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Distribution and Conservation Status of the freshwater gastropods of Nebraska

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Abstract: This survey of freshwater gastropods within Nebraska includes 159 sample sites and encompasses the four primary level III ecoregions of the State. I identified sixteen species in five families. Six of the seven species with the highest incidence, *Physa gyrina*, *Planorbella trivolvis, Stagnicola elodes, Gyraulus parvus*, *Stagnicola caperata*, and *Galba humilis* were collected in each of Nebraska's four major level III ecoregions. The exception, *Physa acuta,* was not collected in the Western High Plains ecoregion. Seven indigenous species, *Valvata tricarinata*, *Helisoma anceps*, *Campeloma decisum, Galba bulimoides*, *Physa jennessi*, *Ferrissia rivularis*, and *Planorbula armigera*, display incidence rarity, being collected at five or fewer samples sites. The non-indigenous Chinese mystery snail, *Bellamya chinensis*, was collected at five sites all within southeastern Nebraska. The Nebraska Sand Hills had the highest species richness, with 12 species. The wetland complex with the highest species richness of 8 was the lakes region of the Nebraska Sand Hills. Reservoirs and permanent/semi-permanent water bodies were the most species rich among water body types and hydrologic conditions with 13 and 14 species respectively. I assign a tentative conservation status to each species of indigenous freshwater snail observed following a modified quartile analysis.

Keywords: Freshwater snails, malacology, macroinvertebrates, conservation, biogeography.

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Introduction

Aquatic invertebrate fauna, including freshwater snails, have high extinction rates. The modeling of extinction rates of freshwater fauna suggests that they are five times those of terrestrial animals (Ricciardi and Rasmussen 1999). The non-marine mollusks collectively are thought be one of the most threatened groups of organisms (Lydeard *et al.* 2004) with freshwater snails, specifically, heading the list of endangered groups in several analyses (Allan and Castillo 2007, Lysne *et al*. 2008). Thirty-nine percent of North American snail species have a conservation ranking of G1, critically imperiled, with a further twelve percent at G2, imperiled (Lysne *et al*. 2008), and many species of freshwater snail in North America are thought to already be extinct (Master *et al*. 2000). Evaluation of IUCN Red List shows that extinction of mollusks in general may be double what has previously been thought, with the greatest number of extinctions from the USA (Régnier *et al*. 2009). These losses may already have greatly altered systems because loss of species alters ecosystem services by altering flow-through of energy and the resilience of the system (Contanza *et al*. 1997). The three leading threats to freshwater fauna are alteration of sediment and nutrient load from agriculture, altered water flow, and non-indigenous species invasions (Richter *et al*. 1997). The 2000 National Water Quality Inventory lists agricultural pollution as the leading impact source on rivers and lakes (EPA 2002) and aquatic habitats have been lost completely in Nebraska because of conversion to agriculture (USGS 1996). Currently in Nebraska a single freshwater gastropod species, *Fossaria techella,* is listed as a conservation concern (Schneider *et al*. 2011). Because no comprehensive study of freshwater snails has ever been conducted in Nebraska this lack of listings of freshwater snail species is due to the absence of data not the absence of species in need. Recent surveys of Nebraska's mollusks include freshwater snails and mussels in the Platte and Niobrara rivers (Freeman and Perkins 1992, 1997) and a statewide survey of mussels (Hoke 2011). An analysis of the conservation status of freshwater snails for North America has been completed recently (Johnson *et al*. 2013). This assessment lacks current survey data, which is sparse in most areas of the continent, relying heavily of historic records and lacks detailed analysis within specific regions and states.

Evaluation of the conservation status of species is based on their abundance or rarity (Master *et al*. 2009). Abundances patterns of species often assume a competitive aspect based on resources within a community being divided among species (MacArthur 1957). One possible pattern is explained by the sequential niche fragmentation model (Tokeshi 1990, 1992). Sequential niche

fragmentation fits the relative abundance of species and the overall pattern suggests a minimal structure of biological communities that can be found in freshwater snail communities (Gaston 1994, Dillon 2000). I utilize this pattern in evaluating the conservation status based on species incidence following Dillon (2012). Incidence based status may be adjusted once other aspects of species rarity including geographic distribution and habitat specificity are taken into account (Rabinowitz 1981).

