Aquatic snails of the Snake and Green River Basins of Wyoming

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Abstract
Freshwater snails are a diverse group of mollusks that live in a variety of aquatic ecosystems. Many snail species are of conservation concern around the globe. About 37-39 species of aquatic snails likely live in Wyoming. The current study surveyed the Snake and Green River basins in Wyoming and identified 22 species and possibly discovered a new operculate snail. We surveyed streams, wetlands, lakes and springs throughout the basins at randomly selected locations. We measured habitat characteristics and basic water quality at each site. Snails were usually most abundant in ecosystems with higher standing stocks of algae, on solid substrate (e.g., wood or aquatic vegetation) and in habitats with slower water velocity (e.g., backwater and margins of streams). We created an aquatic snail key for identifying species in Wyoming. The key is a work in progress that will be continually updated to reflect changes in taxonomy and new knowledge. We hope the snail key will be used throughout the state to unify snail identification and create better data on Wyoming snails.

Introduction
Freshwater mollusks are a diverse group of animals that are declining worldwide (Lydeard et al. 2004). Mollusks are composed to two main groups: bivalves (e.g., mussels and clams) and gastropods (e.g., snails and limpets). About 99% of animal species on earth are invertebrates (Ponder and Lunney 1999), yet far less is known about spineless creatures. About 7000 species of freshwater mollusks are described and perhaps again that many freshwater mollusks are undescribed in the world (Lydeard et al. 2004). Freshwater mollusks are listed as the animal group in most need of conservation because of their declines. For example, 10% of the described species of freshwater mollusks were listed on the ICUN Red list and 37.5% of recorded animal extinctions have been gastropods.

Knowledge of freshwater mollusks in Wyoming has grown in recent years. Beetle (1989) published a paper listing the mollusks occurring in Wyoming. Dorothy Beetle accumulated a lot of knowledge about mollusks in Wyoming, but the information is usually at the county- or state-level. Little aquatic snail work was done until Narr (2011) collected 16 species or species groups of aquatic snails in the North Platte and Bighorn Basins of Wyoming for her thesis work 20 years later. Our currently study surveyed aquatic snails in the Green and Snake River Basins of Wyoming to expand our knowledge of these mollusks in Wyoming. Our goal was to describe the distribution and habitat associations of aquatic snails. Our specific goals were: 1.) To develop a list and synonymies of aquatic snail taxa that inhabit Wyoming, 2.) Develop a key to identify aquatic snails in Wyoming, 3.) Survey a variety of aquatic habitats for aquatic snails and 4.) Collect habitat information to learn about where each snail species lives. Several aquatic snails are of conservation concern and understanding their distribution and status in the state will help manage these mollusks.

Study Area
We collected snails in aquatic ecosystems in the Green and Snake River basins of western Wyoming. The Snake River is a tributary of the Columbia River basin and has an area of 281,000 km^2 in Idaho, Washington, Oregon, Nevada and Wyoming (Stanford et al. 2005). The river drops 3048 m from the headwaters in the Teton Mountains to flowing into the Columbia River. Annual precipitation in the basin averages 36 cm and the river flows through temperate mountain forest and desert biomes. Landuse is dominated by scrub and rangeland (50%), agriculture (30%) and forest (10-15%). In Wyoming, the Snake River is a popular fisheries and flows from its headwaters in and around Grand Teton National Park south through the valley near Jackson, Wyoming and west to Idaho. The Salt and Grey Rivers are major tributaries that flow into the Snake River near Alpine, Wyoming.

The Green River is part of the Colorado River basin and has an area of 116,200 km^2 in Wyoming, Utah, Colorado, Nevada, Arizona, New Mexico, California and Mexico (Blinn and Poff 2005). The river drops 2950 m from the headwaters to flowing into the Colorado River at Canyonlands National Park. Annual precipitation in the basin averages 31.9 cm and the river flows through temperate mountain forest and desert biomes. Landuse is dominated by agriculture (80%) and forest (15%). In Wyoming, the Green River originates in the Wyoming, Gros Ventre and Wind River ranges and flows south. The headwaters of the Green River are northeast of Pinedale, Wyoming where glacial fjord lakes were formed. Two major reservoirs are on the mainstem of the Green River in Wyoming: Fontenelle and Flaming Gorge Reservoirs. Several major tributaries flow into the Green River in Wyoming, including the Ham's Fork, Big Sandy and Black's Fork Rivers.

Methods
We sampled snails in a variety of aquatic habitats (ponds, lakes, streams, rivers, springs, and wetlands) in the Snake and Green River basins of Wyoming. Snails were preserved in ~75% ethanol and identified in the laboratory using a key developed by Rob Dillon and Lusha Tronstad for Wyoming (Appendix 1).

We sampled each basin to deliberately collect a high diversity of snail taxa. Using GIS, we stratified each basin into watersheds (HUC 10) and five aquatic habitat types (large streams, small streams, palustrine, lacustrine and springs). Stream Strahler order was estimated based on the National Hydrography dataset. Large streams were lotic ecosystem with a stream order of 3 or higher. Small streams were stream order 1 or 2. Lentic ecosystems where divided into palustrine and lacustrine using the National Wetlands Inventory dataset. Palustrine ecosystems are wetlands that are <8 ha in surface area and >30% vegetated cover. Lacustrine ecosystems are lakes that are >8 ha in surface area and < 30% vegetated cover. We sampled springs whenever we encountered them. We randomly selected four locations of each type in each HUC 10 watershed using GIS. One type of each aquatic ecosystem type was visited in as many watersheds as possible depending on conditions and access. Additionally, we selected sites in each basin to deliberately target particular taxa of conservation concern (i.e., species of greatest conservation concern; SGCN). We captured snails using a variety of techniques depending on the ecosystem. We primarily used dip nets and hand collecting to capture snails. We searched in different microhabitats by completing five 10 minute surveys at each site. We had crews in the Snake and Green River basins surveying ponds for amphibians and we asked them to collect snails. These collections did not estimate the abundance of snails at a site, but they did allow us to discover additional sites were snail species were living.

We recorded site conditions to describe areas where snails were living. We recorded the type of ecosystem we sampled (i.e., large or small stream, wetland, lake or spring) at each site. We documented the type of substrate snails were collected on as fine substrate (clay, sand or silt), gravel, cobble or wood. The type of vegetation was noted as submerged aquatic vegetation, emergent aquatic vegetation or algae (lacking vascular plants). The microhabitats we sampled during each 10 minute survey was recorded. In streams, we categorized microhabitats as main channel (usually riffles and runs), pools, stream margin, side channel and backwater habitats. In lakes and wetlands, we categorized microhabitats as aquatic vegetation (submerged and emergent vegetation, rushes, willows, or other plants growing out of the water), fine sediment, wood or rock. Springs were categorized as either standing or flowing water. We ranked the standing stock of algae from 1 (little visible algae) to 3 (very green). We recorded habitat features at each site, regardless of capture success. Snails with opercula were relaxed in water with methanol crystals before preserving in ethanol to aid identification. Samples were taken back to the lab where we identified specimens under dissecting and compound microscopes. At each site, we collected basic water quality (water temperature, dissolved oxygen, specific conductivity, pH, and oxidation-reduction potential) using a Yellow Springs Instrument Professional Plus where dissolved oxygen (DO) was calibrated daily and specific conductivity (SPC), pH and oxidation-reduction potential (ORP) was calibrated every 2-3 days. We calculated an estimate of abundance (catch per unit effort) based on the number of snails we collected divided by the time searched (snails/minute). Analyses and plots were done in R (R core development Team, 2017) using the plyr package (Wickham 2011).

Results

Through data collections in the literature, museums and reports, we found records for 55 species of aquatic snails in Wyoming. Rob Dillon, snail expert for North America, refined the list to 37-39 species in Wyoming based on his knowledge of snail taxonomy. Several species were lumped together and the synonymies are listed in Table 1.

Table 1. Snail taxonomy in Wyoming with synonymies. Valid names with a question mark indicate that the species has not been collected in Wyoming but they may occur in the state. An asterisk indicates the species is not native to Wyoming.

Family	**Valid Scientific Name**	**Former Names**
Acroloxidae	*Acroloxus coloradensis* (?)	*Acroloxus coloradensis*
Ancylidae	*Ferrissia fragilis*	*Ferrissia fragilis*
Ancylidae	*Ferrissia rivularis*	*Ferrissia rivularis*
Amnicolidae	*Amnicola limosa*	*Amnicola limosa*
Amnicolidae	*Colligyrus greggi*	*Colligyrus greggi*
Lithoglyphidae	*Fluminicola coloradoensis*	*Fluminicola coloradoensis*
Lithoglyphidae	*Fluminicola fuscus*	*Fluminicola coloradoensis*
Hydrobiidae	*Pyrgulopsis pilsbryana*	*Pyrgulopsis pilsbryana*
Hydrobiidae	*Pyrgulopsis robusta*	*Pyrgulopsis robusta*
Lymnaeidae	*Fisherola nuttalli* (?)	*Fisherola nuttalli*
Lymnaeidae	*Lymnaea auricularia**	*Radix auricularia*
Lymnaeidae	*Lymnaea bulimoides*	*Galba bulimoides*
Lymnaeidae	*Lymnaea caperata*	*Stagnicola caperata*
Lymnaeidae	*Lymnaea catascopium*	*Stagnicola apicina*
Lymnaeidae	*Lymnaea catascopium*	*Stagnicola bonnevillensis*
Lymnaeidae	*Lymnaea catascopium*	*Stagnicola catascopium*
Lymnaeidae	*Lymnaea catascopium*	*Stagnicola hinkleyi*
Lymnaeidae	*Lymnaea catascopium*	*Stagnicola montanensis*
Lymnaeidae	*Lymnaea columella*	*Pseudosuccinea columella*
Lymnaeidae	*Lymnaea elodes*	*Stagnicola elodes*
Lymnaeidae	*Lymnaea elodes*	*Stagnicola traski*
Lymnaeidae	*Lymnaea humilis*	*Galba dalli*
Lymnaeidae	*Lymnaea humilis*	*Galba modicella*
Lymnaeidae	*Lymnaea humilis*	*Galba obrussa*
Lymnaeidae	*Lymnaea humilis*	*Galba parva*
Lymnaeidae	*Lymnaea stagnalis*	*Lymnaea stagnalis*
Physidae	*Aplexa hypnorum*	*Aplexa elongata*
Physidae	*Physa acuta*	*Physa acuta*
Physidae	*Physa acuta*	*Physella mexicana*
Physidae	*Physa columbiana*	*Physella columbiana*
Physidae	*Physa gyrina*	*Physa ancillaria*
Physidae	*Physa gyrina*	*Physa gyrina*
Physidae	*Physa gyrina*	*Physa gyrina utahensis*
Physidae	*Physa gyrina*	*Physella cooperi*
Physidae	*Physa gyrina*	*Physella propinqua*
Physidae	*Physa jennessi*	*Physa megalochlamys*
Physidae	*Physa jennessi*	*Physa skinneri*
Physidae	*Physa spelunca*	*Physa spelunca*
Planorbidae	*Gyraulus circumstriatus*	*Gyraulus circumstriatus*

Family	Valid Scientific Name	Former Names
Planorbidae	*Gyraulus crista*	*Gyraulus crista*
Planorbidae	*Gyraulus parvus*	*Gyraulus parvus*
Planorbidae	*Helisoma anceps*	*Helisoma anceps*
Planorbidae	*Helisoma newberryi*	*Helisoma newberryi*
Planorbidae	*Helisoma trivolvis*	*Planorbella duryi*
Planorbidae	*Helisoma trivolvis*	*Planorbella scalaris*
Planorbidae	*Helisoma trivolvis*	*Planorbella subcrenata*
Planorbidae	*Helisoma trivolvis*	*Planorbella trivolvis*
Planorbidae	*Menetus opercularis*	*Menetus opercularis*
Planorbidae	*Planorbula campestris*	*Planorbula campestris*
Planorbidae	*Promenetus exacuous*	*Promenetus exacuous*
Planorbidae	*Promenetus umbilicatellus*	*Promenetus umbilicatellus*
Tateidae	*Potamopyrgus antipodarium**	*Potamopyrugus antipodarium*
Thiaridae	*Melanoides tuberculate**	*Melanoides tuberculatus*
Valvatidae	*Valvata humeralis*	*Valvata humeralis*
Valvatidae	*Valvata sincera*	*Valvata sincera*
Valvatidae	*Valvata tricarinata*	*Valvata tricarinata*

We collected 4096 snails at 148 sites in the Snake and Green River Basins. These snails consisted of 22 known species and 1 possibly new species. Physidae were the most abundant family of snails collected in western Wyoming (40% of individuals), followed by Lymnaeidae (37%), Amnicolidae (8%) Planorbidae (5%), Lithoglyphidae (4%) and Tateidae (3%). The family Thiaridae (9.1 snails/min) had the highest mean catch per unit effort followed by Amnicolidae (7.7 snails/min), Tateidae (6.1 snails/min), Lithoglyphidae (3.6 snails/min), Physidae (2.3 snails/min) and Lymnaeidae (2.1 snails/min). *Physa* (40% of individuals) and *Lymnaea* (40%) were the most common genera of snails collected followed by *Colligyrus* (8%), *Fluminicola* (4%), *Gyraulus* (4%), *Potomopyrgus* (3%), *Helisoma* (2%), *Promenetus* (<1%) and *Valvata* (<1%). The genus Melanoides had the highest mean catch per unit effort (9.1 snails/min) but they were only collected at one site where they were very abundant. The genus *Colligyrus* (7.7 snails/min) had a high catch per unit effort wherever we found them followed by *Potomopyrgus* (6.1 snails/min), *Fluminicola* (3.6 snails/min), *Physa* (2.3 snails/min), *Lymnaea* (2.1 snails/min), *Helisoma* (1 snails/min), *Gyraulus* (0.7 snails/min), *Promenetus* (0.2 snails/min) and *Valvata* (0.1 snails/min). *Physa gyrina*, *Lymnaea catascopium*, *Physa columbiana*, *Colligyrus greggi* and *Fluminicola coloradensis* were the most numerous species collected (Table 2). *Lymnaea columella*, *Valvata sincerea*, *Helisoma anceps*, *Lymnaea stagnalis* and *Gyraulus crista* were the least numerous species we collected. *Lymnaea humilis* (17.7 snails/min), *Colligyrus greggi* (7.7 snails/min), *Physa jennessi* (7.1 snails/min), *Potomopyrgus* (6.1 snails/min), *Melanoides* (9.1 snails/min), *Fluminicola coloradensis* (3.6 snails/min) and *Lymnaea catascopium* (2.7 snails/min) were the snail species with the highest mean catch per unit effort. *Valvata sincera* (0.1 snails/min), *Lymnaea stagnalis* (0.1 snails/min), *Lymnaea columella* (0.1 snails/min), *Gyraulus crista* (0.1 snails/min), *Promenetus umbilicatellus* (0.2 snails/min), *Helisoma anceps* (0.4 snails/min) *and Physa acuta* (0.5 snails/min) had the lowest mean catch per unit effort.

Table 2. The total number of individuals collected for each snail species from least to most abundant. Non-native species are marked with an asterisk.

