THE FRESHWATER GASTROPODS OF NEBRASKA AND SOUTH DAKOTA: A REVIEW OF HISTORICAL RECORDS, CURRENT GEOGRAPHICAL DISTRIBUTION AND CONSERVATION STATUS

By

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I explore the historical and current distribution of freshwater snails in Nebraska and South Dakota. Current knowledge of the distribution of species of freshwater gastropods in the prairie states of South Dakota and Nebraska is sparse with no recent comprehensive studies. Historical surveys of gastropods in this region were conducted in the late 1800's to the early 1900's, and most current studies that include gastropods do not identify individuals to species. I summarize historical data from both states and provide recent survey results for this prairie region. Historical records suggest 31 species reside in Nebraska and 25 species reside in South Dakota. My survey includes 262 sites within eight EPA level III ecoregions and includes palustrine, riverine, reservoir, and lacustrine water bodies under a variety of hydrologic conditions. These recently sampled sites that contained snails had 1 to 6 species, with an average of 2.4 species per site, a total of 638 species records. I observed no snails at eight sample sites. I identified twenty total species in seven families within the two–state region. The five most abundant species were *Physa gyrina*, *Helisoma trivolvis*, *Lymnaea elodes*, *Lymnaea caperata*, and *Gyraulus parvus* were observed in all eight of the ecoregions sampled. Seven species were observed at five or fewer sites including two non–indigenous species, *Bellamya chinensis* and *Melanoides tuberculata*. Species similarity metrics demonstrate that many of the sampled ecoregions have similar species composition. Estimates from rarefaction analysis allow comparison of species richness among geographic covariates. The Prairie Coteau and the Middle Rockies regions of South Dakota are the most species rich areas within the region. Checkerboard analyses suggest that competition is responsible for species absences at some sample sites. Evaluation of the quartile incidence of species and comparison to historical data suggests three species are imperiled, one species is critically imperiled, and at least seven species, observed only in historic studies, may also be critically imperiled or extirpated. A strategy is needed to more fully explore and conserve freshwater gastropods in the region.

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CHAPTER ONE: INTRODUCTION

This is a survey of the freshwater snails of Nebraska and South Dakota. Freshwater snails play a key role in the ecology of aquatic systems by occupying a central part of the ecological food web. They feed on periphyton and in turn are eaten by a number of invertebrate and vertebrate species including turtles (Folkerts, 1968), waterfowl (Swanson and Duebbert, 1989; Tietje and Teer, 1996; Dillon, 2000) and a diverse group of fishes including sunfish, darters and catfish (Lauder 1983, Haag and Warren 2006, Tieman *et al*. 2011). Freshwater snails even make up a small portion of the winter diet of whooping cranes (Hunt and Slack, 1989). Competitive and more complex interactions are observed between freshwater snails and tadpoles (Brönmark, *et al* 1991; Smith *et al* 2012). A complex interaction also exists among snails, fish and epiphyton (Brönmark and Vermaat, 1998). A large amount of the energy passing through aquatic systems involves snails (Newbold *et al*. 1983; Richardson *et al*. 1988, Brown, 2001). A trophic cascade involving predators of marine snails shows the dramatic effects on primary production and the health of coastal marshes, dictated by snails (Silliman and Bertness 2002, Silliman *et al*. 2005). Snails are also intermediate hosts for parasites including including Schistomiasis and liver flukes (Dillon 2000). The parasite load in snails has been implicated in mass die–offs of waterfowl (Wilkins and Otto 2006)

Most common freshwater gastropods are eurytrophic, some exceptions are *Valvata sincera,* which appears to favor oligotrophic waters, while *Amnicola limosus*, *Lymnaea stagnalis*, and *Planorbula armigera* tend to be present under mesotrophic conditions (Clarke 1979). Many freshwater snails have a broad tolerance for environmental perturbation and common species are observed in environments altered by pollutants (Harman 1974). Exceptions to the broad tolerance of most freshwater snails allow the presence or absence of specific species to be used as water quality indicators (Harman 1974, Clarke 1979, Johnson 2009).

Available calcium, and related variables such as pH and alkalinity, is the major limiting factor to freshwater snail presence (Dillon, 2000). Other chemical variables appear to limit species presence as well; for example, in a Central Canada study *Lymnaea caperata* was never observed in waters without sulphate, and *Lymnaea megasoma* favored low phosphorus levels (Pip 1986). There appears to be some differentiation between presence/absence of species within the genus *Helisoma* when sulphate and dissolved organic matter are combined (Pip 1987), although this difference may be attributable to broader habitat differences such as water body type. Most species are present throughout a wide range of chemical composition and very little connection to natural levels of these substances has been observed (Pip 1986). Analyses of snail distribution based on chemical features have been done in a small number of areas such as central Canada (Pip 1987). Besides calcium and related variables, the distribution of freshwater snails may be influenced more by geographic features than chemical attributes. Freshwater mollusk populations in general have a high level of ecological overlap (Brown 1982, Dillon 2000).

Large–scale geographic factors are often used to describe species distributions. For example, species ranges are temperature related, with northern or southern limits (Burch 1989). Smaller scale features such as the type of water body also play a role. *Ferrissia rivularis* and species within the family Pleuroceridae tend to be present in rivers where flowing water is required for survival because of their need for high oxygen levels

(Jokinen 1992). Species are also listed with apparent habitat restrictions, or at least habitat preferences as a general rule; for example, *Lymnaea elodes* is known as a 'marsh' snail: however, it is present in other water body types as well (Burch 1989). Species diversity, rather than presence of a particular species, is influenced by pond area (Brönmark 1985, Jokinen 1987). Hydrologic conditions also play a role in species distribution with several species known to aestivate while other species cannot tolerate ephemeral conditions (Jokinen 1992, Dillon 2000).