Though many species appear in danger of extinction, information on presence, habitat use, and geographic distribution is absent for many freshwater snails within North America (Brown *et al*. 2008, Lysne *et al*. 2008). The need for surveys and distributional trends of freshwater gastropods is urgent (Lydeard *et al*. 2004, Lysne *et al*. 2008). A survey of Nebraska freshwater gastropods is essential to providing data on population decline or demise, which may in turn inform other issues including habitat suitability, water quality, and influences of snail populations on other species. By utilizing recent survey data of others and surveying across the State I assess species distribution and the conservation status of Nebraska's freshwater snails.

Materials and Methods

I surveyed freshwater snails from 91 sample sites throughout Nebraska between 2007 and 2014. In addition, 68 samples, collected primarily by Steve Schainost between 2001 and 2010, were obtained from the Nebraska Game and Parks Commission. I targeted areas of high wetland density or wetland complexes such as sections of the Nebraska Sand Hills and the Rainwater Basin Plain but attempted to cover the entire State sampling within each of four level III ecoregions, the Western High Plains (WHP), the Central Great Plains (CGP), the Nebraska Sand Hills (NSH), and the Western Cornbelt Plains (WCBP). Some sampling sites were chosen from historical literature, this included sampling in regions without specific historical locality data. In areas with a high density of water bodies I choose sample sites systematically each day of sampling or from a map prior to visiting in the case of the Crescent Lake Wildlife Refuge (as part of the requirement to sample these federal lands). During sampling I used a weighted-effort approach, which entails searching using dip net, hand net, and by hand, and includes visual examination of shorelines, bottom substrate, vegetation, detritus, and shallow water structures. Searching continued until 30 minutes had elapsed since finding an additional species (species identity based on gross morphological characteristics).

Water body type and hydrologic condition was obtained from the U.S. Fish and Wildlife Service Wetlands Mapper (FWS 2013) for each water body.

Analysis of species incidence data via the quartile method, suggested by Gaston (1994), as modified by the FWGNA project (Dillon 2012) allowed division of species into regional conservation ranks as developed by the Nature Conservancy and NatureServe (Master *et al*. 2009): Following this, the 5% of species with the lowest incidence are designated S1, critically imperiled regionally. The 20% left in the first quartile are S2, imperiled regionally. The second quartile are S3, uncommon in region, the third S4, apparently secure, and the fourth quartile are S5, demonstrably secure. Some adjusting of species quartiles was done to keep species with the same incidence value within the same conservation status. This resulted in different number of species in each quartile.

Species identification proceeded first by separating snails by gross morphological characteristics. I examined at least three specimens, when available, from each morphologic type using a hand lens or microscope to determine species via fine morphological characters. Unless a distinct morphological difference was apparent I assumed all specimens from a gross morphologic group were the same species. Species identification is challenging for some freshwater snails, contrasting characteristics and a glut of taxonomic names are used (Burch 1989). I use the taxonomy advocated by Johnson *et al*. (2013): Appendix A includes my assessment of generic and specific synonyms. Species of Physidae, in particular, are problematic to identify (Wu 2004-2005, Dillon *et al*. 2013). I identified Physidae species as *Physa acuta* when a distinct shoulder was present and as *Physa gyrina* when whorls partially overlapped. Externally *Physa acuta* and *Physa pomilia* are morphologically similar and I did not determine any distinct difference that enabled me to identify any snail as *Physa pomilia*. A few specimens were sub-fossils or were very small making identification even more difficult. If I lacked confidence in identification to the species level, I recorded only the genus. Specimens categorized in this way were not used in any analysis.