Species	Family	Live snails	Shell only	Total
Gyraulus crista	Planorbidae	0	1	1
Lymnaea stagnalis	Lymnaeidae	1	0	1
Valvata sincera	Valvatidae	1	0	1
Lymnaea columella	Lymnaeidae	1	1	2
Promenetus umbilicatellus	Planorbidae	1	4	5
Helisoma anceps	Planorbidae	3	2	5
Physa acuta	Physidae	29	2	31
Gyraulus circumstriatus	Planorbidae	35	1	36
*Lymnaea auricularia**	Lymnaeidae	32	13	45
Helisoma trivolvis	Planorbidae	48	15	63
Physa jennessi	Physidae	71	0	71
Lymnaea elodes	Lymnaeidae	78	6	84
*Melanoides**	Thiaridae	91	0	91
Gyraulus parvus	Planorbidae	104	11	115
*Potamopyrgus antipodarum**	Tateidae	124	0	124
Lymnaea bulimoides	Lymnaeidae	146	5	151
Lymnaea humilis	Lymnaeidae	177	0	177
Fluminicola coloradensis	Lithoglyphidae	179	2	181
Colligyrus greggi	Amnicolidae	308	1	309
Physa columbiana	Physidae	531	28	559
Lymnaea catascopium	Lymnaeaidae	874	36	910
Physa gyrina	Physidae	924	24	948

Mean catch per unit effort of snails did not vary by most of the parameters we measured. Total snail catch per unit effort was higher in springs compared to other ecosystem types ($F=5.9$, $p < 0.001$) but the difference was probably driven by a few springs that had very high abundances of snails (Figure 1A). Snails had the widest range of abundance on wood, but the difference was not significant ($F=1.8$, $p = 0.14$; Figure 1B). Snail abundance did not vary among aquatic vegetation types ($F=0.4$, $p = 0.95$; Figure 1C). We collected fewer snails in the main channel of streams compared to the other microhabitat types ($F = 3.94$, $p < 0.000$; 1Figure 2A, Tukey's HSD, $p > 0.05$). Snail abundance was lower in springs with standing water compared to flowing water (Tukey's HSD, $p < 0.001$). Aquatic vegetation and wood had higher snail abundance than other microhabitats in lentic ecosystems (Tukey's HSD, $p > 0.05$). Snail abundance was higher in ecosystems that had higher biomass of algae as assessed with our biofilm rank, but the pattern was not significant ($F = 1.08$, $p = 0.28$; Figure 2B). The highest abundance of snails was sampled in smaller ecosystems; however, the abundance of snails was not related to ecosystem width ($t = 0.09$, $p = 0.93$, Figure 2C).

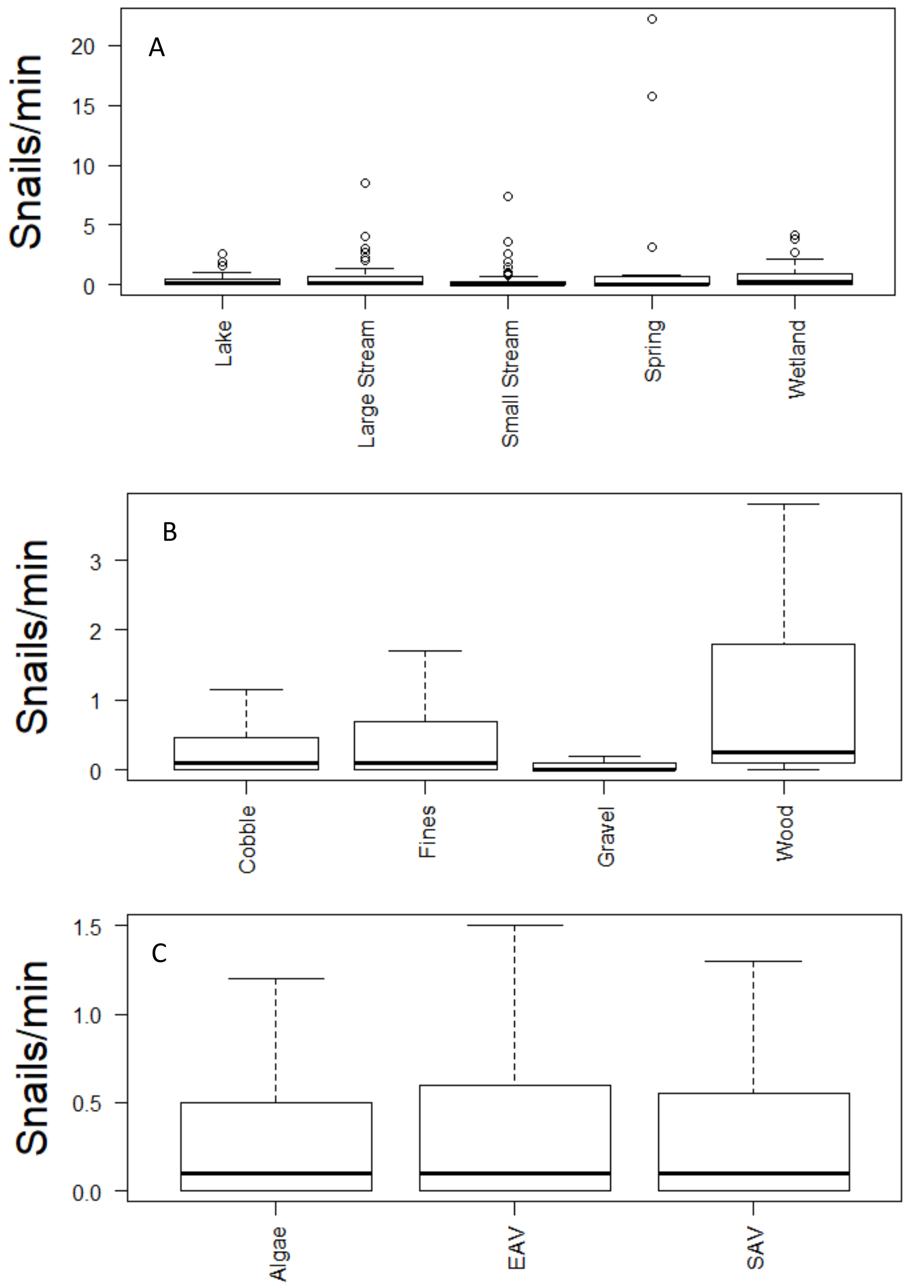


Figure 1. Mean catch per unit effort (snails/minute) of snails in A.) the different ecosystem types we sampled, B.) the types of substrate we sampled and C.) the vegetation sampled (emergent aquatic vegetation (EAV) and submerged aquatic vegetation (SAV)).

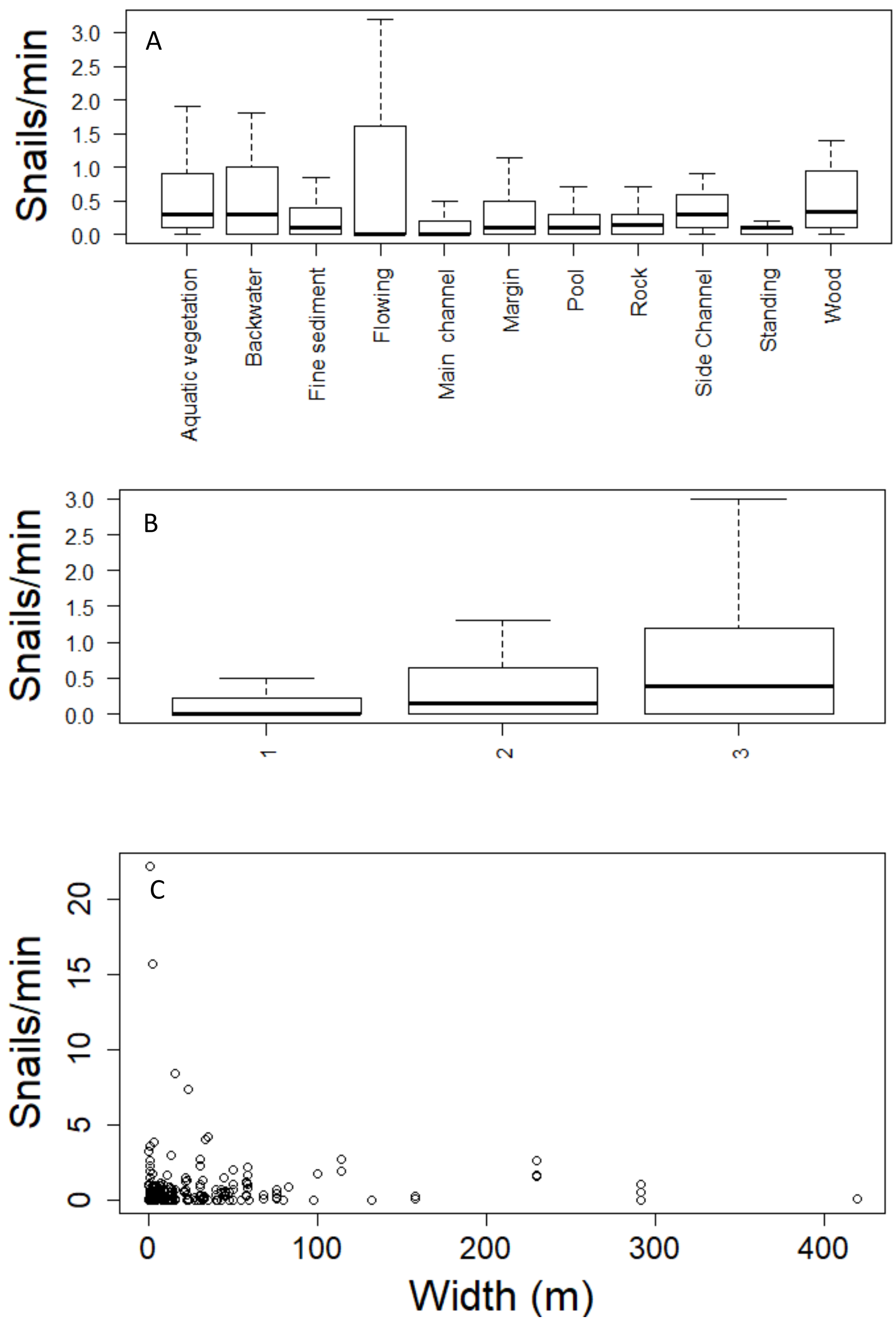


Figure 2. Mean catch per unit effort (snails/minute) of snails A.) in different habitat types, B.) low (1), medium (2) and very green (3) biofilm rank and C.) ecosystem width (m).

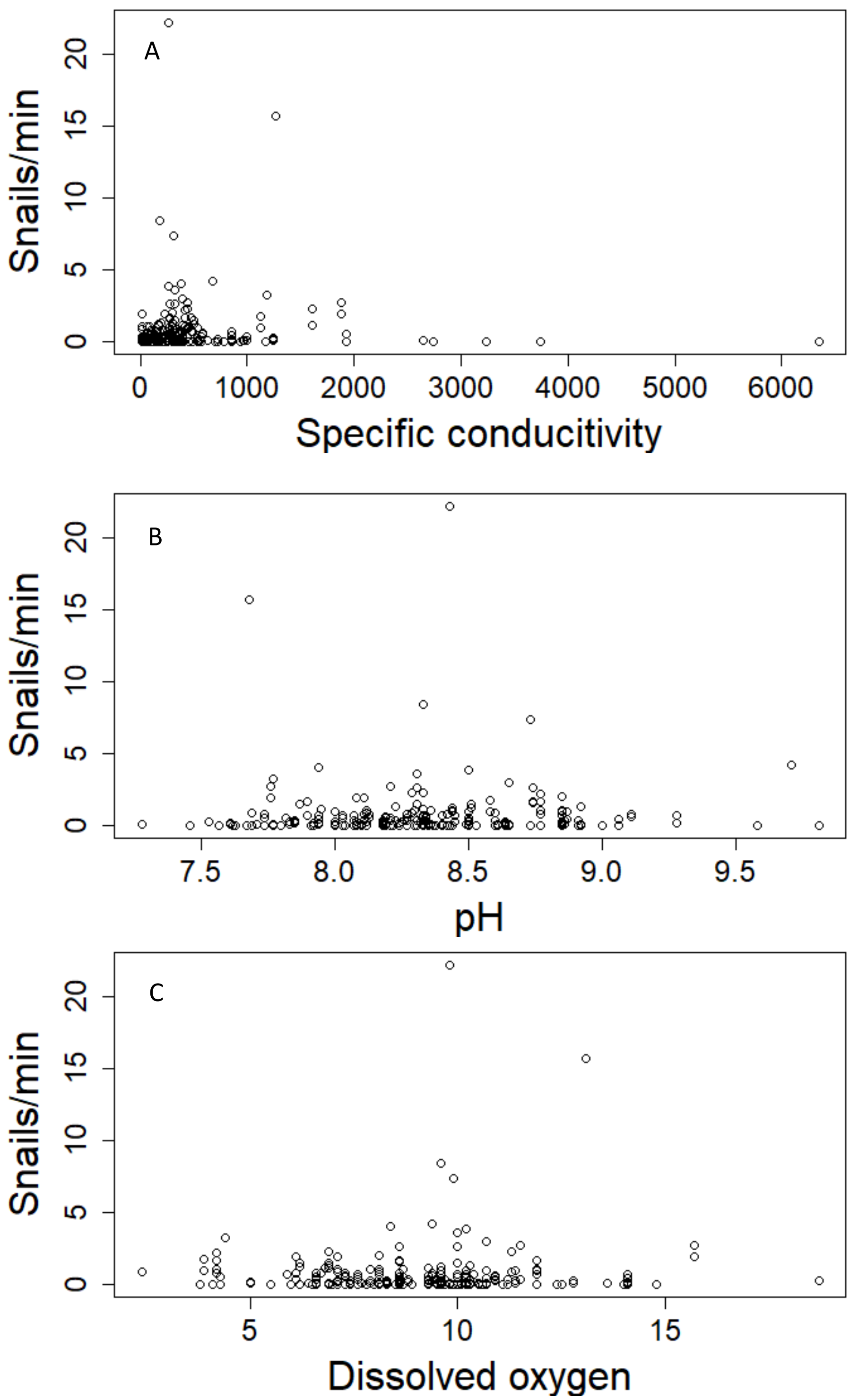


Figure 3. Mean catch per unit effort (snails/minute) of snails A.) at various concentrations of specific conductivity (µS/cm), B.) versus pH, and C.) compared to dissolved oxygen concentrations (mg O_2/L).

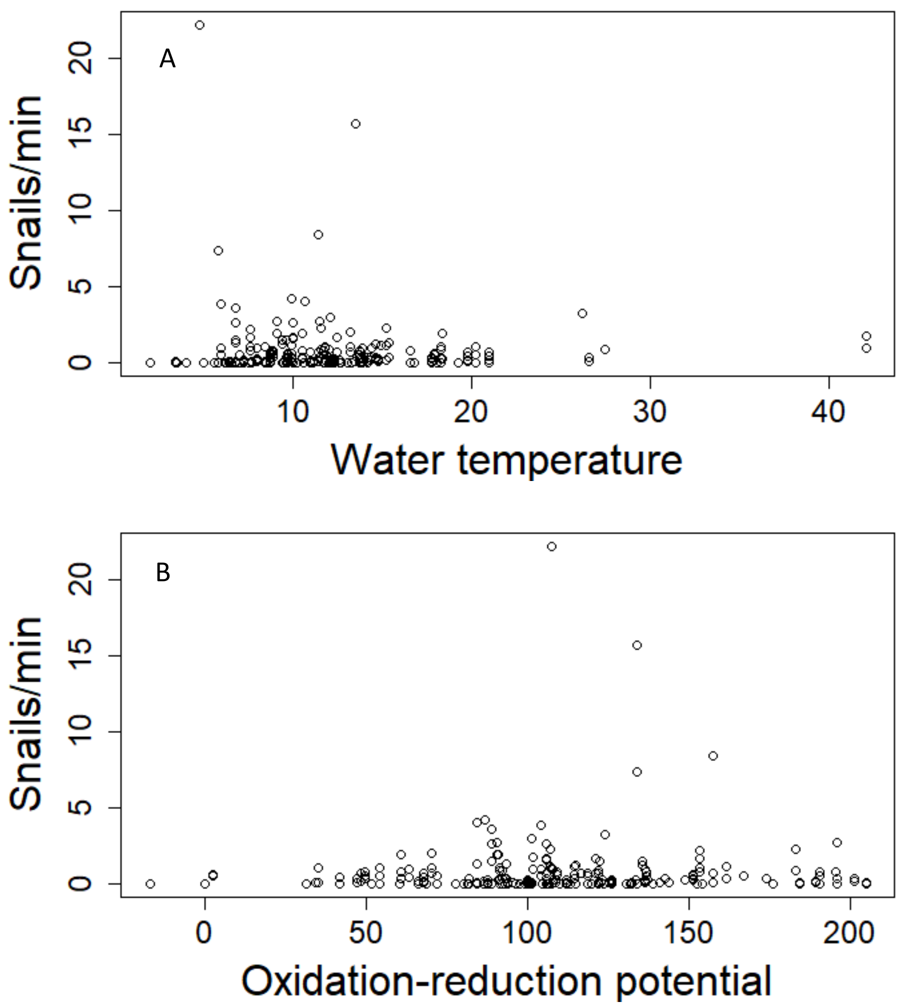


Figure 4. Mean catch per unit effort (snails/minute) of snails A.) at various water temperatures (°C) and B.) versus oxidation-reduction potential (mV).

