental Divide: *californiensis, dejecta, nuttalliana*, *oregonensis*, *kennerlyi*, and *beringiana*. We depart from this standard reference by not considering *dejecta* a distinct species, but rather a form of *californiensis*. The following section summarizes western *Anodonta* in general. Then, we provide a shorter account for each species, including distribution, natural history, and conservation.

Anodonta Description

Size: Up to eight inches, but more commonly four to five inches.

Shape: Elliptical or ovate; length to height (L:H) ratio ranges from about 1.5 (ovate) to 2.0 (elliptical). Valves thin and fragile. Laterally inflated. Commonly, valves are slightly compressed toward the posterior dorsal margin and raised to form a "wing", the height of which varies among species.

Beaks: Small; usually slightly elevated above the hinge line or not at all.

Periostracum: Color usually includes some combination of yellow, green, brown, or black. Young animals are usually lighter and shinier than adults; most shells become brownish or black with age. May have greenish rays on the posterior slope. Growth lines are usually prominent, except in old dark shells.

Hinge Teeth: None

Nacre: Usually white, though sometimes with a pinkish or bluish tint toward the posterior end.

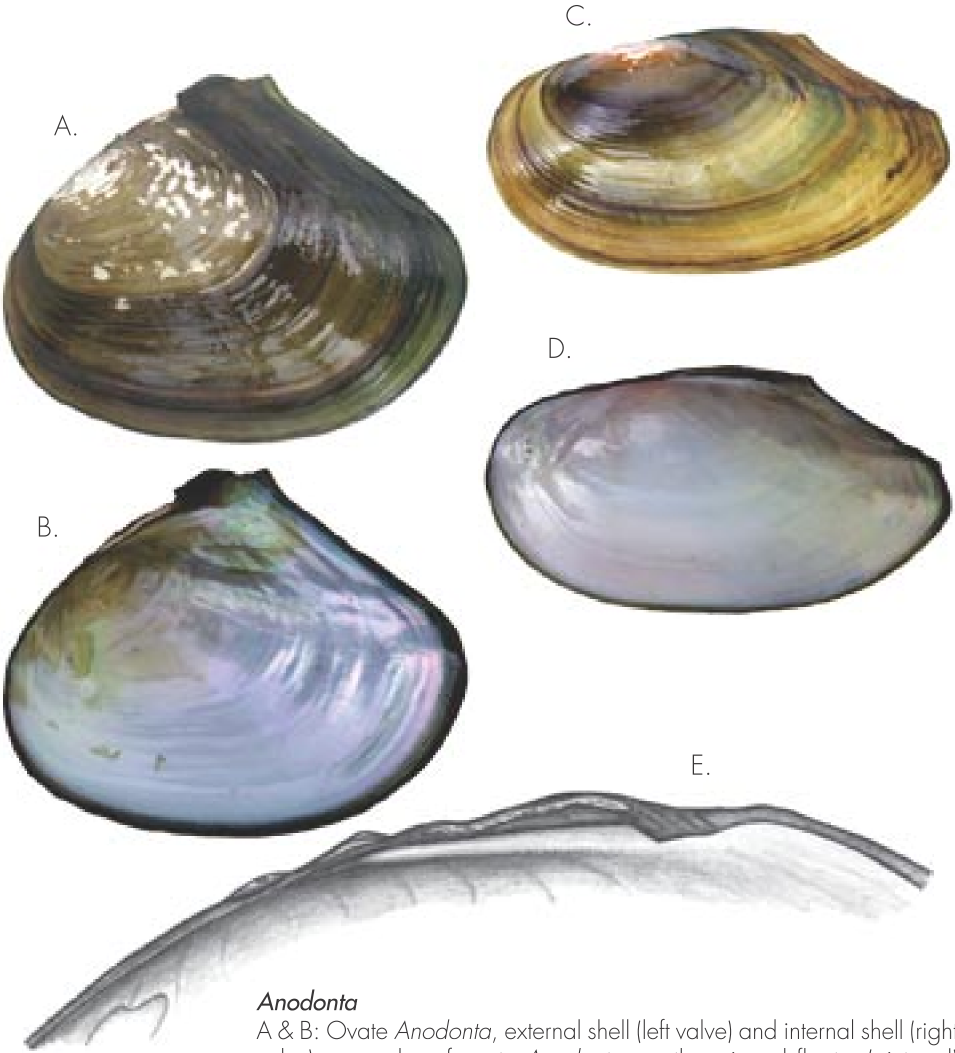
Anodonta Distribution

In western North America, the five endemic *Anodonta* are widely distributed from Baja California to the Yukon Territory and Alaska. Most are west of the Continental Divide, though the western floater is found east of the divide in northern Saskatchewan and Alberta. The Yukon floater is found on the Aleutian Islands and into Kamchatka in eastern Asia. Most species do not make it into the high elevation watersheds of the Cascades or Rockies and are confined to low elevation watersheds. Thus, they are scarce in Montana and western Wyoming.

Anodonta Life History

Anodonta are short-lived, fast growing mussels that are considered generalists in terms of their reproductive requirements. They are usually long-term brooders; fertilization usually occurs in late summer or early fall, embryos develop during the winter, and glochidia are released the following spring and summer. Glochidia are relatively large, with ventral hook-like projections on each valve that enables them to attach firmly to the fins or gills of host fish. *Anodonta* are usually not highly host specific; they may be able to use several fish species. Glochidia remain attached to a fish for several weeks (depending on species and water temperature) before excysting, dropping to the bottom, and burrowing into the sediment.