Results

Across Nebraska samples collected from 159 water bodies yielded 333 records of freshwater snails. No snails were detected at five sample sites. Approximate locations of each sample site within the State are shown in Figure 1. The greatest number of sample sites, 54, was within the Western Cornbelt Plains (WCBP) with the fewest, 20, in the Western High Plains (WHP). Among water body types 90 were palustrine, 40 riverine, 6 lacustrine, and 23 were reservoirs. The majority of sites, 50, were permanent, with 68 semi-permanent, and 41 temporary water bodies. All five sites where no snails were observed were permanent water bodies; one reservoir (Sutherland

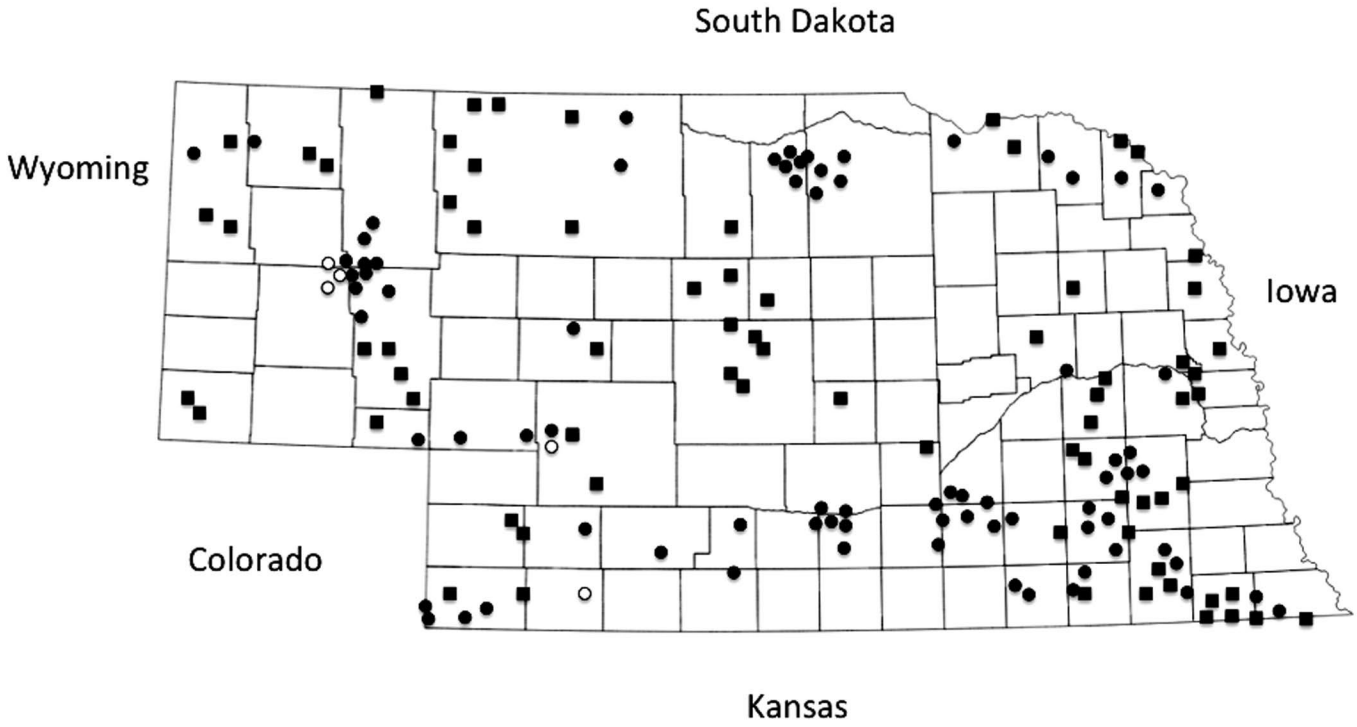

Figure 1. Approximate locations of sample sites in Nebraska. Closed circles are my sample sites. Closed squares are sample sites from the Nebraska Game and Parks Commission. Open circles are sample sites where no snails were observed.

Reservoir) and one riverine site (Medicine Creek) within the Central Great Plains, and three palustrine sites within the Nebraska Sand Hills ecoregion. I identified sixteen freshwater snail species in five families. The species collected, ranked by incidence, are shown in Table 1. Appendix A lists systematics, taxonomy (including possible synonyms), and a brief description of each species collected.

The seven most common species, *Physa gyrina*, *Planorbella trivolvis*, *Stagnicola elodes, Physa acuta*, *Gyraulus parvus, Stagnicola caperata*, and *Galba humilis* are widespread and with two exceptions (*Physa acuta* and *Galba humilis*) were collected in each ecoregion, high water body density area, water body type, and hydrologic condition sampled (Tables 2 and 3). Eight species were found at five or fewer sites; these were, *Valvata tricarinata*, *Helisoma anceps*, *Campeloma decisum*, *Galba bulimoides, Physa jennessi, Ferrissia rivularis*, *Planorbula armigera,* and the non-indigenous species *Bellamya chinensis*.