Mean snail catch per unit effort did not relate to water quality measurements. Aquatic ecosystems with the highest specific conductivity tended to have a low abundance of snails ($t = 0.24$, $p = 0.81$; Figure 3A). All ecosystems we measured had neutral to basic pH and pH did not relate to snail abundance ($t = 0.56$, $p = 0.57$; Figure 3B). We measured higher snail abundance in some ecosystems with moderate dissolved oxygen concentration (~10 mg/L), but the relationship was not linear ($t = 0.91$, $p = 0.36$; Figure 3C). Colder ecosystems had higher snail abundance at some sites and only a few sites with warm water were sampled ($t = 0.53$, $p = 0.59$; Figure 4A). Oxidation reduction potential did not alter the abundance of snails in an ecosystem ($t = 1.09$, $p = 0.28$; Figure 4B). More sampling will help untangle the relationships between habitat characteristics and water quality with snail abundance.

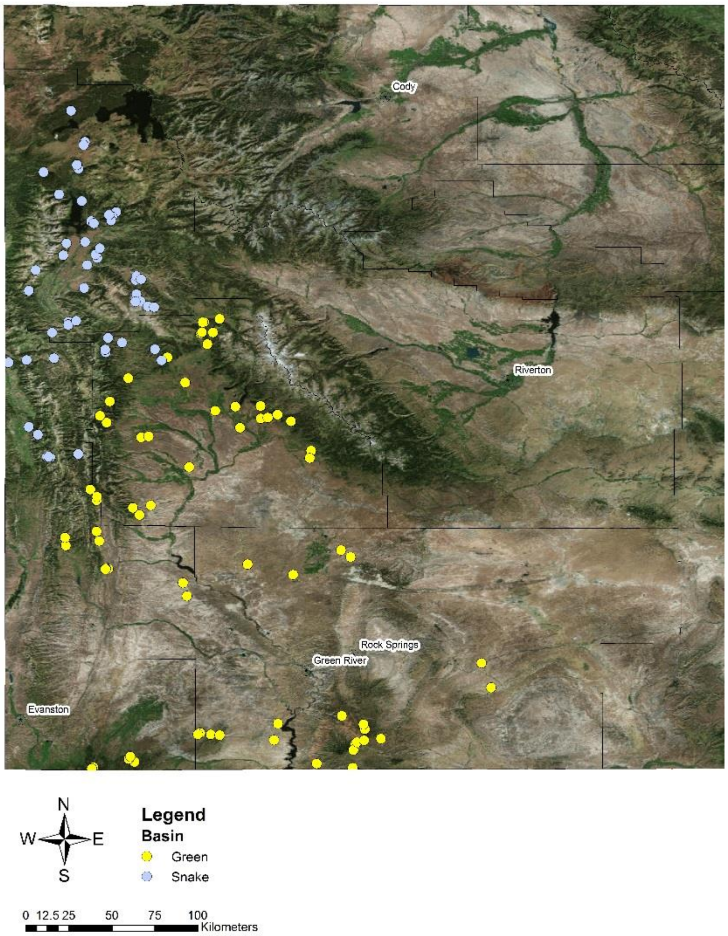
The following pages provide species-specific information. The *All Sites Sampled* account provides a map of all the sampled locations as well as all the categories of habitat characteristics. We provide the mean and range in water quality measurements for all ecosystems sampled. If the species was collected at a single location, the range of values were not reported.

Account description
Basins: What river basin the species was collected in
Number of sites: Number of sites the species was collected at
Aquatic ecosystem type: Type of aquatic ecosystem the species was collected in
Substrate: Type of substrate we collected the species on
Vegetation: Type of vegetation the species was collected on
Habitat: Microhabitat type the snail was collected in

Streams: main channel, side channel, backwater, pool and margin
Wetlands and *lakes*: rock, wood, aquatic vegetation and fine sediment
Springs: standing or flowing

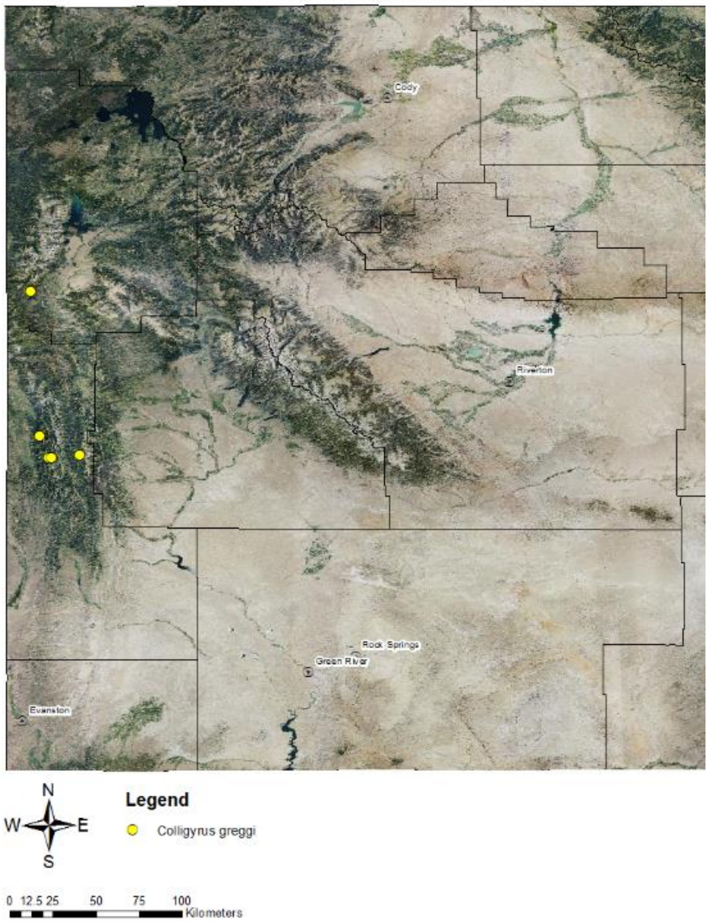
Ecosystem width: Width of the stream, river, wetland, lake or spring
Size range collected: The smallest and largest shell length of the species collected
CPUE: Catch per unit effort of the species (snails/min; mean and range)
Water temperature: Water temperature (°C; mean and range)
% DO: Percent saturation of dissolved oxygen (mean and range)
DO: Dissolved oxygen (mg O_2/L; mean and range)
Specific conductivity: Concentration of dissolved salts in the water (µS/cm; mean and range)
pH: pH of the water (mean and range)
Oxidation-reduction potential: Correlated with oxygen concentration and groundwater fluxes. Indicates the types of reactions occurring in an ecosystem (mV; mean and range)
Note: Comments or observations about the species in Wyoming.

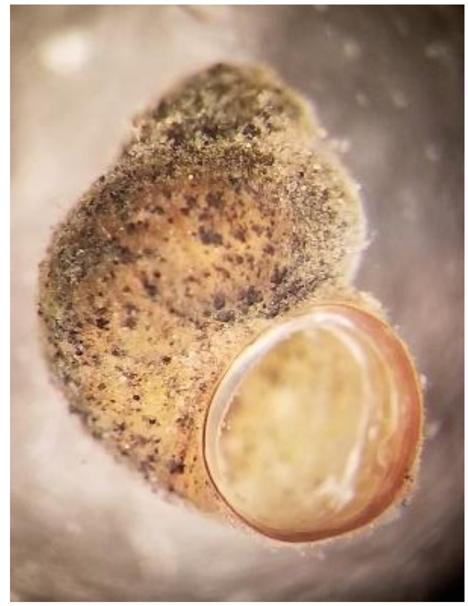
All Sites Sampled



Basins: Snake and Green
Number of sites: 148
Aquatic ecosystem type: Large and small streams, lakes, wetlands and springs
Substrate: Fine sediment, gravel, cobble and wood
Vegetation: Submerged and emergent aquatic vegetation, and lacking vascular plants
Habitat: Streams (main channel, side channel, backwater, pool and margin), wetlands and lakes (rock, wood, aquatic vegetation, and fine sediments), and springs (standing or flowing)
Ecosystem width: 32 m (0.3->500)
Size range collected: 1-37 mm length
CPUE: 0.6 snails/min (0-22)
Water temperature: 12.2°C (2.0-42)
% DO: 101% (35-240)
DO: 9.0 mg O_2/L (2.4-18.7)
Specific conductivity: 448 µS/cm (14.6-6347)
pH: 8.3 (7.28-9.81)
Oxidation-reduction potential: 105 mV (-17-204.8)

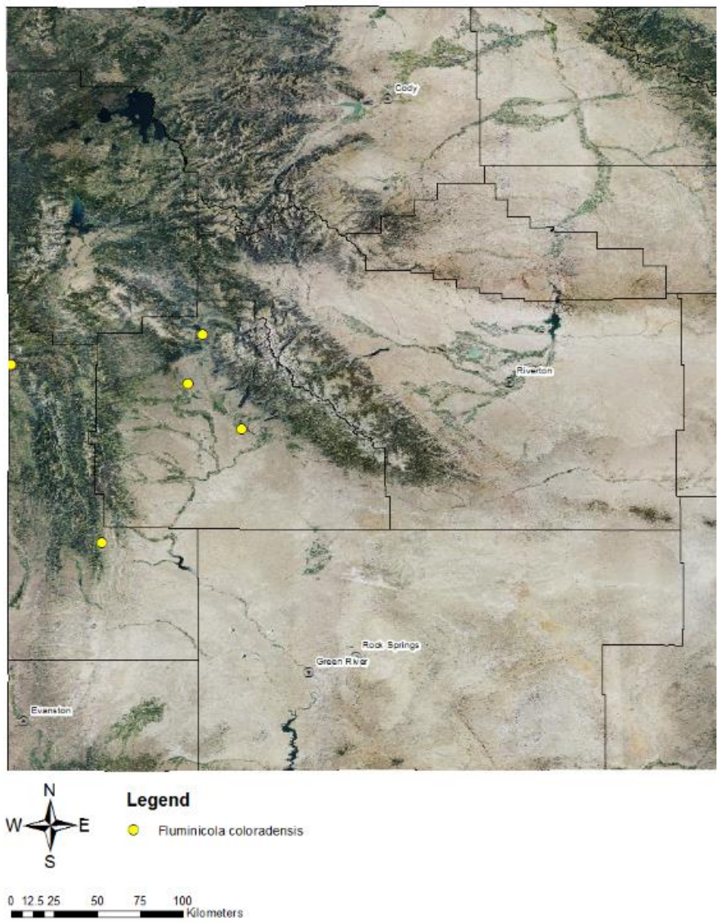
Family Amnicolidae
Species: *Colligyrus greggi*





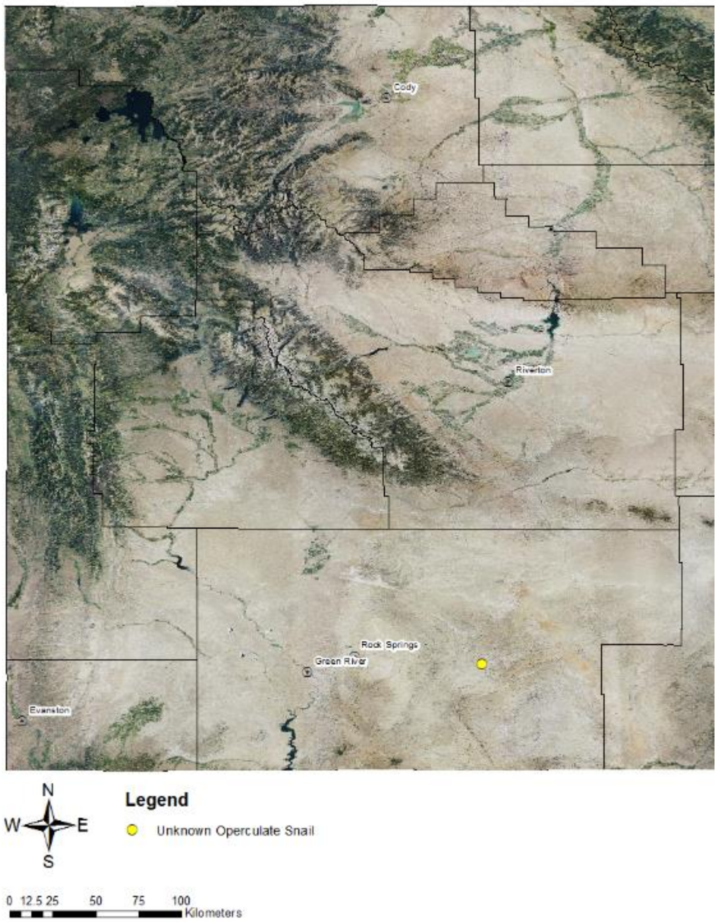
Basins: Snake
Number of sites: 6
Aquatic ecosystem type: Large and small streams, wetlands and springs
Substrate: Fine sediment, cobble and wood
Vegetation: Seldom on vegetation
Habitat: Main channel of streams, on rock, wood or fine sediment in wetlands and in flowing springs
Ecosystem width: 5.1 m (1-24)
Size range collected: 1-2.75 mm length
CPUE: 3.3 snails/min (0.1-22.2)
Water temperature: 6.5°C (4.8-7.7)
% DO: 108% (101-110)
DO: 10.1 mg O_2/L (9.8-10.2)
Specific conductivity: 305 µS/cm (261-353)
pH: 8.4 (8.2-8.7)
Oxidation-reduction potential: 101 mV (89-134)
Notes: *Colligyrus greggi* is an operculate snail (has gills) that is only known from the Snake River basin. This snail was often abundant when observed.

