Utah and Colorado
Water Survey for Mussels and Snails

Final Report
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Cooperators

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Attachments:

Tabular Data (Tabular_Data_10Nov17.xlsx)
ArcGIS Map Package (DEQMolluskMapping2017329.mpk)
MAPIT Online Utility (https://qcnr.usu.edu/wmc/data, Project UT-CO-Mollusks)

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INTRODUCTION

The United States Environmental Protection Agency has released updated water quality criteria for ammonia (Table 1 in the Executive Summary of USEPA 2013a). These new criteria are designed to ensure that ammonia-sensitive species (specifically unionid mussels and non-pulmonate snails) are protected (USEPA 2013a). Meeting these new criteria may require that existing facilities discharging into waters inhabited by ammonia-sensitive species be upgraded to meet the new, more stringent standards. The USEPA recognizes that the new criteria may be overly stringent for waters that do not naturally support ammonia-sensitive species, and allows states to derive site-specific criteria reflecting the potential of individual water bodies to support the aquatic life expected at each site (USEPA 2013b,c). Site-specific (or watershed-specific) ammonia criteria may make sense for Utah and Colorado if ammonia-sensitive mollusk species are less common in Utah and Colorado than in other states.

The overarching goal of the study was to conduct a comprehensive search and synthesis of existing records on the historical and current presence of ammonia-sensitive freshwater mussels (Superfamily Unionoidea) and non-pulmonate snails (Valvatidae, Hydrobiidae) in Utah and Colorado. The earliest record identified was from 1871. In addition to these targeted species, other species belonging to Class Bivalvia and freshwater Gastropoda were also included. Though they were not actively sought during record searches, occurrence of non-native species such as the New Zealand mud snail (*Potamopyrgus antipodarum*), Asian clam (*Corbicula fluminea*), quagga mussel (*Dreissena burgensis*) and the Chinese mystery snail (*Cipangopaludina chinensis*) were also noted.

Historical and current distribution records for mussels in the family Unionidae indicate that potentially suitable habitats for these sensitive species represent a smaller fraction of the streams, lakes, and wetlands in Colorado and Utah than in either eastern or far western states. Of the nearly 300 freshwater mussel species in the United States and Canada (Williams et al. 1993), only three species have been reported in Colorado by the Colorado Natural Heritage Program and in Utah (Hovingh 2004). However, other freshwater mollusks can be much more common, especially spring snails in the genus *Pyrgulopsis* (family Hydrobiidae) in Utah and Pisidiidae (= Sphaeriidae) (fingernail and pea clams) in both states. Although some non-pulmonate snails are known to be sensitive to ammonia, the ammonia sensitivity of most freshwater mollusk species in Utah and Colorado is unknown.

Synthesis of these data in a user-friendly format, presented as part of this report in the Tabular Data supporting document, will enable Utah and Colorado agencies to identify specific water bodies that may be subject to the new ammonia criteria and represents the first step in identifying the types of water bodies that are likely to contain ammonia sensitive mollusks. We do not assume that water bodies lacking records of occurrence by sensitive mollusks do not (or did not) support those species. To fully justify exclusion from the new ammonia standards, additional studies based on other approaches will be needed. These other approaches may include extensive physical surveys to document species absence, environmental DNA surveys, and ecological modeling to predict habitat suitability.

SEARCH METHODS/DATA COLLECTION

Assembly of information from literature and databases required use of an array of resources. We first searched large previously-compiled databases available online such as USGS BISON and Global Biodiversity Information Facility (GBIF) (See Table 1 for a complete list). These databases were used to identify primary sources (defined as where the data were originally published), including museums, peer and non-peer reviewed literature and reports, and direct contacts. Once primary sources were identified, museums and online databases were searched for online records of target species. The purpose of searching these online resources first was to identify the bulk of available records in Utah and Colorado that would likely also be found during literature searches, thus minimizing time spent entering data. By initially collecting records from museums, online databases, and direct contacts, we could obtain the most current records available from institutions and organizations responsible for collection and reporting of specimens.

Table 1. List of previously-compiled databases initially searched for records of target species occurrence.

Database	Curating Institution	Access Date	Website
BISON	USGS	5/5/2016	https://bison.usgs.gov/
GBIF	(Participating governments)	6/27/2016	http://www.gbif.org/
iDigBio	ADBC	8/1/2016	https://www.idigbio.org/
iNaturalist	California Academy of Sciences (CAS)	6/27/2016	https://www.inaturalist.org/
MAPIT	WMC/NAMC	5/25/2016	http://www.qcnr.usu.edu/wmc/data
NatureServe Explorer	NatureServe	5/25/2016	http://explorer.natureserve.org/
MUSSELp	University of Wisconsin-Steven Point	5/25/2016	http://mussel-project.uwsp.edu/
(Direct Contact)	Xerces Society	5/25/2016	http://xerces.org/
NPSpecies	IRMA	5/25/2016	https://irma.nps.gov/NPSpecies/

If records were not available online, the identified source was contacted via email followed by a phone call. All institutions contacted replied to our information requests, although several had specimens that had not yet been catalogued (Table 2) and were therefore not accessible for the purposes of this report. We suggest following up with these institutions later and incorporating any new records into the compiled database.

Table 2. Institutions and individuals which may have specimens that have not yet been catalogued or fully entered into digital databases and warrant future investigation for applicable records of target species.

Institution	Curating Institution	Website
Denver Museum of Natural and Science	Denver, City	http://www.dmns.org/
Monte L. Bean Life Science Museum	Brigham Young University	https://mlbean.byu.edu/
Bell Museum of Natural History	University of Minnesota	https://www.bellmuseum.umn.edu/
Natural History Museum of Los Angeles County	Los Angeles, County	https://nhm.org/site/
Museum of Biological Diversity	Ohio State University	https://mbd.osu.edu
Santa Barbara Museum of Natural History	Private, Non-profit	http://www.sbnature.org/
Museum of Zoology	University of Michigan	http://lsa.umich.edu/ummz/
Dan Gustafson	Montana Entomology Collection (collection donated)	http://mtent.org

Following searches of online databases, we used physical and online resources at the Utah State University Merrill-Cazier Library to identify additional relevant records. We also used subject librarian search services at the S.J. & Jessie E. Quinney Natural Resources Research Library to perform focused searches of target taxa. Web of Science, Google Scholar, and other online resources to find literature on target species, genera, and families. The advent of genetic, morphological, and computational tools has resulted in many taxonomic changes in unionid freshwater mussels and non-pulmonate snails in recent decades. As a result, searching database entries, scientific publications, and museum records for these species required the use of multiple nomenclatures. As we encountered nomenclature changes in these searches, taxonomic synonymies and common names were added to the search terms. In general, we conducted a series of searches based on different criteria and search terms until no additional references were discovered. We then searched the bibliographies and cited literature sections of each of the publication discovered in these searches for additional literature that may have been missed by the online searches.

State and non-government agencies and universities were also considered potential sources of unpublished records or records that were not part of more generally accessible databases. To discover these records, we contacted invertebrate biologists at the Departments of Natural Resources in both Utah and Colorado. We also contacted aquatic invertebrate researchers at other colleges and universities in both states about these types of records and collections. Contacts included:

- Peter Hovingh, Salt Lake City, Utah
  - Contact Note: Peter Hovingh supplied both data from the Natural History Museum of Utah Inverterbrate Division as well as surveys conducted without any affiliation or financial support.
- Russ Rader, Professor of Aquatic Ecology, Brigham Young University
- Krissy Wilson, Native Aquatic Species Program Coordinator, Utah Division of Wildlife Resources.
- BIO-West, Inc., Logan, Utah
- Molecular Ecology Laboratory, USU, Wildland Resources
- The USU/BLM National Aquatic Monitoring Center, Logan, Utah
- David C. Richards, OreoHelix Consulting, Moab, Utah
- Lawrence Gray, Professor of Biology, Utah Valley University
- Robert C. Guralnick, Associate Curator of Biodiversity Informatics, FMNH (No Reply)
- Utah Natural Heritage Program (UNHP)
- Colorado Natural Heritage Program (CNHP)

We used an EndNote™ (Clarivate Analytics) bibliographic database to compile and manage museum, literature, and personal contact information. Sources were entered whether or not they contained a record of a target species. This approach allowed us to track records that had already been reviewed as well as sources that did not contain records. A list of these sources is included in Appendix A and Appendix B.

In addition to compiling primary sources with applicable records, secondary sources were also compiled. We defined ‘secondary source’ as any literature that led us to a primary source of information, e.g., an applicable record was first seen in Chamberlin and Ernest (1948), but the primary reporting of this specimen, or earliest published record, was found in Gregg (1942). In this case, the data provided from Gregg (1942) were entered into the Tabular Data.

DATA ENTRY

All records were assigned a geographic location. Some form of geographic location had been assigned by the primary source. In addition, some primary sources augmented the original coordinate data with descriptive data. Because the accuracy and precision of location data varied among records, we assigned location confidence scores to both descriptive locations and geographic coordinates. If records contained only descriptive location data, we assigned geographic coordinates and confidence scores based on the descriptions provided. A number of records (n=85) contained no descriptive location data or geographic coordinates and could only be assigned to County or State. These records were assigned geographic points at the centroid of

their respective State or County and can be identified in the Tabular Data 'USU_Location_Name' field listed under its respective State or County.

We made every effort to remove duplicate records from the database but cannot guarantee that each species record is unique within the database. As specimens are loaned or moved between institutions, records may or may not be updated, and it was not feasible to track individual records to point of origin.

Data were recorded verbatim from the primary source. We occasionally found that initial species identifications had been challenged or later changed, and we made corresponding changes to our reported data. Other than correcting for published synonymies, we could not independently determine the accuracy of species identifications. While the data presented in this report is as accurate as the scope and intention of this project allows, there is a degree of taxonomic uncertainty, as is present with any taxonomy. As such, records should be thoroughly vetted and specimen of interest may require re-examination by species experts.

As records were located, they were recorded into a Microsoft Excel worksheet. Due to the sensitive nature of some locational data for some species, two separate tabular data sheets were created. The first sheet, "Tabular Data," contains records of species and data that are not considered to be sensitive and can be shared publicly. A second sheet, "Protected Tabular Data", was created to contain records protected by Data Use Agreements with cooperating agencies (Utah and Colorado Natural Heritage Programs; Appendix C).

For each species reported in the Tabular Data, we used the Integrated Taxonomic Information System (ITIS; itis.gov) to determine its current taxonomic status. If ITIS did not contain a species, other taxonomic authorities were searched. The taxonomic authority for each species was included in the Tabular Data.

RESULTS

To meet the goals of this study, we created three supporting data resources to this report: 1) a database of tabular data containing Mollusca occurrence records 2) an ArcGIS Map Package to allow further geospatial analysis by report cooperators as desired, and 3) incorporation of the geospatial records in the tabular data to the MAPIT (Mapping Application for Freshwater Invertebrate Taxa) online mapping utility jointly supported by the Western Center for Monitoring and Assessment (WMC) and the National Aquatic Monitoring Center (NAMC). These resources provide complementary information.

The tabular data contains the data associated with each individual record discovered in this study. For example, the tabular data include each record's identifying information, conservation status, native status, and the verbatim data on taxonomy, geospatial descriptors and coordinates, and survey dates that accompanied each record. A full list of tabular data fields and their respective definitions are included in Appendix D as well as in the 'Tabular_Data_Definitions' sheet of the Tabular Data file.

The ArcGIS Map Package and MAPIT online utility can be used to visually inspect the tabular data. The map package allows for assessment of the data at different spatial scales and relative to other layers of interest. Figure 1 is an example of the map package output and shows the spatial distribution of records identified in this study. The MAPIT online utility provides an abbreviated version of the tabular data and provides access to record locations by Utah and Colorado water quality authorities as well as the general public and researchers interested in the data set. The MAPIT version of the data does not include any records from the tabular data that are protected under agreements made with the Natural Heritage Programs of each State. The protected data are only available to State water quality authorities and **are not to be made publicly available**. For access to these records, permission needs to be granted from the respective Natural Heritage Program.

We compiled 4,863 records of the target taxa (Tables 3-5). An additional 269 non-target species records were also included in our compilation. Records included 2,643 bivalves (Class Bivalvia) and 2,489 freshwater gastropods (Class Gastropoda), of which 2,479 records belonged to the superfamily Unionoidea and 2,384 records belonged to the families Valvatidae and Hydrobiidae.

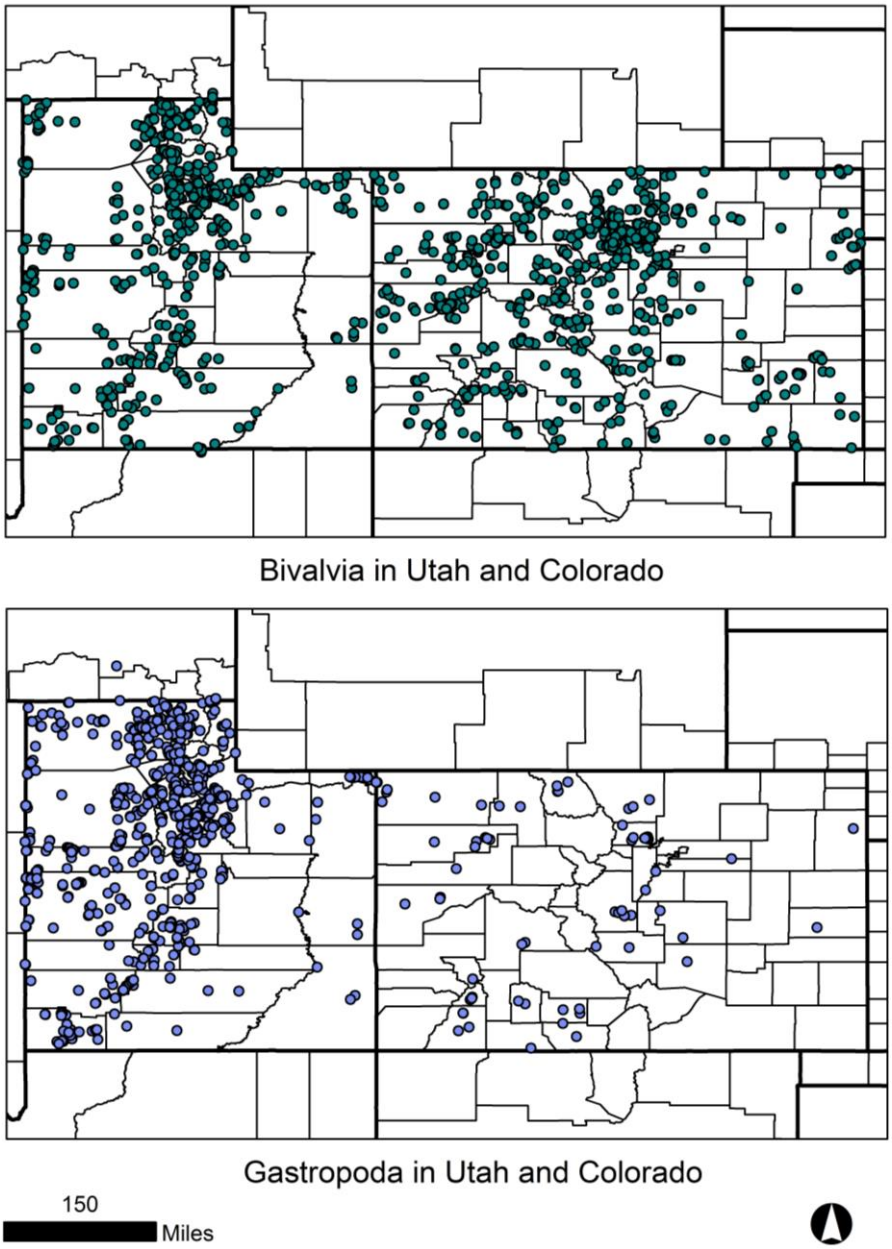

Figure 1. Maps showing record coverage of bivalves and gastropods in Utah and Colorado.