Bellamya chinensis, the Chinese mystery snail, was collected only in southeast Nebraska from Hedgefield Reservoir, Wild Plum Reservoir, (both in Lancaster county), a pond on Rose Creek State Wildlife Management Area, the pond in Hooper Memorial Park, and the Wildwood golf course (in Jefferson, Dodge, and Otoe counties respectively).

Based on incidence, the conservation status of two species, *Ferrisia rivularis,* and *Planorbula armigera*, are S1, critically imperiled. A single species, *Physa jennessi* earns a S2 status, with all other indigenous species collected from five or fewer sites falling within S3. In addition to incidence rarity several species have limited geographic or habitat distribution. *Galba bulimoides* was observed at three sites and all were semi-permanent or temporary palustrine wetlands within the Rainwater Basin Plain (a level IV ecoregion). *Physa jennessi* was observed at just two palustrine sites within the Lakes Region of the Nebraska Sand Hills. *Ferrissia rivularis* and *Planorbula armigera* were each found at just a single site (within a river of the WHP and a reservoir of the SHP respectively).

Discussion

This survey of the freshwater snails of Nebraska provides current distribution records of the freshwater snails of the region. Sixteen species of freshwater gastropods were collected including one non-indigenous species. Not surprisingly, species with the highest incidence are also the most widespread. The seven indigenous species collected at five or fewer sites suggest a high level of rarity among Nebraska's freshwater gastropod fauna. The most species rich areas appear to be the permanent and

Table 1. Incidence, tentative conservation status, range and habitat limitations of sixteen freshwater gastropod species within Nebraska based on 159 recently sampled sites.

Species	Site Incidence	Conservation Status	Limited Habitat (Single type)	Limited Distribution (Single level IV ecoregion)
Physa gyrina	91	S5	No	No
Planorbella trivolvis	68	S5	No	No
Stagnicola elodes	39	S5	No	No
Physa acuta	28	S5	No	No
Gyraulus parvus	28	S5	No	No
Stagnicola caperata	23	S4	No	No
Galba humilis	15	S4	No	No
Aplexa elongata	13	S4	No	No
Valvata tricarinata	5	S3	No	No
Bellamya chinensis	5	NA	Yes	No
Helisoma anceps	5	S3	No	No
Campeloma decisum	3	S3	No	No
Galba bulimoides	3	S3	Yes	Yes
Physa jennessi	2	S2	Yes	Yes
Ferrissia rivularis	1	S1	Yes	Yes
Planorbula armigera	1	S1	Yes	Yes

semi-permanent water bodies and the Nebraska Sand Hills (Table 2 and 3). However, richness values do not differ dramatically among geographic covariates. The data presented here provide a good benchmark of the geographic distribution of aquatic snail species of Nebraska, however a direct comparison of species richness among geographic covariates is problematic as it likely correlates to sampling effort.

The reason for the complete absence of snails is apparent for several sites where snails were not detected. In the Sutherland Reservoir, water levels change frequency and little or no shoreline vegetation is present. It is still likely that snails are present within the reservoir but longer and more in-depth sampling would be required to collect them. Three-palustrine sites within the Nebraska Sand Hill Plain that housed no snails were alkaline water

Table 2. Distribution of freshwater gastropod species among Nebraska's Level III ecoregions (left four columns). Ecoregions are the Western High Plains (WHP), Central Great Plains (CGP), Nebraska Sand Hills (NSH), and Western Cornbelt Plains (WCBP). Right columns are areas of high water body density (Rainwater Basin (RWB), western Nebraska Sand Hills (Lakes Region), and the Wet Meadow and Marsh Plain (WMMP) of the eastern Nebraska Sand Hills). Species are listed in order of high to low site incidence based on 159 recently sampled sites within Nebraska.