Family Lithoglyphidae
Species: *Fluminicola coloradensis*



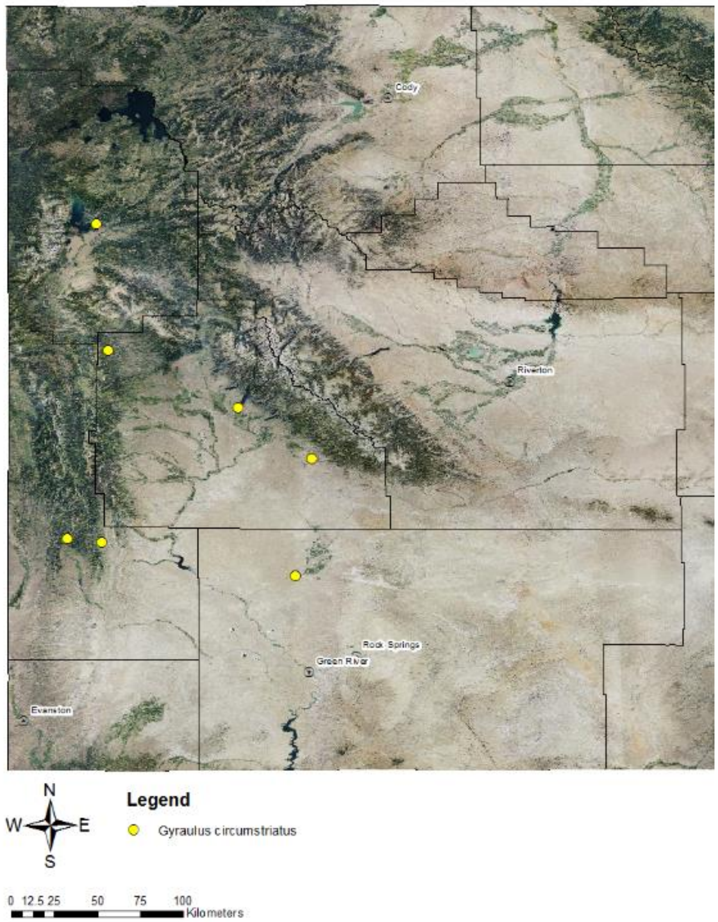
Basins: Snake and Green
Number of sites: 5
Aquatic ecosystem type: Large streams
Substrate: Cobble and occasionally on wood
Vegetation: Submerged aquatic vegetation or lacking aquatic vegetation
Habitat: Main channel, side channel, margin or wood
Ecosystem width: 35 m (6-50)
Size range collected: 2-8 mm length
CPUE: 1.3 snails/min (0.1-5.6)
Water temperature: 11.9°C (8.7-15.4)
% DO: 110% (84-133)
DO: 9.6 mg O_2/L (8.1-11.5)
Specific conductivity: 313 µS/cm (188-446)
pH: 8.6 (8.0-9.1)
Oxidation-reduction potential: 111 mV (70.1-196)
Notes: Recently *Fluminicola fuscus* (living in the upper Snake River Basin) was combined with *Fluminicola coloradensis* (inhabiting the Green River Basin) and now called *Fluminicola coloradensis* (Lui et al. 2013).

Family Unknown
Species: Unknown Operculate snail



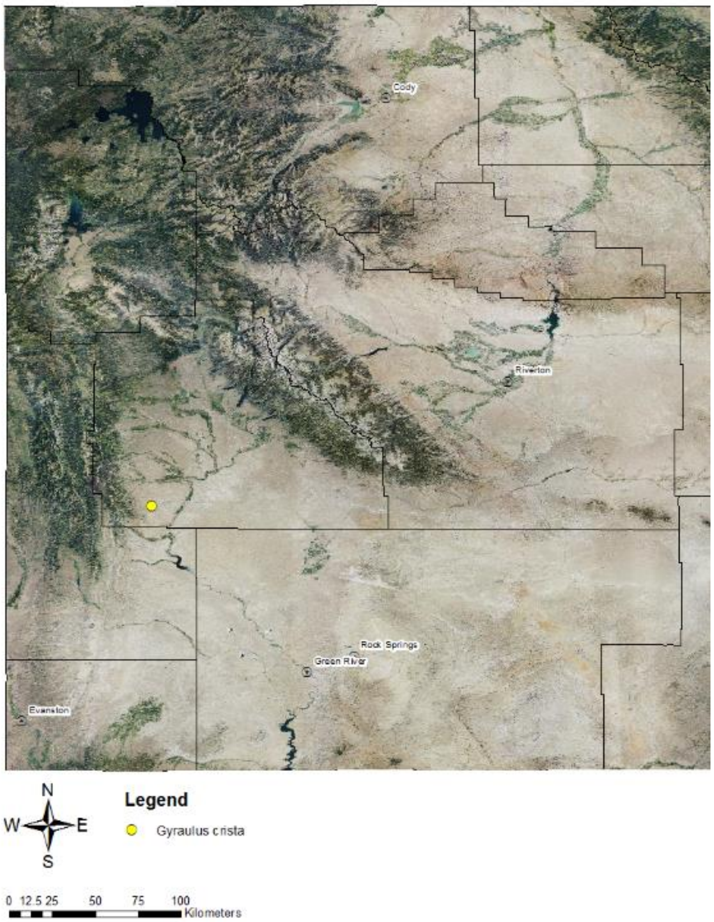
Basins: Green
Number of sites: 1
Aquatic ecosystem type: Small stream
Substrate: Fine substrate
Vegetation: None
Habitat: Margin
Ecosystem width: 2 m
Size range collected: 3 mm length
CPUE: 0.6 snails/min
Water temperature: 12.6°C
% DO: 84%
DO: 7.1 mg O_2/L
Specific conductivity: 718 µS/cm
pH:7.9
Oxidation-reduction potential: 66 mV
Notes: Potentially a new species of operculate snail that we collected in Bitter Creek. We plan to collect more individuals and send them to the operculate snail expert for further study.

Family Planorbidae
Species: ***Gyraulus circumstriatus***



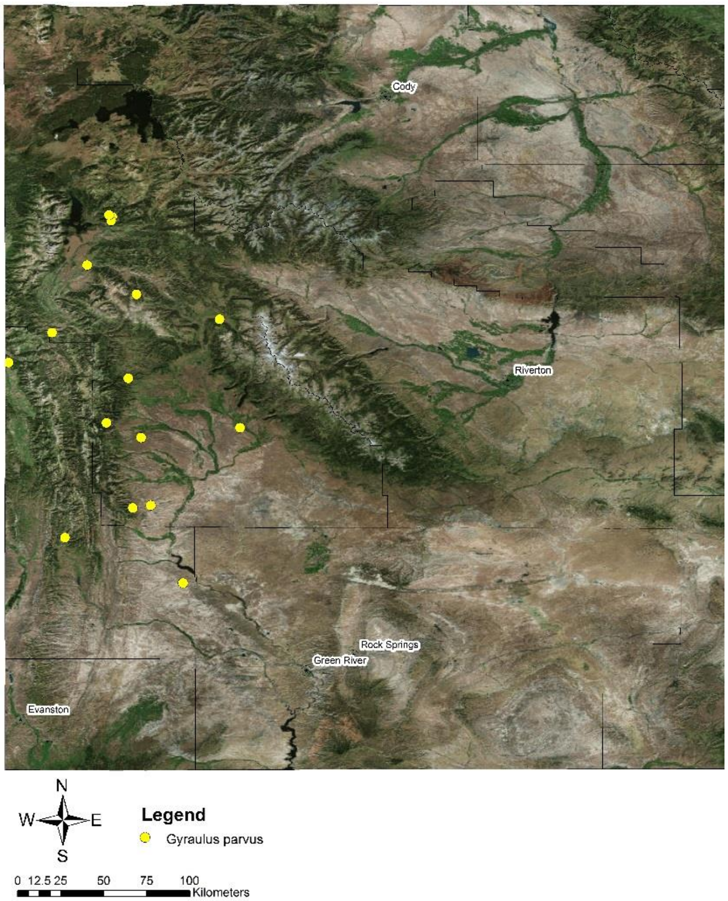
Basins: Green and Snake
Number of sites: 7
Aquatic ecosystem type: Large and small streams, and wetlands
Substrate: Fine substrate and cobble
Vegetation: Submerged and emergent aquatic vegetation or lacking aquatic vegetation
Habitat: Streams (main channel, pools, margins and backwaters) and wetlands (aquatic vegetation)
Ecosystem width: 12 m (2.5-21.5)
Size range collected: 1.25-3.25 mm width
CPUE: 0.5 snails/min (0.1-1.6)
Water temperature: 14.9°C (8.8-21)
% DO: 111% (73-147)
DO: 8.9 mg O_2/L (6.6-10.4)
Specific conductivity: 251 µS/cm (16.8-585)
pH: 8.9 (8.1-9.3)
Oxidation-reduction potential: 74 mV (2.6-137)
Notes: A small Planorbidae collected mainly in streams.

Family Planorbidae
Species: ***Gyraulus crista***



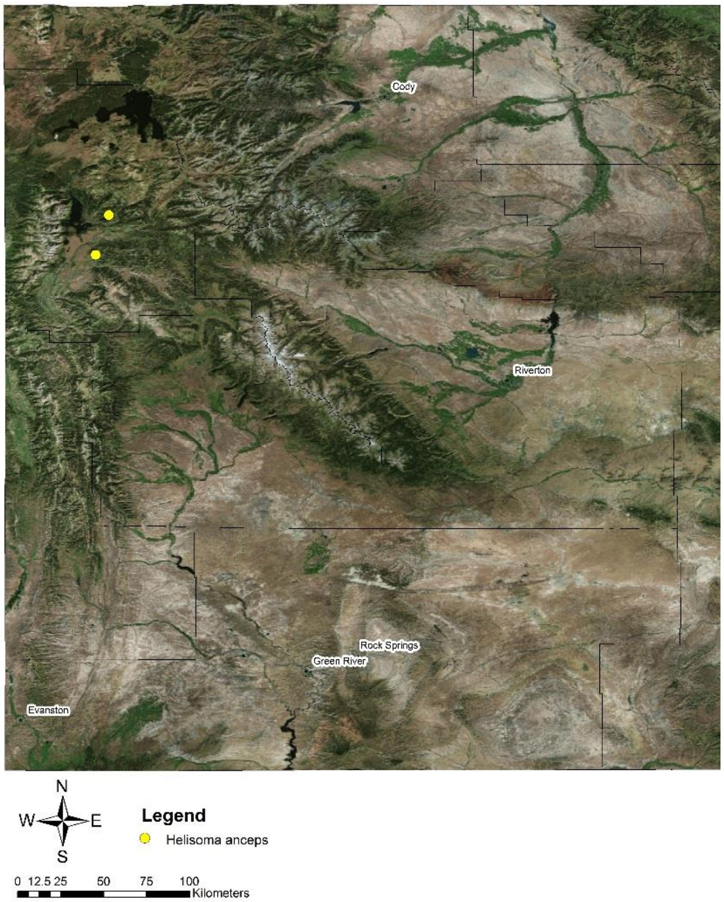
Basins: Green
Number of sites: 1
Aquatic ecosystem type: Large stream
Substrate: Fine substrate
Vegetation: Submerged aquatic vegetation
Habitat: Main channel
Ecosystem width: 1 m
Size range collected: 2-3 mm width
CPUE: 0.1 snails/min
Water temperature: 17.8°C
% DO: 153%
DO: 11.2 mg O_2/L
Specific conductivity: 574 µS/cm
pH: 8.2
Oxidation-reduction potential: 93 mV
Notes: A small Planorbidae that was collected in one stream. Only shells were collected and no live individuals.

Family Planorbidae
Species: *Gyraulus parvus*



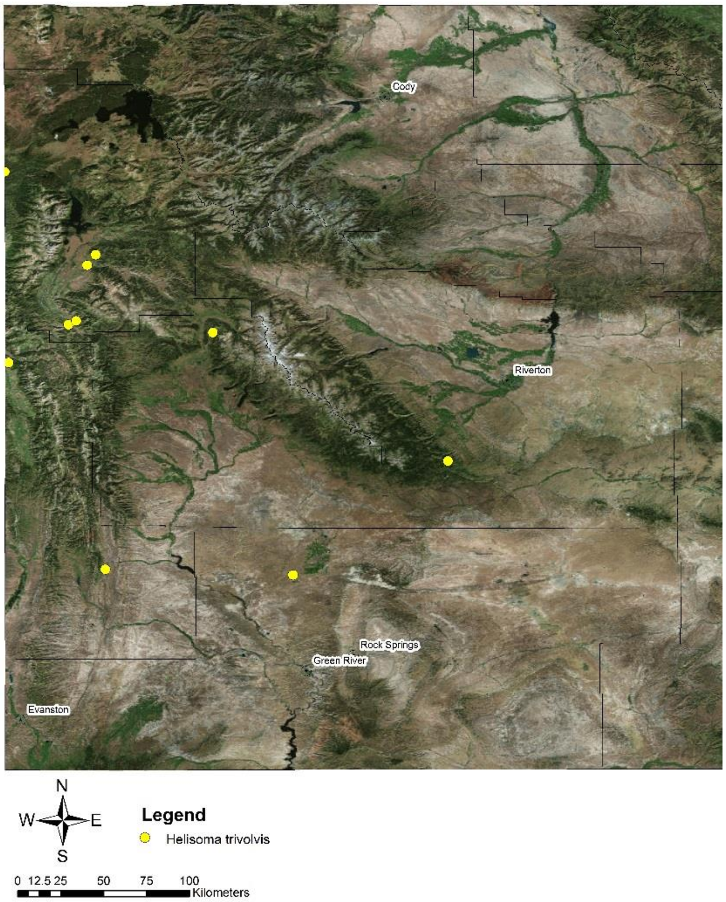
Basins: Green and Snake
Number of sites: 16
Aquatic ecosystem type: Large and small streams, springs, wetlands, and lakes
Substrate: Fine substrate, gravel and cobble
Vegetation: Submerged and emergent aquatic vegetation or lacking aquatic vegetation
Habitat: Streams (main channel, pools, margins, side channels and backwaters), wetlands and lakes (fine sediment, aquatic vegetation and wood), and springs (standing water)
Ecosystem width: 24.5 m (1-83)
Size range collected: 1-6.5 mm width
CPUE: 0.4 snails/min (0.1-2.5)
Water temperature: 13.8°C (6.8-27.5)
% DO: 123% (39-240)
DO: 10.2 mg O_2/L (2.4-18.7)
Specific conductivity: 386 µS/cm (58.2-1608)
pH: 8.5 (8.2-8.9)
Oxidation-reduction potential: 114 mV (60.8-196)
Notes: A common Planorbidae snail collected in all aquatic ecosystem types and micohabitats. This snail appears to be habitat generalist.

Family Planorbidae
Species: *Helisoma anceps*



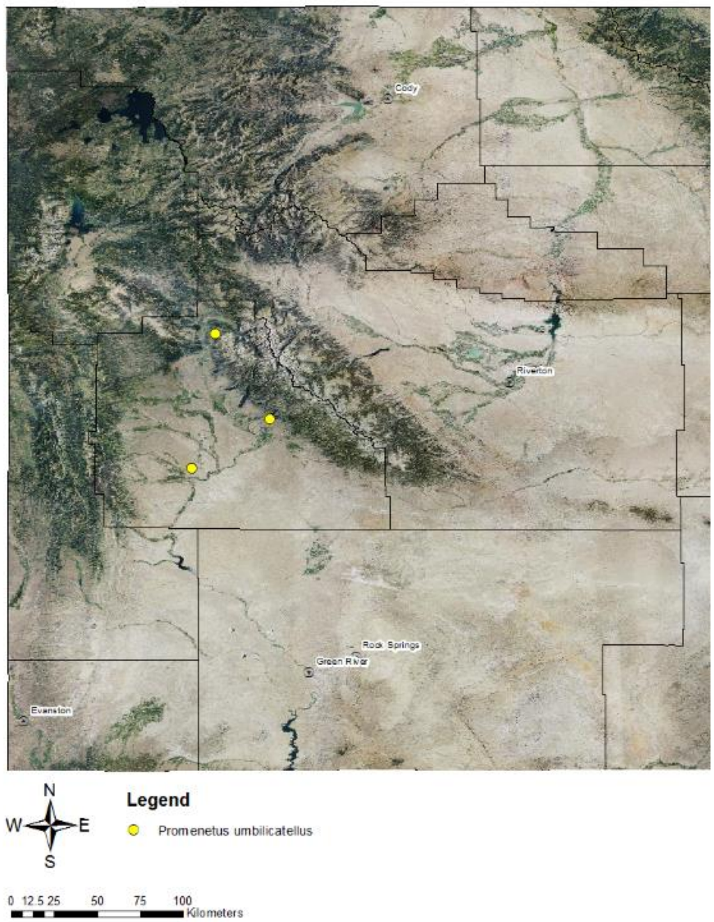
Basins: Snake
Number of sites: 2
Aquatic ecosystem type: Lake
Substrate: Fine substrate
Vegetation: Submerged aquatic vegetation
Habitat: Fine sediment
Ecosystem width: >500 m
Size range collected: 32-37 mm width
CPUE: 0.18 snails/min (0.15-0.20)
Water temperature: 19.25°C (14.4-24.1)
% DO: 139.5% (136-143)
DO: 11.5 mg O_2/L (10.7-12.3)
Specific conductivity: 364 µS/cm (143-385)
pH: 8.16 (7.42-8.9)
Oxidation-reduction potential: 20.2 mV (-22.7-63.1)
Notes: An uncommon, large Planorbidae snail collected in Two Ocean Lake and a wetland in the Gros Ventre Mountains. These snails were not abundant in Two Ocean Lake and were found on fine sediments in the littoral zone.