Anodonta grow fast, often reaching sexual maturity within four to five years. Growth rate depends on the productivity of their environment and water temperature. *Anodonta* grow very fast in stable, nutrient-rich water bodies such as lakes. *Anodonta* have one of the shortest life spans of all freshwater mussels, often only living ten to fifteen years. They have very thin



Anodonta

A & B: Ovate *Anodonta*, external shell (left valve) and internal shell (right valve); examples of ovate *Anodonta* are the winged floater (pictured) and California floater

C & D: Elliptical *Anodonta*, external shell (left valve) and internal shell (right valve); examples of elliptical *Anodonta* are the Oregon floater (pictured), Western floater, and Yukon floater

E: *Anodonta* hinge without lateral or pseudocardinal teeth

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shells compared to most freshwater mussels. Their thin shells are vulnerable to damage from erosion and predators. Because their shells are easy to crush and pry open, predators—such as muskrats, otters, and raccoons—prefer them to other mussels. During drought periods or low tides in freshwater tidal areas, predators probably take a large portion of the *Anodonta* populations in shallow sloughs.

Anodonta and *Gonidea* situated in the substrate. photo: CTUIR Freshwater Mussel Project

Anodonta Habitat

Anodonta are considered habitat generalists and are more tolerant of lentic (lake-like) conditions than most other freshwater mussels. *Anodonta* inhabit natural lakes, reservoirs, and downstream, low-gradient reaches of rivers in depositional habitats. Three *Anodonta* species can be found together in sloughs along the lower Columbia and Willamette Rivers. In the Portland area, even degraded urban habitats often support one or more of these species.

The common name “floater” has been given to all North American species of *Anodonta*. All species have thin fragile shells compared to most other native mussels, enabling them to inhabit silt because they can “float” on semi-liquid substrates. A second origin of the descriptor “floater” is more morbid—these species can thrive in small nutrient-rich waterbodies that are subject to oxygen and temperature stress in the summer. Mussel die-offs can occur during stressful periods, and the build-up of gases in the shell cavity of decaying animals may “float” the light shells to the water’s surface.

Anodonta are more tolerant of low-oxygen than most species and can thrive in small nutrient-rich waterbodies such as permanently flooded marshes, oxbow lakes, and farm ponds. Their thin shells and inflated shape allows them to inhabit silt found in the deeper areas of lakes and reservoirs. Small rocky streams, favored by other western species such as western pearlshells and western ridged mussels, are difficult environments for *Anodonta* because their thin shells are prone to damage in such habitats. Sandbars near the mouths of tributary streams or below riffles are important habitats.

Anodonta are particularly vulnerable to water-level fluctuations. Dry periods and reservoir drawdowns usually expose animals. As water levels recede, you can usually see trails that *Anodonta* create in the sediment as they move toward deeper water. Few make it to deeper water—most will burrow into the sediment and die if water levels do not quickly return to normal before the mussels desiccate and overheat. Marauding birds and mammals will eat many that remain exposed.

Anodonta Conservation

It is difficult to assess rarity of individual species because the taxonomy of *Anodonta* is still unresolved. In general, *Anodonta* have declined dramatically in parts of western North America. Populations have been extirpated from many historic sites, especially in Arizona, Utah, California, Oregon, and Washington. Populations are more stable in northern areas where human influence is minimal; for example, the Yukon floater is thriving throughout most of its range in Canada and Alaska. The California floater is the species of greatest concern in the West.

The main threat to western *Anodonta* is water diversion for irrigation, water supply, and power generation. Water extraction to supply expanding human populations and agricultural demands lowered groundwater tables and caused chronic low flows in many rivers. Dams have greatly altered natural habitat and fish communities in most rivers. Although *Anodonta* can tolerate impoundments and thrive in reservoirs (unlike *Margaritifera* or *Gonidea*), many reservoirs experience severe annual water-level fluctuations that greatly reduce the standing crop of mussels in shallow water. A drawdown of the Lower Granite Reservoir on the lower Snake River in 1992 killed many California floaters, Western floaters, and Western ridged mussels.

Anodonta usually live in depositional habitats in downstream reaches of watersheds, where chemical and organic pollution from the watershed accumulates. Industrial wastes, oil and chemical spills, and urban runoff deliver enormous amounts of harmful materials into the water. Excessive turbidity, low dissolved oxygen, and toxic contaminants likely have a strong negative effect on mussel health. Dredging, shipping, and gravel removal also affect mussels.

Nonnative species are prevalent in California floater habitat. Nearly two-dozen nonnative fish exist in some watersheds; these fish may affect the distribution or abundance of native fish hosts, or consume mussels directly (such as the carp). Unfortunately, we do not know the host fish of most western *Anodonta*, so the best conservation strategy is to protect healthy native fish communities. The introduced Asian clam (*Corbicula fluminea*) is found in many Pacific drainages and may compete with native mussels for food or space.

The John Day River is home to the California floater. photo: Dennis Frates

California Floater

Anodonta californiensis Lea, 1852

Description

Size: Up to five inches.

Shape: Elliptical or ovate; L:H ratio usually less than 1.5. Laterally inflated. Valves slightly compressed toward the posterior dorsal margin, broad, and raised to form a "wing". Valves are thin and fragile.