Species	WHP	CGP	NSH	WCBP	RWB	Lakes Region	WMMP
Physa gyrina	X	X	X	X	X	X	X
Planorbella trivolvis	X	X	X	X	X	X	X
Stagnicola elodes	X	X	X	X	X	X	X
Physa acuta		X	X	X			
Gyraulus parvus	X	X	X	X	X	X	X
Stagnicola caperata	X	X	X	X	X	X	X
Galba humilis	X	X	X	X			
Aplexa elongata		X	X			X	X
Valvata tricarinata	X	X	X				X
Bellamya chinensis		X		X			
Helisoma anceps	X		X	X			
Campeloma decisum				X			
Galba bulimoides		X			X		
Physa jennessi			X			X	
Ferrissia rivularis	X						
Planorbula armigera			X			X	
Species Richness	9	11	12	10	6	8	7

Table 3. Distribution of freshwater gastropod species among water body types; Pal (palustrine), Lac (lacustrine), Res (reservoir). Riv (riverine), and wetland hydrology; Perm (permanent), Semi-perm (semi-permanent), Temp (temporary) in Nebraska based on 159 recently sampled sites. Species are listed in order of high to low species incidence.

Species	Pal	Lac	Res	Riv	Perm	Semi-perm	Temp
Physa gyrina	X	X	X	X	X	X	X
Planorbella trivolvis	X	X	X	X	X	X	X
Stagnicola elodes	X	X	X	X	X	X	X
Physa acuta	X	X	X	X	X	X	X
Gyraulus parvus	X	X	X	X	X	X	X
Stagnicola caperata	X	X	X	X	X	X	X
Galba humilis	X		X	X	X	X	X
Aplexa elongata	X		X		X	X	X
Valvata tricarinata	X	X	X		X	X	X
Bellamya chinensis	X		X		X	X	
Helisoma anceps			X	X	X	X	X
Campeloma decisum			X	X	X	X	
Galba bulimoides	X					X	X
Physa jennessi	X					X	
Ferrissia rivularis				X	X		
Planorbula armigera			X		X		
Species Richness	12	7	13	10	14	14	11

bodies with pH values above 10. I could not establish an obvious reason for the absence of snails in the one riverine site, Medicine Creek, in the CGP in southwestern Nebraska.

I separate species into conservation status categories based on a modified quartile ranking of incidence data (Table 1). Based on this ranking several species are at risk of extinction. Two species, *Ferrissia rivularis* and *Planorbula armigera*, fall into the critically imperiled category S1 and one species, *Physa jennessi* falls under S2, imperiled. *Galba bulimoides*, though falling under S3 status, may warrant adjustment into S2 or S1 because of its limited habitat and geographic distribution, though this may be a false distinction that appears simply due to incidence rarity.

Species at or near the edge of their range will appear more imperiled locally than throughout the broader region (Gaston 1994). I expect this is the case for many species listed here. For example, *Campeloma decisum,* ranked S3, appears very abundant in the northeastern US (Burch 1989, Dillon *et al*. 2013). *Ferrissia rivularis* is also more common to the north and east of Nebraska and *P. armigera* is widespread across much of North America (Burch 1989). However, the conservation status of most species of freshwater snail is not known due to the absence of current survey work (Brown *et al*. 2008, Lysne *et al*. 2008).

There are 16 species of freshwater snail not observed recently but with historic records in Nebraska (Stephen 2015). Evaluating the conservation status of these species is difficult. Simply listing as rare, possibly extirpated, those species not observed in recent surveys is confounded by (1) the lack of breadth of current survey work, (2) historical taxonomic confusion, and (3) phenotypic plasticity of species causing one species to be listed under two or more names. The first issue can be alleviated by more survey data but the last two place doubt on the validity of historic records and are difficult or impossible to verify. I suspect several errors in species listings from the work of Samuel Aughey (Aughey 1877). The accuracy of Samuel Aughey's work in other fields has faced criticisms (Bolick 1993, Hoke 2000). Aughey's work on freshwater snails has more species listed than any other Nebraska resource and is the sole source for several species (Stephen 2015). I believe it extremely unlikely that all 16 species not observed recently are true Nebraska residents, but some are expected to be present based on regional literature of adjacent states, these include *Amnicola limosus*, *Lymnaea stagnalis*, *Promenetus exacuous* and *Pleurocera canaliculata*. (Stewart 2006, Stephen 2015).