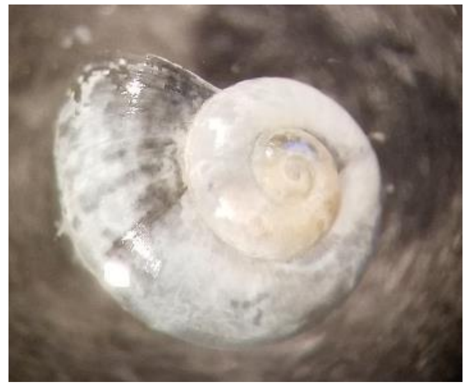
Family Planorbidae
Species: *Helisoma trivolvis*



Basins: Green and Snake
Number of sites: 10
Aquatic ecosystem type: Large streams, springs and wetlands
Substrate: Fine substrate and gravel
Vegetation: Submerged and emergent aquatic vegetation
Habitat: Streams (pools), wetlands (aquatic vegetation) and springs (standing water)
Ecosystem width: 33 m (11-83)
Size range collected: 1-20 mm width
CPUE: 0.6 snails/min (0.1-2.6)
Water temperature: 16.3°C (9.9-27.5)
% DO: 106% (39-147)
DO: 8.9 mg O_2/L (2.4-11.9)
Specific conductivity: 424 µS/cm (146-678)
pH: 8.2 (7.7-9.7)
Oxidation-reduction potential: 111 mV (48-134)
Notes: A large Planorbidae snail collected in both lotic and lentic aquatic ecosystems. This snail was always collected on aquatic vegetation.

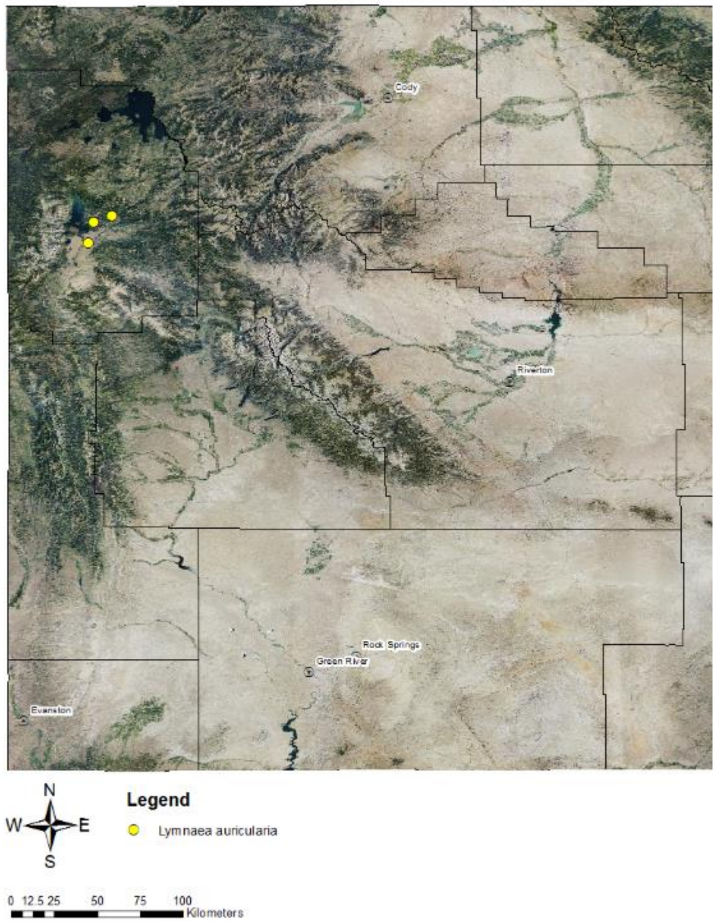
Family Planorbidae
Species: *Promenetus umbilicatellus*





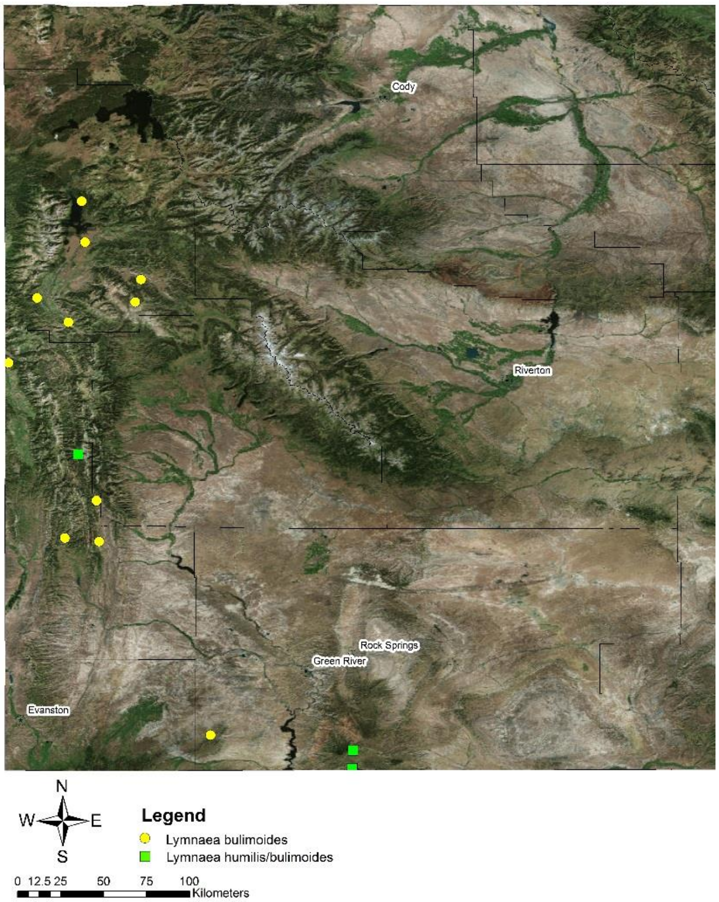
Basins: Green
Number of sites: 3
Aquatic ecosystem type: Large streams, lakes and wetlands
Substrate: Fine substrate and wood
Vegetation: Submerged and emergent aquatic vegetation or lacking vegetation
Habitat: Streams (main channel), lakes and wetlands (aquatic vegetation)
Ecosystem width: 14 m (5-33)
Size range collected: 2-3.5 mm width
CPUE: 0.15 snails/min (0.1-0.2)
Water temperature: 14.5°C (10.5-17.8)
% DO: 97% (72-108)
DO: 8.1 mg O_2/L (7.4-8.6)
Specific conductivity: 684 µS/cm (15-1241)
pH: 8.1 (7.9-8.2)
Oxidation-reduction potential: 124 mV (112-134)
Notes: A small Planorbidae snail collected in lentic and larger lotic aquatic ecosystems.

Family Lymnaeidae
Species: ***Lymnaea auricularia*** **(Non-native)**



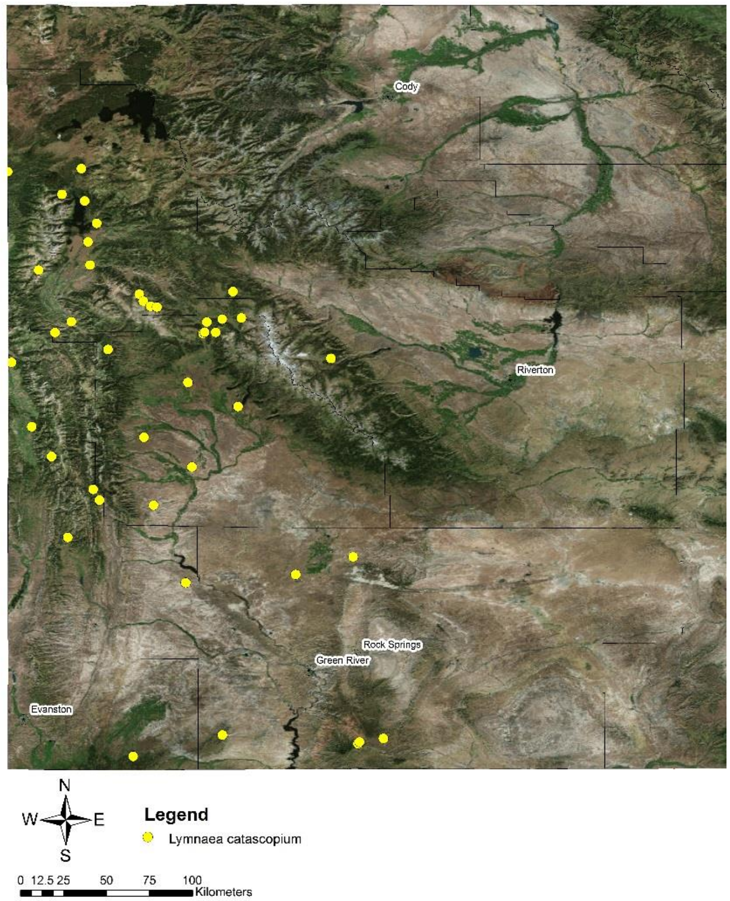
Basins: Snake
Number of sites: 3
Aquatic ecosystem type: Large streams, lakes and wetlands
Substrate: Fine substrate and cobble
Vegetation: Submerged aquatic vegetation or lacking vegetation
Habitat: Streams (backwater), lakes and wetlands (aquatic vegetation and fine sediment)
Ecosystem width: 21 m (12-58)
Size range collected: 6.5-32 mm length
CPUE: 0.4 snails/min (0.1-1.6)
Water temperature: 14.5°C (14.4-14.9)
% DO: 127% (80-136)
DO: 10.0 mg O_2/L (6.8-10.7)
Specific conductivity: 147 µS/cm (143-167)
pH: 8.7 (8.0-8.9)
Oxidation-reduction potential: 80 mV (63-162)
Notes: A large Lymnaeidae snail that is non-native in Wyoming. We collected this snail in two new locations in Wyoming and they have been reported from three other waters in the state (Larson 2018). Also known as *Radix auricularia*.

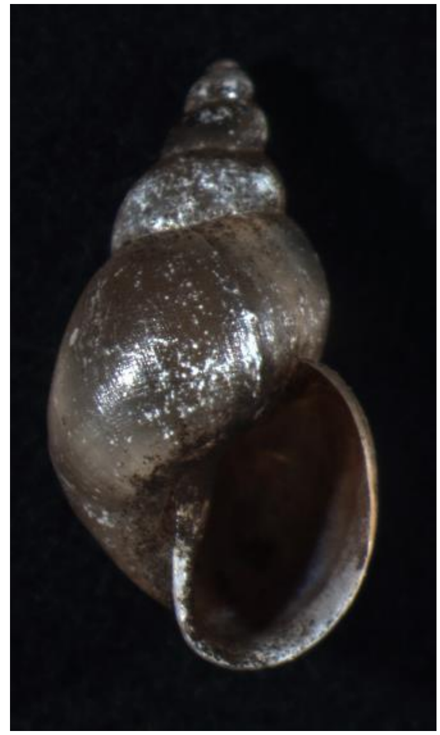
Family Lymnaeidae
Species: *Lymnaea bulimoides*



Basins: Snake and Green
Number of sites: 11 (3 other locations where *L. bulimoides* and *L. humilis* could not be distinguished)
Aquatic ecosystem type: Large and small streams, springs and wetlands
Substrate: Fine substrate and wood
Vegetation: Emergent aquatic vegetation or lacking vegetation
Habitat: Streams (main channel, side channel, margin, pool and backwater), wetlands (aquatic vegetation), and springs (standing water)
Ecosystem width: 24 m (0.3-58)
Size range collected: 1.5-13 mm length
CPUE: 0.7 snails/min (0.1-2.0)
Water temperature: 11.9°C (8.8-16.6)
% DO: 110% (80-136)
DO: 9.5 mg O_2/L (6.6-11.9)
Specific conductivity: 320 µS/cm (164-475)
pH: 8.3 (7.9-9.1)
Oxidation-reduction potential: 131 mV (49-196)
Notes: A small Lymnaeidae snail that lives at the margins of aquatic ecosystems (in or out of the water). Distinguished from *L. humilis* by the teeth on the radula (see image above).

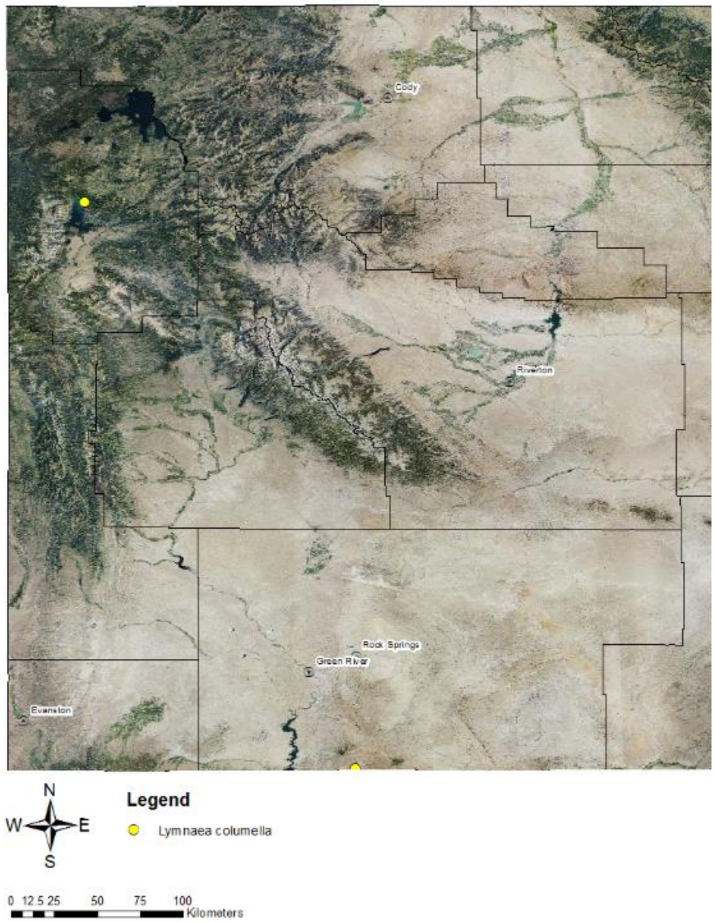
Family Lymnaeidae
Species: *Lymnaea catascopium*





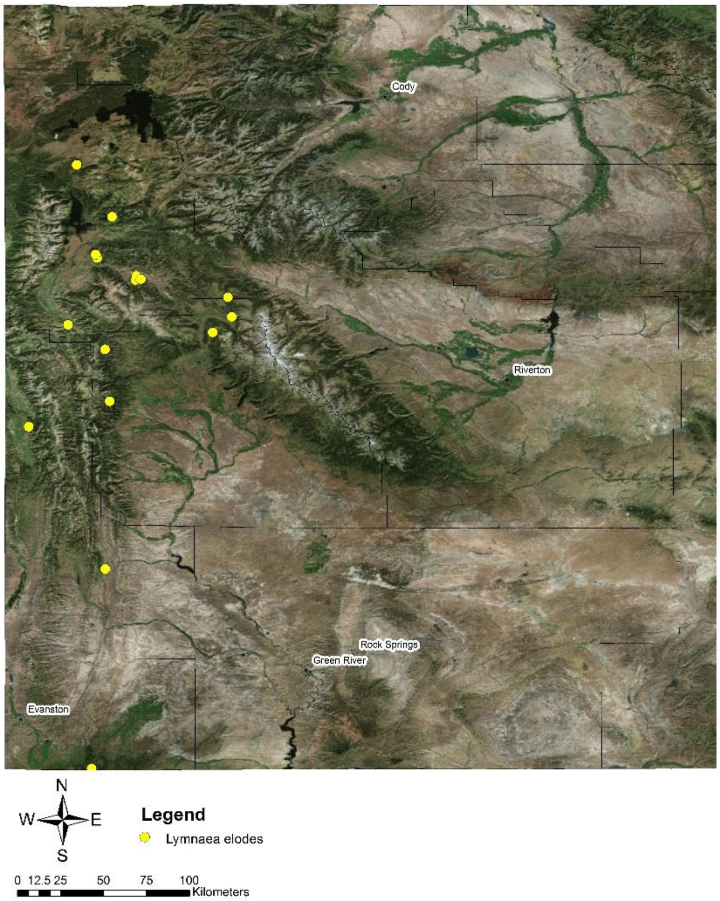
Basins: Snake and Green
Number of sites: 47
Aquatic ecosystem type: Large and small streams, springs, lakes and wetlands
Substrate: Fine substrate, gravel, cobble and wood
Vegetation: Submerged and emergent aquatic vegetation or lacking vegetation
Habitat: Streams (main channel, side channel, margin, pool and backwater), wetlands and lakes (aquatic vegetation, fine sediment, wood and rock), and springs (standing water)
Ecosystem width: 66 m (0.5->500)
Size range collected: 1-32 mm length
CPUE: 1.3 snails/min (0.1-15.7)
Water temperature: 12.8°C (7.0-27.5)
% DO: 101% (39-153)
DO: 9.2 mg O_2/L (2.4-15.7)
Specific conductivity: 602 µS/cm (17-2651)
pH: 8.3 (7.3-9.3)
Oxidation-reduction potential: 98 mV (2.6-196)
Notes: A large Lymnaeidae snail that we observed in all aquatic ecosystem types. This snail appears to be a habitat generalist.