Beaks: Small; scarcely elevated above the hinge line.

Periostracum: Color olive, pale brown, reddish brown, or black. There are greenish rays on the posterior slope. The periostracum is smooth and growth lines are prominent.

Hinge Teeth: None

Nacre: Usually white, but sometimes with a flesh-colored or purplish tint.

Distribution

The native range of the California floater extended from Baja California to southern British Columbia, and east to western Wyoming, eastern Arizona, and Chihuahua (Mexico). It was originally widespread in California, but its distribution is now greatly reduced. It was once distributed throughout six major drainages in Arizona, but today only remnant populations are thought to exist in portions of the Black River drainage and Little Colorado River. In

California floater
A. External shell (left valve)
B. Internal shell (right valve)

Washington, recent records are mainly from the Columbia and Okanogan Rivers and some ponds adjacent to the Columbia River.

Life History and Habitat

The California floater reaches maturity within four to five years and has a short life span of ten to fifteen years. The full range of host fish are not known, but they may parasitize native minnows as well as the nonnative mosquito fish. The California floater exists in shallow muddy or sandy habitats in larger rivers, reservoirs, and lakes.

Conservation

The California floater is a federal species of concern. Most natural populations in California have been extirpated, particularly in southern California and most of the Central Valley. It may be nearly extirpated from Arizona, and it is a candidate for protection in Washington.

The main reasons for its decline are thought to be water diversion for irrigation, water supply, and power generation. The California floater thrives in reservoirs, but many reservoirs experience severe annual water-level fluctuations that decimate the standing crop of mussels in shallow water. Nonnative species may compete with their host fish, eat young mussels (e.g., common carp), or compete with mussels for food and space (Asian clams).

Winged floaters inhabit sloughs of the lower Columbia River. photo: Allan Smith

Winged Floater

Anodonta nuttalliana Lea, 1838

Description

Size: Up to 4.25 inches. Smaller than other western *Anodonta*.
Shape: Elliptical or ovate; L:H ratio usually 1.5 or less. Dorsal posterior margin compressed and raised into a high prominent wing. Wing less conspicuous in some individuals. Valves slightly inflated, though compressed in some individuals. Valves very thin.
Beaks: Flattened, usually not raised above the hinge line. Beak sculpture with up to 20 irregular single or double-looped concentric ridges.
Periostracum: Yellowish-green, yellowish-brown, or brown. Growth lines sometimes prominent.
Hinge Teeth: None
Nacre: White or bluish.

Distribution

The winged floater is the least common western *Anodonta*, confined to California, Oregon, Washington, and southern British Columbia. There were several historical records for Utah. Unfortunately, historical data are difficult to assess because people often included this species under other species names. For example, specimens with a low dorsal wing can be nearly indistinguish-

Winged floater
A. External shell (left valve)
B. Internal shell (right valve)

able from California floaters. Without good voucher specimens, historical records are of limited use for understanding species distribution.

Life History and Habitat

The winged floater inhabits rivers and lakes in muddy or sandy bottoms, especially in low gradient, low elevation areas of coastal watersheds. They are probably long-term brooders, because gravid females have been observed in October. The host fish species are unknown.

Conservation

The current range and taxonomic standing of the winged floater is not well understood. It is likely affected by the same factors that affect other western *Anodonta*, including water diversion, dams, pollution, and invasive species.

Oregon floaters can be found in Upper Klamath Lake. photo: Dennis Frates

Oregon Floater

Anodonta oregonensis Lea 1838

Description

Size: Up to 7.25 inches.
Shape: Elliptical; L:H ratio close to, or exceeding, 2. Dorsal posterior margin compressed and formed into slight wing. Valves laterally inflated, particularly over the median portion of the valves. Valves thin and fragile.
Beaks: Low; do not project above the hinge line.
Periostracum: Light brown (juveniles) to dark brown; smooth and shiny. Growth lines usually evident.
Hinge Teeth: None
Nacre: White

Distribution

Originally, the Oregon floater ranged from California to Alaska and east to Nevada and Utah. However, many museum specimens examined from northern areas labeled as Oregon floaters turned out to be Yukon floaters. In a monograph on Canadian freshwater mollusks, Oregon floaters were not included as a separate species but rather a synonym of winged floaters, with a northern limit of southern British Columbia. The taxonomic standing of this species remains questionable. Specimens identified as Oregon floaters have

Oregon floater
A. External shell (left valve)
B. Internal shell (right valve)

recently been collected in parts of the Willamette and Columbia Rivers.

Life History and Habitat

The Oregon floater inhabits low gradient and low elevation rivers, lakes, and reservoirs. They prefer shallow water in mud, sand, or fine gravel. They often share habitat with California floaters. Like other *Anodonta*, they are likely long-term brooders that breed in late summer and spawn in the spring. Coho salmon are known hosts (Moles, 1983).

Conservation

The current range of the Oregon floater is not well understood, much less its taxonomic standing. It is likely affected by the same factors that affect other western *Anodonta*, including water diversion, dams, pollution, and invasive species.