The greatest threat to freshwater snails of the region is loss of aquatic habitat and degradation from agriculture. Some species, such as *Valvata sincera* and *Cincinnatia integra,* are known to need waters with high oxygen content (Jokinen 1992) and oxygen levels tend to be depleted by adjacent agriculture (EPA 2002). Another threat to local snails is species invasions. I collected the non-indigenous Chinese mystery snail, *Bellamya chinensis*, from five sites in the southeastern part of the State, previous work has noted their presence in this part of Nebraska (Chaine *et al*. 2012). The impacts of this species on local snails and ecosystems is unknown. Other potential freshwater snail invaders, not

yet found in Nebraska, include the New Zealand mudsnail, *Potamopyrgus antipodarum*, observed in Colorado (McKenzie *et al*. 2012) and the faucet snail, *Bithynia tentaculata*, observed in Wisconsin (Sauer *et al*. 2007).

The large number of rare species (incidence of five or fewer sample sites) and the large number of species not observed recently underscores the need to collect more survey data. This will allow clarification and refinement of the conservation status of freshwater snails in the region. Surveys should include expansion of the current work presented here as well as targeted searches for rare and historically listed species.

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Literature cited

Allan DJ and MM Castillo. (2007) *Stream Ecology: Structure and function of running water* 2nd edition. (The Netherlands: Springer).

Aughey S. (1877) Catalogue of the land and fresh-water shells of Nebraska. *Bulletin of the U.S. Geological and Geographical Survey of the Territories.* (Hayden Survey) 3: 697–704.

Bolick MR. (1993) Samuel Aughey, Jr.: The controversial first director of the University of Nebraska State Museum. Museum Notes (University of Nebraska State Museum) No. 84: 1-4.

Brown KM, B Lang, and KE Perez. (2008) The conservation ecology of North American pleurocerid and hydrobiid gastropods. *Journal of the North American Benthological Society* 27: 484-495.

Burch JB. (1989) *North American freshwater snails*. (Hamburg, Michigan: Malacological Publications).

Chaine NM, CR Allen, KA Fricke, DM Haak, ML Hellman, RA Kill, KT Nemec, KL Pope, NA Smeenk, BJ Stephen, DR Uden, KM Unstad, AE VanderHam. (2012) Population estimate of Chinese mystery snail (Bellamya chinensis) in a Nebraska reservoir. *Bioinvasion Records* 1(4): 283-287.

Contanza R, R d'Arge, R de Groot, S Farber, M Grasso, B Hannon, K Limburg, S Naeem, RV O'Neill, and J Paruelo. (1997) The value of the world's ecosystem services and natural capitals. *Nature* 387: 253-260.

Dillon RT, M Ashton, M Kohl, W Reeves, T Smith, TW Stewart, and B

Watson. (2013) The freshwater gastropods of North America. Retrieved from the internet Nov 2016: http://www.fwgna.org.

Dillon RT. (2012) Toward the scientific ranking of conservation status. http://www.fwgna.org/downloads/Conservation-status-separate-vMar12.pdf

Dillon RT. (2000) *The ecology of freshwater molluscs.* Cambridge: Cambridge University Press.

EPA. (2002) US Environmental Protection Agency. National Water Quality Inventory: 2000 Report. EPA-841-R-02-001. http://www.epa.gov/305b.

Freeman P.W. and Perkins, K. 1992. Survey of Mollusks of the Platte River: Final Report. U.S. Fish and Wildlife Service. Grand Island, Nebraska. 37 pp.

Freeman P. W., and Perkins, K. 1997. Survey of mollusks of the Niobrara river: Final Report. U.S. Fish and Wildlife Service. Grand Island, Nebraska. 22 pp.

FWS. (2013). U.S. Fisheries and Wildlife Service Wetlands Mapper. Retrieved from the internet July 2013: https://www.fws.gov/wetlands/data/mapper.html

Gaston KJ. (1994) *Rarity*. Population and Community Biology Series 13. (London: Chapman and Hall).

Hoke E. (2000) A critical review of the unionid mollusks reported for Nebraska by Samuel Aughey (1877). *Central Plains Archeology* 8(1): 35-47.