Family Lymnaeidae
Species: ***Lymnaea columella***



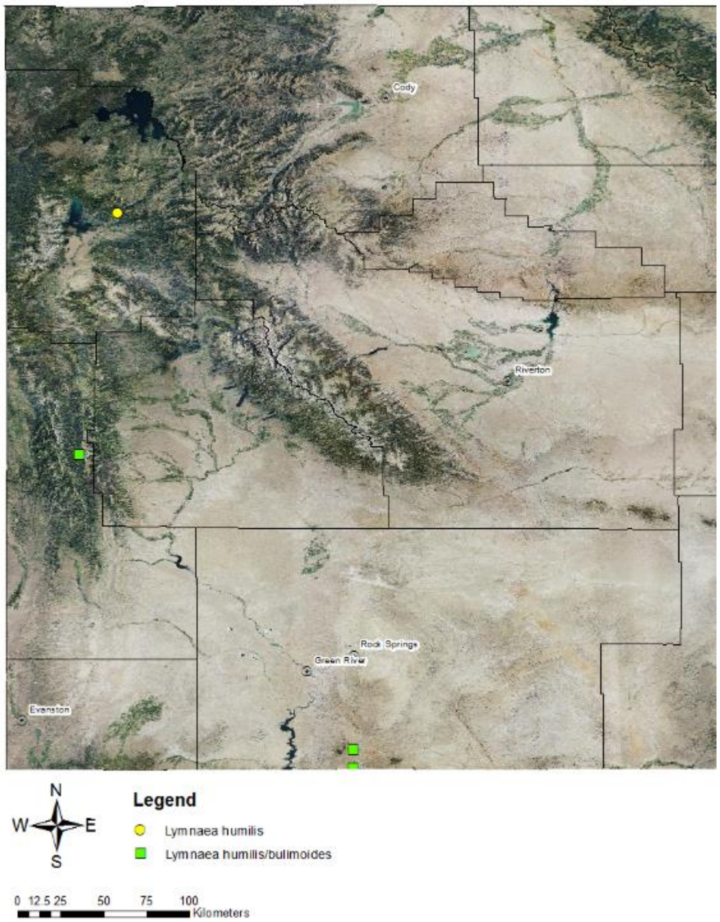
Basins: Snake and Green
Number of sites: 2
Aquatic ecosystem type: Small streams and springs
Substrate: Fine substrate and cobble
Vegetation: Emergent aquatic vegetation or lacking vegetation
Habitat: Streams (backwater) and springs (standing water)
Ecosystem width: 4 m (1-7)
Size range collected: 5.5-10.5 mm length
CPUE: 0.1 snails/min (0.1-0.1)
Water temperature: 9.3°C (8.9-9.7)
% DO: 83% (70-96)
DO: 7.5 mg O_2/L (6.4-8.6)
Specific conductivity: 454 µS/cm (281-627)
pH: 8.2 (8.0-8.3)
Oxidation-reduction potential: 42 mV (34-49)
Notes: An uncommon Lymnaeidae snail that we observed in small aquatic ecosystems.

Family Lymnaeidae
Species: ***Lymnaea elodes***



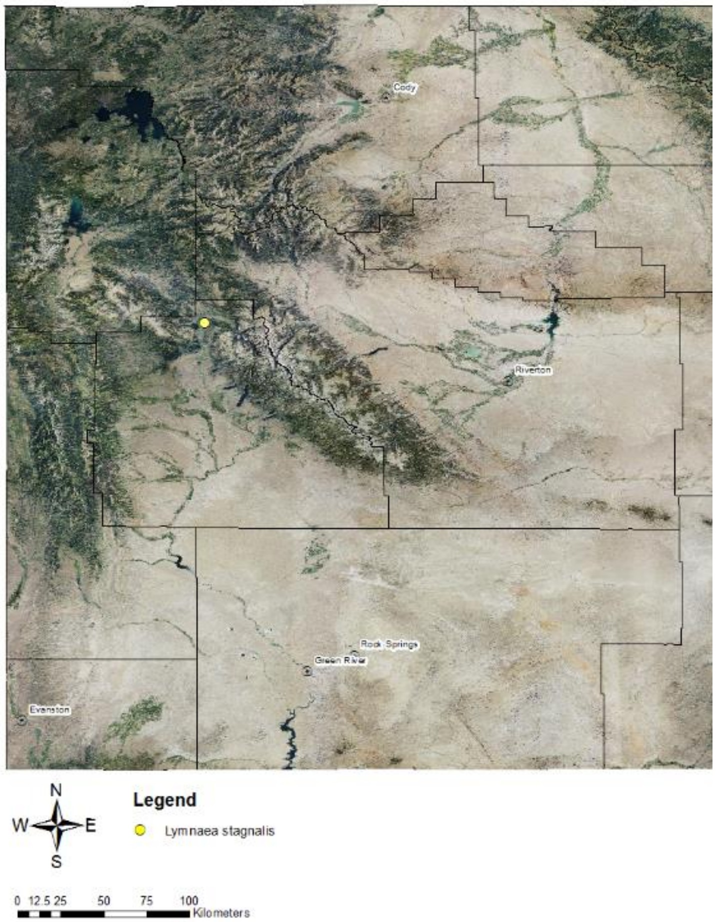
Basins: Snake and Green
Number of sites: 16
Aquatic ecosystem type: Wetlands and springs
Substrate: Fine substrate and wood
Vegetation: Submerged and emergent aquatic vegetation
Habitat: Wetlands (aquatic vegetation and wood) and springs (standing water)
Ecosystem width: 20 m (1-35)
Size range collected: 1-34 mm length
CPUE: 0.5 snails/min (0.1-2.8)
Water temperature: 13.8°C (7.2-42)
% DO: 81% (53-109)
DO: 6.5 mg O_2/L (3.9-9.4)
Specific conductivity: 400 µS/cm (139-1119)
pH: 8.0 (7.6-9.7)
Oxidation-reduction potential: 120 mV (2.6-189)
Notes: A large Lymnaeidae snail that we observed in lentic ecosystems.

Family Lymnaeidae
Species: *Lymnaea humilis*



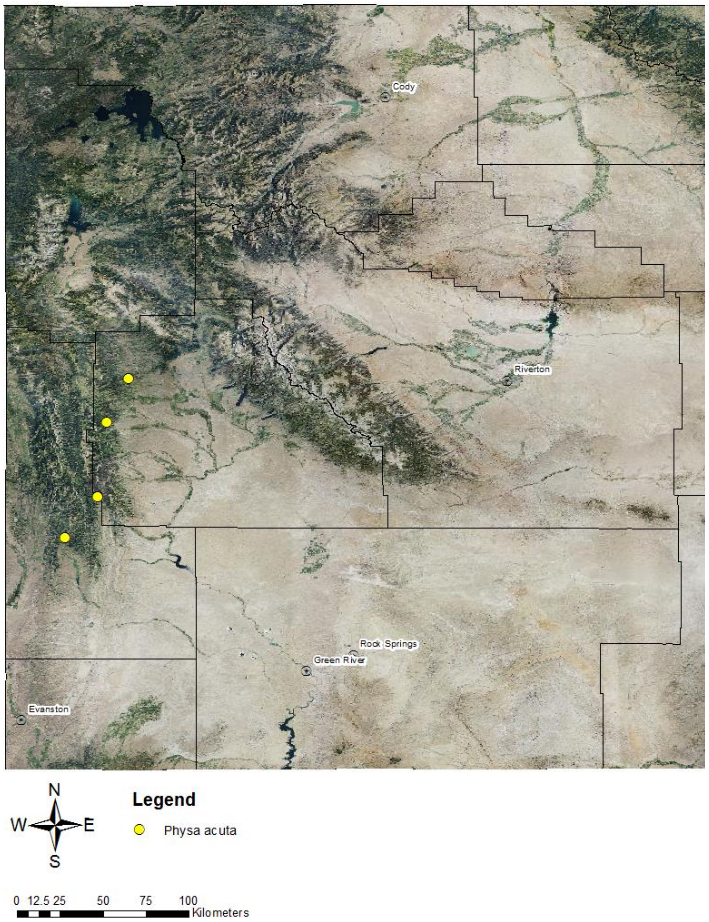
Basins: Snake
Number of sites: 1 (3 other locations where *L. bulimoides* and *L. humilis* could not be distinguished)
Aquatic ecosystem type: Large stream
Substrate: Fine substrate and cobble
Vegetation: None
Habitat: Streams (main channel, pool and backwater)
Ecosystem width: 16 m
Size range collected: 2.5-12 mm length
CPUE: 4.4 snails/min (0.1-8.7)
Water temperature: 11.4°C
% DO: 113%
DO: 9.6 mg O_2/L
Specific conductivity: 185 µS/cm
pH: 8.3
Oxidation-reduction potential: 157 mV
Notes: A small Lymnaeidae snail that lives at the margin of aquatic ecosystems (in or out of the water). Distinquished from *L. humilis* by the teeth on the radula (see image above). This snail was far more abundant in the backwaters of the stream.

Family Lymnaeidae
Species: *Lymnaea stagnalis*



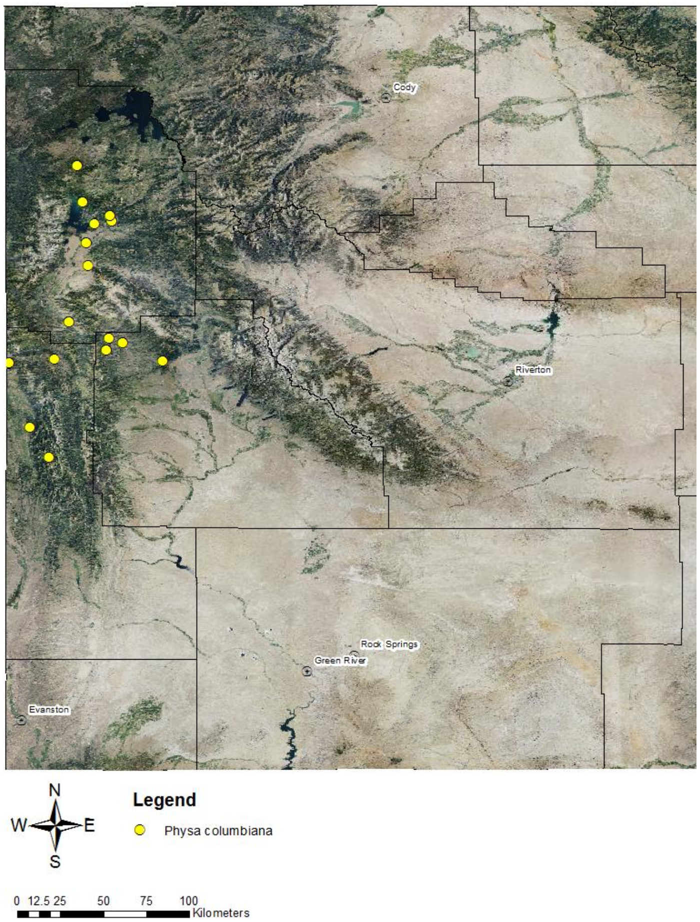
Basins: Green
Number of sites: 1
Aquatic ecosystem type: Lake
Substrate: Fine substrate
Vegetation: Submerged aquatic vegetation
Habitat: Lake (aquatic vegetation)
Ecosystem width: 419 m
Size range collected: 8.5 mm length
CPUE: 0.1 snails/min
Water temperature: 11.2°C
% DO: 69%
DO: 7.7 mg O_2/L
Specific conductivity: 158 µS/cm
pH: 7.7
Oxidation-reduction potential: 125 mV
Notes: A large Lymnaeidae snail that lives in lakes. The individual we collected was a juvenile which indicates recruitment.

Family Physidae
Species: ***Physa acuta***



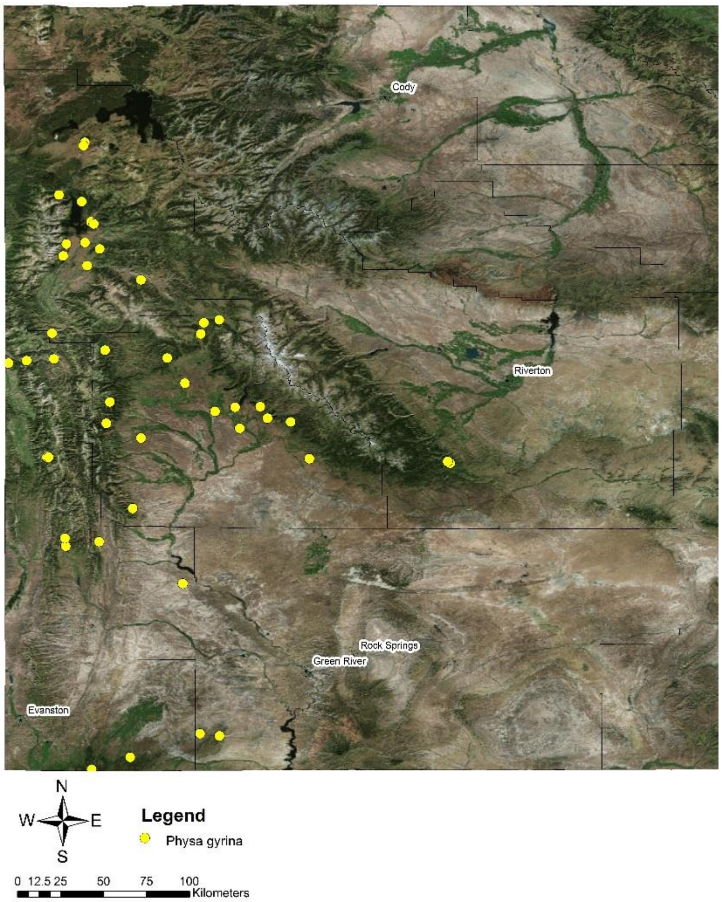
Basins: Green
Number of sites: 5
Aquatic ecosystem type: Large streams and wetlands
Substrate: Fine substrate and cobbles
Vegetation: Submerged aquatic vegetation and lacking vegetation
Habitat: Streams (main channel, side channel, margin and backwaters) and wetlands (aquatic vegetation)
Ecosystem width: 8.7 m (3-32)
Size range collected: 4-17 mm length
CPUE: 0.3 snails/min (0.1-0.9)
Water temperature: 10.1°C (6.8-16.6)
% DO: 134% (56-240)
DO: 11.5 mg O_2/L (6.7-18.7)
Specific conductivity: 316 µS/cm (296-341)
pH: 8.5 (7.5-8.9)
Oxidation-reduction potential: 133 mV (84-196)
Notes: A large Physidae snail that can live in a range of water quality.