Kachess Lake in Washington is home to Western floaters. photo: Molly Hallock, WDF&W

Western Floater

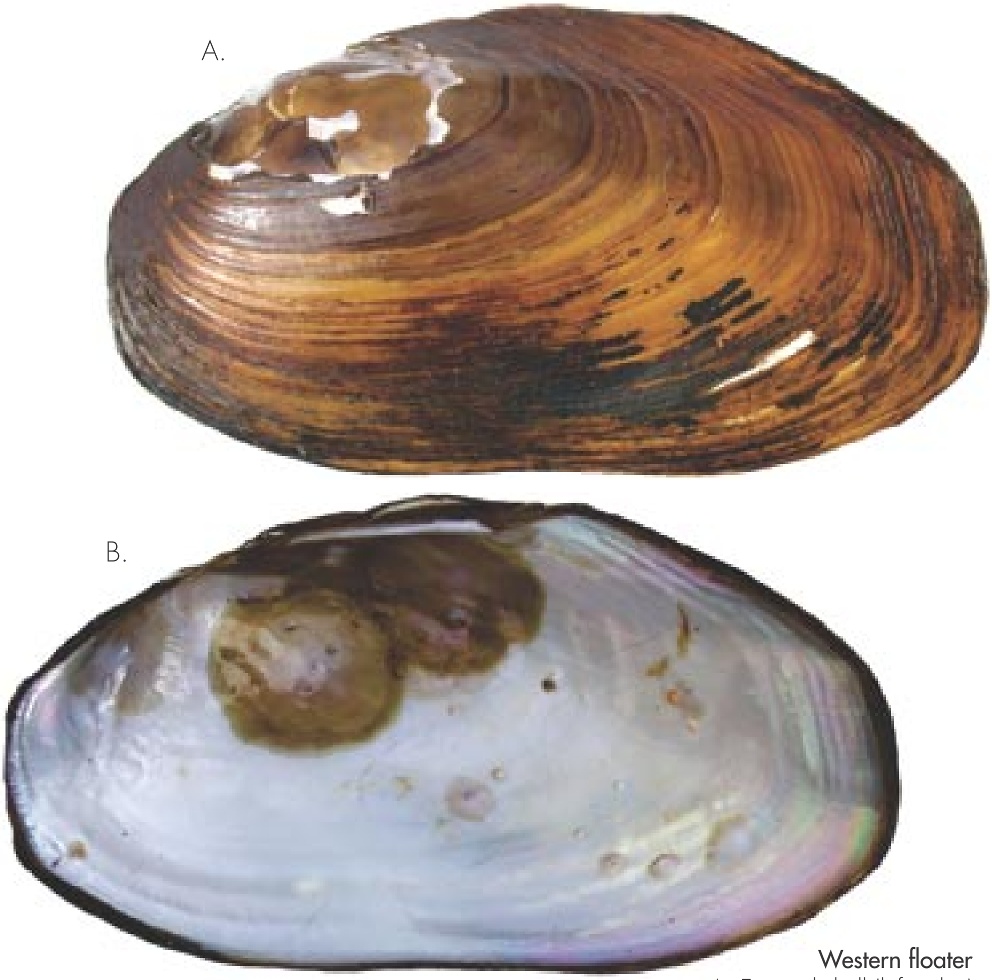
Anodonta kennerlyi Lea, 1860

Description

Size: Up to 4.75 inches.
Shape: Elliptical or elongate; L:H ratio near or exceeding 2. Rounded anterior and bluntly pointed posterior. Valves laterally inflated. The dorsal posterior wing is absent or only slightly elevated and truncate. Valves thin and fragile.
Beaks: Low and flat, scarcely projecting above the hinge line. Beak sculpture with about 15 concentric irregular ridges.
Periostracum: Yellowish, yellowish-brown, or brown, with a tinge of green in some specimens. They often have prominent brown growth lines. Periostracum is shiny, but sometimes rough from growth lines.
Hinge Teeth: None
Nacre: White or bluish-white, with some pink toward the central portion of the nacre, and sometimes iridescent toward the posterior end.

Distribution

The western floater is a more northern species found in watersheds of Oregon, Washington, British Columbia, Alberta, and northern Saskatchewan. It is found in the Peace River in British Columbia, part of the Arctic watershed. It is also found on coastal islands in British Columbia.



Western floater
A. External shell (left valve)
B. Internal shell (right valve)

Life History and Habitat

The western floater inhabits muddy or sandy habitats in rivers and lakes, particularly in mid- to high elevation watersheds. Nothing is known about its reproductive biology or host fish. It can reach high densities in places.

Conservation

Since the western floater is distributed in less-disturbed northern areas, it has not experienced the full range of stressors experienced by more southern and coastal *Anodonta*. It remains common and abundant in northern parts of its range. Land use, water diversion, pollution, and dams may affect populations in the Columbia River in Washington.

The Yukon floater is found in lakes and rivers of northwestern Canada and Alaska.

Yukon Floater

Anodonta beringiana Middendorff, 1851

Description

Size: Up to 8.25 inches.
Shape: Elliptical or elongate; L:H ratio near 2. Posterior narrowly rounded. Laterally inflated over the anterior half of the shell. Valves thin but relatively strong. No wings on the dorsal posterior slope.
Beaks: Inflated and raised above the hinge line. Beak sculpture consists of a series of straight, irregular bars parallel to the hinge line.
Periostracum: Olive-green (juveniles) to nearly black in old individuals. Surface rough from growth lines.
Hinge Teeth: None
Nacre: Lead-color to dull blue.