Freshwater snails are important, but current knowledge of their geographic distribution and conservation status is desperately lacking for most of North America. Much of the information we have about freshwater snail distribution in North America comes from a series of guides (Burch and Tottenham 1980, Burch 1982, Burch 1988), later compiled into a book (Burch 1989). Valid up–to–date information for most States does not exist (Stewart and Dillon 2004, Stewart 2006) but inventories have been completed in New York, Connecticut, and Indiana (Jokinen 1992, Jokinen 1983, Pyron *et al*. 2009) and several southeastern states (Dillon *et al*. 2006).

The current state of knowledge regarding the distribution of freshwater gastropods in Nebraska and South Dakota comes primarily from just six historical studies (Tryon 1868, Aughey 1877, Walker 1906, Over, 1915, 1928, Henderson 1927). More recent studies specifically targeting snails are rare but include meeting abstracts (Gugler 1969), reports to Federal agencies (Freeman and Perkins 1992, Freeman and Perkins 1997), studies targeting specific families (Hershler 1996), and lists of recent snails included within studies on fossils (Taylor 1954, Hibbard and Taylor 1960, Jass *et al*. 2002). Samuel Aughey, who lists the largest number of species from Nebraska (Aughey 1877), was the first "keeper of the cabinet" in what would become the University of Nebraska State Museum. A complication of this Aughey's work is that his record keeping has been labeled as not precise (Bolick 1993).

Taxonomic issues

An invaluable resource regarding freshwater snails in North America is *the North America Freshwater Snails* (Burch 1989), which lists over 500 species of freshwater snail in North America. The Freshwater Snails of North America was first produced as an EPA report (Burch, 1980) then as a series (Burch and Tottenham 1980, Burch 1982, Burch 1988) and then as a book (Burch 1989). Due to the redundancy of the information I will use the last compact citation (Burch 1989) hereafter. Areas of taxonomic confusion and uncertainty exist in this guide, particularly in the snail families, Ancylidae, Lymnaiedae, and Physidae (Burch 1989). The Ancylids are historically plagued with inadequate generic and species level descriptions (Basch 1963) and these freshwater limpets are now placed within the family planorbidae (Bouchet and Rocroi 2005). Confusion among species in the families Amnicolidae, Hydrobiidae, and Pomatiopsidae, all of which contain tiny to small conical snails, is also common (Burch 1989). The family Amnicolidae was often placed as a subfamily of Hydrobiidae, however, recent molecular work separates the families into separate clades (Wilke *et al*. 2001). Among freshwater gastropods phenotypic plasticity is pronounced; the Lymnaeidae in particular have been studied in this regard (Arthor, 1982, Brown 1985, Lam and Cowel 1988, Brönmark *et al*. 2011). This phenotypic plasticity has led to a large number of synonymies within families.

The pulmonates in particular have been the focus of large amount of recent systematic studies. Systematic treatments of the families Ancylidae and Physidae, underscore that the huge array of species listed as being present in North America has been overstated (Hubendick 1951, Wethington and Dillon 1993, Dillon *et al*. 2002, Dillon and Wethington 2004, Dillon *et al*. 2005, Walther *et al*. 2006, Wethington and Lydeard 2007, Walther *et al*. 2010). Using the Physidae as an example, it was once thought there were over forty species within North America. However, research studies from traditional mating experiments (Dillon *et al*. 2002) to molecular phylogenetics (Wethington and Lydeard, 2007) have now shown only about ten species of Physidae occur in North America. The Lymnaeidae have also received some in–depth treatment (Hubendick 1951) including some molecular studies: however, these recent molecular studies are not specifically focused on snail systematics but on the snails as hosts of parasites (Remigio, 2002, Correa *et al*. 2010). The most recent treatment of the Planorbidae is Hubendick and Rees (1955) and does not include molecular data.

Although Burch, (1989) provides a valuable resource for freshwater snails in North America, clarification and updating, particularly when considering species within a region, is needed. Recent systematic studies will help clarify the species of Nebraska and South Dakota, but no recent comprehensive freshwater snail phylogeny exists for North America (Dillon 2000).

Recent hypotheses of gastropod systematics have left the relationships of several groupings still unresolved, and thus becoming informal, with several groupings being placed in unranked clades (Bouchet and Rocroi 2005). I separate the families into the higher but still unranked clades, Heterobranchia and Caenogastropoda. The Heterobranchia include the now informal group Pulmonata, represented here by the families Lymnaiedae, Physidae, and Planorbidae. The Valvatidae, non–pulmonates, are now placed in the informal Lower Heterobranchia. The Caenogastropoda are a monophyletic group formed from the Prosobranchia, a group now known to be polyphyletic. The Caenogastropda families here are Amnicolidae, Hydrobiidae, Pleuroceridae, Pomatiopsidae, and the Viviparidae. Generic and species epithets are also in a state of flux and unless otherwise noted I follow the recommendations of the Freshwater gastropods of North America project (Dillon *et al*. 2006). Table 1.1 lists the taxonomic position of species detailed here.

The non–marine mollusks collectively are one of the most threatened groups of organisms (Lydeard *et al*. 2004) and freshwater snails, specifically, head the list of endangered groups (Lysne *et al*. 2008). Threats to gastropod fauna including loss of habitat, competition by invasive species, such as the New Zealand mudsnail and Chinese mystery snail, and climate change. Non–marine mollusks collectively are thought to be one of the most threatened groups of organisms (Lydeard *et al*. 2004). Freshwater snails, specifically, head the list of endangered groups in some analyses (Allan and Castillo 2007, Lysne 2008). Some freshwater snail species appear to be extirpated in North America (Bogan 2000) or from specific States (Smith 1984; Oliver and Bosworth 1999). An assessment of conservation status of all North American freshwater snails has been attempted (Johnson *et al*. 2013) but the current status of most species is unknown. To more fully evaluate how many species are extinct or imperiled cannot be done without current survey data and a fuller understanding of the distribution and habitat requirements of freshwater gastropods.