Table 3. Summary of the number of records in the tabular data. These data include 2 classes, 13 families, and 30 genera within the phylum Mollusca.

Record type	# records
Total number of records	5,132
Target taxa records	4,863
Non-target taxa records	269

Table 4. Number of records in different families and genera of Bivalvia.

Family/Genus	# records
Corbiculidae	144
Above genus	1
Corbicula	143
Dreissenidae	20
Dreissena	20
Margaritiferidae	26
Margaritifera	26
Sphaeriidae	2,042
Above genus	53
Musculium	140
Pisidium	1637
Sphaerium	212
Unionidae	411
Above genus	30
Anodonta	318
Elliptio	1
Pyganodon	51
Strophitus	3
Uniomerus	7
Utterbackia	1
Total Bivalvia records	2,643

Table 5. Number of records in different families and genera of Gastropoda.

Family/Genus	#records
Bithyniidae	56
Paludestrina	56
Cochlicopidae	24
Cochlicopa	24
Hydrobiidae	2,189
Above Genus	255
Amnicola	98
Cincinnatia	24
Fluminicola	252
Fontelicella	87
Fontigens	1
Hydrobia	70
Lyogyrus	1
Potamopyrgus	483
Pyrgulopsis	821
Tryonia	97
Planorbidae	7
Helisoma	7
Pleuroceridae	3
Juga	3
Pomatiopsidae	4
Pomatiopsis	4
Valvatidae	195
Above Genus	27
Valvata	168
Viviparidae	11
Above Genus	3
Cipangopaludina	7
Viviparus	1
Total Gastropoda Records	2,489

Most of the taxa we encountered were not present in the national toxicity dataset (USEPA 2013a). In such cases, the EPA recommends "…to consider which tested species are most closely related to those occurring at the site and to delete those for which another tested species would better represent the species occurring at the site" (USEPA 2013b). We therefore identified the most closely related taxa in the national toxicity dataset (USEPA 2013a), noting taxa within the same family, genus, or species (Table 6). We note three important caveats relating to this work. First, taxonomic relationships may not be consistent with phylogenetic relationships, and both are frequently modified based on new genetic or other information. We used taxonomic information currently available in ITIS as well as in other sources (cited in Table 6). Second, evolutionary differences/distances between identical taxonomic levels are not equal. For example, all genus-level taxonomic distinctions do not reflect equal levels of evolutionary (and hence potential toxicological) divergence. Third, and perhaps most importantly, phylogenetic similarity may not predict toxicological similarity (Blomberg et al. 2003; Losos 2008). The probability of toxicological similarity is presumably greatest when taxa are identical at the species or genus level due to shared life-history, morphological, or physiological traits (USEPA 2013a,b). However, traits related to toxicological susceptibility may evolve at rates not reflected in overall phylogenetic (or taxonomic) similarity.

LIMITATIONS AND RECOMMENDATIONS FOR NEXT STEPS

Historical records rarely include documented absences, and are usually based on opportunistic rather than systematic surveys. Detection probabilities based on these opportunistic surveys are expected to differ dramatically based on observer skills, sampling methods, and field conditions. Thus, while documented occurrences of targeted taxa are an important first step in understanding potential applicability of the new ammonia standards, both historical and present-day occurrences may be greatly underestimated. We recommend two approaches to improve assessment of potential and present-day species occurrences: habitat suitability modeling and environmental DNA (eDNA) monitoring.

Habitat suitability modeling can quantify the likelihoods that different water bodies support (or supported) distinct species of interest (e.g., Elith and Leathwick 2009, Cao et al 2017)). One type of habitat suitability model (maximum entropy models – Phillips and Dudik 2008) are relatively insensitive to absence data and thus can be calibrated with survey records of the type compiled here. These models can then be applied to all water bodies within a region of interest to estimate their likely potential for supporting individual species of interest. These estimates, in turn can be used to inform survey programs designed to confirm if target species are present or not.

To confirm present-day occurrences, either traditional survey methods (e.g., USEPA 2013c) or highly sensitive and less time-consuming eDNA surveys or both can be used. eDNA surveys are an emerging approach that has been shown to be more sensitive and less costly in many cases than traditional survey methods (Lodge et al. 2012). eDNA is DNA shed by organisms living in or passing through water, and is detected by filtering large volumes of water and subsequently obtaining DNA sequences from the filter. DNA detection can be accomplished using targeted quantitative polymerase chain reaction (qPCR) or generalized metagenomic approaches (Keck et al. 2017).

Table 6. Nearest taxonomic relatives between UT and CO species listed in the Tabular Data and those listed in Appendices A, B, and C of USEPA (2013a).

Closest Species in USEPA 2013 Appendices A, B, C/ Species in Tabular Data			
Alasmodonta heterodon (1)			
Anodonta californiensis			
Lasmigona subviridis (1)			
A. californiensis/nuttalliana	*Anodonta ferussacianus*	*Anodonta nuttalliana*	*Strophitus undulatus*
Anodonta cygnea	*Anodonta kennerlyi*	*Anodonta oregonensis*	*Utterbackia imbecillis*
Fluminicola spp. (2)			
Fluminicola coloradoensis	*Fluminicola fuscus*	*Fluminicola nuttallianus*	
Fluminicola columbiana	*Fluminicola hindsi*	*Fluminicola seminalis*	
Fontigens aldrichi (3)			
Fontigens binneyana			
Fusconaia masoni (1)			
Elliptio pullata			
Helisoma trivolvis (6)			
Helisoma newberryi			
Musculium transversum (4)			
Musculium lacustre	*Pisidium compressum*	*Pisidium miliva*	*Pisidium ventricosum*
Musculium partumeium	*Pisidium conventus*	*Pisidium nitidum*	*Sphaerium dentatum*
Musculium securis	*Pisidium exiquum*	*Pisidium parvus*	*Sphaerium nitidum*
Musculium transversum	*Pisidium ferrugineum*	*Pisidium punctatum*	*Sphaerium occidentale*
Musculium truncatum	*Pisidium hallae*	*Pisidium rotundatum*	*Sphaerium patella*
Musculium uintaense	*Pisidium huachucanum*	*Pisidium stigosa*	*Sphaerium simile*
Pisidium avum	*Pisidium insigne*	*Pisidium subtruncatum*	*Sphaerium striatinum*
Pisidium calcolus	*Pisidium lilljeborgii*	*Pisidium supinum*	
Pisidium casertanum	*Pisidium milium*	*Pisidium ultramontanum*	
Pisidium coarctatum	*Pisidium milium\ventricosum*	*Pisidium variabile*	
Pyrgulopsis idahoensis (7)			
Pyrgulopsis anguina	*Pyrgulopsis kolobensis*	*Pyrgulopsis transversa*	*Fontelicella pavantica*
Pyrgulopsis californiensis	*Pyrgulopsis longinqua*	*Pyrgulopsis variegata*	*Fontelicella pilsbryana*
Pyrgulopsis chamberlini	*Pyrgulopsis nonaria*	*Cincinnatia cincinnatiensis*	*Fontelicella sanpetensis*
Pyrgulopsis deserta	*Pyrgulopsis peculiaris*	*Cincinnatia peracuta*	*Fontelicella sevierensis*
Pyrgulopsis fusca	*Pyrgulopsis pilsbryana*	*Fontelicella bonnevillensis*	*Fontelicella stearnsiana*
Pyrgulopsis hamlinensis	*Pyrgulopsis pinetorum*	*Fontelicella deserta*	
Pyrgulopsis inopinata	*Pyrgulopsis plicata*	*Fontelicella glenwoodensis*	
Pyrgulopsis intermedia	*Pyrgulopsis saxatilis*	*Fontelicella koosharensis*	
Pleurocera canaliculata			
Juga bairdiana			
Pleurocera uncialis			
Juga bulbosa	*Juga silicula*		
Pyganodon grandis (1)			
Pyganodon grandis			
nothing in same order			
Cochlicopa lubrica			
nothing in same superfamily			
Dreissena burgensis	*Dreissena polymorpha*		
nothing in same family			
Cipangopaludina chinensis	*Pomatiopsis cincinnatiensis*	*Valvata malleata*	*Corbicula fluminalis*
C. chinensis malleata	*Pomatiopsis lapidaria*	*Valvata sincera*	*Corbicula fluminea*
Cipangopaludina malleata	*Valvata humeralis*	*Valvata utahensis*	*Margaritifera falcata*
Pomatiopsis binneyi	*Valvata lewisi*	*Viviparus*	*Margaritifera margaritifera*
nothing in same subfamily			
Amnicola greggi	*Amnicola longinqua*	*Hydrobia stagnalis*	*Tryonia clathrata*
Amnicola integra	*Amnicola pilsbryi*	*Lyogyrus pilsbryi*	*Tryonia exigua*
Amnicola limosus	*Hydrobia atea*	*Paludestrina longinqua*	*Tryonia longinqua*
Amnicola limosus limosus	*Hydrobia longinqua*	*Potamopyrgus antipodarum*	*Tryonia protea*
nothing in same tribe or genus			
Uniomerus tetralasmus			

Sources: (1) LopesLima et al 2017, (2) Thompson (1984:120-122,127), (3) Hershler et al. (1990), (4) Cooley & Foighil 2000, (5) now *Ortmanniana pectorosa* , (6) now *Planorbella trivolvis* , (7) Thompson (1979:47)

CITATIONS

Cao, Y., K. Cummings, L. Hinz, S. A. Douglass, A. P. Stodola, A.P. and A. M. Holtrop. 2017. Reconstructing the natural distribution of individual unionid mussel species and species diversity in wadeable streams of Illinois, USA, with reference to stream bioassessment. Freshwater Science. 36:669-682.

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Cooley, L.R., and D. Ó Foighil. 2000. Phylogenetic analysis of the Sphaeriidae (Mollusca: Bivalvia) based on partial mitochondrial 16S rDNA gene sequences. Invertebrate Biology 119:299-308.

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Gregg, W. 1942. Additional Utah Records. Nautilus 55:143-144.

Hershler, R. J.R. Holsinger and L. Hubricht. 1990. A revision of the North American freshwater snail genus *Fontigens* (Prosobranchia: Hydrobiidae). Smithosonian Contributions to Zoology 509:1-48.

Hovingh, P. 2004. Intermountain freshwater mollusks, USA (*Margaritifera*, *Anodonta*, *Gonidea*, *Valvata*, *Ferrissia*): Geography, conservation, and fish management implications. Monographs of the Western North American Naturalist 2:109–135.

Integrated Taxonomic Information System (ITIS) (http://www.itis.gov)

Keck, F., V. Vasselon, K. Tapolczai, F. Rimet, and A Bouchez. 2017. Freshwater biomonitoring in the information age. Frontiers in Ecology and the Environment 15:266-274.

Lodge, D. M., C.R. Turner, C.L. Jerde, M.A. Barnes, et al. 2012. Conservation in a cup of water: Estimating biodiversity and population abundance from environmental DNA. Molecular Ecology 21:2555-2558.

Lopes-Lima, M., E. Froufe, V. Tu Do and A. Bogan. 2016. Phylogeny of the most species rich freshwater bivalve family (Bivalvia: Unionida: Unionidae): Defining modern subfamilies and tribes. Molecular Phylogenetics and Evolution 106:174-191.

MAPIT – Mapping Application for Freshwater Invertebrate Taxa. 2017. Western Center for Monitoring and Assessment of Freshwater Ecosystems, BLM/USU National Aquatic Monitoring Center, Utah State University (https://qcnr.usu.edu/wmc/data).

Phillips, S.J. and Dudík, M. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31:161-175.

Thompson, F. G. 1979. The systematic relationships of the hvdrobiid snail genus Nymphophilus Taylor 1966 and the status of the subfamily Nymphophilinae. Malacological Review 12:41-49.

Thompson, F. G. 1984. North American freshwater snail genera of the hydrobiid subfamily Lithoglyphinae. Malacologia 25:109-141.

United States Environmental Protection Agency (USEPA). 2013a. Aquatic life ambient water quality criteria for ammonia – Freshwater. 2013. EPA-822-R-13-001. National Technical Information Service, Springfield, VA.

United States Environmental Protection Agency (USEPA). 2013b. Revised deletion process for the site-specific recalculation procedure for aquatic life criteria. EPA-823-R-13-001. National Technical Information Service, Springfield, VA.

United States Environmental Protection Agency (USEPA). 2013c. Technical support document for conducting and reviewing freshwater mussel occurrence surveys for the development of site-specific water quality criteria for ammonia. EPA 800-R-13-003. National Technical Information Service, Springfield, VA.

United States Environmental Protection Agency (USEPA) National Aquatic Resource Surveys (http://water.epa.gov/type/watersheds/monitoring/aquaticsurvey_index.cfm).

Williams JD, M.L. Warren Jr., K.S. Cummings, J.L. Harris and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18(9):6–22.

APPENDIX A - List and descriptions (in quotes) of annotated sources which contain applicable records (primary sources) to this study. This list does not include secondary sources, which noted records in the primary source. See Appendix B for list of sources not used in the Tabular Data including secondary sources. Source annotations were derived from their respective abstracts, database summaries, and personal correspondence; see citation for annotation source.

AMNH. 2016. American Museum of Natural History, Division of Invertebrate Zoology. New York, NY, < http://www.amnh.org/>. Accessed July 18, 2016.
"The staff in the Division of Invertebrate Zoology study and archive the living non-vertebrate animals, which make up 95% of all animal species. The Division houses more than 24 million specimens, which comprises about 500,000 species. Most of these specimens are terrestrial arthropods, but there are large collections of marine and freshwater invertebrates. Strengths of the collections reflect the research of current and past curators: Arachnids (especially spiders and scorpions), aculeate (sting-bearing) Hymenoptera (including bees, wasps and ants), gall wasps (Cynipoidea), certain Diptera (especially Drosophilidae, Syrphidae and Tachinidae), Hemiptera, Isoptera (termites) and their symbiotic protists, macro-Lepidoptera (particularly of the New World), rove beetles (Staphylinidae), the primitively wingless insects (bristletails and silverfish), marine Mollusca, and fossils in amber. Research centers around field exploration, the collections, and laboratory studies using morphology and DNA sequences to examine the evolutionary relationships of a spectrum of groups from species to phyla."

ANSP. 2016. Academy of Natural Sciences of Drexel University, Invertebrates and Malacology Collections. Philadelphia, PA, < http://www.ansp.org/>. Accessed June 20, 2016.
"Malacology, the study of mollusks, has been part of the Academy since its founding in 1812. Thomas Say (1787-1834), Isaac Lea (1792-1886), Samuel S. Haldemann (1812-1880), George W. Tryon, Jr. (1838-1888), Henry A. Pilsbry (1862-1957), H. B. Baker (1889-1971), and R. Tucker Abbott are some of the more notable malacologists associated with the Academy. The collection of recent mollusks at The Academy of Natural Sciences of Philadelphia (ANSP) is the oldest in the country, and the second largest catalogued one in the world. It currently has more than 430,000 catalogued lots containing about 10 million specimens, including 30,000-35,000 lots preserved in ethanol. Type specimens of more than 400 authors are represented in more than 12,000 type lots. ANSP has specimens from all over the world. Greatest strengths are in shallow-water marine mollusks from the tropical Indo-Pacific and the Western Atlantic and worldwide freshwater and land mollusks."