Distribution

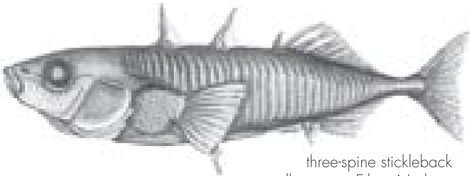
The Yukon Floater is a northern species of the Yukon Territory, Alaska, Aleutian Islands, and Kamchatka in eastern Asia.

Life History and Habitat

The Yukon floater inhabits lakes and rivers in sand and gravel substrates. It is often very abundant, providing a staple food source for otter and muskrat.

Yukon floater
A. External shell (left valve)
B. Internal shell (right valve)

Host fish include sockeye salmon, Chinook salmon, and three-spined stickleback.



three-spine stickleback
illustration: Ethan Nedeau

Conservation

The Yukon floater is probably the most stable of western *Anodonta* because of its northern distribution, with little human disturbance in its range.

Small wooded creeks often have abundant populations of western pearlshells. photo: Danielle Warner

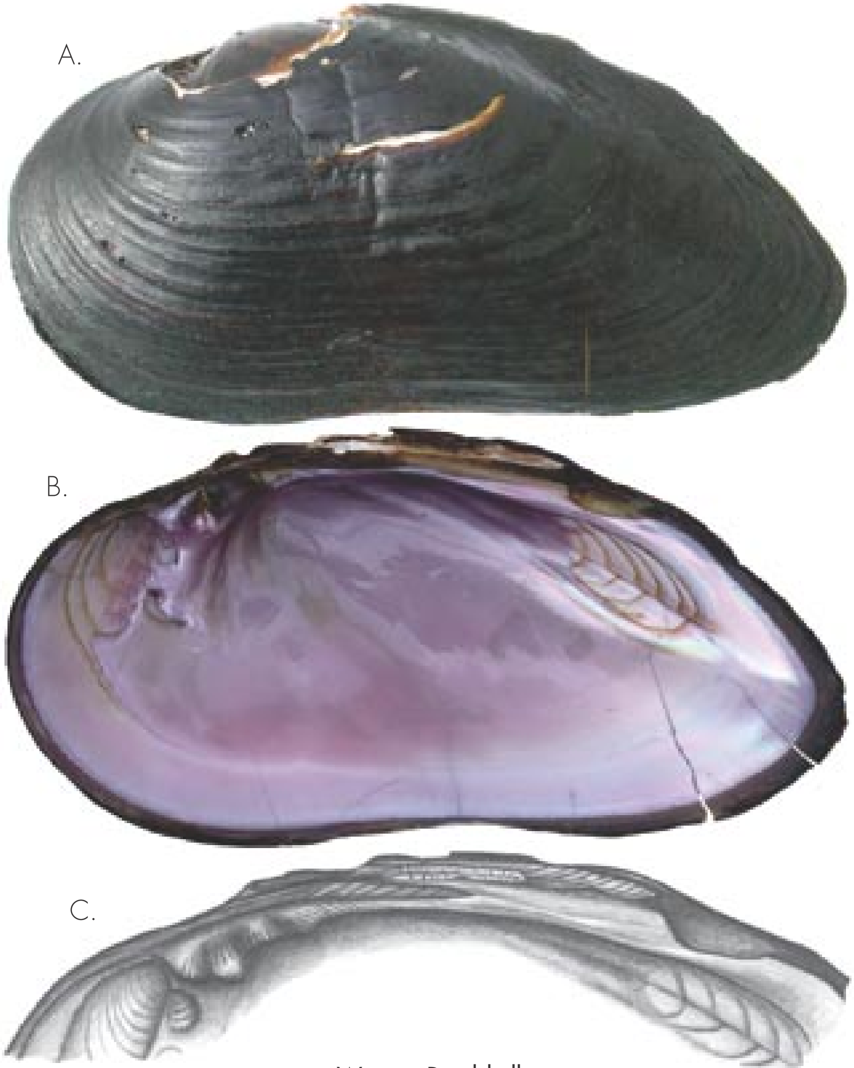
Western Pearlshell

Margaritifera falcata (Gould, 1850)

The western pearlshell is a species of cold clean creeks and rivers where sea-run salmon spawn or native trout reside. Decimated in the mainstem of some of the West's great rivers and coastal streams, they fare better in the highlands, far from dams, agriculture, and cities. They can disperse far into the headwaters, as far as trout will take them, and are even thought to have crossed the Continental Divide during the last glacial period on the gills of west-slope cutthroat trout. With a maximum lifespan exceeding one hundred years, they have experienced the effects of water resource management in the West more than any species; some individuals that are alive today were in the same spot years before the Grand Coulee Dam was built! This is the most common species in the Pacific Northwest, and though they were once present in most coastal watersheds, they are becoming scarcer in urbanized areas. They will be sentinels of aquatic ecosystem health in the West for generations to come.