This dissertation has several related aims. The first goal is a review the fresh water snail species listed in historical literature and museum records from Nebraska (Chapter 2) and South Dakota (Chapter 3). Each species is re–evaluated in light of taxonomic revisions and treatments of snails in adjacent states including: Colorado (Harrold and Gurainick 2010); Iowa (Stewart 2006); Kansas (Leonard 1959); and North Dakota (Cvancara 1983). Next, using recent survey data, I identify and evaluate the current distribution of freshwater snails in Nebraska and South Dakota (Chapter 4). This includes assessment of the geographic distribution of each species based on geographic features of ecoregion, water body type, hydrologic conditions, and latitudinal and longitudinal coordinates. Areas of high snail biodiversity are indentified throughout the region along with any species assemblages that occur. Finally, I evaluate the conservation status of each species within the region by combining the historical and museum records with current surveys (Chapter 5). The end result is a list of the conservation ranking of freshwater snail species within Nebraska and South Dakota. I summarize this dissertation in chapter 6.

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Table 1.1 Systematic Position and Taxonomy of the Freshwater Gastropods listed herein.

Clade	Informal / Clade	Family	Species
	Pulmonata		
Heterobranchia	Basommatophora		
		Lymnaeidae	
			Lymnaea bulimoides
			Lymnaea caperata
			Lymnaea catascopium
			Lymnaea elodes
			Lymnaea humilis
			Lymnaea stagnalis
		Physidae	
			Aplexa elongata
			Physa acuta
			Physa jennessi
			Physa gyrina
			Physa pomilia
		Planorbidae	
			Ferrissia fragilis
			Ferrissia rivularis
			Gyraulus circumstriatus
			Gyraulus crista
			Gyraulus deflectus
			Gyraulus parvus
			Helisoma anceps
			Helisoma trivolvis
			Planorbula armigera
			Promenetus exacuous
			Promenetus umbilicatellus
	Lower Heterobranchia		
		Valvatidae	
			Valvata sincera
			Valvata tricarinata
Caenogastropoda			
	Architaenioglossa		
		Viviparidae	
			Bellamya chinensis
			Campeloma decisum
	Cerithioidae		
		Pleuroceridae	
			Pleurocera canaliculata

Hypsogastropoda		
	Amnicolidae	
		Amnicola Limosus
	Hydrobiidae	
		Cincinnatia integra
		Probythinella emarginata
Rissooidae		
	Pomatiopsidae	
		Pomatiopsis lapidaria
Sorbeoconcha	Thiaridae	
		Melanoides tuberculatus

CHAPTER TWO: SPECIES COMPOSITION OF NEBRASKA'S FRESHWATER GASTROPODS FAUNA: A REVIEW OF HISTORICAL RECORDS

Freshwater gastropods are central components of aquatic ecosystems. Most snails feed on periphyton and in turn are eaten by a number of invertebrate and vertebrate species, particularly waterfowl (Swanson and Duebbert 1989, Dillon 2000) and a diverse group of fishes from sunfishes to catfishes (Lauder 1983, Tiemann *et al.* 2011). A large amount of the energy throughput in aquatic systems involves snails (Newbold *et al.* 1983, Richardson *et al.* 1988, Brown 2001). These important ecosystem components are in a conservation crisis. The non–marine mollusks collectively are thought be one of the most threatened groups of organisms (Lydeard *et al.* 2004). Freshwater snails specifically head the list of endangered groups in some analyses with > 70% of the species imperiled or extinct (Lysne *et al.* 2008, Johnson *et al.* 2013). Yet current knowledge of their distribution and incidence in North America is lacking.

In Nebraska the most comprehensive list of freshwater gastropods, which contained 49 species, was recorded more than 100 years ago (Aughey 1877). Since this report systematic studies have reduced the array of valid species, merging synonymous species names within North America (Hubendick 1951, Dillon *et al.* 2002, Walther *et al.* 2006, Wethington and Lydeard 2007, Walther *et al.* 2010). For example, in the Physidae, these studies show that what was once thought to be more than forty species in North America (Burch 1989) is actually only about ten (Wethington and Lydeard 2007). The need to provide regional reviews with updated taxonomy of freshwater gastropods species is clear.

I have created a list of Nebraska's freshwater gastropod species based on historical and recent literature as well as natural history collection holdings. Each species is evaluated in light of taxonomic revisions and regional literature. This is the first comprehensive review of Nebraska's freshwater gastropods and is the starting point for assessing the current status of freshwater snails in Nebraska, U.S.A.

METHODS

Study region

Nebraska has an area of approximately 200,000 km^2 extending from 40°N to 43°N latitude and 95° to 104°W longitude (USGS 2009). In July–August the average high temperature range is from 26 to 33 °C while in January the average low temperature range is –12 to –8 °C (PCG 2014). Annual precipitation ranges from above 80 cm in the eastern part of the state to below 50 cm in the west (PCG 2014). Nebraska contains six level III EPA ecoregions including the Western High Plains, Central Great Plains, Western Cornbelt Plains, and over 50,000 km^2 of Nebraska Sand Hill Plains (Chapman *et al.* 2001). Nebraska has fourteen EPA level 3 hydrologic units (6–digit code) with major rivers including the White, the North and South Platte rivers, the Niobrara, the Republican River, the Loup and Dismal rivers, the Elkhorn, the Nemaha, and the Big Blue River (EPA 2014). The Missouri River forms the northeast border with South Dakota and continues to form the eastern border with Iowa. Wetlands of the state, such as the basin of the Platte River and the Rainwater Basin, are valuable resources providing waterfowl habitat, including for migrating waterfowl across the Central Flyway, and ecosystem services (LaGrange 2005, Costanza *et al*. 1997).