Family Physidae
Species: ***Physa columbiana***



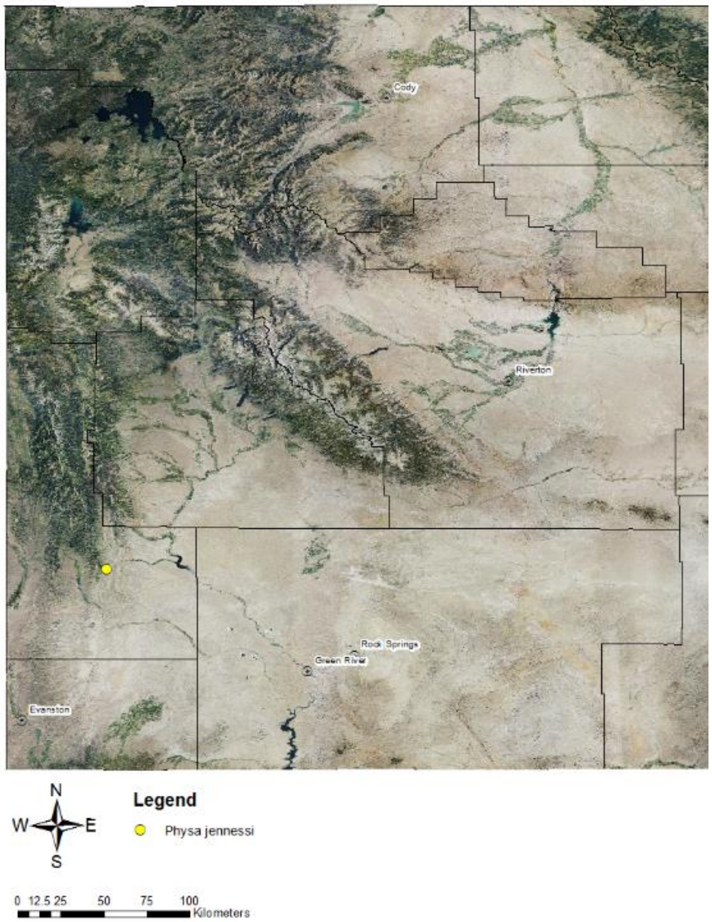
Basins: Snake
Number of sites: 16
Aquatic ecosystem type: Large and small streams, springs, lakes and wetlands
Substrate: Fine substrate, gravel, wood and cobble
Vegetation: Submerged and emergent aquatic vegetation and lacking vegetation
Habitat: Streams (main channel, side channel, margin and backwaters) and wetlands (aquatic vegetation)
Ecosystem width: 27.3 m (1-230)
Size range collected: 1-16 mm length
CPUE: 1.1 snails/min (0.1-5.3)
Water temperature: 14.8°C (3.4-42)
% DO: 98% (39-136)
DO: 8.1 mg O_2/L (2.4-11.9)
Specific conductivity: 430 µS/cm (143-1119)
pH: 8.3 (7.7-8.9)
Oxidation-reduction potential: 103 mV (2.6-196)
Notes: A large Physidae snail that can live in a range of water quality. These snails look similar to *Physa acuta* but live in the Snake River Watershed.

Family Physidae
Species: *Physa gyrina*



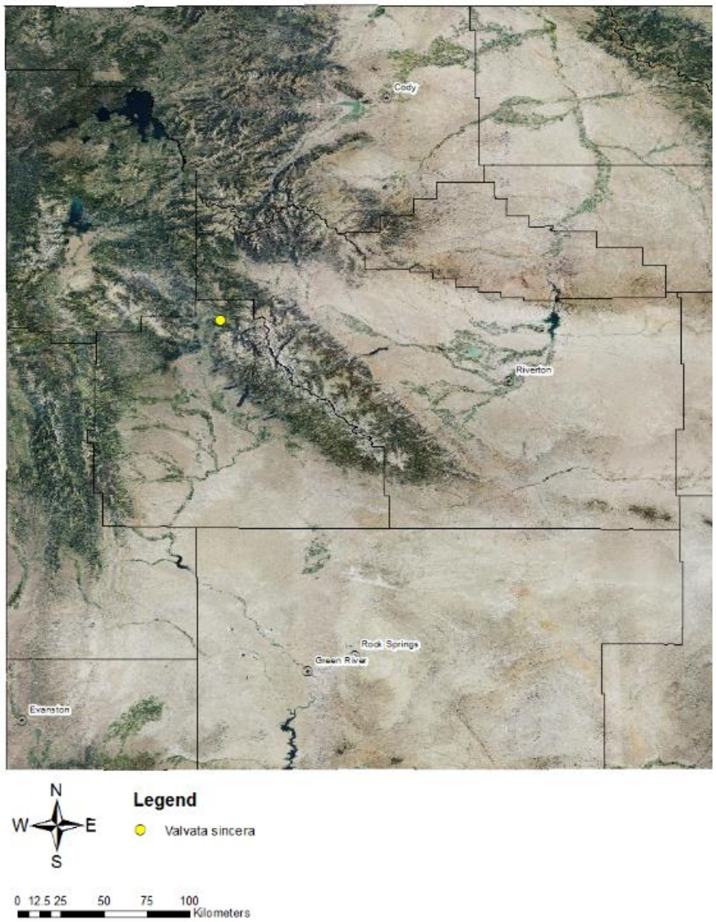
Basins: Snake and Green
Number of sites: 45
Aquatic ecosystem type: Large and small streams, springs, lakes and wetlands
Substrate: Fine substrate, gravel and cobble
Vegetation: Submerged and emergent aquatic vegetation and lacking vegetation
Habitat: Streams (main channel, side channel, pool, margin and backwater), wetlands and lakes (aquatic vegetation, fine sediment and wood), and springs (flowing and standing water)
Ecosystem width: 41 m (0.4->500)
Size range collected: 1.3-20 mm length
CPUE: 0.8 snails/min (0.06-9.2)
Water temperature: 12.8°C (3.4-27.5)
% DO: 105% (39-208)
DO: 8.9 mg O_2/L (2.4-14.1)
Specific conductivity: 320 µS/cm (15-1608)
pH: 8.3 (7.7-8.9)
Oxidation-reduction potential: 113 mV (2.6-205)
Notes: A large Physidae snail that lives in all types of aquatic ecosystems and in most microhabitats. The most common Physidae snail encountered.

Family Physidae
Species: ***Physa jennessi***



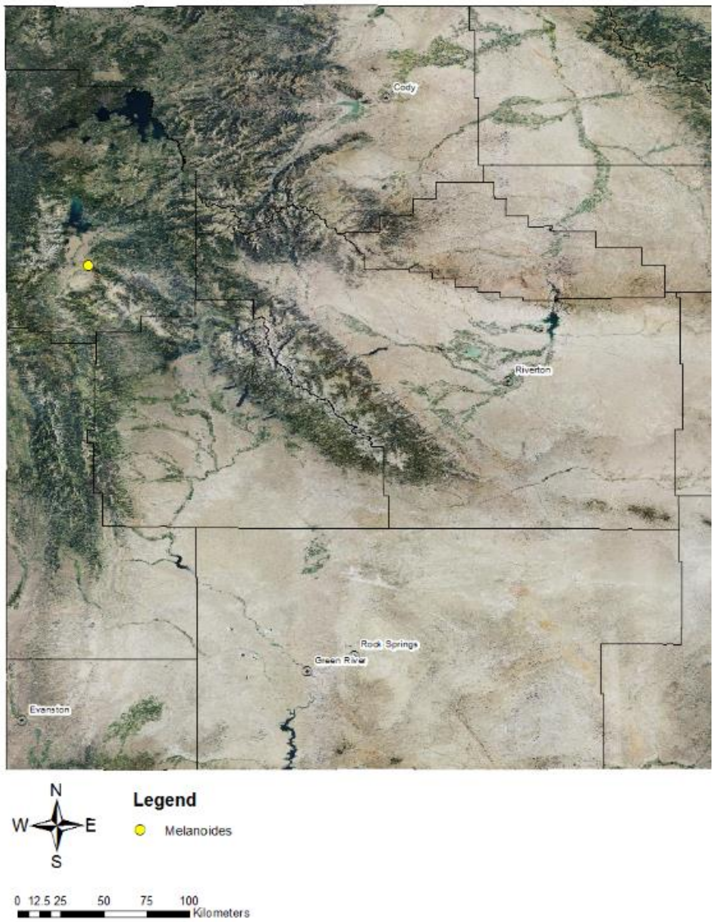
Basins: Green
Number of sites: 1
Aquatic ecosystem type: Wetland
Substrate: Fine substrate
Vegetation: Submerged aquatic vegetation
Habitat: Wetland (aquatic vegetation)
Ecosystem width: 36 m
Size range collected: 1.5-6 mm length
CPUE: 7.1 snails/min
Water temperature: 9.9°C
% DO: 109%
DO: 9.4 mg O_2/L
Specific conductivity: 678 µS/cm
pH: 9.7
Oxidation-reduction potential: 87 mV
Notes: A unique Physidae snail only found in one pond. These snails were very abundant in the pond we sampled.

Family Valvatidae
Species: ***Valvata sincera***



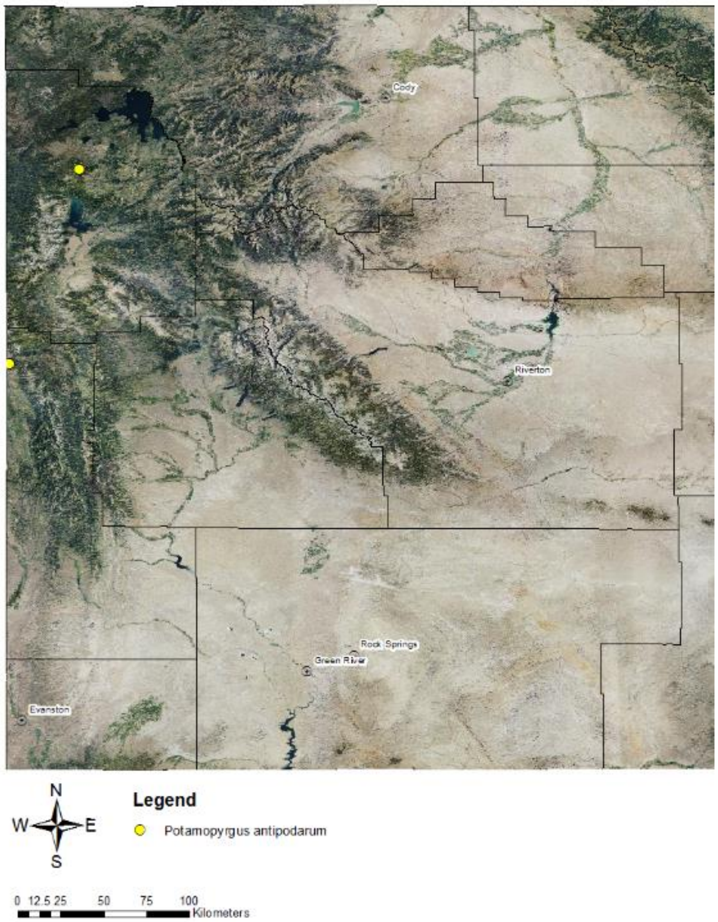
Basins: Green
Number of sites: 1
Aquatic ecosystem type: Large stream
Substrate: Fine substrate
Vegetation: Submerged aquatic vegetation
Habitat: Stream (margin)
Ecosystem width: 46 m
Size range collected: 2 mm length
CPUE: 0.1 snails/min
Water temperature: 9.7°C
% DO: 96%
DO: 10.9 mg O_2/L
Specific conductivity: 58 µS/cm
pH: 8.3
Oxidation-reduction potential: 151 mV
Notes: An operculate snail that was only collected at one site.

Family Thiaridae
Species: *Melanoides* (Non-native)



Basins: Snake
Number of sites: 1
Aquatic ecosystem type: Spring
Substrate: Gravel
Vegetation: Submerged aquatic vegetation
Habitat: Spring (standing water)
Ecosystem width: 83 m
Size range collected: 1.5-22 mm length
CPUE: 4.6 snails/min (0.1-9)
Water temperature: 27.5°C
% DO: 39%
DO: 2.4 mg O_2/L
Specific conductivity: 424 µS/cm
pH: 7.69
Oxidation-reduction potential: 122 mV
Notes: A non-native snail that needs warm water to survive. Only collected in Kelly Warm Springs. These snails probably came from an aquarium (frequently sold in the aquarium trade). They live in waters between 14 and 31°C, are parthenogenetic and embryos develop internally (Hotchkiss and Hall 2010).

Family Tateidae
Species: *Potamopyrgus antipodarum* (Non-Native)



Basins: Snake
Number of sites: 2
Aquatic ecosystem type: Large streams
Substrate: Cobble and wood
Vegetation: None
Habitat: Streams (side channel and margin)
Ecosystem width: 31.7 m (31.1-34)
Size range collected: 2-5 mm length
CPUE: 2.4 snails/min (0.1-7.6)
Water temperature: 11.4°C (10.7-11.6)
% DO: 121% (97-129)
DO: 10.8 mg O_2/L (8.4-11.5)
Specific conductivity: 432 µS/cm (379-446)
pH: 8.2 (7.9-8.3)
Oxidation-reduction potential: 154.3 mV (84-196)
Notes: A small invasive snail that is parthenogentic (females make copies of themselves). Collected in the mainstem of the Snake and Salt Rivers. Common name is New Zealand Mudsnail.

Discussion
Aquatic snails are a diverse group of animals in the Phylum Molluska that are distinguished by having shells. Snails and bivalves differ in that snails have one shell and bivalves have two. Most snails have a spiral shell but limpets have a cone-shaped shell. Snails have a single foot which they use to move, eat, sense their environment and reproduce. They are both food for predators as well as consumers themselves. Aquatic snails are eaten by a variety of animals such as shore birds, ducks and fish. Snails eat algae that grows on all surfaces underwater such as wood, rocks and macrophytes. A radula is a ribbon of teeth they use to scrape algae from surfaces. Snails are great scrapers and help control the algae growing in lotic and lentic ecosystems. Snails can be quite small (~1 mm) to large (>35 mm length) and live in many aquatic ecosystems.