Description

Size: Up to five inches
Shape: Elongate, with a broadly curved dorsal margin and slightly concave ventral margin.
Periostracum: Light brown (juveniles) to dark brown or black. No shell rays,



Western Pearlshell
A. External shell (left valve) B. Internal shell (right valve) C. Hinge (right valve)

but growth lines are prominent and heavy.
Lateral Teeth: One poorly defined lateral tooth on each valve, though these are sometimes hard to distinguish.
Pseudocardinal Teeth: Right valve has one triangular-shaped tooth that is slightly down-turned. Left valve has two triangular-shaped teeth; the posterior tooth is larger with a ragged edge, and the anterior tooth is smaller and sometimes indistinguishable.
Nacre: Usually purple, salmon-colored, or pink (sometimes white). Nacre color fades to white over time. Anterior adductor muscle scar is sharply defined, whereas the posterior adductor muscle scar is less defined. Tiny faint pits are sometimes evident on the central part of the nacre.

Distribution

The western pearlshell is found in Pacific drainages from California to British Columbia and southern Alaska. Many coastal and large-river populations are extirpated. Although the species' geographic range is shrinking, it remains common throughout parts of the northern Rockies. It is also found east of the Continental Divide in the headwaters of the Missouri River. Originally, these populations were thought to be the eastern pearlshell but recently scientists have confirmed that the populations are western pearlshells and that the species crossed the divide. The most likely explanation for this distribution is headwater capture, where pre-glacial watersheds were cut and reconfigured by glacial advance or retreat. West-slope cutthroat trout are thought to have crossed the Continental Divide from the West into the headwaters of the present-day Missouri River during the Pleistocene glaciation, over 20,000 years ago. Since cutthroat trout are an important host for western pearlshells, it is likely that mussels hitched a ride on the trout.

Life History

Western pearlshells are one of four North American species that may be hermaphrodites, meaning that individuals may have both male and female reproductive traits. However, this condition is rare in western pearlshells, and most populations of this species have separate sexes. Fertilization occurs in the early spring and females are usually gravid between May and early July before releasing glochidia, depending on water temperature. Host fish include native cutthroat trout, rainbow trout, Chinook salmon, Coho salmon, Sockeye salmon, speckled dace, Lahontan redside, Tahoe sucker, and nonnative brook trout and brown trout. The mussels become sexually mature at nine to twelve years, depending on size and rate of growth. Average life spans are sixty to seventy years, with some capable of living over one hundred years, making these one of the longest-lived animal species on Earth.

Habitat

Western pearlshells prefer cold clean creeks and rivers that support salmonid populations. They can inhabit headwater streams less than a few feet wide, but are more common in larger rivers. This species can even be found in some irrigation ditches in Oregon.

Sand, gravel, and cobble are preferred substrates, especially in stable areas of the streambed. Large boulders help create these stable environments by anchoring the substrate and creating a refuge from strong currents on their downstream side. Banks are often favorable habitats because the current is slack and the substrates are more stable. Scientists in Idaho found that when these mussels were covered with a substantial amount of fine sediment, they were

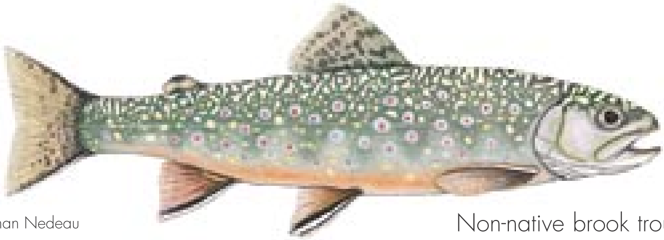


illustration: Ethan Nedeau

Non-native brook trout may compete with native cutthroat trout, but are also hosts for western pearlshells.

unable to move to the surface and perished. In environments where host fish are abundant and human threats are minimal, western pearlshells can attain very high densities (>300 per square yard), often carpeting the stream bottom.

Conservation

Recent conservation concerns about western pearlshells closely mirror well-known stories of the loss and decline of Pacific salmon fisheries. Both need clean cold streams and rivers, and western pearlshells need salmon and trout to reproduce. The greatest threats to western pearlshells come from water diversion projects for irrigation, power generation, and water supply, particularly in Washington, Oregon, Idaho, and California. Dams destroyed many miles of free-flowing rivers, disrupted native fish communities, and caused the demise of many populations of western pearlshells. Agriculture and rapid urbanization are affecting aquatic ecosystems throughout the West through nutrient enrichment, siltation, and chemical pollution.

Invasive species that compete with native fish may affect western pearlshells. In some locations where western pearlshells are still abundant, native cutthroat trout are being replaced by nonnative rainbow, brown, and brook trout. The long-term effects of extirpating the primary host fish on a native mussel, albeit with a species that may also serve as a host, is unknown. Native fish hosts—that mussels have coevolved with—might be better hosts than nonnative species because they are better adapted to local environmental conditions and their populations may be more stable in the long-term. Also, the mussel may have evolved specializations for unique traits of its native host fish such as habitat use, behavior, and immune responses to parasitism.

The western pearlshell is extirpated throughout much of the mainstem Snake River and Columbia River of Oregon and Washington, and remnant populations often show few signs of recent reproduction. Many historic sites have been lost, not all populations show evidence of recruitment, and the fate of this species throughout much of its native range remains uncertain.