Baily, J. and R. Baily. 1951. Further observations on the Mollusca of the relict lakes in the Great Basin. Nautilus 65:46-53.
"In the summer of 1949 the authors visited some of the relict lakes in the Great Basin for the purpose of observing at first hand the evidence of Pleisotocene lacustration and to gather some of the semi-fossil mollusca for which this region is noted. A preliminary account of our peregrinations has been published (Baily, 1950) in which no attempt was made to assign names below generic rank to any of the material taken."

Baily, J. and R. Baily. 1952. Further observations on the Mollusca of the relict lakes in the Great

Basin. Nautilus 65:85-93.
Continuation of Baily & Baily (1951).

Baker, F.C. and F. Smith. 1919. Fresh water Mollusca from Colorado and Alberta. Bulletin of the American Museum of Natural History 41:527-539.
"During the months of July and August, 1916, Professor Frank Smith, of the Department of Zoology, University of Illinois, while engaged in biological work at the School of Mountain Biology of the University of Colorado, at Tolland, Gilpin County, collected a number of mollusks that are of more than passing interest, several of the species being new to the Colorado fauna and two new to science. Professor Smith made careful field notes concerning the different lakes visited and these are of value in connection with the ecology of these mollusks. These notes, as far as they relate to the collection herein considered, appear below, contributed by Professor Smith."

Berry, E.G. 1931. Mollusca of Lamb's Canyon, Utah. Nautilus 44:113-114.
"Bear Lake is situated in extreme southeastern Idaho and northeastern Utah, about equally divided between the two states. Utah Lake is some distance south of Salt Lake City with Provo as the largest city on its shore."

BISON. 2017. USGS Biodiversity Information System (BISON). <https://bison.usgs.gov>. Accessed January 1, 2017.
"USGS Biodiversity Information Serving Our Nation (BISON) is a unique, web-based Federal mapping resource for species occurrence data in the United States and its Territories. Researchers collect species occurrence data, records of an organism at a particular time in a particular place, as a primary or ancillary function of many biological field investigations. Presently, these data reside in numerous distributed systems and formats (including publications) and are consequently not being used to their full potential. As a step toward addressing this challenge, the Core Science Analytics, Synthesis, and Libraries (CSAS&L) program of the U.S. Geological Survey (USGS) is developing Biodiversity Information Serving Our Nation (BISON), an integrated and permanent resource for biological occurrence data from the United States. BISON will leverage the accumulated human and infrastructural resources of the long-term USGS investment in research and information management and delivery. Read the DOI Official Press Release in which BISON's public debut was announced."

Buglab, USU. 2016. Buglab - BLM/USU National Aquatic Monitoring Center. Logan, UT, <http://www.usu.edu/buglab/>. Accessed May 25, 2017.
"The National Aquatic Monitoring Center is a cooperative venture between Utah State University and the U.S. Bureau of Land Management. Our purpose is to encourage and foster scientifically sound watershed monitoring programs on public lands. Our goals are to increase the consistency and quality of aquatic resource assessments and provide clear, accurate, and timely information to resource managers and the public. A primary focus at our laboratory is the processing of aquatic invertebrate samples. Please contact us if you are in need of our assistance."

Call, R.E. and G.K. Gilbert. 1884. On the Quaternary and recent mollusca of the Great Basin,

with descriptions of new forms. Bulletin of the United States Geological Survey. No. 11.
"The biologic investigation reported in this bulletin grew out of an inquiry into the physical history of the Great Basin during the Quaternary. It will be introduced by a brief account of that inquiry, with especial reference to a climatic problem which it was hoped the biologic investigation would aid in solving."

Carlson, C., et al. 1979. Fishes and macroinvertebrates of the White and Yampa Rivers, Colorado: Final report on a baseline survey. Biological Sciences Series, Bureau of Land Management, Colorado State University.
"In July, 1975, the Bureau of Land Management contracted with Colorado State University for a baseline survey of the fishes and aquatic macroinvertebrates of selected reaches of the White and Yampa Rivers in Colorado. This survey was proposed to compliment work done by the Colorado Division of Wildlife and other resource agencies prior to the onset of coal strip-mining activities in northwestern Colorado. General objectives of the study were to gather quantitative data on."

CAS. 2016. California Academy of Sciences, Invertebrate Zoology and Geology Department. San Francisco, CA. <http://www.calacademy.org/>. Accessed June 17, 2016.
"Our invertebrate collections originally focused on California and Baja California, then broadened to the entire Pacific Coast (from Alaska to the Galapagos Islands), and are now worldwide in scope. Our diatom collection remains the best-documented and third largest in the world. Our mineral collection includes meteorite and gemstone holdings, while our fossil collection's strengths highlight ammonites from northern California, and fossil fish and Foraminifera from the western United States."

Chamberlin, R.V. and E. Berry. 1929b. Notes of the mollusca of southeastern Utah. Nautilus 42:123-125.
"The mollusca listed in the present paper were for the most part taken by the authors and associate members of the field expedition from the University of Utah during April 1928. While most of the collection, which was carried on in connection with other work, was done in San Juan County, some material was secured in adjacent parts as indicated under the separate forms below. The region covered is largely desert in character and so unfavorable for the group. Mr. Berry deserves the credit for the material obtained."

Chamberlin, R.V. and D.T. Jones. 1929a. A descriptive catalog of the mollusca of Utah. Bulletin of the University of Utah 19:213.
"In the preparation of this bulletin an effort has been made to bring together what was previously known of recent Utah mollusks and to incorporate with this the results of the authors' special studies. The form of presentation has been determined by the fact that, in the first place, the paper is intended to serve as a basis for further scientific work and, in the second place, to serve as a reference text for teachers of zoology in Utah colleges and high schools and as an aid to amateur collectors. The article is based primarily upon a study of upward of one thousand sets of shells collected during the year 1927 and a lesser number collected during 1928, all of which are now deposited in the Zoological Museum of the University of Utah. Trips totaling approximately three thousand miles, within the borders of the state, were taken to secure these specimens. An accompanying map is

given to facilitate reference to the principal localities visited or referred to. Such Utah material as is contained in the Dr. Orson Howard collection, also deposited in the University, has been included; but that collection is largely of fresh-water bivalves from all parts of the United States."

CHAS. 2016. Chicago Academy of Sciences, Peggy Notebaert Nature Museum, Invertebrates Collection. Chicago, IL. <http://www.naturemuseum.org/the-museum/collections/invertebrates/>. Accessed July 28, 2016.
"Malacology is the study of mollusks-soft bodied animals that include snails and slugs, clams and squids. Conchology is the study of the shells these animals make. This is the Academy's largest collection with over 113,300 specimens of primarily freshwater and terrestrial species but also includes marine snails and other groups. Notably, we have a large, early collection of Unionidae. These are freshwater clams that are very diverse in our region and are the most endangered group of animals in the world. Another key portion of the collection comes from former curator Frank C. Baker, whose pioneering work on fresh water gastropods is cited to this day."

CM. 2016. Carnegie Museum of Natural History. Pittsburgh, PA.
<http://www.carnegiemnh.org/>. Accessed July 23, 2016.
"Carnegie Museum of Natural History was founded in 1895. Malacology (the study of mollusks) has been an integral part of the Museum of Natural History since the museum's establishment. These pages introduce you to the interesting world of mollusks. Read about the ways different cultures have used mollusks throughout history. You can also learn about the history of the Mollusks section, including the curators and other notable people. Finally, learn about what is in the collection."

CMNH. 2016. Cleveland Museum of Natural History, Invertebrate Zoology. Cleveland, OH.
<https://www.cmnh.org/>. Accessed August 3, 2016.
"The Department of Invertebrate Zoology at the Cleveland Museum of Natural History is devoted to the study and curation of its entomology collection (insects) and malacology collection (mollusks including mussels, clams, snails, limpets and other related organisms). Currently, the Museum's entomology collection is home to the largest collection of praying mantises (Mantodea) in the Western Hemisphere at more than 14,000 specimens, rivaling the largest collections housed in Europe. Department scientists have built internationally recognized research programs supported by federal funding from the US National Science Foundation."

CNHP. 2013. Colorado Natural Heritage Program. Fort Collins, CO.
<http://www.cnhp.colostate.edu/>. Accessed May 25, 2016.
"The Colorado Natural Heritage Program is Colorado's only comprehensive source of information on the status and location of Colorado's rarest and most threatened species and plant communities. We share information with a wide range of stakeholders in partnerships that work to ensure the Colorado's biodiversity resources are not diminished. CNHP has an enormous impact on conservation in Colorado through these partnerships. CNHP tracks and ranks Colorado's rare and imperiled species and habitat and provides scientific information and expertise to promote the conservation of Colorado's wealth of

biological resources. Established in 1979, the CNHP is a non-profit scientific organization affiliated with the Warner College of Natural Resources at Colorado State University."

Cordeiro, J.R., et al. 2007. Corbicula fluminea (Bivalvia: Sphaeriacea: Corbiculidae) in Colorado. Southwestern Naturalist 52:424-430.
"We documented range expansion of the Asiatic clam, *Corbicula fluminea*, in Colorado since its first occurrence in 1993 in the South Platte River drainage. Using recent surveys and literature records, we compiled known occurrences of the Asiatic clam over the past 12 years and determined that it has expanded beyond the initial confines of the Platte River and Arkansas River drainages into the Colorado River and San Juan River drainages. All previously reported occurrences are still extant and the species continues to spread to new localities, especially in the Arkansas River drainage. We speculate on potential negative impacts to native freshwater mussels in Colorado, but have not conducted any definitive studies."

DELMNH. 2016. Delaware Museum of Natural History, Mollusks Collection. Wilmington, DE. <http://www.delmnh.org/>. Accessed July 26, 2016.
"The Museum's mollusk collection consists of more than 2 million specimens, making it one of the top twelve in the United States. The 220,000 cataloged lots represent more than 18,000 species. Worldwide in scope and covering all seven living classes of mollusks, our holdings comprise marine Gastropoda (50%), land and freshwater Gastropoda (25%) , marine Bivalvia (15%), and freshwater Bivalvia (5%). The Museum's mollusk collection is primarily dry shells, with some alcohol preserved cephalopod specimens. Most specimens are recent; however, there is some Cenozoic fossil material. Our type collection contains more than 1,200 lots. Type catalogs listing all molluscan type specimens (except Pulmonata) are available in Nemouria issues 36 and 41. The collection continues to grow through research activities of staff and donations of scientifically significant specimens."

Doyle, G. 2003. Survey of selected seeps and springs within the Bureau of Land Management's Gunnison Field Office Management Area (Gunnison and Saguache Counties, CO). Colorado State University, Fort Collins, CO.
"Springs and seeps are unique habitats and serve many important hydrological, biological, and biogeochemical functions. In addition to serving as water sources, specific interest in seeps and springs in the Gunnison Basin is driven by their potential importance as brood rearing habitat for Gunnison Sage Grouse (*Centrocercus minimus*). The range and number of individuals of Gunnison Sage Grouse have been undergoing long-term decline and the largest remaining population is within the Gunnison Basin. The Gunnison Sage Grouse use riparian areas, wet meadows, seeps, and springs as brood rearing habitat (Gunnison Sage Grouse Working Group 1997)."

Ellis, M.M. 1916. *Anodonta danielsi* Lea. in Colorado. Nautilus 29(10):116-119.
"While collecting fishes during October in Black Wolf Creek, a tributary of the Arikaree River in eastern Colorado, a large, isolated colony of bivalves was discovered, specimens from which have been identified by Mr. Bryant Walker as *Anodonta danielsi* Lea. This

collection constitutes the first record of this species from Colorado. The only other species of *Anodonta* known to occur in Colorado is *Anodonta grandis*, listed from two localities, Lodgepole Creek in the extreme northeastern corner of the state and a reservoir about 30 miles north of Denver. (Henderson, Mollusca Colo. 1912)."

EOL. 2016. Encyclopedia of Life. <http://eol.org/>. Accessed May 25, 2016.
"The Encyclopedia of Life (EOL) began in 2007 with the bold idea to provide "a webpage for every species." EOL brings together trusted information from resources across the world such as museums, learned societies, expert scientists, and others into one massive database and a single, easy-to-use online portal at EOL.org . While the idea to create an online species database had existed prior to 2007, Dr. Edward O. Wilson's 2007 TED Prize speech was the catalyst for the EOL you see today. The site went live in February 2008 to international media attention. The initiative was started with generous seed funding from the John D. and Catherine T. MacArthur and Alfred P. Sloan Foundations. The five original EOL cornerstone institutions included the Field Museum, Harvard University, the Marine Biological Laboratory, Missouri Botanical Garden and the Smithsonian Institution. Today, the Encyclopedia of Life is expanding to become a global community of collaborators and contributors serving the general public, enthusiastic amateurs, educators, students and professional scientists from around the world. It is sustained through the contributions of its supporting institutions and individual donors around the world, as well as through collaborations on a broad portfolio of grants."

FLMNH. 2016. Florida Museum of Natural History, Malacology Collection. Gainesville, FL. https://www.floridamuseum.ufl.edu/. Accessed June 24, 2016.
"The Malacology collection is the 4th largest in North America, and the 2nd largest in the world in terms of online access. Its extensive holdings provide some of the best documentation available of change and extinction in North American freshwater habitats during the last century. The collection is renown for land and freshwater snails, and tropical reef mollusks. The Invertebrate Zoology collection, currently housed with Malacology, is the newest addition to the museum. Initiated in 2000, it is already among the 10 largest in the US, with a rapidly growing collection of reef invertebrates worldwide in scope."

FMNH. 2016. Field Museum of Natural History, Invertebrates Collection and Mollusk Collection. Chicago, IL. <https://www.fieldmuseum.org/>. Accessed June 20, 2016.
"Invertebrates Collection: The collections currently exceeds 340,000 catalogued lots (= specimen series) with continuing growth. Research and collecting traditionally focused on the phylum Mollusca with more than 328,000 cataloged lots. Non-mollusk invertebrates are represented by ca. 14,500 cataloged lots with the Arthropoda (ca. 50%), Annelida (20 %), Echinodermata (8%), Cnidaria (7%) and Porifera (5%) best represented. Mollusk Collection: At present the Division of Invertebrates, which began in 1938 with a collection of 16,000 lots, manages more than 328,000 cataloged mollusk lots, with approximately 4.5 million specimens. Our molluscan collection now ranks among the top three or four in North America."

Gaufin, A.R. 1951. Production of bottom fauna in the Provo River, Utah. Iowa State College, Iowa State University. Paper 12831.
"Life is precarious in the mountain streams and a fine degree of fitness is necessary for those plants and animals found there. Constantly changing from day to day, from month to month, and from season to season, stream conditions offer a highly unstable and complicated environment. Man has further accentuated the instability of this environment by his various activities. The seasons often bring sudden changes in volume and speed of water that wipe out whole aquatic populations in a short time. The specialized conditions restrict the number of animal and plant species very markedly. Indeed, in our best trout waters--clear, cold, mountain streams, the larger aquatic plant, upon which many aquatic invertebrates depend for their livelihood, are practically eliminated by the current. The biota is further limited to species that are either strong swimmers or have special structural adaptations for clinging."

GBIF. 2016. Global Biodiversity Information Facility, multiple databases. Lisbon, Portugal. <http://www.gbif.org/>. Accessed June 27, 2016.
"The Global Biodiversity Information Facility (GBIF) is an international open data infrastructure, funded by governments. It allows anyone, anywhere to access data about all types of life on Earth, shared across national boundaries via the Internet. By encouraging and helping institutions to publish data according to common standards, GBIF enables research not possible before, and informs better decisions to conserve and sustainably use the biological resources of the planet. GBIF operates through a network of nodes, coordinating the biodiversity information facilities of Participant countries and organizations, collaborating with each other and the Secretariat to share skills, experiences and technical capacity. GBIF's vision: "A world in which biodiversity information is freely and universally available for science, society and a sustainable future."