Study design

I created a database of species presence records from published literature, the University of Nebraska State Museum collection (UNSM), and the online database of the Museum of Comparative Zoology at Harvard (MCZ). Other online databases were searched (the Florida Museum of Natural History, the Academy of Natural Sciences of Philadelphia, the North Carolina State Museum, the National Museum of Natural History (Smithsonian), the Yale Peabody Museum, the Illinois Natural History Survey (Mollusk Collection), and the University of Michigan Museum of Zoology) but none had records from Nebraska. The principal sources for species records were three historic studies (Tryon 1868, Aughey 1877, Walker 1906) and two reviews of regional fossils, which also include recent collections of live snails (Hibbard and Taylor 1960, Taylor 1960). More recent literature also provided records (Freeman and Perkins 1992, Freeman and Perkins 1997, Wu 2004–2005). The collections from the University of Nebraska State Museum (UNSM) are from a variety of collectors and are uncatalogued. Some historic and museum records contain a listing from a river or city without details. Each such listing was counted as a single record in my Nebraska snail database.

I follow the taxonomy given in Johnson *et al.* (2013) with a few revisions. I use the two–genus system proposed by Wethington and Lydeard (2007) for the Physidae. Lumping or taxonomic changes of species were based primarily on the following studies: Planorbidae (Hubendick and Rees 1955), Physidae (Dillon and Wethington 2004, Wethington and Lydeard 2007), Lymnaeidae (Baker 1911, Hubendick 1951), Ancylidae (Walther *et al.* 2006, Walther *et al.* 2010), and Pleuroceridae (Goodrich 1939). Once I condensed species based on synonyms, I evaluated listed records for the likelihood of presence in Nebraska based on Burch (1989) and regional literature from the surrounding states of Kansas (Leonard 1959), Wyoming (Beetle 1989), South Dakota (Stephen and Winkler 2007), Iowa (Stewart 2006), Missouri (Wu *et al.* 1997), and Colorado (Harrold and Guralnick 2010).

RESULTS

My literature and museum survey returned over 80 nominal species from 296 records of freshwater snails within Nebraska. The database created is appendix A. Analysis, primarily by lumping species names due to systematic revision, reduces that number to a more realistic 31 species, including one non–indigenous species (Table 1). Discussed below, but not included in the table are species I suspect of being misidentified and placed within Nebraska in error. For each species the synonyms used in Nebraska studies, locality and regional presence is provided. County distribution maps are provided for species when this information is known (Figs. 2–5). Records that had no specific county locality are not mapped. Species suspected of being misidentified are also not included on maps.

Amnicolidae – Confusion among species in this family, the Hydrobiidae, and the Pomatiopsidae, all of which contain tiny to small conical snails, is common (Burch 1989). The family Amnicolidae was often placed as a subfamily of Hydrobiidae, however, recent molecular work separates the families into separate clades (Wilke *et al.* 2001, Bouchet and Rocroi 2005) but historical works on these families may contain overlapping identifications.

Amnicola limosus (Say, 1817). Synonym: *Amnicola limosa* (Say, 1817). This snail was listed by two studies (Aughey 1877, Walker 1906) from the Bow, Elkhorn, Blue, and Nemaha rivers, and the city of Lincoln. This species appears widespread regionally being recorded from Wyoming, Missouri, Iowa, South Dakota, and Colorado (Beetle 1989, Wu *et al.* 1997, Stewart 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010). Kansas also has historic records, but recent surveys failed to locate this species prompting a tentative listing of it being extirpated (Angelo *et al.* 2002). A total of five records from two Nebraska counties are listed in the database.

Lyogyrus granum (Say, 1822). Synonym: *Amnicola granum* (Say, 1822). This tiny snail was recorded only from the Nemaha River (Aughey 1877). It has not been reported from other states in this region (Leonard 1959, Wu *et al.* 1997, Stewart 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010). Burch (1989) does not consider its range extending into this region and I suspect this species of being a misidentified in the historic literature. The database contains a single record of this species.

Hydrobiidae – As stated above, confusion among species in this family, the Amnicolidae, and the Pomatiopsidae is common (Burch 1989). Recent molecular work separates the families (Wilke *et al.* 2001, Bouchet and Rocroi 2005). Historical works on species within these families are likely to contain misidentifications.

Cincinnatia integra (Say, 1821). Synonym: *Amnicola cincinnatiensis* (Anthony 1865). This tiny snail is recorded as being present in Omaha (Tryon 1868). Observed regionally in Kansas and Iowa (Leonard 1959, Stewart 2006). This species is widespread in eastern and northern North America (Burch 1989). The Nebraska snail database contains a single record of this species.

Probythinella emarginata (Küster, 1842). Synonym: *Probythinella lacustris* (Baker 1928). A single study lists this species from Salt Creek in Lincoln (Hibbard and Taylor 1960). Regionally they are present to the east in Missouri and Iowa (Wu *et al.* 1997, Stewart 2006). The database contains a single record of this species.

Lymnaeidae – Historic studies list twenty species of right–handed pond snail within Nebraska. I reduce the number of species expected to be present in Nebraska to eight by lumping synonyms primarily following Baker (1911) and Hubendick (1951). I suspect two species listed herein as being misidentified.

Acella haldemani (Binney, 1867). Synonym: *Limnaea gracilis* (Jay, 1839). This species is listed from the Bow and Elkhorn rivers (Aughey 1877). Regionally its range is considered to include Iowa but no regional records are evident (Stewart 2006). My database contains two records of this species. Though the thin elongate morphology of this species seems unmistakable this species is out of range in Nebraska (Burch 1989) and I consider this species record erroneous.