Hoke E. (2011) The freshwater mussels (mollusca: bivalvia: unionoida) of Nebraska. Transactions of the Nebraska Academy of Sciences 32: 1–46.

Jokinen EH. (1992) The Freshwater Snails (Mollusca: Gastropoda) of New York State. New York State Museum bulletin (USA).

Johnson PD, AE Bogan, KM Brown, NM Burkhead, JR Cordeiro, JT Garner, PD Hartfield, DAW Lepitzki, GL Mackie, E Pip, TA Tarpley, JS Tiemann, NV Whelan, and EE Strong. (2013). Conservation status of freshwater grastopods of Canada and the United States. *Fisheries* 38(6): 247-282.

Lydeard C, RH Cowie, WF Ponder, AE Bogan, P Bouchet, SA Clark, KS Cummings, TJ Frest, O Gargominy, and DG Herbert. (2004). The global decline of nonmarine mollusks. *BioScience* 54(4): 321-330.

Lysne SJ, KE Pereze, KM Brown, RL Minton, and JD Sides. (2008). A Review of Freshwater Gastropod Conservation: Challenges and Opportunities. *Journal of the North American Benthological Society* 27(2): 463-470.

Master LL, D Faber-Langendoen, R Bittman, GA Hammerson, B Heidel, J Nichols, L Ramsay, and A Tomaino. (2009) NatureServe conservation status assessments: factors for assessing extinction risk. NatureServe, Arlington, Virginia.

Master LL, BA Stein, LS Kutner, and GA Hammerson. (2000) Vanishing assets: conservation status of U.S. species. In BA. Stein, LS. Kotner, and JS. Adams (Editors). Precious heritage, the status of biodiversity in the United States, pp. 93-115. (New York: Oxford University Press).

MacArthur RH. (1957) On the relative abundance of bird species. *Proceedings of the National Academy of Sciences of the United States of America* 43(3): 293-295.

Mckenzie VJ, WE Hall, and RP Guralnick. (2012) New Zealand Mudsnails (*Potamopyrgus Antipodarum*) in Boulder Creek, Colorado: Environmental Factors Associated with Fecundity of a Parthenogenic Invader. *Canadian Journal of Zoology* 91(1): 30-36.

Rabinowitz D. (1981) Seven forms of rarity. In H. Synge (Editor), *The biological aspects of rare plant conservation*, pp. 205-217. (New York: Wiley).

Regnier C, B Fontaine B, and P Bouchet. (2009). Not knowing, not recording, not listing: numerous unnoticed mollusk extinctions. *Conservation Biology 23*: 1214-1221.

Ricciardi A and JB Rasmussen. (1999). Extinction rate of North American freshwater fauna. Conservation Biology 13(5): 1220-1222.

Richter B. D Braun, M Mendelson, and L Master. (1997) Threats to imperiled freshwater fauna. *Conservation Biology* 11(5): 1081-1093.

Sauer JS, RA Cole, and JM Nissen. (2007) Finding the Exotic Faucet Snail. *(Bithynia tentaculata*): Investigation of waterbird die-offs on the Upper Mississippi River National Wildlife and Fish Refuge. *U.S. Geological Survey Open-file Report* 2007-1065: 1-3.

Schneider R, K Stoner, G Steinauer, M Panella, and M Humpert (Editors). (2011) The Nebraska Natural Legacy Project: State Wildlife Action Plan. 2nd ed. The Nebraska Game and Parks Commission, Lincoln, NE. 344 pp.

Stephen BJ. (2015) Species composition of Nebraska's freshwater gastropod fauna: A review of historical records. *American Malacological Bulletin* 33(1): 1-11.

Stewart TW. (2006) The freshwater gastropods of Iowa (1821-1998): Species composition, geographic distributions, and conservation concerns. *American Malacological Bulletin* 21(1/2): 59-75.

Tokeshi M. (1990) Niche apportionment or random assortment: species abundance patterns revisited. *The Journal of animal ecology* 59(3): 1129-1146.

Tokeshi M. (1992) Dynamics of distribution in animal communities: theory and analysis. *Researches on Population Ecology* 34(2): 249-273.