Gray, L. 2004. Changes in water quality and macroinvertebrate communities resulting from urban stormflows in the Provo River, Utah, U.S.A. Hydrobiologia 518:33-46.
"Short-term changes in water quality from 7 summer stormflows and long-term changes in substrates and macroinvertebrate communities resulting from urban runoff from the city of Provo, Utah, were examined from 1999–2002 in the lower Provo River. Stormflows resulted in increased total suspended solids and concentrations of dissolved copper, lead and zinc, and decreased conductivity and dissolved oxygen. The degree of change was generally in proportion to the magnitude of the storm. However, changes were temporary with water quality parameters returning to pre-storm levels within 12 hours. River substrates showed a trend of increased compaction and decreased debris dam area downstream through the urban corridor. Macroinvertebrate communities showed trends of decreased abundance and total species diversity with increasing urbanization. Compared to non-urban reaches, communities in urban reaches had few `sensitive' species and were dominated by tolerant species, particularly snails and leeches. Comparisons with previous studies show that changes in macroinvertebrate community composition in the urban reaches reflected shifts in land use during the past 15–25 years and corresponded to expected threshold levels of impact for amount of impervious surface cover."

Gray, L. 2016. FW: *Anodonta* Specimen, *Anodonta* specimen collected at the public shooting grounds near Corinne, UT. Email Correspondence, May 19, 2016.
Anodonta specimen collected near the public shooting grounds near Corinne, UT.

Gregg, W. 1940. Mollusca of Zion National Park, Utah. Nautilus 54:30-32.
"A three-month stay in Zion National Park during 1935 gave opportunity for a rather thorough search for the members of its molluscan fauna. I arrived there early in May when conditions are most favorable for finding the minute species of land snails. In my list I have combined the results of this study with what published records I have been able to find. In 1929 Mr. A. M. Woodbury reported fifteen species of mollusca from this park. *Microphysula ingersolli* is reported to have been taken by Dr. Pilsbry. Chamberlin and Berry report *Gastrocopta ashmuni*. In addition to these forms the five previously unreported species which I too there bring the total number of species to twenty-two. Two of the species I found, *Vallonia perspectiva* and *Hawaiia minuscula neomexicana*, have not been reported from Utah. Three other species not previously taken in the park are *Pisidium abditum*, *Vallonia pulchella* and *Lymnaia bulimoides cassi*."

Gregg, W. 1941. Mollusca of Cedar Breaks National Monument, Utah. Nautilus 54:116-117.
"During the summer of 1935 it was my privilege to spend nearly three months at Cedar Breaks National Monument. This area is about 20 miles east of Cedar City, Utah. Here the Pink Cliffs, in some places exposed for a depth of nearly 2,000 feet, display a great variation of shades of color ranging from white or orange at the top to deep rose and coral. in contrast is the dark green of the heavily forested rim which attains an altitude of 10,400 feet. Though awed by the vastness of this spectacular beauty, my thoughts turned to the molluscan inhabitants which find shelter in these lofty forests of Engelmann spruce and alpine fir."

Gregg, W. 1942. Additional Utah records. Nautilus 55:143-144.
"Additional Utah Records - A number of specimens of *Columella alticola* Ingersoll were taken while collection along the head of Mammoth Creek, southwest corner of Garfield County, Utah. They were found under pieces of rotten wood in well shaded places within a rather closely restricted area where the road diverges from the creek and turns south. The altitude at this point was about 8,000 feet. Associated with it were *Oreohelix stigosa depressa* Cockerell, *Microphysula ingersollie meridionalis* Pilsbry and Ferriss, *Vallonia gracilicosta* Reinhardt, *Pupilla blandi* Morse, *Pupilla hebes* Anceey, *Vertigo gouldii arizonensis* Pilsbry and Vanatta, *Discus cronkhitei cronkhitiei* Newcomb, *Vitrina alaskana* Dall, *Zonitoides arborea* Say, *Euconulus fulvus alaskensis* Pilsbry, *Deroceras gracile* Rafinesque and *Succinea avara* Say. In the stream we found *Stagnicola bulmoides techella* Haleman."

Henderson, J. 1931. The problem of the mollusca of Bear Lake and Utah Lake, Idaho–Utah. Nautilus 44:109-113.
"Lamb's Canyon, a small tributary of parley's Canyon, is situated about twenty-three miles from Salt Lake City. The altitude rises from about 7,500 feet at the mouth to about 11,000 feet at its head, a distance of only seven miles. The dense verdure and frequent

rainfall which occur in this canyon creates an ideal collection ground for the conchologist. This canyon is typical of nearly all Salt lake County canyons with similar altitudes. The list below comprises the collection of three summers."

Henderson, J. and L. Daniels. 1916. Hunting mollusca in Utah and Idaho. Proceedings of the Academy of Natural Sciences of Philadelphia 69:315-339.
"We were in Utah and southern Idaho from June 10 to July 24, 1916, continuing the work begun in 1915.' More attention was given to fresh-water species and the smaller land snails than before, with some interesting results. A vast amount of work remains to be done in this region before the molluscan faunas and the significance of their present distribution are thoroughly understood."

Henderson, J. and L. Daniels. 1917. Hunting mollusca in Utah and Idaho in 1916. Proceedings of the Academy of Natural Sciences of Philadelphia 69:48-81.
"We were in Utah and southern Idaho from June 10 to July 24, 1916, continuing the work begun in 1915.' More attention was given to fresh-water species and the smaller land snails than before, with some interesting results. A vast amount of work remains to be done in this region before the molluscan faunas and the significance of their present distribution are thoroughly understood."
This works is a continuation of Henderson and Daniels, 1916.

Hildebrand, S.F. and I.L. Towers. 1927. Food of trout in Fish Lake, Utah. Ecology 8:389.
"The present report is a result of the examination of a series of 181 trout stomachs from fish caught in Fish Lake, Utah, within the Fishlake National Forest, during the summers of 1922, 1923 and 1924. The stomachs were collected and preserved principally by the Forest Rangers in cooperation with local fishermen under plans made by S. B. Locke, District Forest Inspector, in charge Fish and Game Cooperation, Intermountain District, and it is through his interest and courtesy that we have had the opportunity of making the examination. The fish, themselves, were not seen by us and, therefore, we use only the common names furnished by Mr. Locke, which stand as follows: eastern brook trout (introduced), Mackinaw trout (introduced), steelhead or rainbow trout, and cutthroat trout."

Hovingh, P. 2016. Personal Survey Data Since 1979. Email Correspondence May 31, 2017.
This data includes all Peter Hovingh's field surveys since 1979. including specimen found in the UU holdings. The UU holdings have not yet been updated and are currently being accessioned and verified by Mr. Hovingh to be completed sometime in 2017. Items in Bold lettering in the original spreadsheets can be found at UU, with the exception of Hydrobiidae. It is suggested by Mr. Hovingh that the records are only accurate and the genus level and species level data would be "unwise" to report.

iNaturalist. 2016. iNaturalist, GBIF-iNaturalist Research-Grade Observations. <https://www.inaturalist.org/>. Accessed June 27, 2016.
"From hikers to hunters, birders to beach-combers, the world is filled with naturalists, and many of us record what we find. What if all those observations could be shared online? You might discover someone who finds beautiful wildflowers at your favorite

birding spot, or learn about the birds you see on the way to work. If enough people recorded their observations, it would be like a living record of life on Earth that scientists and land managers could use to monitor changes in biodiversity, and that anyone could use to learn more about nature."

Ingersoll, E. 1877. On a collection of mollusks from Utah and Colorado. Proceedings of the Davenport Academy of Natural Sciences 2:130-134.
"The following list is a catalogue of an interesting collection of Mollusks from Colorado, Utah and Southern Wyoming, made by Mr. J. D. Putnam, a member of the Academy, in the years 1872, 1873 and 1875. The collection, although embracing on thirty-two species, is typical of the Molluscan fauna of that region, affords one or two names not hitherto recorded from beyond the Rocky Mountains, and is particularly interesting as including specimens of two species discovered only two years ago in the mountains of Colorado."

INHS. 2016. Illinois Natural History Survey, Biological Collections, Mollusks. Champaign, IL. <http://www.inhs.illinois.edu/>. Accessed July 22, 2016.
"The Illinois Natural History Survey Mollusk Collection contains over 190,000 catalogued specimens in nearly 50,000 lots, most of which were collected in Illinois and the southeastern United States. The collection is about 95% freshwater bivalves and gastropods (mussels, fingernail clams, and snails), 1% land snails and 4% marine gastropods, almost all of which are cones. Most of the specimens were collected as a result of various faunal surveys conducted by INHS biologists from the late 1800's until the present. The early collections were made by such naturalists as John Wesley Powell, Robert Kennicott, Richard E. Call, William A. Nason, Frank C. Baker, Robert E. Richardson, and Charles A. Hart. The largest and best documented collection of landsnails at the INHS was compiled by Thural D. Foster and organized by Frank C. Baker as part of his study on the "Landsnails of Illinois" published in 1939. The Baker snail collection numbers 1632 lots containing 11,970 specimens. The University of Illinois Museum of Natural History Collection contains over 250,000 catalogued specimens in nearly 32,000 lots, and is global in scope with significant holdings of freshwater and terrestrial species from North and Central America. The collection is about 35% freshwater bivalves and gastropods, 35% land snails and 30% marine bivalves and gastropods. Together the collections have over 80,000 lots (58,000 FW, 12,000 marine & and 10,000 landsnails) and nearly 450,000 specimens. Over 135 countries are represented, but the collection is especially strong in freshwater mollusks from the Midwest and Southeastern United States and land snails from Southwestern United States and Central America. Over 40,000 soft parts of more than 200 species have been preserved (approximately half in ethanol) and available for study. All specimens that can be geo-referenced have been assigned latitude and longitudinal coordinates."

ITIS. 2016. Integrated Taxonomic Information System. <http://www.itis.gov/>. Accessed May 25, 2016.
"Welcome to ITIS, the Integrated Taxonomic Information System! Here you will find authoritative taxonomic information on plants, animals, fungi, and microbes of North America and the world. We are a partnership of U.S., Canadian, and Mexican agencies (ITIS-North America); other organizations; and taxonomic specialists. ITIS is also a

partner of Species 2000 and the Global Biodiversity Information Facility (GBIF). The ITIS and Species 2000 Catalogue of Life (CoL) partnership is proud to provide the taxonomic backbone to the Encyclopedia of Life (EOL)."

JFBM. 2016. Bell Museum of Natural History, University of Minnesota, Mollusks & Crustaceans. Minneapolis, MN. <https://www.bellmuseum.umn.edu/>. Accessed August 4, 2016.
"The mollusks and crustaceans' collection contains nearly 18,000 lots, some of which date to 1875. The majority of specimens are freshwater mollusks collected in Minnesota, and represent an important Upper Midwest Collection. All specimens are entered into a database searchable by collection staff. The collection also contains the old Minneapolis Library collection of Indo-Pacific mollusks. Specimens are stored as shells or in ethanol."

Jones, D.T. 1940a. Mollusks of the Oquirrh and Stansbury mountains, Utah. Nautilus 54:27-29.
"This study was undertaken in a region that no malacologist would select for good collection. the object was to find out what was there, if anything. The results have been quite surprising and informative. The comparatively barren Oquirrh and Stansbury Ranges, immediately south of the Great Salt Lake, receive much less precipitation than the Wasatch Range to the east. The vegetation in most places is scanty and of the desert type, which conditions are very unfavorable for mollusks. The study included the intervening Tooele and Stockton Valleys, also the eastern slopes of the Oquirrh Range in Jordan Valley."

Jones, J.T. 1940. Recent collections of Utah Mollusca, with extralimital records from certain Utah cabinets. Utah Academy of Sciences, Arts and Letters 17:33-45.
"During the past few years, in connection with the work of the class on Utah Mollusks, also in aiding other amateur collectors, the authors have made numerous identifications. Generally the specimens are placed in the private collection of these amateurs. Many valuable records, some from practically inaccessible places, are thus ordinarily lost to science. However, in Utah, as the specimens were identified, a record has been kept with a view of publishing the same when enough data have accumulated. This article consists of such records. An attempt has been made to credit each collector with the shells he collected and now possesses."

LACM. 2016. Natural History Museum of Los Angeles County, Research Library Collections. Los Angeles, CA. <http://www.lacm.edu/>. Accessed June 20, 2016.
"Malacology is the study of mollusks (snails, clams, octopods, etc.). The Malacology Department promotes the scientific study, conservation, and acquisition of extant mollusk species including gastropods (marine, terrestrial, and freshwater snails and slugs), bivalves (marine and freshwater clams), cephalopods (octopus, squid, cuttlefish, and nautilus), polyplacophorans (chitons), scaphopods (tusk shells), aplacophorans (wormlike mollusks), and monoplacophorans ('primitive' limpetlike snails). The collection is worldwide in scope with an emphasis on the eastern Pacific Ocean (arctic Alaska to southern Chile) and includes an estimated 500,000 lots containing approximately 4.5 million specimens."

McKenzie, V., et al. 2012. New Zealand mudsnails (*Potamopyrgus antipodarum*) in Boulder Creek, Colorado: environmental factors associated with fecundity of a parthenogenic invader. Canadian Journal of Zoology 91:30-36.
"New Zealand mudsnails (*Potamopyrgus antipodarum* (Gray, 1853)) are non-native snails that are increasingly spreading in freshwater systems in North America. Most invasive populations are parthenogenic and threaten native freshwater diversity. We observed variability of *P. antipodarum* fecundity each month for 16 months at a recently invaded site in Boulder Creek, Colorado. We collected 100 snails each month and dissected them to count embryos in the brood sac. We used a general linear model analysis to examine water-quality variables as predictors of the monthly variability in *P. antipodarum* fecundity. After dissecting 1600 snails, we observed four male individuals (<1%), brood sizes ranging from 0 to 70 embryos per snail, reproductively mature females at 3.2 mm in length or greater, and a significant relationship between snail length and embryo counts ($r2 = 0.38$, $p < 0.001$). The model with the highest level of support for predicting variability in snail fecundity included water temperature, snail shell length, water hardness (calcium carbonate), and nutrient levels (total phosphate) (adjusted $r2 = 0.53$, $p < 0.01$). These variables may be important for snail growth and promote increased rates of reproduction in this parthenogenic, invasive snail. These results can further inform efforts to model geographic areas at high risk of *P. antipodarum* establishment and rapid demographic growth."

MCZ. 2016. Museum of Comparative Zoology, Harvard University, Malocology Department. Berkeley, CA. <http://www.mcz.harvard.edu/>. Accessed June 20, 2016.
"The mollusk collection began in 1860 with the purchase of the land and freshwater snails of J.G. Anthony, who later joined the staff of the MCZ in 1865 as its first curator. Until his death in 1877, he carried on a very active exchange with museums and private collectors all over the world including England, France, Germany, Spain and Australia and tried to acquire authentic specimens of every species he could. In 1876 he began a special effort to exchange with people describing new species in order to obtain type-specimens and as a result, the collection is rich in type material received from workers of the day. The outstanding purchase during Anthony's curatorship was that of the William Harper Pease collection primarily of Pacific mollusks."

MEL. 2016. Molecular Ecology Laboratory, College of Natural Resources, Utah State University. Logan, UT.
This source contains all pertinent records of bivalves from the USU Molecular Ecology Laboratory. Karen Mock is the Principal Investigator.