Lymnaea bulimoides (Lea, 1841). Synonyms: *Galba bulimoides* (Lea, 1841), *Lymnaea cockerelli* (Pilsbry and Ferriss, 1906), *Stagnicola bulimoides techella* (Haldeman, 1867), *Stagnicola cockerelli* (Pilsbry and Ferriss, 1906). I follow Baker (1911) in treating *L. techella* and *L. cockerelli* as subspecies of *L. bulimoides*. This small snail is listed in Nebraska by a single study and two records are in the natural history collection at Harvard (Hibbard and Taylor 1960, MCZ). Regional listings are from Kansas, Wyoming, Missouri, Iowa and Colorado (Leonard 1959, Beetle 1989, Wu *et al.* 1997, Stewart 2006, Harrold and Guralnick 2010). The database contains a total of four records from two counties.

Lymnaea humilis (Say, 1822). Synonyms: *Fossaria obrussa* (Say, 1825), *Fossaria dalli* (Baker, 1907), *Limnaea desidiosa* (Say, 1834), *Limnaea humilis* (Say, 1822). I lump *Fossaria dalli*, *Fossaria obrussa*, and *Limnaea desidiosa* under *L. humilis* following Baker (1911) and Hubendick (1951). Historic records of this species include a listing of "all the streams of Nebraska" (Aughey 1877) and a single county record (Walker 1906). More recent records include several western Nebraska streams and the Niobrara River (Taylor 1960, Freeman and Perkins 1997). In addition the University of Nebraska State Museum houses shells of this species from the Nebraska towns of Sidney, Chambers, and Ashland, as well as Pioneers Park within Lancaster County. Regional records for *L. humilis* include Kansas, Wyoming, Missouri, Iowa, South Dakota and Colorado (Leonard 1959, Beetle 1989, Wu *et al.* 1997, Stewart 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010). The Nebraska snail database contains a total of 12 records from seven counties.

Lymnaea stagnalis (Linnaeus, 1758). Synonym: *Limnaea stagnalis* (Linnaeus, 1758). This large distinct species is listed by one study from a single locality, Smith's Lake in Dakota County (Aughey 1877). Regionally this species is more common being observed in Wyoming, Iowa, South Dakota, and Colorado (Beetle 1989, Stewart 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010). This species accounts for a single database record.

Pseudosuccinea columella (Say, 1817). Synonym: *Limnaea columella* (Say, 1817). This medium sized snail is listed from a single specimen from one locality, Smith's Lake in Dakota County (Aughey 1877). None of the references from surrounding states include this species with the exception of their presence in the Ozark lowlands in Southeast Missouri (Wu *et al.* 1997). I suspect this species of being erroneously placed within Nebraska.

Lymnaea caperata (Say, 1829). Synonym: *Lymnaea caperata* (Say, 1829). Records of this species are from the western part of the state (Walker 1906, Taylor 1960) and include an undated museum record (MCZ). Regional records are from Wyoming, Missouri, Iowa, South Dakota, and Colorado (Beetle 1989, Wu *et al.* 1997, Stewart 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010). The database contains eight records from five counties.

Lymnaea catascopium (Say, 1816). Synonyms: *Limnaea catascopium* (Say, 1816), *Lymnaea emarginata* (Say, 1821), *Limnaea pallida* (Adams, 1840), *Limnaea sumassi* (Baird, 1863). This species was recorded from the Bow River (Aughey 1877) and Platte City (MCZ). Regionally records are from Wyoming and Iowa (Beetle 1989, Stewart 2006). Burch (1989) does not include Nebraska in the range of this species but includes Iowa and South Dakota. The Nebraska snail database contains four records of this species from two counties.

Lymnaea elodes (Say, 1821). Synonyms: *Stagnicola elodes* (Say, 1821), *Lymnaea palustris* (Müller, 1774), *Lymnaea reflexa* (Say, 1821), *Limnaea haydeni* (Lea, 1858). I lump *Lymnaea haydeni, L. reflexa and L. palustris*, into *Lymnaea elodes* following Baker (1911) and Hubendick (1951). All three primary historical studies, a natural history collection, and recent studies have records of this species in Nebraska (Tryon 1868, Aughey 1877, Walker 1906, MCZ, Freeman and Perkins 1992, Freeman and Perkins 1997). In addition the Nebraska State Museum collection houses uncatalogued shells of this species. Regionally it is common with records from Wyoming, Missouri, Iowa, South Dakota and Colorado (Beetle 1989, Wu *et al.* 1997, Stewart 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010). Twenty–three records of this species from ten counties are in the database.

Physidae – I follow the recommendation of Dillon *et al.* (2006), following Walker (1906) and more recent molecular work (Wethington and Lydeard 2007), and use a two–genus system for this family. The genera used are *Physa* (Draparnaud, 1801) and *Aplexa* (Fleming, 1820).

Aplexa elongata (Linnaeus, 1758). Synonyms: *Aplexa hypnorum* (Linnaeus, 1758), *Bulla hypnorum* (Linnaeus, 1758), *Bulinus distortus* (Haldeman, 1840). This large snail is listed historically by two authors from “all quiet waters of the state” and Cherry

County (Aughey 1877, Walker 1906). More recent authors list this species from several western Nebraska locations including the Middle Loup River and roadside ditches (Taylor 1960, Wu 2004–2005). It is observed regionally in Wyoming, Iowa, South Dakota, and Colorado (Beetle 1989, Stewart 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010) but is not listed by Leonard (1959) from Kansas. This species is common in northern North America (Burch 1989). I have a total of 18 records from nine counties in my database.