Snails can be difficult to identify because most of the keys are out-of-date, only identify individuals to genus or couplets do not separate species. Prior surveys of aquatic snails in Wyoming have suffered from this poor taxonomy and availability of keys. Additionally, shell traits are plastic meaning that the same species can change the shape of their shell because of habitat characteristics. For example, snails that live in faster current often have a larger foot, such as *Lymnaea catascopium* that had a larger aperture in the Snake River compared to other ecosystem types we collected them in. These differences in shell shape have caused a lot of confusion in snail taxonomy over time. We were fortunate to work with Rob Dillon, a snail expert in North America who has studied these creatures his entire career. With his help, we made a functioning key with up-to-date taxonomy. Based on Rob's expert knowledge, he grouped some species together (e.g., *Stagnicola apicina*, *S. bonnevillensis*, *S. catascopium*, *S. hinkleyi* and *S. montanensis* now under *Lymnaea catascopium*) and identified species that may occur in Wyoming that have not been observed (e.g., *Acroloxus coloradensis*; Table 1). Many of the species he grouped could not be distinguished from one another and no molecular data was available to support their species status. For example, *Stagnicola bonnevillensis* was a Candidate species under the Endangered Species Act until 2009 when it was removed from the list because the species was discovered to be much more widely distributed. We expect that snail taxonomy will change further, and we will follow the literature and alter the key to match the findings. However, we are pleased to have a snail key for Wyoming that identifies individuals to species. Having a standardized key with which to identify snails will greatly advance our knowledge of these animals in Wyoming.

We discovered snails in many of the aquatic ecosystems we surveyed. Snails appeared to be most abundant in ecosystems with higher standing stocks of algae, on solid substrate (e.g., wood or aquatic vegetation) and habitats with slower water velocity (e.g., backwater and margins of streams). Higher standing stocks of algae may support more snails as this probably indicates higher food availability or productivity. Snails are efficient scrapers that remove biofilm from solid substrate in aquatic ecosystems. Likewise, solid substrate in an ecosystem provides places for biofilm to develop. Biofilm can grow on most solid surfaces such as rocks, wood and macrophytes. Snails were often collected in aquatic vegetation that have very high surface areas and therefore a lot of biofilm. Most snails in Wyoming do not have gills and need to periodically come to the water's surface for a breath of air. Emergent vegetation is an ideal avenue to reach the surface. Snails hold on to substrate using their foot. In lotic ecosystems, faster water velocities are more likely to dislodge snails and carry them downstream. We collected higher abundances of snails in stream microhabitats with slower water velocities. Locomotion and surfacing for a breath of air is probably easier for snails in microhabitats with slower water velocities as well as being less vulnerable to predators.

Several habitat and snail-traits may limit the distribution of snails. For example, water quality is vital to snails. Snails need enough calcium in order to secrete their shell. In general, Wyoming has high concentrations of calcium that do not limit snails; however, granite geology probably limits snails in some parts of the state. For example, some areas in the Teton and Wind River Ranges have granite geology and very low calcium concentrations (L. Tronstad, unpublished data). We have not observed snails in these areas during surveys in this study and others (L. Tronstad, personal observation). Low pH can also impede shell growth because the acidity inhibits shell secretion (Hotchkiss and Hall 2010). The pH of water in Wyoming generally is >7 and a low pH is generally not a concern in Wyoming except perhaps in granite geology especially during snowmelt. On the other hand, snail traits may also limit their distribution. Unlike insects, snails do not have a winged stage that enables them to disperse across the terrestrial landscape. Unlike fish, snails are unable to disperse upstream or quickly under their own steam. Snails may disperse by hitchhiking on other animals, such as ducks or fish. Despite these limitations, we collected snails in many of the ecosystems we sampled.

Our study produced some surprising results. First, we did not collect any limpets. Limpets are generally found a solid, smooth surfaces, such as rocks. In the eastern US, limpets are usually found on bottles discarded in streams (R. Dillon, personal communication). We did not find any bottles in streams likely because of the lower population densities in Wyoming. Limpets probably live in other basins in the state. Additionally, we collected three invasive snails. *Melanoides tuberculata* was collected in Kelly Warm Springs and was previously known from this location. This snail was introduced between 2001 and 2005, likely from an aquarium release (Hotchkiss and Hall 2010). *Potamopyrgus antipodarum* (New Zealand Mudsnails) are known from a few locations in Wyoming: Pole Cat Creek (Rockefeller Parkway), Firehole River (Yellowstone National Park), Snake River (south of Yellowstone Entrance), in the canyon north of Boysen Reservoir, Green River (inlet of Flaming Gorge Reservoir) and in the Shoshone River (east side of Cody; USGS website). We collected these snails near the previous collection location in the Snake River and at a new location in the Salt River. Like many of the sites where *P. antipodarum* are found (i.e., Firehole River, Snake River, Shoshone River, Green River and Wind River Canyon), the Salt River is frequented by recreationists, which may be their source. *Potamopyrgus antipodarum* are parthenogenetic meaning that introducing one individual to a site can start a new population, because females reproduce without mates. We took precautions between sampling sites by having multiple wading gear, letting wading gear dry, not using felt bottom soles, and cleaning and inspecting gear. Finally, we discovered *Lymnaea auricularia* at two new sites in Wyoming. Larson (2018) reported this snail from three locations in Grand Teton National Park and the Laramie River west of Laramie. We discovered the snail in a wetland by Jackson Lake and the Snake River. Our study has produced many new records of snails in Wyoming and advanced our knowledge of aquatic snail taxonomy in the state. The new information will be incorporated into future State Wildlife Action Plans and added to the Wyoming Natural Diversity Database so that the information can be used to base management decisions on.

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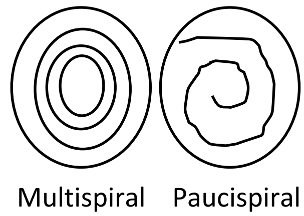
Appendix 1. Key to the Freshwater Gastropods inhabiting Wyoming

Rob Dillon and Lusha Tronstad 2018
Direct questions to Lusha Tronstad, Invertebrate Zoologist, Wyoming Natural Diversity Database, University of Wyoming, tronstad@uwy.edu, 307-766-3115

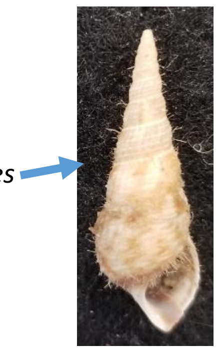
1a) Operculum present. . . . . . Subclass Prosobranchia (2)
1b) Operculum absent . . . . . . Subclass Pulmonata (10)

2a) Operculum multispiral (Valvatidae) . . . . (3)
2b) Operculum paucispiral. . . . . . . (4)
*Remove operculum and view with transmitted light from below

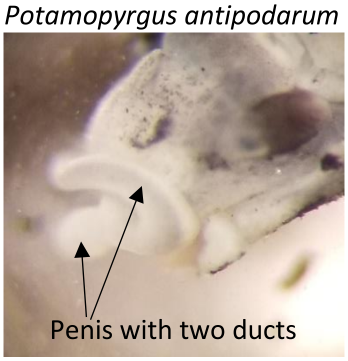


3a) Shell smooth, without carination … *Valvata sincera*
3b) Shell with a single carina, becoming obsolete … *Valvata utahensis*
3c) Shell with three spiral carinae … *Valvata tricarinata*

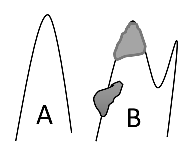
4a) Adults >12 mm shell length, all female, ovoviviparous brooders (Thiaridae) . . . *Melanoides tuberculata*
4b) Adults <12 mm shell length, sexes separate (Hydrobiod taxa) . . . . . (5)



5a) Penis with a single duct under mantel . . . (6)
5b) Penis with two ducts under mantel (Amnicolidae) . . . (9)
5c) Males rare or entirely absent, females parthenogenic, usually full of embryos (live bearers) . . . *Potamopyrgus antipodarum*



6a) Penis simple, with a single duct (**A**). Inhabits rocky riffles (Lithoglyphidae) . . . (7)
6b) Penis with a single duct and a glandular (grey on drawing), terminal lobe (**B**; Hydrobiidae) … (8)



7a) Snake River drainage … *Fluminicola coloradoensis* (via Lui et al. 2013)
7b) Green River drainage … *Fluminicola coloradoensis*

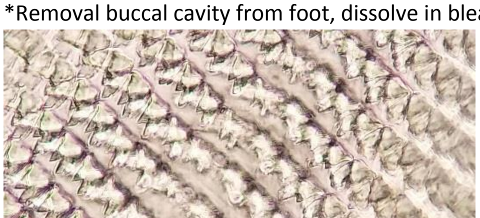
8a) Dorsal surface of penis bearing an elongated gland extending from the base of filament. Snake River drainage … *Pyrgulopsis robusta*
8b) Bear Creek drainage… *Pyrgulopsis pilsbryana*

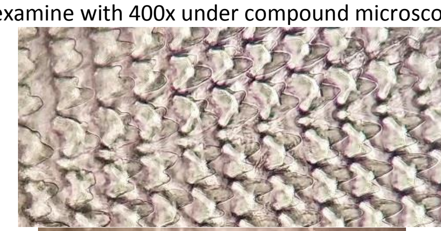
9a) Adult shell length approx. 3 mm, sutures notched. Snake River Basin … *Colligyrus greggi*
9b) Adult shell length 4 – 5 mm, shell sutures not notched. Widespread in lentic waters throughout North America … *Amnicola limosa*

10a) Shell dextral . . . Family Lymnaeidae (11)
10b) Shell sinistral, not planispiral . . . Family Physidae (17)
10c) Shell sinistral, planispiral . . . Family Planorbidae (21)
10d) Shell patelliform . . . (28)

Lymnaeidae
11a) Adult shell 13 mm standard length or less, generally on mud above water (≥4 whorls) … (12)
11b) Adult shell between 13 and 35 mm standard length, apex not concave, various habitat … (13)
11c) Adult shell >35 mm length, apex concave, lakes … *Lymnaea stagnalis*

12a) Adult shell narrow, usually <10 mm standard length, lateral teeth of radula tricuspid … *Lymnaea (Galba) humilis*
12b) Adult shell broader, rounded, often >10 mm standard length, lateral teeth of radula bicuspid … *Lymnaea (Galba) bulimoides*
*Removal buccal cavity from foot, dissolve in bleach and examine with 400x under compound microscope

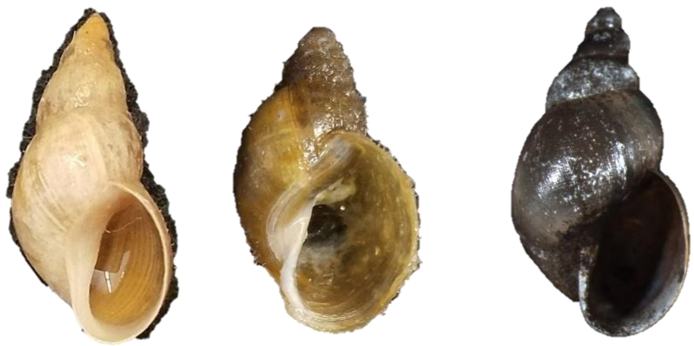




13a) Shell sturdy, aperture ≤60% of shell length … (14)
13b) Shell fragile, aperture >60% of shell length … (16)

14a) Shell sculptured with fine periostracal ridges (fuzz at apex) … *Lymnaea (Galba) caperata*
14b) No periostracal ridges… (15)

15a) Shell with relatively narrower body whorl … *Lymnaea (Stagnicola) elodes*
15b) Shell with relatively wider body whorl … *Lymnaea (Stagnicola) catascopium*

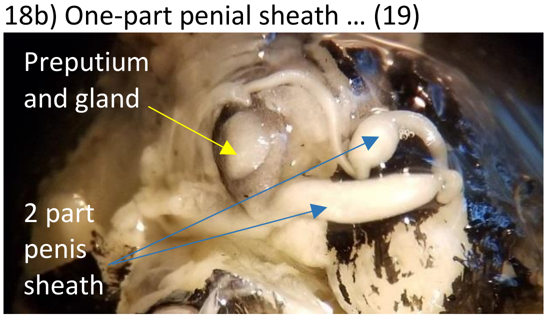


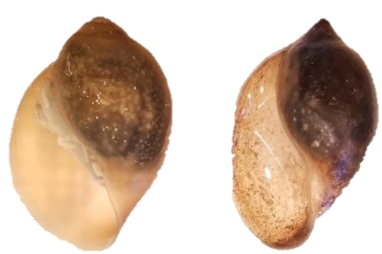
L. elodes *L. catascopium*

16a) Body whorl moderately expanded … *Lymnaea (Pseudosucinea) columella*
16b) Body whorl globose (inflated) … *Lymnaea (Radix) auricularia*

Physidae
17a) Shell slender, glossy. Penis lacks a preputial gland. Ditches, vernal habitats . . . *Aplexa hypnorum*
17b) Shell unremarkable, habitat unremarkable, penis bearing a preputial gland . . . (18)

18a) Two-part penial sheath. Shell apex notably convex. Widespread, but generally in nutrient-poor waters … *Physa gyrina*
18b) One-part penial sheath … (19)





P. gyrina *P. acuta*

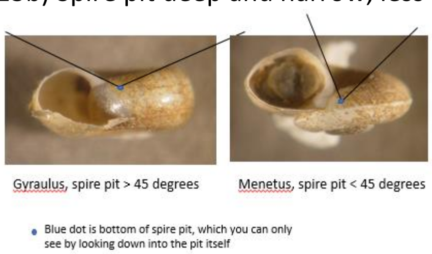
19a) One-part, glandular penial sheath. Adult sizes smaller. Shell apex convexish.   Enlarged mantle enfolds the shell. Mountain lakes and ponds . . . *Physa jennessi*
19b) One-part, muscular penial sheath. Shell apex concave … (20)

20a) Cosmopolitan, especially in rich, disturbed habitats . . . *Physa acuta*
20b) Snake River, but otherwise indistinguishable to my eye … *Physa columbiana*, maybe
20c) Just that one cave … *Physa spelunca*

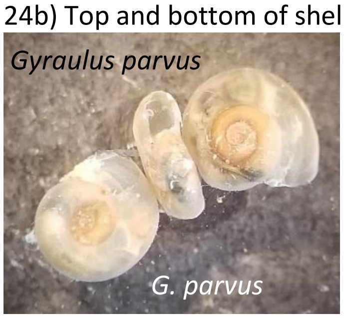
Planorbidae
21a) Adult shell small, less than 8 mm diameter … (22)
21b) Adult shell larger … (26)

22a) Shell costate … Gyraulus crista
22b) Shell not costate … (23)

23a) Spire pit shallow and wide, greater than 45 degrees … (24)
23b) Spire pit deep and narrow, less than 45 degrees … (25)



24a) Top and bottom of shell nearly identical, whorls increase uniformly in size … *Gyraulus circumstriatus*
24b) Top and bottom of shell differ, whorls increase more rapidly with size … *Gyraulus parvus*



25a) Shell periphery rounded … *Promenetus umbilicatellus*
25b) Shell periphery weakly angular, distinctly off mid-whorl … *Menetus operularis*
25c) Shell periphery strongly carinate, approximately mid-whorl … *Promenetus exacuous*

26a) Shell compressed, thin and weak … *Planorbula campestris*
26b) Shell broad, too solid to crush accidentally … (27)

27a) Shell deeply pitted when viewed from either aspect … *Helisoma anceps*
27b) Shell bearing a spire pit on one side and a flattened concavity on the other … *Helisoma trivolvis*
27c) Shell bearing a spire pit on one side and an apparent "apex" on the other … *Helisoma (Carinifex) newberryi*

Helisoma trivolvis

Limpets
28a) Adult shell larger than 7 mm, Snake River basin (a patelliform lymnaeid) … *Fisherola nuttalli*
28b) Adult shell smaller than 7 mm … (29)

29a) Apex acute, to the left of midline, habitat high mountain lakes (Acroloxidae) … *Acroloxus coloradensis* (not confirmed in Wyoming)
29b) Apex low, not acute, cosmopolitan habitat … (30)

30a) Apex distinctly to the right of the midline . . . *Ferrissia fragilis*
30b) Apex approximately in the midline . . . *Ferrissia rivularis*