The Crooked River is home to populations of western ridged mussels. photo: Dennis Frates

Western Ridged Mussel

Gonidea angulata (Lea, 1838)

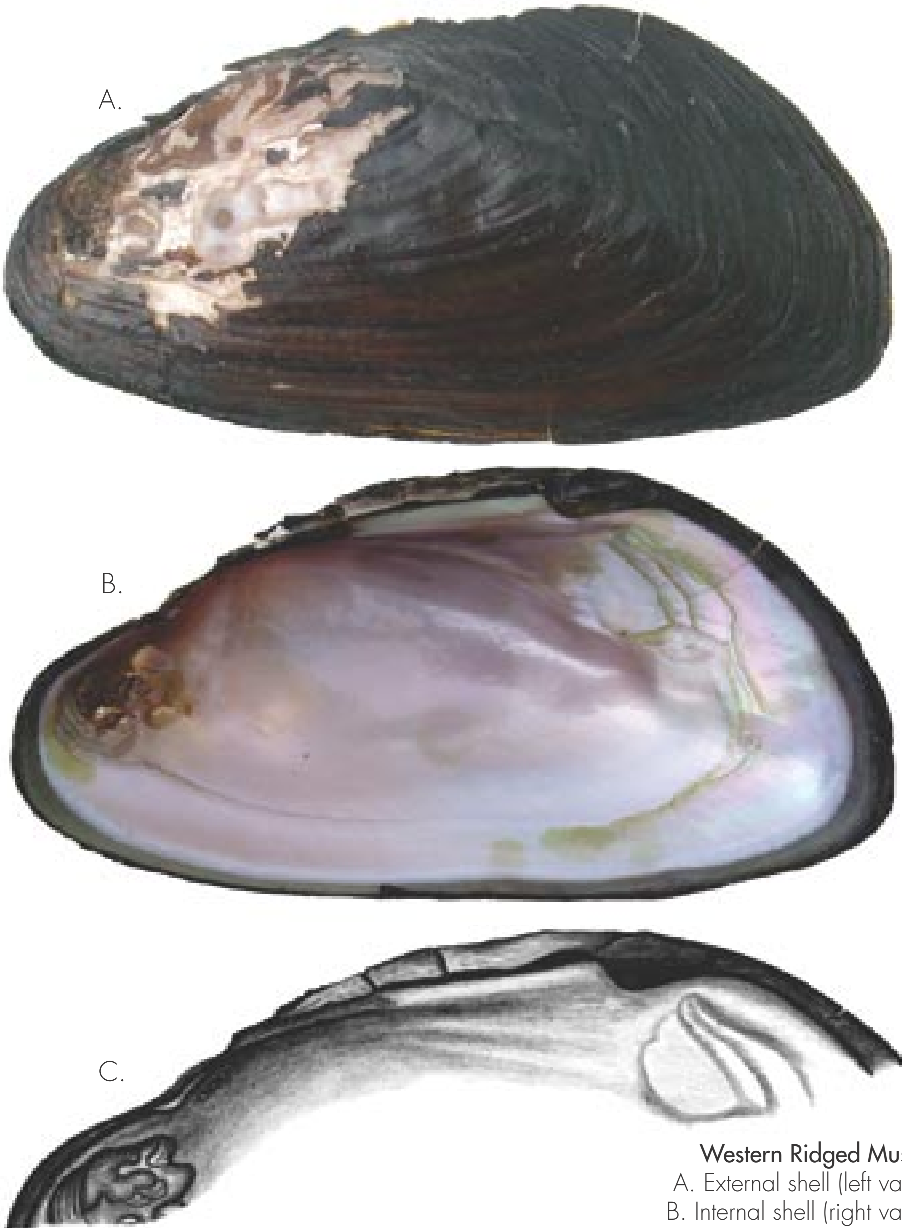
Also known as the Rocky Mountain ridged russel, this species is widely distributed west of the Continental Divide from California to British Columbia. It's ridged shell makes it unmistakable among the West's native freshwater mussels. It shares habitat with western pearlshells throughout much of its range, in cold clean creeks and rivers. Unfortunately, little is known about the ecology of this species, especially fish hosts and reproduction. It has been extirpated from parts of its native range, but without a good understanding of its ecology, scientists do not fully understand why. Efforts to protect river corridors, maintain river flows, reduce pollution, and promote native biodiversity will likely have a lasting positive effect on this species.

Description

Size: Up to five inches

Shape: Obovate to trapezoidal. Slightly laterally compressed. The shell has an angular ridge that runs from the beak to the basal part of the posterior margin; this ridge may be less angular in specimens living in slow-moving water. The ventral margin is usually straight. The shell is heavier than that of all other native species.

Periostracum: Color yellowish-brown to brown or black. No shell rays or



Western Ridged Mussel
A. External shell (left valve)
B. Internal shell (right valve)
C. Hinge (right valve)

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sculpturing on the shell.
Lateral Teeth: Absent.
Pseudocardinal Teeth: The right valve has one small tooth and the left valve has either one small tooth or none at all. The teeth are small and compressed, sometimes hard to distinguish.
Nacre: Usually white, but sometimes salmon-colored in fresh specimens and pale blue toward the posterior margin and beak cavity.

Distribution

Western ridged mussels inhabit Pacific drainages from southern California to southern British Columbia. They are found east to Idaho and Nevada, and in the northern part of their range are mainly distributed east of the Cascades. They have a limited distribution west of the Cascades in Oregon and Washington. There are historical records in the upper Columbia River watershed in western Montana, perhaps the Clark Fork River or Kootenai River, but these have not been confirmed recently. Its stronghold is large tributaries of the Snake River and Columbia River in Washington, Idaho, and Oregon.