NAS, USGS. 2016. Unites States Geological Survey, Nonindigenous Aquatic Species. Gainesville, FL. <https://nas.er.usgs.gov/>. Accessed June 30, 2016.
"Welcome to the Nonindigenous Aquatic Species (NAS) information resource for the United States Geological Survey. Located at Gainesville, Florida, this site has been established as a central repository for spatially referenced biogeographic accounts of introduced aquatic species. The program provides scientific reports, online/real-time queries, spatial data sets, distribution maps, and general information. The data are made available for use by biologists, interagency groups, and the general public. The

geographical coverage is the United States."

NatureServe. 2016. NatureServe Explorer. <http://explorer.natureserve.org/>. Accessed January 4, 2017.
"The NatureServe network includes many faces, names, and expertise from the United States, Canada, and Latin America. More than 1,000 conservation professionals work to ensure that relevant and reliable science is driving important conservation action. When we look out our windows, stand in our yards, hike our mountains, we have a front row seat to our precious natural heritage. We believe the beauty of natural life that exists all around us must be discovered, documented, protected, and saved."

NCSM. 2016. North Carolina Museum of Natural Sciences, Mollusks Collection. Raleigh, NC. <http://collections.naturalsciences.org/>. Accessed June 27, 2016.
"A collection of over half a million specimens that is comprised 83% freshwater species (mussels, fingernail clams and snails), 10% marine species and 7% terrestrial species (snails)
The North Carolina Museum of Natural Sciences' is divided into three major sections: Terrestrial Invertebrates (focusing mainly on millipedes, centipedes, and gastropods), Crustaceans (focusing on crayfish and their symbionts), and Aquatic Invertebrates (focusing on mollusks). The Invertebrates Collection is worldwide in scope, with emphasis on localities in the Eastern United States. The collection contains specimens from over 100 countries, and currently contains of over 2.3 million specimens. Specimens also represent collections acquired from foreign researchers, individual donors, and specimens from international expeditions. The collection contains dry and alcohol-preserved specimens representing 13 phyla which include Annelida, Arthropoda, Brachipoda, Cnidaria, Echinodermata, Ectoprocta, Mollusca, Nemata, Nematophora, Nemertea, Platyhelminthes, and Porifera. In addition, the collection contains an actively growing collection of ethanol preserved tissues for DNA studies."

OMNH. 2016. Sam Noble Oklahoma Museum of Natural History, Recent Invertebrates Collection. Norman, OK. < http://samnoblemuseum.ou.edu/>. Accessed June 24, 2016.
"Invertebrates comprise an overwhelmingly large portion of the earth's biodiversity. By some estimates they constitute more than 95 percent of the world's animals, accounting for many millions of species. Insects alone, for example, include more than a million described species. The collection of recent invertebrates, with more than 500,000 specimens, presents a nice sampling of invertebrate diversity. Focus of the collection is on Oklahoma invertebrates, but it also contains specimens from more than 100 countries and territories. We are unique among invertebrate collections by pursuing cataloging of all of our specimens. To date, more than 280,000 individual specimens have been cataloged and are available online or via the portals of Global Biodiversity Information Facility (GBIF) and National Biological Information Infrastructure (NBII). Revitalization of the collection has been supported by grants from the Institute of Museum and Library Services."

OSM. 2016. Museum of Biological Diversity, Ohio State University, Molluscs Collection. Columbus, OH. <https://mbd.osu.edu/collections>. Accessed June 20, 2016.

"The Division of Molluscs is divided into two major collections, housed in separate ranges. The bivalve collection consists of 78,000 catalogued lots, mainly composed of North American freshwater mussels. The gastropod collection (and a small amount of material of other molluscan orders) consists of 20,000 catalogued lots, primarily North American freshwater snails. The collections are among the largest in the world for freshwater Mollusca. Computers in each range link to central bivalve and gastropod databases."

Rader, R.B. 2016. Macroinvertebrates from springs of the Bonneville Basin (three worksheets of data). Email Correspondence November 3, 2016.
Three files showing data for macroinvertebrates from springs of the Bonneville Basin. The first is one of several compilations, the second is just for snails, and the third are UTM coordinates for sites. All macroinvertebrate IDs were confirmed by Rich Durfee, and hydrobiids were 'ID'ed by Robert Hershler.

RBCM. 2016. Royal British Columbia Museum, Invertebrate Zoology Collection. Victoria, BC. <http://www.royalbcmuseum.bc.ca/>. Accessed August 16, 2016.
"The invertebrate collection is composed entirely of animals that lack a backbone. Prominent invertebrate groups include: sponges; corals, anemones and jellyfish; worms; snails, clams and octopuses; crabs and shrimp; sea stars and urchins; sea squirts; and a wide variety of microscopic animals. While the invertebrate collection spans a variety of taxonomic groups (including representatives from more than 20 phyla and 700 families), it does not include insects, arachnids, centipedes, or millipedes, which are housed separately in the entomology collection. Overall, the collection holds more than 60,000 specimen lots. A "lot" may contain a single specimen, or it may consist of multiple individuals from a single sampling event. The collection also houses over 250 "type" specimens that have been referenced in original species descriptions. The majority of the collection contains invertebrates collected from marine, freshwater, and terrestrial ecosystems of British Columbia and adjacent regions. A relatively small fraction of the collection represents material obtained from other parts of the world. Together, these specimens represent over 125 years of active collecting carried out by researchers and the general public. The earliest collected specimens date to the late 1800s, many of which were collected by Dr. Charles Newcombe, one of British Columbia's most notable natural historians. Today the collection continues to grow through donations, targeted sampling, and research."

Richards, D.C. 2015. Activities Report 2015, OreoHelix Consulting, Inc.
"Dr. David Richards and several trained mollusk surveyors conducted surveys throughout water bodies in the Utah Lake/Jordan River drainage and other site specific locations outside of this drainage in 2014 and 2015. The purpose of the surveys was primarily to assess the status and viability of two species/clades of native Unionoida mussels, *Margaritifera falcata* (Family Margaritiferidae) and *Anodonta californiensis/nuttalliana* (Family Unionidae). The only two locations where extant populations of *A. californiensis/nuttalliana* were found were Salt Creek at the Salt Creek Waterfowl Management Area near Corrine UT and Beer Creek a tributary of Utah Lake near Benjamin, UT, in Utah County. The only location where an extant population of *M.*

falcata was found was Beaver Creek, near Samak, UT. Two individual mussels from the Salt Creek *A. californiensis/nuttalliana* population, one individual from the *A. californiensis/nuttalliana* population in Beer Creek, and three individual *M. falcata* from the Beaver Creek population were sacrificed to develop eDNA probes. Genetic analyses for eDNA are temporarily on hold until funding is secured. Tissue samples from *A. californiensis/nuttalliana* in Beer Creek and Salt Creek were also sent to Dr. Karen Mock's geneticist group at Utah State University to better understand genetic distances among several known *A. Californiensis/nuttalliana* populations and thus, their metapopulation viability in UT. Results of the USU genetics analysis are forthcoming."

Richards, D.C. 2015. Unionoida mussel and non-pulmonate snail survey and status in the Jordan River, UT, 2014. Final Draft. OreoHelix Consulting, Inc., Moab UT.
"North America supports the richest diversity of freshwater mollusks on the planet. These taxa serve vital ecosystem functions. However, many species in the western USA, particularly snails, are narrow endemics and their populations are in sharp decline. Freshwater snails have the dubious distinction of having the highest modern extinction rate yet observed, a distinction almost entirely bestowed upon by human activities. The greatest diversity of North America's freshwater mollusks occurs in the southeastern USA, although the Great Basin, Snake River Basin and Bonneville Basins, including the Great Salt Lake area, is a freshwater mollusk hotspot, particularly for freshwater non-pulmonate snails with at least seventy freshwater mollusk taxa reported from UT. Freshwater mollusk taxonomy, distribution, status, and ecologies are poorly known in UT and very few mollusk specific surveys have been conducted. Specialized training, survey methods, and taxonomic identification is required for successful freshwater mollusk surveys."

Richards, D.C. 2015. Utah Lake watershed mollusk survey update summary for ULCTAC. OreoHelix Consulting, Inc., Moab, UT.
"The Utah Lake watershed including tributaries such as the: Provo, Spanish Fork, and American Rivers, Currant, Beer, Mill Race, Spring, and Hobble Creeks historically supported one of the richest and diverse freshwater mollusk assemblages in the western USA (Hovingh 2004, Oliver and Bosworth 1999) with possibly more than fifty species of snails, mussels, and clams (Hershler and Sada 2002, Polhemus and Polhemus 2002, Mock et al. 2004 Hovingh 2004, Oliver and Bosworth 1999). Indeed, this is (was) a Utah Natural Heritage. Utah Lake alone supported more than a dozen mollusk species (Hovingh 2004, Oliver and Bosworth 1999). Unfortunately, most of these species are either extinct or their populations are fragmented and isolated and their populations are in such rapid decline that, for the most part, many of Utah's freshwater mollusk species are now ecologically irrelevant. Almost all of Utah Lake's native mollusk species have vanished."

RNHM. 2016. Natural History Museum Rotterdam, general collections. Rotterdam, Netherlands. <http://www.hetnatuurhistorisch.nl/>. Accessed June 27, 2016.
"The Natural collection is the foundation of exhibitions, museum lessons, research and publications. The collection has about 390,000 "monsters" (collection units) whose foundation was laid long before the founding of the museum (in 1927), in 1859 to be

precise, when the old Rotterdamsche Diergaarde a collection of East Indian shells and Dutch birds acquired. These and other nineteenth-century collections came in 1939 in the possession of the Museum of Natural History. The biggest increase was in the insects (butterflies, beetles) and mollusks (clams). These subsets still form the bulk of the collection: 90% of the number of objects consists of arthropods (insects, spiders, crustaceans) and molluscs. In addition, a wide spectrum of animal and plant life represented in the collection, especially with a regional, but also partly with a worldwide origin. The proportion of vertebrates, including fossil remains and recently skeletal material is more than 5% of the total collection. The collection is largely behind the scenes stored in collection depots. The numbers are simply too large to exhibit everything, and not everything is worth respect. Only the finest museum pieces we exhibit them. Headlong preparations of African mammals and deer antlers, and only large mammal skeletons (elephant, giraffe, sperm) are located permanently in public spaces. Hundreds of large and small vertebrates and invertebrates, and plants are exhibited in the permanent collection presentation 'Biodiversity'. The collection of Dr. AB of Deinse (rarities and marine mammal residues) is largely included in a permanent exhibition. In the semi-permanent exhibition picked Fished Carved, in addition to many loans, including fossils of various animal groups exhibited through ownership."

Roscoe, E.J. 1948. Some mollusca collected in the vicinity of Kanab, Kane County, Utah. Proceedings of the Utah Academy of Sciences, Arts and Letters 25:169-171.
"From March 3 to 6, 1946 a small party under the direction of Dr. William H. Behle from the Department of Biology, University of Utah, made a reconnaissance trip to the southwestern part of Kane County, Utah. The party included Rudolph Glauser, Irving B. McNulty, George Todd, and the writer."

Russell, R. 1971. Mollusca of Fish Springs, Juab County, Utah: rediscovery of *Stagnicola pilsbryi* (Hemphill, 1890). Great Basin Naturalist 31:223-236.
Twelve species of Mollusca are reported from the Fish Springs area in west central Utah, including *Stagnicola pilsbryi* (Hemphill, 1890). Most of the species are well known from Utah or the southwestern United States except *S. pilsbryi*, which is apparently endemic to Fish Springs."

Sabaj Perez, M.H. 2014. Standard symbolic codes for institutional resource collections in herpetology and ichthyology: an online reference, Version 5.0, Washington, DC. American Society of Ichthyologists and Herpetologists.
Contains acronyms standards used in this report as they relate to museum sources.

Schisler, G.J., N. Vieira and P.G. Walker. 2008. Application of household disinfectants to control New Zealand mudsnails. North American Journal of Fisheries Management 28:1172-1176.
"The New Zealand mudsnail, *Potamopyrgus antipodarum*, was recently discovered in Colorado, thereby expanding its invasion of the western United States. This exotic snail may invade streams through transport on angling gear and fishery equipment. Previous studies have demonstrated that some household cleaning products are lethal to New Zealand mudsnails and can be used to disinfect waders and boots. Two disinfectants,

antibacterial Formula 409 All-Purpose Cleaner and Sparquat 256, were compared as potential control agents. Snails were submersed for 5 or 10 min in one of two Formula 409 solutions (50% or 100%) or one of three Sparquat 256 solutions (1.6, 3.1, or 4.7%). We used distilled water as the control treatment. Snail mortality at 48 h and 56 d after exposure was evaluated. Our findings suggest that the current recommendation (5-min application of 50% Formula 409) is not sufficient; half of the snails survived this treatment in our study. In contrast, a 10-min exposure to 100% Formula 409 or to a Sparquat 256 solution of at least 3.1% resulted in 100% snail mortality. In addition to its effectiveness in controlling New Zealand mudsnails, Sparquat 256 has also proven useful as a disinfectant for whirling disease spores and other fish pathogens."

Smart, E.W. 1958. An ecological study of the bottom fauna of Bear Lake Idaho and Utah. Graduate Theses and Dissertations, Doctor of Philosophy in Aquatic Biology, Utah State University, Logan, UT.
"The study of the bottom fauna of Bear Lake was a part of the investigation of its limnology and fisheries, begun in 1952. This study was sponsored through federal monies made available through the Dingle-Johnson Act. The primary purpose of the study was to examine all the evidence in estimating the fish producing capacity of the lake. Bear Lake is the second largest fresh water lake in Utah but has a relatively poor fishery. It has the characteristics of an oligotrophic lake. It is a deep, cold lake with little food and an abundance of dissolved oxygen. The lake is a beautiful blue on clear days, further evidence of an oligotrophic condition. Only water poor in organic productivity can be blue (Ruttner, 1953). My specific objective was to sample the bottom macrofauna at all depths and in all areas of the lake to determine what organisms are present and to what extent. This was necessary to estimate the supply of food for bottom feeding fish. The dredging was as extensive as possible in the time which could be allotted to this phase of the work. The large area of the open and deeper water region supports a comparatively uniform bottom population. The inshore rocky zones were exposed because of low water during most of this study, and the inshore regions of rooted plants were practically nonexistent."

UCDC. 2016. Utah Conservation Data Center. Salt Lake City, UT. <http://dwrcdc.nr.utah.gov/ucdc/>. Accessed May 25, 2016.
Contains contact information for the Utah Natural Heritage Program.

UCM. 2016. Museum of Natural History, University of Colorado, Invertebrates Collection. Boulder, CO. <http://www.colorado.edu/cumuseum/>. Accessed June 24, 2016.
"When using the following data portal sites, select the University of Colorado Museum of Natural History (CUMNH) as a data provider and search our collections. If you need further assistance or have any questions, or located errors in UCM specimen records, please contact Heather Robson. The cataloged invertebrate zoology collection records except non-molluscan invertebrates are available for searching online through the Global Biodiveristy Information Facilty (GBIF) database federation project."

UMMZ. 2016. Museum of Zoology, University of Michigan, Mollusk Division. Ann Arbor, MI. <http://lsa.umich.edu/ummz/>. Accessed June 20, 2016.