Physa acuta (Draparnaud, 1805). Synonyms: *Physa anatine* (Lea, 1864), *Physa heterostropha* (Say, 1817), *Physa halei* (Lea, 1864), *Physa virgata* (Gould, 1855), *Physa whitei* (Lea, 1864). I follow Burch (1989) and Wethington and Lydeard (2007) in lumping five historically listed species into *Physa acuta*. This medium–sized snail is listed by two historical studies from "all streams from Nebraska" and the Roca and Platte rivers (Aughey 1877, Walker 1906). More recent studies and museum collections contain records from rivers and streams in western Nebraska but also include Nuckoll and Richardson counties in eastern Nebraska (Taylor 1960, Wu 2004–2005, MCZ). This snail is abundant in the region, being observed in Kansas, Wyoming, Missouri, Iowa, and Colorado (Leonard 1959, Beetle 1989, Wu *et al.* 1997, Stewart 2006, Harrold and Guralnick 2010). A total of 38 records from 25 counties within the database suggest this species is common.

Physa gyrina (Say, 1821). Synonyms: *Physella gyrina* (Say, 1821), *Physa ancillaria* (Say, 1825), *Physa gouldi* (Clench, 1935), *Physa lordi* (Baird, 1863), *Physa saffordi* (Lea, 1864), *Physa sayi* (Tappan, 1838), *Physa virginea* (Gold, 1847), *Physa warreniana* (Lea, 1864). I follow Wethington and Lydeard (2007) in lumping a large number of nominal species under *Physa gyrina*. This medium to large snail is recorded by the earliest historic studies from locations in eastern Nebraska (Aughey 1877, Walker 1906). More recent and museum records are from western Nebraska (Taylor 1960, Wu 2004–2005, MCZ). Recent studies also record this species from 22 sites along the Niobrara and Platte rivers (Freeman and Perkins 1992, 1997). Specimens of this species are also in collections of the University of Nebraska State Museum. It is ubiquitous throughout North America (Burch 1989) and throughout the region with records from Wyoming, Missouri, Iowa, South Dakota, and Colorado (Beetle 1989, Wu *et al.* 1997, Stewart, 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010). My database contains 63 records from 28 counties.

Physa jennessi (Dall, 1919). Synonym: *Physa skinneri* (Taylor, 1954). I use the oldest nomen in North America, *Physa jennessi*, described by Dall (1919) following Wethington and Lydeard (2007). This small species is not listed in any of the major historic studies examined and the only records come from the western Nebraska counties of Cherry, Grant, and Sheridan (Wu 2004–2005). This species is reported as widespread further north in North Dakota (Cvancara 1983). Listings from adjacent states are only from Wyoming (Beetle 1989) but also include the possibility, not confirmed, of their presence within the Iowa prairie potholes (Stewart 2006). The database contains only three records of this species from three counties.

Physa pomilia (Conrad, 1834). This small snail is not listed in any of the principal historical studies examined here. The records of this species come from collections of the University of Colorado Museum (Wu 2004–2005). Identification of this species is problematic as it is morphologically nearly identical to *Physa acuta.* This species is listed regionally only to the south and east in Kansas (Wu and Liu 2006) and Missouri (Wu *et al.* 1997). The database contains 15 records of this species from 13 counties.

Planorbidae – I follow Burch (1989) and Hubendick and Rees (1955) and eliminate two listed by Aughey (1877); *Gyraulus albus* (O. F. Müller, 1774) and *Planorbis glabratus* (Say, 1818). Neither species is historically present in the U.S.A. although *P. glabratus* is a recent invader to Florida (Burch 1989). The systematics of the limpets has benefited from recent molecular phylogenetic work (Walther *et al.* 2006, Walther *et al.* 2010). These analyses leave just three species of limpets in the U.S.A. all of which have records from Nebraska.

Ferrissia fragilis (Tryon, 1863). Synonym: *Ancylus shimekii* (Pilsbry, 1890). This small limpet is listed by a single study with a single locality in Nebraska, the town of Colloway (Walker 1906). Regional records of this species are from Kansas, Missouri, Iowa, and Colorado (Leonard 1959, Wu *et al*. 1997, Stewart 2006, Harrold and Guralnick 2010).

Ferrissia rivularis (Say, 1817). Synonyms: *Ancylus rivularis* (Say, 1817), *Ancylus caurinus* (Binney, 1865). I follow Basch (1963) in lumping *Ancylus caurinus* under *Ferrissia rivularis.* This small limpet was listed by two historical studies (Aughey 1877, Walker 1906). Aughey (1877) lists them from Logan, Elkhorn, Nemaha, Blue, and Bow Rivers. Walker (1906) lists one locality, Dead Man's Run, which runs through Lincoln, Nebraska. Regional listings are from Wyoming, Missouri, Iowa, and Colorado (Beetle 1989, Wu *et al.* 1997, Stewart 2006, Harrold and Guralnick 2010). The Nebraska database contains six records from two counties.

Gyraulus circumstriatus (Tyron, 1866). Records for this tiny snail include Cherry, Brown, and Lancaster counties (Taylor 1960, Hibbard and Taylor 1960). Regional records are from Kansas, Wyoming, Iowa, and Colorado (Leonard 1959, Beetle 1989, Stewart 2006, Harrold and Guralnick 2010). The database contains five records from three counties.

Gyraulus crista (Linnaeus, 1758). Synonym: *Armiger crista* (Linnaeus, 1758). This tiny snail is recorded from a single site from a creek in Cherry County (Taylor 1960). Regionally this snail is listed just from Wyoming (Beetle 1989). Others records exist from further north in North Dakota (Cvancara 1983).

Gyraulus deflectus (Say, 1824). Synonym: *Planorbis deflectus* (Say, 1824). This small snail is recorded historically from "all streams in eastern Nebraska" (Aughey 1877). More recent records are from two localities in western Nebraska (Taylor 1960, Freeman and Perkins 1992). Regional records are from Missouri and Iowa to the east (Wu *et al.* 1997, Stewart 2006). The database contains three records from two specific counties.