Life History

Little is known about the life history of this species. Fish hosts are unknown, but its habitat preference suggests that it parasitizes coldwater stream fish such as trout and salmon. It is a relatively slow-growing, long-lived species.

Habitat

Western ridged mussels occur in streams of all sizes and are rarely found in lakes or reservoirs. They are found mainly in low to mid-elevation watersheds, and do not often inhabit high elevation headwater streams where western pearlshells can be found. They often share habitat with the western pearlshell throughout much of the Pacific Northwest. They are more tolerant of fine sediments than western pearlshells and occupy depositional habitats and banks. They can withstand moderate amounts of sedimentation, but are usually absent from habitats with unstable or very soft substrates.

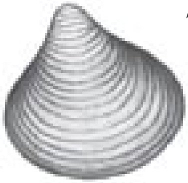
Conservation

Western ridged mussels have been extirpated throughout their original range in California, particularly in southern California and the Central Valley. They have also been extirpated from many sites in the Snake and Columbia watersheds. Elsewhere, they are thought to be declining, mainly because the perceived environmental threats to this species are universal throughout its range. However, the magnitude and geographic extent of the declines are unknown.

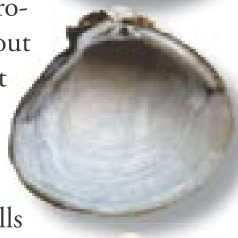
Lack of information on life history, reproduction, and ecology of western ridged mussels will hinder effective conservation and management. For now, the only measures are to protect the ecosystems where they live.

INTRODUCED BIVALVES

Asian Clam
Corbicula fluminea (Müller, 1774)



The Asian clam is a small bivalve, usually less than one inch long, which resembles a small marine clam. The beak is centrally located on the dorsal margin and there are lateral teeth on both sides of the beak. The beak is high, giving Asian clams a triangular or acutely oval shape. The serrated lateral teeth are a very distinct character for identifying Asian clams. They are usually yellowish, light to dark brown, or black, depending on age and environmental conditions. Growth ridges on the outer shell are prominent.



The Asian clam is native to Southeast Asia and was introduced to North America in the early 1900s. It spread throughout southern parts of North America and became very abundant in some locations. In the Pacific Northwest, Asian clams are often the most numerous bivalve in some waterbodies, especially in shallow water. In some places in the lower Columbia River, hundreds of thousands of Asian clam shells litter the shoreline. It is tolerant of a variety of environmental conditions, and seems to prefer medium to large rivers in sand or gravel substrates. Water temperatures below 35-37°F are considered lethal, and its presence in cold northern waters is usually the result of thermal pollution, such as industrial cooling water. They may compete with native mussels for food, consume larval or juvenile mussels, or affect cycling of nutrients. It has the reproductive advantage of not requiring a host fish.

Zebra Mussel
Dreissena polymorpha (Pallas, 1771)

Zebra mussels are native to the Caspian and Black Sea region of Eastern Europe. They were accidentally introduced to the Great Lakes and St. Lawrence River in North America in the late 1980s, arriving in ballast water of trans-Atlantic freighter ships. The species quickly spread throughout the Great Lakes and Mississippi River drainage, and within a decade its range spanned much of the eastern two-thirds of the United States. To date, zebra mussels have not been intro-

Zebra mussels
photo: U.S. Geological Survey

duced into waters west of the Continental Divide. Please contact your local natural resource agency if you think that you have found zebra mussels.

Zebra mussels are one of the most destructive nonnative aquatic species ever to reach the North American continent. They have economic consequences for water-dependent industries, boating, and fishing. They clog intake pipes and cover boat hulls, docks, piers, and virtually any other underwater structure. Zebra mussels also have dramatic effects on aquatic ecosystems because of their enormous biomass, filtering ability, and effect on native species. They have great reproductive and colonization capabilities, having free-swimming larvae and not requiring host fish to complete their life cycle. Densities are reported to be as high as 750,000 per square yard, and the cumulative filtering capacity of billions of zebra mussels has profound effects on water clarity, nutrient cycling, and food webs. In Lake St. Clair in the Great Lakes region, once zebra mussels reached maximum densities of more than 5,000 per square yard, they filtered the entire volume of the lake 1-2 times daily! Native freshwater mussels have been particularly hard-hit because zebra mussels attach to their shells, smother them, inhibit feeding, and restrict mobility. Zebra mussels may ultimately be responsible for the extirpation of dozens of native mussel species throughout North America.

Humans are responsible for spreading zebra mussels within watersheds and into new watersheds. Adult and juvenile zebra mussels may attach to boat hulls or to vegetation that gets entwined in boat propellers or trailers. Boats transported from infected waterbodies may spread zebra mussels into new waterbodies if the boat and trailer are not properly cleaned. Bilge water, live wells, and bait buckets are other means of introduction. In June 2004, a westbound trailer carrying a boat infected with live zebra mussels was stopped at a truck weigh station near the Washington-Idaho border. The boat was ordered sterilized, but the event was an important reminder of how easily this destructive species could be transported to Pacific drainages.

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Web Sites

Pacific Northwest Native Freshwater Mussel Workgroup
www.fws.gov/pacific/columbiariver/musselwg.htm

Freshwater Mollusc Conservation Society
http://ellipse.inhs.uiuc.edu/FMCS/

Mollusk Bibliography Database
http://ellipse.inhs.uiuc.edu:591/mollusk/biblio.html