"The UMMZ Mollusk Division, through the help of the National Science Foundation's Biological Research Collections program, is currently databasing its catalog of nearly 5 million specimens. The primary goal of this project is to enter all of the University of Michigan's Museum of Zoology Mollusk Collection (UMMZ-MC) cataloged lots into an online Specify database. This process will involve georeferencing the data for GIS purposes, and also re-housing the dry specimens for their protection. A secondary goal is to develop an online type catalog with high-resolution images. The UMMZ-MC has long ranked amongst the most important freshwater and land snail collections in North America, being most notable for its excellent taxonomic and geographic coverage, type collection, and also for its relative age. A large fraction of its freshwater lots predate the major wave of extirpation and extinction associated with watershed industrialization, and the recent renaissance in the scientific and conservation biology study of the North American freshwater malacofauna has significantly heightened the UMMZ-MC's research saliency."

UNHP. 2016. Utah Natural Heritage Program Endangered Species Points. Salt Lake City, Utah. (See also UCDC).
Shapefile containing exact points of threatened or endangered Utah and Colorado freshwater mollusks. This data is not to be shared publicly.

USNM. 2016. National Museum of Natural History, Smithsonian Institute, Research Collections. Washington, D. C. <http://naturalhistory.si.edu/rc/>. Accessed June 29, 2016.
"Within the Department of Invertebrate Zoology, scientists conduct original research on all 30 major invertebrate animal groups (phyla) of the world (except insects), and are stewards for the 35 million specimens of invertebrates that comprise the U.S. National Collection. The study of invertebrates offers great challenges and opportunities to contribute to the world's knowledge of these organisms."

Vinson, M. 2004. The occurrence and distribution of New Zealand mud snail (*Potamopyrgus antipodarum*) in Utah. Final report for Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, UT. Utah State University, Logan, UT.
"The purpose of this project was to determine the occurrence of New Zealand mud snails in Utah. The NZMS is a small to medium sized Hydrobiidae snail that is native to New Zealand. Since the mid-1800s and in particular during the last few years, the snail has spread from New Zealand to freshwater environments throughout the United States, Europe, Asia, and Australia. New Zealand mud snails were first collected in Utah on 18 September 2001 in the Green River downstream from Flaming Gorge Dam. Between September 2001 and May 2004, 477 locations were sampled in Utah. New Zealand mud snails were found at 28 locations within 16 stream basins. Their dispersal throughout Utah and in particular along the Wasatch Front appeared to be rapid. In 2001 they were found in 3 basins, in 2002 they were found in 8 basins, and in 2003 they were found in 16 basins. They can currently be found in many of the State's quality trout waters including the Green, Bear, Provo, Weber, Ogden, and Logan River Basins. At individual sites, population abundances were highest in stream habitats characterized by slower water velocities and abundant aquatic vegetation that were adjacent to higher water velocity run

and riffle habitats."

Winger, P.V., E.J. Peters, M.J. Donahoo, J.R. Barnes and D.A. White. 1972. A checklist of the macroinvertebrates of the Provo River, Utah. The Great Basin Naturalist 32:211-219. "A checklist of the aquatic macroinvertebrate species from the Provo River, Utah, was compiled from field collections and from literature sources."

Woodbury, A.M. 1929. The snails of Zion National Park. Nautilus 43:54-61. "Fifteen species of snails have to date been collected in Zion National Park, Utah. One of them, *Oreohelix*, is large enough to readily attract attention and common enough to be seen on most all of the trails of the Park. The balance is smaller, not readily seen and must be hunted for in order to be found. Of the fifteen species, two are fresh water snails with well-developed shells. The other thirteen are terrestrial snails, of which, one is a slug."

Woolstenhulme, J. 1942b. Uinta Mountain mollusks. Nautilus 56:50-55. "The following collection from the Uinta Mountains of Utah and the vicinity were made in 1939-41. Earlier records from this area were published in a previous report (Woolstenhulme, J., May 20, 1942. new records of Mollusca. Bull. U. of Utah, Vol. 32, No. 11 - Biol. Ser., Vol. 6, No. 9 - pp. 3-14. This study represents a preliminary printing of a portion of the material for the Master's thesis at the University of Utah, prepublished because of interruption of my graduate work by call of duty in the U. S. Marine Corps."

Woolstenhulme, J.P. 1942a. New records of Mollusca. Nautilus 6:50. "Recent work on the molluscan collection of the University of Utah, involving the transferring of sets from the accession lots to the systematic series and the cataloging of the new accessions to the museum, has brought out several unpublished records and many gifts of recent date. Among the former are records of Dr. R. V. Chamberlin from the western deserts of Utah, and also from Idaho and Yellowstone National Park; the records of Willis Gertsch from the east shore of Bear Lake; and of Elmer Berry from the Raft River Mountains. Among the recent gifts are the important accessions of Dr. Walter Cottam from the Aquarius Plateau of southern Utah, of Kenneth Brizzee from the Humboldt River Valley of Nevada, and of several sets from the Uinta Mountains, some of which were Collected by Mary Lou Thorne, others by the author."

Xerces. 2016. Xerces Society. Portland, OR. Email Correspondence June 22, 2016. "The Xerces Society is a nonprofit organization that protects wildlife through the conservation of invertebrates and their habitat. Established in 1971, the Society is at the forefront of invertebrate protection worldwide, harnessing the knowledge of scientists and the enthusiasm of citizens to implement conservation programs. Butterflies, dragonflies, beetles, worms, starfish, mussels, and crabs are but a few of the millions of invertebrates at the heart of a healthy environment. Invertebrates build the stunning coral reefs of our oceans; they are essential to the reproduction of most flowering plants, including many fruits, vegetables, and nuts; and they are food for birds, fish, and other animals. Yet invertebrate populations are often imperiled by human activities and rarely accounted for in mainstream conservation. The Society uses advocacy, education, and

applied research to defend invertebrates. Over the past three decades, we have protected endangered species and their habitats, produced ground-breaking publications on insect conservation, trained thousands of farmers and land managers to protect and manage habitat, and raised awareness about the invertebrates of forests, prairies, deserts, and oceans."

YPM. 2016. Yale Peabody Museum of Natural History, Invertebrate Zoology Collection. New Haven, CT. <http://peabody.yale.edu/>. Accessed June 29, 2016.
"Primary strengths of the Division of Invertebrate Zoology include large holdings of Western Atlantic invertebrates represented not only by recently acquired specimens, but also by a strong historical component dating to the late 1800s, totaling approximately 3 million individuals, thousands of which are the type specimens of species new to science. The Yale Peabody Museum's collections are available to legitimate researchers for scholarly use. Loans are issued to responsible individuals at established institutions."

APPENDIX B - List of sources which listed or led to primary sources (Secondary Sources) and sources which were checked for applicable records but in which none were found.

Abbott, R.T. 1989. Compendium of landshells: a color guide to more than 2,000 of the world's terrestrial shells. American Malacologists, Melbourne, FL.

Anderson, T. 2005. *Oreohelix strigosa cooperi* (Cooper's Rocky Mountain snail): a technical conservation assessment, USDA Forest Service, Rocky Mountain Region.

Anthony, J. 2014. Mollusk Inventory - Excel Spreadsheet. J. Anthony, Oregon State University.

Arter, H.E. 1990. Spatial Relationship and Gene Flow Paths between Populations of the Alpine Snail *Arianta arbustorum* (Pulmonata: Helicidae). Evolution 44:966-980.

Bahls, P. 1992. The status of fish populations and management of high mountain lakes in the western United States. Northwest Science 66:183.

Barnes, J.R. and T.W. Toole. 1981. Macroinvertebrate and zooplankton communities of Utah Lake: A review of the literature. Great Basin Naturalist Memoirs 5:101-106.

Bartsch, P. and USNM. 1916. Two new land shells from the Western States. Proceedings of the US National Museum 51:331-333.

Basch, P. 1963. A review of the recent freshwater limpet snails of North America. Bulletin of the Museum of Comparative Zoology at Harvard College 129**:**399-461.

Baur, B. 1986. Patterns of dispersion, density and dispersal in alpine populations of the land snail *Arianta arbustorum* (L.) (Helicidae). Holarctic Ecology 9:117-125.

Beck, D.E. 1954. Ecological and distributional notes on some Utah Hirudinea. Utah Academy Proceedings 31:73-78.

Beetle, D.E. 1989. Checklist of recent mollusca of Wyoming, USA. Great Basin Naturalist 49:637-645.

Beetle, D.E. 1997. Recolonization of burned aspen groves by land snails. Yellowstone Science 5:6-8.

Bequaert, J.C. and W.B. Miller. 1973. The mollusks of the arid southwest. The University of Arizona Press, Tucson, Arizona.

Berry, S.S. 1922. Notes on the mollusks of the Colorado Desert: I. Proceedings of the Academy of Natural Sciences of Philadelphia 74:69-100.

Binney, W.G. 1864. Bibliography of North American conchology previous to the year 1860. Smithsonian Miscellaneous Collections, Volume 5.

Binney, W.G. 1885. A manual of American land shells, U.S. Government Printing Office.

Bishop, M. 1977. Approaches to the quantitative description of terrestrial mollusc populations and habitats. Malacologia 16:61-66.

Bisson, P.A. 1978. Diet food selection by two sizes of rainbow trout (*Salmo gairneri*) in an experimental stream. Journal Fisheries Research Board Canada 35:971-975.

BMNSM. 2016. Bailey-Mathews National Shell Museum, Malacological Collection. Sanibel, FL. <http://www.shellmuseum.org/>. Accessed July 28, 2016.

Boag, D. 1982. Overcoming sampling bias in studies of terrestrial gastropods. Canadian Journal of Zoology 60:1289-1292.

Bogan, A.E. 1993. Freshwater bivalve extinctions (Mollusca: Unionoida): A search for causes." American Zoologist 33:599-609.

Box, J.B., R.M. Dorazio and W.D. Liddell. 2002. Relationships between streambed substrate characteristics and freshwater mussels (Bivalvia: Unionidae) in Coastal Plain streams. Journal of the North American Benthological Society 21:253-260.

Boyko, C.B. and J.R. Cordeiro. 2001. Catalog of recent type specimens in the Division of Invertebrate Zoology, American Museum of Natural History. V. Mollusca, part 2 (class Gastropoda [exclusive of Opisthobranchia and Pulmonata], with supplements to Gastropoda [Opisthobranchia], and Bivalvia). Bulletin of the American Museum of Natural History 262:1-170.

BPBM. 2016. Bernice Papuahi Bishop Museum, Invertebrate Zoology Collection. Honolulu, HI. <http://www.bishopmuseum.org/>. Accessed July 28, 2016.

Bradford, D.F., S.D Cooper, T.M Jenkin Jr., K. Kratz, O. Sarnelle and A.D. Brown. 1998. Influences of natural acidity and introduced fish on faunal assemblages in California alpine lakes. Canadian Journal of Fisheries and Aquatic Sciences 55:2478-2491.

Bramblett, R.G. and K.D. Fausch. 1991. Fishes, macroinvertebrates, and aquatic habitats of the Purgatoire River in Pinon Canyon, Colorado. The Southwestern Naturalist 36:281-294.

Brandauer, N. and S.-K. Wu. 1978. The Bivalvia of Colorado. Part 2. The freshwater mussels. Natural History Inventory of Colorado 2:41-60.

Brooks, S.T. 1936. Some mollusks from Utah. Nautilus 50:13-14.

Brooks, S.T. and H.B. Herrington. 1943. The Sphaeriidae, a preliminary survey. Nautilus 57:93-97.

Burch, J.B. 1989. North American freshwater snails. Malacological Publications, Hamburg, MI.

Burke, T.E., J.S. Applegarth and T.R. Weasma. 1999. Management recommendations for survey and manage; terrestrial mollusks. Version 2.

BYU. 2016. Monte L. Bean Life Science Museum, Shell Collection. Provo, UT. <https://mlbean.byu.edu/>. Accessed June 29, 2016.

Call, R.E. 1882. Zoology - Note on the Geographical Distribution of Certain Mollusks. The American Naturalist 16:400-408.

Carpenter, P.P. 1872. Mollusks of western North America. Smithsonian Miscellaneous Collections 10.

Chamberlin, R.V., Ernest J. 1948. Check list of recent Utah mollusca. 11:13.

Chamberlin, R.V. and E.G. Berry 1930. Mollusca from the Henry Mountains and some neighboring points in Utah. Bulletin of the University of Utah 19:1-203.

Cherry, D.S., J.L. Scheller, N.L. Cooper and J.R. Bidwell. 2005. Potential effects of Asian clam (*Corbicula fluminea*) die-offs on native freshwater mussels (Unionidae) I: water-column ammonia levels and ammonia toxicity. Journal of the North American Benthological Society 24:369-380.

Chong, J.P., J.C. Brim Box, J.K. Howard, D. Wolf, et al. 2008. Three deeply divided lineages of the freshwater mussel genus *Anodonta* in western North America. Conservation Genetics 9:1303-1309.

Christensen, E.M. 1962. Bibliography of Utah aquatic biology, No. II. The Great Basin Naturalist 22:32-53.

Clarke, A.H. 1973. The freshwater molluscs of the Canadian Interior Basin. Malacologia 13:1-509.

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APPENDIX C - Protected data use agreements from the Utah Natural Heritage Program (Utah Division of Wildlife Resources) and the Colorado Natural Heritage Program.

Utah Division of Wildlife Resources
Protected Records Acceptance and Use Agreement

I, Jim Walton (print name), representing Utah State University (print governmental entity name)

understand that species locality data managed by the Utah Division of Wildlife Resources (UDWR) are classified as **protected** under the Government Records Access Management Act (Utah Code Annotated 63G-2-305 et seq.). By accepting protected records from the UDWR, we certify the following:

1. All records provided pursuant to this Agreement are necessary in the performance of our governmental duties and functions;
2. All records will be used for the benefit of Utah's wildlife resources; and
3. No records will be further distributed, released, disclosed, or otherwise made available to any outside individual or group, including contractors, without prior written authorization from UDWR.

In the event that records are released in violation of this Agreement, we agree to notify UDWR immediately, to provide all necessary assistance to UDWR, and to assume responsibility for damages and claims arising from that release.

Signed Jim Walton Date 9/15/16

Please sign and return to:

Attention: Sarah Lindsey
Utah Division of Wildlife Resources
1594 W. North Temple, Suite 2110
P.O. Box 146301
Salt Lake City, Utah 84114-6301
Fax: (801) 538-4745

DATA LICENSE AND USE AGREEMENT
between
Colorado State University – Colorado Natural Heritage Program
&
Colorado Dept. of Public Health and Environment: Water Quality Control Division

Under this Data License and Use Agreement (Agreement), the Colorado Natural Heritage Program (CNHP) agrees to provide for a period of five years from the Effective Date sensitive species and natural communities data to the Colorado Dept. of Public Health and Environment: Water Quality Control Division (LICENSEE) for the stated purposes of biological research and conservation planning for areas of interest in Colorado as subject to the terms and conditions set forth herein.

CNHP agrees to provide the following Data for (LICENSEE) project areas or species of interest requested under the terms of this license: 1) Level 1 Data for **internal use only** (ArcView shapefiles) for Public Lands; 2) Level 2 Data for **internal use only** (ArcView shapefiles) for all other lands; 3) Level 3 Data (ArcView shapefiles) for all lands external use and/or display; and 4) FGDC-compliant metadata files.

1. DEFINITIONS

Internal Use. Use of Data for analysis, summarization, display, or other use of the data by a party to this Agreement that does not result in the production of a product for External Use.

External Use. Use of Data in any publication, report, press release, or other hard-copy, machine-readable material, or electronic product provided to the general public or to any corporation, organization, or other entity or person not a party to this Agreement.