Gyraulus parvus (Say, 1817). Synonym: *Planorbis parvus* (Say, 1817). This small snail was recorded by Aughey (1877) and Walker (1906), from eastern Nebraska, and Taylor (1960), from western Nebraska. It is abundant in the region with records from Kansas, Wyoming, Missouri, Iowa, and Colorado (Leonard 1959, Beetle 1989, Wu *et al.* 1997, Stewart 2006, Harrold and Guralnick 2010). A total of nine records from five counties are in my database.

Helisoma anceps (Menke, 1830). Synonym: *Planorbis bicarinatus* (Say, 1819). This large snail is listed by all primary historical studies from eastern Nebraska and

Cheyenne County (Tryon 1868, Aughey 1877, Walker 1906). This species was also observed recently along the Niobrara River (Freeman and Perkins 1997). The Museum of Comparative Zoology contains two undated records and uncatalogued specimens are in collections of the University of Nebraska State Museum. Regionally this species is common in Kansas, Wyoming, Missouri, Iowa, South Dakota, and Colorado (Leonard 1959, Beetle 1989, Wu *et al.* 1997, Stewart 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010). Though apparently abundant, Aughey (1877) lists them from "all streams of eastern Nebraska", my Nebraska snail database contains just seven specific records from four counties.

Planorbella campanulata (Say, 1821). This large snail is recorded from the Bow River (Aughey 1877). It is reported from Iowa within this region but regional listings from other states are absent (Stewart 2006). The range of this species does not specifically include Nebraska (Burch 1989). Nebraska is either at the edge of its range or, as I suspect, it has been misidentified in the historic literature. The database contains a single record of this species.

Planorbella multivolvis (Case, 1847). This species is listed from a single historic study from the Bow River (Aughey 1877). *Planorbella multivolvis* is not listed in the surrounding states of Kansas, South Dakota, Iowa, or Colorado (Leonard 1959, Stephen and Winkler 2007, Stewart 2006, Harrold and Guralnick 2010). I suspect this species of being erroneously placed within this region. One author thinks this species is now extinct (Bogan 2000). On the other hand this species has been treated as a subspecies of *Planorbella campanulata* (Say, 1821) (Clarke 1973, Burch 1989).

Helisoma trivolvis (Say, 1817). Synonyms: *Planorbella trivolvis* (Say, 1816), *Planorbis trivolvis* (Say, 1817). This large and common snail is recorded by all primary historical studies from eastern Nebraska and Dakota County (Tryon 1868, Aughey 1877, Walker 1906). It is represented in the UNSM and MCZ collections. Later records include western Nebraska and the Platte River (Taylor 1960, Freeman and Perkins 1992). It is widely distributed and abundant in adjacent states (Leonard 1959, Beetle 1989, Wu *et al.* 1997, Stewart 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010). It is considered widespread in North America (Burch 1989). The database contains 12 records from nine counties.

Laevapex fuscus (Adams, 1841). Synonym: *Ancylus diaphanous* (Haldeman, 1841). This limpet was recorded from a single historical study from the Bow River (Aughey 1877)**.** Regionally this species is listed from Missouri and Iowa (Wu *et al.* 1997, Stewart 2006). Burch (1989) considers Iowa the western edge of its range. Given the historic taxonomic uncertainty among limpets (Walther *et al.* 2006) and Nebraska being outside of its range I suspect this species of being misidentified.

Planorbula armigera (Say, 1821). Synonym: *Segmentina armigera* (Say, 1821). This small snail is recorded from the Bow, Loup, and Niobrara rivers (Aughey 1877, Taylor 1960). Regionally it is recorded from Missouri and Iowa (Wu *et al.* 1997, Stewart 2006). Burch (1989) lists this species specifically from Nebraska. The database contains three records of this species from two counties.

Promenetus exacuous (Say, 1821). Synonym: *Planorbis exacutus* (Say, 1821). This small snail is listed from “all streams in eastern Nebraska” (Aughey 1877) and four specific counties (Taylor 1960, Hibbard and Taylor 1960). Observed regionally in

Kansas, Wyoming, Iowa, South Dakota and Colorado (Leonard 1959, Beetle 1989, Stewart 2006, Stephen and Winkler 2007, Harrold and Guralnick 2010). The database contains five records of this species.

Promenetus umbilicatellus (Cockerell, 1887). Records for this tiny snail are from Cherry, Brown, Cheyenne, and Lancaster counties (Hibbard and Taylor 1960, Taylor 1960). Regional records are from Kansas, Wyoming, Iowa, and Colorado (Leonard 1959, Beetle 1989, Stewart 2006, Harrold and Guralnick 2010). Four records of this species are within the database.

Pleuroceridae – Historically five species in this family are recorded in Nebraska (Aughey 1877). Goodrich (1939) in analyzing these records considered one species, *Leptoxis carinata* (Bruguiére, 1792), clearly an error as it is present only along the eastern seaboard. I lump the remaining four species into two following Goodrich (1939) and Tyron (1873).

Elimia semicarinata (Say, 1829). Synonyms: *Goniobasis larveaformis*(Lea, 1841), *Goniobasis occulta* (Anthony, 1860), *Goniobasis semicarinata* (Say, 1829). Records are from the Big Blue and Nemaha rivers (Aughey 1877). No listings of this species are in adjacent states. The database contains four records from two rivers, but I suspect this species is a misidentified.

Pleurocera acuta (Rafinesque, 1831). Synonym: *Pleurocera neglectum* (Anthony, 1860). I follow the taxonomy in Johnson *et al.* (2013) although the Pleuroceridae express ecophenotypic plasticity and it may be that *Pleurocera canaliculata* (Say, 1821) is conspecific to *Pleurocera acuta* (Dillon *et al.* 2013). This species is listed only by one study (Aughey 1877). Regionally listings are from Kansas, Missouri, and Iowa (Leonard

1959, Wu *et al.* 1997, Stewart 2006). The database contains a single record from the Big Blue River without more specific locality and so the county distribution is not mapped.