USGS. (1996) United States Geological Survey. National water summary on wetland resources. Compiled by Fretwell JD, JS Williams, and PJ Redman. USGS Water Supply Paper: 2425. 431 pp.

Wu S-K. (2004-2005) Nebraska Physidae (Gastropoda: Pulmonata: Hygrophila). *Malacological Review* 37/38: 185-196.

Appendix A. Taxonomy, synonyms, and a brief description of freshwater snails collected during recent surveys in Nebraska. Sizes listed here: Micro is less than 5 mm, small is 5-10 mm, medium is 10-20, large is any snail over 20 mm. Unless otherwise noted, snails are hermaphroditic and do not have an operculum.

Family	Name Herein (common name)	Synonyms	Brief Description
Lymnaeidae	*Galba bulimoides* (Prairie lymnaenid)	*Lymnaea bulimoides, Lymnaea cockerelli, Stagnicola bulimoides techella, Stagnicola cokerelli, Galba techella, Galba cockerelli, Fossaria techella*	Micro to small dextral snail; short spired; nearly globose; whorls 5 to 6.
	Stagnicola caperata (Wrinkled marshsnail)	*Lymnaea caperata*	Medium sized dextral snail; elongate; whorls 5 to 6; tiny striae along whorls.
	Galba humilis (Golden pondsnail)	*Fossaria obrussa, Fossaria dalli, Lymnaea desidiosa, Lymnaea humilis*	Small dextral snail; elongate; whorls 5, oval aperture.
	Stagnicola elodes (Marsh pondsnail)	*Lymnaea elodes, Lymnaea palustris, Lymnaea reflexa, Limnaea haydeni*	Large dextral snail; elongate; shell often hammered (malleated) in appearance; whorls 6.
Physidae	*Aplexa elongata* (Lance aplexa)	*Aplexa hypnorum*	Large sinistral snail; elongate; shell of live specimens has oily appearance; whorls 6.
	Physa acuta (Bladder snail)	*Physa anatine, Physa heterostropha, Physa halei, Physa virgata, Physa whitei*	Medium sinistral snail; spire moderate, acute, pointed; whorls 5 to 6; large body whorl.
	Physa gyrina (Tadpole physa)	*Physa lordi, Phya gouldi, Physa saffordi, Physa sayi, Physa virginea, Physa warreniana, Physella gyrina*	Medium to large sinistral snail; spire short to long; whorls 5 to 6, rounded, each partially overlap preceding whorl.
	Physa jennessi (Blunt-nose Physa)	*Physa skinneri*	Sinistral microsnail; shell apex appears cut off (blunted).
Planorbidae	*Ferrissia rivularis* (Creeping ancylid)	*Ancylus rivularis, Ancylus caurinus*	Micro to small limpet; apex on midline.
	Gyraulus parvus (Ash gyro)	*Planorbis parvus*	Planispiral micro snail; umbilical (under) side concave; whorls increase rapidly in size.
	Helisoma anceps (Two-ridged ramshorn)	*Planorbis anceps, Planorbis bicarinatus*	Large planispiral snail; carinate (ridges) on top and bottom of whorl; whorls 3.5.
	Planorbella trivolvis (Rough ramshorn)	*Planorbis trivolvis, Planorbella trivolvis*	Large planispiral snail; shell often carinate on upper side; whorls 4.
	Planorbula armigera (Thicklip ramshorn)	*Segmentina armigera*	Micro to small planispiral snail; internal lamellae ¼ whorl back from aperture.
Valvatidae	*Valvata tricarinata* (Threeridge valvata)	Taxonomy appears stable	Micro to small dextral snail; globose; three distinct carina (ridges) follow whorls; round multispiral operculum; feathery external gill.
Viviparidae	*Bellamya chinensis* (Chinese mystery snail)	*Cipangopaludina chinensis, Viviparus malleatus*	Largest freshwater snail in region; dextral snail; thick globose to elongate shell; concentric operculum; sexes separate.
	Campeloma decisum (Pointed campeloma)	*Melantho decisa, Melantho ponderosa, Vivipara contectoides, Vivipara integra, Vivipara intertexta, Vivipara subpurpurea*	Large dextral snail; thick globose shell; concentric operculum; sexes separate.