BIOTICS. The proprietary Biodiversity and Tracking Conservation System in which CNHP Data, including Element Occurrences and Potential Conservation Areas, are maintained. Data maintained in the CNHP's BIOTICS database are an integral part of ongoing research at Colorado State University and reflect the observations of many scientists, institutions and our current state of knowledge. CNHP BIOTICS is the aggregation of all data developed and maintained using natural heritage methodology by CNHP and cooperating organizations. These data are acquired from various sources, with varying levels of accuracy, and are continually being updated and revised. CNHP BIOTICS includes species and vegetation data, including various types of information from range-wide status to specific locations.

Data. Any information provided under this Agreement regardless of format (i.e., electronic, paper, or verbal).

Element. A global or state rare species, subspecies, or unique natural community tracked by the CNHP.

Element Occurrence (EO). An Element Occurrence represents a location in which an element is, or was, present. An EO has continued (or historic) presence and/or regular recurrence at a given location and has practical conservation value.

> **Precision**. Precision refers to the accuracy of the mapped location of an EO. General (G) precision is assigned to EO records whose locational uncertainty exceeds approximately 1 mile. Minutes (M) precision is assigned to EOs mappable within approximately 1 mile in any direction. Seconds (S) precision is assigned to EOs mappable to within approximately 3 arc seconds of latitude and longitude.
>
> **Sensitive EO**. EOs may be marked sensitive either due to collection value, susceptibility to disturbance, federal status, or other factors (record displays a "Y" in the CNHPSENS field) or due to land status, i.e., private landowner request (record displays a "Y" in the DATASENS field).
>
> **Generalized EO**. Please refer to the "CNHP Methodology for Generalizing Element Occurrence Data" document in the Supporting Documents directory for a detailed explanation.

Observations Database. Repository for data on elements not currently fully tracked by CNHP, i.e., watchlisted. Data may be points, lines, or polygons and are maintained with minimal attributes.

Public Lands: Public lands include those lands managed by the U.S. Forest Service, Bureau of Land Management, Bureau of Reclamation, National Park Service, U.S. Fish and Wildlife Service, Department of Defense, Colorado Parks and Wildlife, Colorado State Land Board, Colorado State Forest Service, and local governments (including counties and municipalities where land ownership data is available).

Private Lands: All lands other than those designated as Public Lands by the definition used in this Agreement.

Level 1 Data. Dataset of CNHP Data which contains information on both non-sensitive and sensitive species and communities provided for **INTERNAL USE ONLY**. **These data are not to be redistributed**. Level 1 Data is provided for Public Lands and/or Private Lands with landowner permission; these data are not generalized. Level 1 Data includes the following items and file formats (if applicable):

a. EO Spatial Data (Arcview SHP) – Non-sensitive and sensitive EOs. Data contain full details maintained in BIOTICS and are provided as precisely as known or "as-is" from BIOTICS (data are not "fuzzed" or generalized).

b. EO Transcription (PDF) – For each EOs provided in the spatial data, reports which contain full details maintained in BIOTICS.

c. PCA Spatial Data (Arcview SHP) – All PCAs (non-sensitive and sensitive).

d. PCA Transcription (PDF) – PCA Reports for all PCAs provided in the spatial data. PCA reports contain full details maintained in BIOTICS.

e. NCA Spatial Data (ArcView SHP) – All NCAs.

f. NCA Transcription (PDF) – NCA Reports for all NCAs provided in the spatial data.

g. Observation Data (ArcView SHP) – All Observations Database records.

h. Metadata (MET) – FGDC-compliant metadata for EOs, PCAs, NCAs, and Observations.

Level 2 Data. Data for all other lands within the LICENSEE Planning Area provided for **internal use only**. Level 2 Data includes the following items and file formats (if applicable):

a. EO Spatial Data (Arcview SHP) – Non-sensitive and sensitive EOs that overlap with the planning area not included in the Level 1 Data described above. The locations of non-sensitive EOs are generalized to 1 sq. mile and sensitive EOs are fuzzed to 4 sq. miles.

b. EO Transcription (PDF) – 1) EO Summary Report for all EOs provided in the spatial data; and 2) EO Reports: The resolution of location information for EOs differs based on EO sensitivity: locations of non-sensitive EOs are reported to PLSS section (1 sq. mile); locations of sensitive EOs are reported to PLSS range (36 sq. miles).

c. PCA Spatial Data (Arcview SHP) – Non-sensitive PCAs only that overlap with non-public lands.

d. PCA Transcription (PDF) – Reports will not list Site Directions, Management Comments, or Protection Comments.

e. Metadata (MET) – FGDC-compliant metadata for EOs and PCAs.

Level 3 Data. Dataset of CNHP Data which contains both non-sensitive and sensitive species and communities provided for **EXTERNAL USE** and mapping display. No transcription reports are provided with Level 3 Data. Level 3 Data includes the following items and file formats (if applicable):

a. EO Spatial Data (ArcView SHP) – For Data with general mapping precision are provided "as-is." Data with seconds and minutes mapping precision are generalized based on sensitivity. Non-sensitive EOs are generalized to 1 sq. mile blocks and sensitive EOs are generalized to 9 sq. mile blocks.

b. EO Summary Report (PDF) - for all EOs provided in spatial data.

c. PCA Spatial Data (Arcview SHP) – Non-sensitive PCAs only.

d. Network of Conservation Areas (NCA) Spatial Data (ArcView SHP) – All NCAs.

2. TERM: The term of the Data license granted herein and the period of performance of this Agreement is from the effective date of signature by both parties through five (5) calendar years from date of signing unless this Agreement is sooner terminated or extended by mutual written agreement of the Parties. Upon termination of this Agreement, all rights granted LICENSEE herein shall immediately expire and LICENSEE shall: (i) cease use of the Data and certify that all copies of these Data have been destroyed or return all copies of these Data to CNHP; or (ii) complete arrangements with CNHP to receive a comprehensive update to these Data. The arrangements shall include an updated license that will conform to the CNHP Data distribution policies in effect at the time of signing.

3. LICENSE FEE AND PAYMENT: If required CNHP will invoice LICENSEE for use of these Data based on the CNHP fee schedule (a current version is always available on the CNHP website), or data may be provided as part of a deliverable at no additional cost. Fees are due within 30 days of receipt of invoice.

4. CONFIDENTIALITY AND NON-DISCLOSURE REQUIREMENTS: LICENSEE acknowledges that Level 1 Data provided by CNHP (described above), are considered **sensitive and confidential** for management and conservation reasons. Therefore, LICENSEE agrees to strictly adhere to the following requirements with respect to Data being provided by CNHP:

a. Level 1 and Level 2 Data are being provided for **internal use only**. LICENSEE will undertake appropriate measures to ensure that these Data will be accessible only to the LICENSEE and to no other entity, nor will these Data be made available for public viewing without prior approval by CNHP.

b. Level 3 Data are being provided for purposes of external CNHP data display, i.e., any printed or electronic items (e.g., maps, tables, charts, graphs, etc.) containing CNHP Data that the licensees wish to publish for public viewing.

c. All CNHP Data are copyrighted and ownership of the Data remains with CNHP. The licensees are being granted use of the Data for the purposes described herein. No interest whatsoever is conveyed to the LICENSEE in right, title, and interest of the Data, the information, and all copyrights (and renewals thereof) secured herein. All publication, dissemination and other rights in the Data are reserved to CSU/CNHP in all languages, formats, and throughout the world for the sole and exclusive use of any other disposition by CNHP or their assignees or grantees at any time and from time to time without any obligation or liability to any Data user.

d. The Data will be used for the requested purposes described above and for no other purpose.

e. The Data may not be transcribed, reproduced in any manner, nor redistributed to any third party, unless authorized in writing by CNHP. Requests for the Data from any other entity will be referred to CNHP.

f. Requests involving biological interpretation or use of the Data beyond the stated purposes will be referred to CNHP.

g. LICENSEE will provide acknowledgement for CNHP Data where appropriate. The correct citation for CNHP Data is as follows:

Colorado Natural Heritage Program. 200x. Biodiversity Tracking and Conservation System.
Colorado State University, Ft. Collins, CO. Data exported *month* 200x.

h. In the event that the LICENSEE receives a demand for disclosure pursuant to applicable law (including, but not limited to, the Colorado Public Records Act, C.R.S. secs. 24-72-201, et seq., as now or hereafter amended), or any lawful order, subpoena, or other process requiring disclosure of the Data, the LICENSEE shall immediately notify CNHP in writing in order to afford CNHP a reasonable opportunity to initiate legal action to enjoin, restrict, or otherwise oppose the disclosure in a court of competent jurisdiction. Such action shall be at the expense of CNHP, but the LICENSEE shall reasonably cooperate with CNHP in seeking protection of the Data.

5. NOTICE REGARDING INFRINGEMENT: LICENSEE shall promptly notify CNHP of any third party that it reasonably believes to be infringing any right of CNHP, and LICENSEE shall use reasonable efforts to provide to CNHP any information LICENSEE has in support of such belief.

6. DISCLAIMER OF WARRANTIES: LICENSEE acknowledges that CNHP Data require a certain degree of biological expertise for proper analysis, interpretation, and application. Care should be taken in interpreting these Data. These Data are dependent on the research and observations of many scientists and institutions, and reflect our current state of knowledge. Data are acquired from various sources, with varying levels of accuracy, and are continually updated and revised. They are provided for planning purposes only. Many areas have never been surveyed, however, and the absence of Data in any particular geographic area does not necessarily mean that species or ecological communities of concern are not present. These Data should not be regarded as a substitute for on-site surveys required for environmental assessments. Absence of evidence is NOT evidence of absence. Absence of any Data does not mean that other resources of special concern do not occur, but rather CNHP files do not currently contain information to document this presence. If ground-disturbing activities are proposed on a site, CNHP should be contacted for a site-specific review of the project area.

LICENSEE acknowledges that the Data and other Confidential Information provided to LICENSEE by CNHP are provided on an **as-is basis, as-available** basis without warranties of any kind, expressed or implied, **INCLUDING (BUT NOT LIMITED TO) WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT**. Although CNHP maintains high standards of Data quality control, CNHP, Colorado State University, and the State of Colorado further expressly disclaim any warranty that the Data are error-free or current as of the date supplied. For more information, see the Colorado Natural Heritage Program website at: www.cnhp.colostate.edu.

LICENSEE acknowledges that CNHP shall have no liability or responsibility to the Data users, or any other person or entity with respect to liability, loss, or damage caused or alleged to be caused directly or indirectly by the Data, including but not limited to any interruption of service, loss of business, anticipatory profits or indirect, special, or consequential damages resulting from the use or operation of the Data. LICENSEE hereby agrees to hold CNHP, Colorado State University, and the State of Colorado harmless from any claim, demand, cause of action, loss, damage or expense arising from or related to LICENSEE's use of or reliance on the Data, regardless of the cause or nature thereof, and even in the event that such cause is attributable to the negligence or misconduct of CNHP.

7. CHOICE OF LAW: This Agreement shall be interpreted, construed, and governed by the laws of the State of Colorado, and such laws of the United States as may be applicable.

8. MODIFICATION AND AMENDMENT OF AGREEMENT: Modifications to this Agreement may be proposed by either party at any time during the period of performance and shall become effective upon written approval by both parties.

In Witness Whereof, CNHP and the Colorado Dept. of Public Health and Environment: Water Quality Control Division have executed this data license and use agreement as of the last date signed below:

Michael Menefee Date

Environmental Review Coordinator
Colorado Natural Heritage Program
Colorado State University
1474 Campus Delivery
Fort Collins, CO 80523-1474

P: (970) 491-7331
Michael.Menefee@ColoState.edu

Blake W. Beyea Date

Colorado Department of Public Health & Environment
Acting Unit Manager
Standards Unit
4300 Cherry Creek Drive South, Denver, CO 80246

P: (303) 692-3656
blake.beyea@state.co.us

APPENDIX D

Tabular Data Notes

A "Rep" – "Rep" in field header refers to data as reported by the primary source. (See 'Primary_Source' field in tabular data.

B "USU" – "USU" in field header refers to current taxonomic synonymies and geographic coordinates identified from reported location information that does not already contain geographic coordinates.

C USU_ID, Primary_AccessionID, Primary_CatalogID, Secondary_ResourceID all may have separate numbering system. USU_ID refers to a unique identifier for each record, while catalogID's or Secondary_ResourceID's may refer to single or multiple records.

D Sources used to assign geolocations to records:

Google Search	https://www.google.com/
Google Earth	https://www.earth.google.com/
USGS, The National Map, Hydrography	https://viewer.nationalmap.gov/viewer/nhd.html?p=nhd
USGS, The National Map, Viewer	https://viewer.nationalmap.gov/viewer/
USGS, Earth Explorer	https://earthexplorer.usgs.gov/

E Sources for USU taxonomy fields:

DiscoverLife.org	http://www.discoverlife.org/
U.S. Fish $ Wildlife Service, Environmental Conservation System	https://ecos.fws.gov/ecp/
Integrated Taxonomic Information System	https://www.itis.gov/
The Mussel Project	http://mussel-project.uwsp.edu/
NatureServe	http://www.natureserve.org/
National Museum of Natural History	http://www.natureserve.org/
Worldwide Mollusc Species Data Base	http://www.bagniliggia.it/WMSD/WMSDhome.htm
World Registry of Marine Species	http://www.marinespecies.org/

F The 'Tabular_Data_Protected' sheet contains sensitive species from the Colorado Natural Heritage Program and the Utah Natural Heritage Program. Data in this table is protected and cannot be made publicly available.

Tabular Data Field Descriptions and Standards

Field #	Field	Field Options	Description
1	Accession_Number	0000	Record number
2	USU_ID		Provides a unique identification number for each record starting at "0001" for each new primary source. Formatted starting with "T" for Tabular Data followed by 4 numeric digits.
		[Author]-[YYYY]_0000 [Institution]_0000	
3	Primary_Resource	[Author]-{YYYY]	Resource in which the data was originally reported If document is not published provide the year the document was created this format also applies to personal communications
		[InstitutionCode]	Museum Records as per Perez, S. (2014)
4	Primary_ID_Type(1)		Defines the type of unique identifier provided by Primary_Source accession, ID, No, or Catalog Number
		USU Generated ID	A unique identifier used to track specific record back to the source if the Primary_Source did not provide one
		Unknown	An identifier was reported but it is known to be unique
5	Primary_ID(1)		The unique identifier provided by the primary source Does not have a duplicate value from the same intuition
6	Primary_ID_Type(2)		A second identifier provided by the primary source
7	Primary_ID(2)		Reported Identifier of specimen May contain duplicate record number as part of a larger collection or group
		Not Reported	A second identifier is not reported by the primary source
		Unknown	An identifier was reported but it is known to be unique
8	Secondary_Resource		Resource which refers to information of the primary source of data or in which the original survey/collection was completed
		Not Applicable	There is no secondary resource associated with the Primary Source
9	Secondary_Resource_ID		Record identifier as reported the Secondary_Resource
10	Peer_Reviewed_Resource		
		Yes	Resource has been peer reviewed prior to publication
		No	Resource has not been peer reviewed
11	Rep_Family	[Family]	Family name as reported in the Primary_Source, if noted in source
		Not Reported	Family name was not reported by the Primary_Source

12	Rep_Taxonomy	Family, Genus or Species as Reported	The reported family, genus and/or species as reported by the Primary_Source
		Not Reported	Taxonomy is only listed at Class level or higher
13	Rep_Genus	[Genus]	Genus as reported by the Primary_Source or filled in from Rep_Taxonomy
		Not Reported	Taxonomy is only listed at Family Level or Higher
14	Rep_Species	[Species]	Species as reported by the Primary_Source or filled in from Rep_Taxonomy
		Not Reported	Taxonomy only listed at Genus level or higher.
15	Rep_Subspecies	[Subspecies]	Subspecies as reported by the Primary_Source or filled in from Rep_Taxomony
		Not Reported	Taxonomy is listed at Species level or higher.
16	Rep_Common_Name	[Common Name]	Common name as reported by the Primary_Source
		Not Reported	Common name was not reported by the Primary_Source
17	Rep_Taxonomy_Level		Lowest level taxonomic rank as provided by the Primary_Source
		Family	
		Genus	
		Species	
		Subspecies	
18	Rep_Authority	[Authority]	Name of the person or people who published the original description for a particular scientific name, followed by the year of publication
		Not Reported	The Rep_Authority was not provided by the Primary_Source
19	USU_Class		Current taxonomic class of specimen as noted by USU.
		Gastropoda	
		Bivalvia	
20	USU_Family	[Family]	Current taxonomic family of specimen as noted by USU. See Tabular Data Notes for sources used to update taxonomy.
21	USU_Genus	[Genus]	Current taxonomic genus of specimen as noted by USU. See Tabular Data Notes for sources used to update taxonomy.
22	USU_Species	[Species]	Current taxonomic species of specimen as noted by USU. See Tabular Data Notes for sources used to update taxonomy.
23	USU_Subspecies	[Subspecies]	Current taxonomic subspecies of specimen as noted by USU. See Tabular Data Notes for sources used to update taxonomy.
24	USU_Scientific_Name	[Genus Species Subspecies]	Combination of USU_Genus, Species, and Subspecies fields.
		*	Reported scientific name not found so record is reported as-is.
25	USU_Common_Name		

		na	Record was reported to genus level or higher. As such, no common name is applied.
		noname	Record reports to species or subspecies level but no common name found.
26	USU_Taxonomy_Source		Authority used to identify current taxonomic naming
		Cannot be verified	Taxonomic hierarchy or naming binomial cannot be identified or found based on information provided.
		Disc.Life	DiscoverLife.org
		ECOS	U.S. Fish $ Wildlife Service, Environmental Conservation System
		ITIS	Integrated Taxonomic Information System
		Musselp	The Mussel Project
		Nat.Serve	NatureServe
		NMNH	National Museum of Natural History
		WMSDB	Worldwide Mollusc Species Data Base
		WoRMS	World Registry of Marine Species
27	Rep_Survey_Date		Year Primary_Source collected or recorded presence of specimen. If no collection or survey date was provided, enter publication year.
		[Date as Reported]	
		*	Indicates Rep_Survey_Date was not found and publication date was used.
		?	Reported survey date is an estimate reported by Primary_Source.
		Not Reported	No date was reported by the Primary_Source.
28	USU_Survey_Month	1-12	January (1) thru December (12)
		0	Indicates no month was reported.
		[Winter]	Defines a general time range of when specimen was collected.
29	USU_Survey_Day	1-31	Indicates day of the month specimen was collected.
		0	The Primary_Source did not report the day of the month.
30	USU_Survey_Year	[YYYY]	The year the Primary_Source collected or recorded presence of specimen. See Rep_Survey_Date for definitions of "*" and "?".
		0	The Primary_Source did not report the year the specimen was collected.
31	Rep_Basis_of_Record		Indicates the preservation or vital status of the specimen in which the record is based upon.
32	Rep_Identifier		Person(s) responsible for taxonomic identification as reported by the Primary_Source.
33	Reported_Collector		Person(s) responsible for collection of the specimen on record as reported by the Primary_Source.
34	Rep_State		State in which Primary_Source reported the specimen collected in.

		CO	Colorado
		UT	Utah
		ID	Idaho
35	Rep_County	[County]	County in which the specimen was collected in as reported by the Primary_Source.
		Not Reported	The Primary_Source did not report a county the specimen was collected in.
36	Rep_Location		Descriptive location information as reported in the Primary_Source
		Not Reported	No descriptive data provided.
37	Rep_Location_Format		Format in which the Primary_Source reported geographic location information.
		None	No geographic location given.
		Descriptive	For use when no latitude/longitude information is given and location data is descriptive only. Descriptive information should be recorded in Rep_Location
		DMS	Degrees, Minutes and Seconds
		DM	Degrees and Decimal Minutes
		DD	Decimal Degrees
		UTM	Universal Transverse Mercator
		Township	Township and Range
38	Rep_Location_Y	[Coordinate]	Latitude, North or South geographic coordinate information as reported by Primary_Source. Enter numbers only separated by spaces, do not include N, E, S, W, deg., ', ", -.
39	Rep_Location_X	[Coordinate]	Longitude, East or West geographic coordinate information as reported by Primary_Source. Enter numbers only separated by spaces, do not include N, E, S, W, deg., ', ", -.
40	Rep_UTM_ Zone	11, 12, or 13	Reported UTM Zone
		na	Record is not a UTM coordinate and is therefore not applicable.
41	Rep_Datum	[Datum]	Datum as reported by the primary source
42	Rep_Township	"5S"	Township as reported by Primary_Source. Example refers to township 5 South.
43	Rep_Range	"7E"	Range as Reported by Primary_Source. Example refers to Range 7 East.
44	Rep_Section		Section as reported by Primary_Source.
		NE	Northeast
		SE	Southeast
		SW	Southwest
		NW	Northwest
45	Rep_Quarter		Quarter as reported by Primary_Source.

		NE	Northeast
		SE	Southeast
		SW	Southwest
		NW	Northwest
46	Rep_Location_Illustrated		Indicates the presence or absence of illustrated location data.
		Yes	Primary_Source includes location of record in an illustration.
		No	Primary_Source does not include an illustration showing location of record.
47	Rep_Loc_Notes		Additional notes regarding geographic location provided by primary source
48	Rep_Citation		Source the record was taken from as reported by primary source
		None	No citation reported in primary source or otherwise
49	USU_State		State identified by USU to be place of record.
		UT	
		CO	
50	USU_County	[County]	County identified by USU as place of record.
		na	Record contains conflicting information. Descriptive data does not identify the County, is not reported, or is too vague to identify.
51	USU_Location_Name	[Location]	Location, nearest location, or water body which most accurately describes place in which specimen was found.
52	USU_Location_Type		Category of USU_Location_Name
		Lake	Includes Reservoirs
		Stream	Includes Rivers and Creeks
		Spring	Springs
		State	The Primary_Source did not identify location information below the state level.
		Populated Place	Includes Cities, unincorporated populated areas, and some ghost towns.
		Valley	Valley's
		Locality	A general area or geographic focal point.
		Protected Area	State and federal protected lands such as national forest, monuments, parks, reserves, refuges and management areas.
		Pond	Pond
		Unknown	The provided information cannot determine Location_Type.
		Canyon	Canyon
		County	County

		Mountain Range	Mountain Ranges
		Canal/Ditch	Includes canals and ditches.
53	USU_Location_Y		Best estimate of Y location in DD, possibly different from reported format
54	USU_Location_X		Best estimate of X location in DD, possibly different from reported format
55	USU_Location_Confidence		General confidence based on reported location descriptive data GPS coordinates when reported. See Confidence Ranking Criteria worksheet for more information. Location_Confidence rankings are based from a finer scaled ranking system in USU_Location_Confidence_Raw.
		High	
		Low	
		Very Low	
		No Location Data	
56	USU_Location_Confidence_Raw		See Confidence Ranking Criteria worksheet for more information.
57	USU_Conf_Score_by		Person who scored location confidence ranking
58	Geocoded_By		Records that provide location description only and no coordinates were assigned coordinates by USU.
59	USU_Contract_Specimen		Does the USU Work Plan identify this species as a target species?
		Yes	
		No	
60	Native_Status		Nonnative species status is identified in the tabular data.
61	State_Conservation_Status		Conservation status as reported by the States of Utah and Colorado.
		na	Only genus level taxonomy and above is listed, therefore, the records conservation status is not listed.
		Not Listed	Species level data is listed but is either not identified by the respective list or is listed and has no official listing.
62	Federal_Conservation_Status		NatureServe Global Status as reported by NatureServe.
		na	Genus level taxonomy and above is listed, therefore, the record cannot be listed.
		Not Listed	The record is listed at species level but is either not identified by the respective list or is listed and has no official listing.
63	Other_Conservation_Status		IUCN Redlist Status as reported by NatureServe.
		na	Genus level taxonomy and above is listed, therefore, the record cannot be listed.
		Not Listed	The record is listed at species level but is either not identified by the respective list or is listed and has no official listing.

64	Notes	Additional notes by USU pertaining to confidence rankings or general record information.

APPENDIX E – Public review comments and responses.

1. Comment: This database compilation provides some historical relevance, however present mollusk distributions, ecologies, life histories, habitat associations, etc. continue to be poorly documented despite the Bonneville Basin being one of the world's hotspots for freshwater mollusks (Richards 2017). No Utah State agency or university, that I am aware of, has conducted close to adequate freshwater mollusk surveys. The only recent freshwater mussel specific survey that has been conducted in Utah in recent years was by Richards 2017. Richards 2017 conducted the most extensive and intensive survey of Anodonta and Margaritifera in the Utah Lake/Jordan River drainage ever conducted.

   DWQ Response: Thank you for the information.

2. Comment: In the spreadsheet, D.T. Jones didn't survey and find Utah valvata in 2027.

   USU Response: The reference was corrected.

3. Comment: *V. utahensis* (heterobranch) is believed to be extinct in UT.

   DWQ Response: The scope of this work did not include determining presence or absence of any species. The report is limited to summarizing the existing records of where mollusks have been identified in Utah. Thank you for the information.

4. Comment: I don't think Peter Hovingh has a Ph.D. even though on page 6 of the report he is listed as Dr. Peter Hovingh. There are at least three contacts in that list that have Ph.D.s and should be cited as such.

   USU Response: Peter Hovingh is an acknowledged expert on Utah freshwater mollusks as evidenced by his many publications and reports. We believe Hovingh has a PhD (in biochemistry), but more importantly, a PhD is not necessarily indicative of an individual's expertise relevant to a specific project or question, but their publication record is. To avoid any confusion regarding what degree of expertise the generic title of PhD implies with respect to expertise relevant to this report, we have simply removed any reference to whether any of the individuals we cited have PhDs since doing so has

little bearing on either the degree of scientific credibility of specific individuals or the report in general.

Comment: Xerces Society has also conducted an extensive review of Margaritifera and Anodonta distributions in North America with a much more comprehensive discussion of life histories, distributions, threats, status, etc. than presented in this report. A thorough examination of this very important and detailed literature review is highly recommended. The link to their website page on Anodonta californiensis is: https://xerces.org/california-and-winged-floaters/. NatureServe, USGS, and other government maintained mollusk websites are poorly maintained and are very incomplete.

DWQ Response: The scope of this work was limited to summarizing the records documenting the presence of *Margatifera* and *Anodonta* in Utah. A review of the databases referenced in the comment was conducted and we believe that all relevant records were captured in our reviews of the primary sources. Characterizing the life histories, threats or status was not included in the scope because DWQ's focus is on current or historical presence. These historical records will be compared to the results of current surveys to determine the appropriate ammonia criteria (see the *Utah Implementation Guidance for the 2013 USEPA Ammonia Criteria for the Protection of Aquatic Life*, September 20, 2017)

5. Comment: The authors recommended developing habitat models for freshwater mollusks such as MaxEnt. MaxEnt models will likely not be of much use in determining mollusk locations in Utah. There is not enough habitat requirement information in UT available other than what is already known by malocologists working with these taxa. Mollusks are where you find them. For example, Anondonta species can be found in just about any type of habitat except high mountain streams or anoxic sediments. Margaritifera, if any populations still remain, other than the one population already documented, can occur in most substrate types where it can secure a footing in cool water salmonid streams and lakes. Both mussel species require high enough densities of fish hosts, without which they will not be viable, although exact fish host densities needed are unkown at this time. A MaxEnt model likely would not be of much use given these types of water bodies are already known and should be in USU or DWQ databases. Similarly, hydrobiids are typical cool water snails that require adequate DO. This could include lake shores, springs, streams, and rivers. The genus Pyrgulopsis (spring snails) can occur in the same types of habitats as other hydrobiids but most are found in springs and even warm springs. I am sure DWQ has maps of springs in UT. Within the springs, Pyrgulopsis can occur on any type of substrate. A simple survey of the literature and consultation with malacologists should suffice to help determine where Utah's mollusks are likely to occur or have occurred in the past. MaxEnt models rely on presence data for their development and there simply isn't enough presence data to populate these types of models.

USU Response: The comment (*Mollusks are where you find them*) seems to imply that the mollusk species covered in this report are potentially in every freshwater waterbody in Utah and Colorado and not constrained by habitat conditions. This is a testable hypothesis, but not a demonstrated fact. Species distribution (or habitat suitability) models are commonly used by ecologists to help identify habitats that are likely either suitable or non-suitable for specific species. They further help ecologists quantify the extent to which individual species are habitat generalists or specialists. As far as we are aware, no habitat suitability models have been developed to date for the species and area covered in this project. Doing so was not within the scope of the project, but developing such models in the future could be of potential value in helping managers understand how general or specialized different species are with respect to different environmental features including type of waterbody; thermal, chemical, and hydrologic regimes; biological interactions; and other factors known to influence both micro- and macro-distributions of aquatic species of interest.

DWQ Response: As explained in the *Utah Implementation Guidance for the 2013 USEPA Ammonia Criteria for the Protection of Aquatic Life*, presence or absence will be based on qualitative physical surveys or potentially eDNA sampling. For the ammonia water quality criteria, the veracity of the assumption that nonpulmonate snails or unionid mussels are likely present in unsurveyed waters will be evaluated after surveys are completed on statewide receiving waters.

6. Malacologists have described many of these Pyrgulopsis species and their spring habitats including Dr. Robert Hershler and Dr. Don Sada at the Desert Research Institute, Nevada. Neither of these springsnail experts appear to have been contacted by the authors of this report. Nor has Dr. Dan Gustufson, who has conducted extensive freshwater mollusk surveys in the Bonneville Basin. Either of these experts could easily lead or direct DWQ to likely locations. I also did not see any references of the authors contacting members of the Freshwater Mollusk Conservation Society. This may have been an oversight by me, as I did not have a chance to thoroughly review the report as of yet.

   USU Response: The work of both Hershler and Sada were covered in the literature search. Hershler was also contacted directly as he is the Curator of Mollusca for the Smithsonian. He helped obtain records as their website was not working correctly at the time of review.

   Dan Gustafson was not contacted, nor did his name come up in the literature search, which is probably why he was missed. He donated his collection to the Montana Entomology Collection (MTEC) housed at Montana State University, but there are no records available for download from the MTEC. If information has not been published (or cataloged), it does not exist as reliable, verified information. Nonetheless, we have added Gustafson to the "follow up" institutions/individuals listed in Table 2.

   We did not contact the Freshwater Mollusk Conservation Society (FMCS) directly. We searched their website, but no database information is housed by FMCS. Instead they list

under "Databases" links to the Ohio State University Freshwater Bivalve Collection and the Illinois Natural History Mollusk Collection, which were checked for records. In response to this comment, we searched through their "journal", but no articles that we saw identified specific records. Most of the journal entries focus on the eastern U.S.

7. As I discussed frequently with DWQ; eDNA methods are very promising however, a non-detect reading will not mean that a mollusk taxon is absent. eDNA positive signals will suggest presence and actual physical surveys will then be required to locate individuals or populations to help verify is the positive eDNA signal was true.

   USU Response: eDNA has been shown to be a more sensitive and cost-effective way to detect the presence or absence of species than traditional physical surveys as documented in may publications. We agree that physical surveys can be an important complement to eDNA approaches, but a 'negative' finding with a well-designed and validated eDNA assay is generally associated with more confidence than a 'negative' finding based on traditional physical surveys.