Pomatiopsidae – There is confusion within snails of the families Hydrobiidae and Pomatiopsidae, as mentioned earlier, because these snails are similar in appearance and very small (Burch 1989). This amphibious group occurs above the water line and, therefore, sometimes considered terrestrial rather than aquatic. A single species within this family appears in Nebraska.

Pomatiopsis lapidaria (Say, 1817). This tiny snail is listed from eastern Nebraska along the Missouri bluffs (Aughey 1877). Regionally this species is recorded from Kansas, Missouri, and Iowa but is not common (Leonard 1959, Wu *et al.* 1997, Stewart 2006). The database contains a single record of this species without specific locality data and so its county distribution is not mapped.

Valvatidae – Nebraska is at the southern edge of the distribution for this family (Burch 1989) and therefore I expect the incidence of the two-species listed historically to be low. I retain both species recorded historically.

Valvata sincera (Say, 1824). Aughey (1877) reported this tiny species from the Bow and Elkhorn rivers. Although *Valvata tricarinata* is widespread, *V. sincera* is less so and is a species of conservation interest in some regions (Smith 1984). It is listed in Wyoming, Iowa, and Colorado but is considered rare (Beetle 1989, Stewart 2006, Harrold and Guralnick 2010). Little other information exists for this species. The database contains two records of this species with only one specific county locale.

Valvata tricarinata (Say, 1817). This tiny snail was recorded in only one historical work from the Bow and Elkhorn rivers and was considered rare at the time (Aughey 1877). However, this species was observed recently in a study of the Niobrara River (Freeman and Perkins 1997). It was also abundant enough in a western Nebraska lake for its use in studies of reproductive biology (Gugler 1969). It is a widespread snail in North America and is a common species in Iowa and South Dakota (Stewart 2006, Stephen and Winkler 2007). My database contains seven records from three counties.

Viviparidae – Historical records from Nebraska include five species within this family (Aughey 1877). However, Burch considers only *Campeloma decisum* (Say, 1817) as being in the region (Burch 1989). Dillon *et al.* (2006) finding no consistent distinctions among the many nominal species of *Campeloma* (Rafinesque, 1819) reduces them to just one, *Campeloma decisum,* across North America. This assessment seems valid, and I follow it here. The other species listed here is a non–indigenous snail not reported in Nebraska until recently.

Bellamya chinensis (Reeve, 1863). Synonyms: *Cipangopaludina chinensis* (Gray, 1834), *Viviparus malleatus* (Reeve, 1863). This large non–indigenous Asian snail first invaded North America in the late 1800s and is now present in most U.S. States (Jokinen 1982). In Nebraska it is reported from the southeast of the state (Chaine *et al*. 2012). There is a single Nebraska record of this species from Lancaster County.

Campeloma decisum (Say, 1817). Synonyms: *Melantho decisa* (Say, 1817), *Melantho ponderosa* (Say, 1829), *Vivipara contectoides* (1865), *Vivipara integra* (Say, 1829), *Vivipara intertexta* (Say, 1829), *Vivipara subpurpurea* (Say, 1829). This large snail has been recorded in “all the streams of Nebraska” (Aughey 1877). It buries within river mud, making detection difficult (Burch 1989). Regionally this species is listed from Kansas, Missouri, and Iowa (Leonard 1959, Wu *et al.* 1997, Stewart 2006). Ten records from four rivers and two specific counties are in the database.

DISCUSSION

Systematic research reduces the number of species of freshwater snails in North America. Using this data I have reduced the number of species of freshwater snail expected to be present in Nebraska. Historic and recent records provide 296 records and more than 80 species names of freshwater gastropods in the state. By lumping species synonyms and excluding invalid records I reduce this to 31 species of freshwater snail within Nebraska (Table 2.1).

My list differs in a number of ways from that of a recent study listing the conservation status of all species of freshwater snail in Canada and the United States (Johnson *et al*. 2013). Amid taxonomic uncertainties, I follow a conservative approach to elevating subspecies or nominal species to species status and thus, *Galba cockerelli* (Pilsbry and Ferriss, 1906) and *Galba techella* (Haldeman, 1867) (the later listed in Nebraska studies as *Stagnicola bulimoides techella*) are lumped with *Lymnaea bulimoides*. I also follow Baker (1911) in lumping *Galba dalli* (Baker 1907), *Galba modicella* (Say, 1825) and *Galba obrussa* (Say, 1825) into *Lymnaea humilis*. I find no Nebraska records for two species of Lymnaeidae, *Galba parva* (Lea, 1841) and *Galba rustica* (Lea, 1841), listed in Johnson *et al*. (2013). I place *Physella virgata* (Gould, 1855) under *Physa gyrina* following Wethington and Lydeard (2007). My list contains seven species not included in Johnson *et al.* (2013); *Lymnaea catascopium*, *Lymnaea stagnalis*, *Physa acuta*, *Gyraulus crista*, *Pomatiopsis lapidaria*, *Valvata sincera* and the non–indigenous *Bellamya chinensis*. Among these species only *Physa acuta* appears abundant within the state. The exclusion of *Lymnaea stagnalis* from Johnson *et al*. (2013) appears to be an error as this species, though mentioned within the publication by name, was not listed specifically for any North American state.

Based on regional and known ranges I suspect several species discussed here of being placed within Nebraska in error and I do not include them on my final list (Table 2.1). Suspect species are *Acella haldemani*, *Gyraulus albus*, *Planorbis glabratus*, *Laevapex fuscus*, *Pseudosuccinea columella*, *Planorbella campanulata*, *Planorbella multivolvis*, *Lyogyrus granum*, *Elimia semicarinata*, and *Leptoxis carinata* discussed under the Pleuroceridae. Aughey (1877) is the only author to list each of these species, most with a single record. Aughey's work in other areas has been criticized for not being precise (Bolick 1993, Hoke 2000) but it is difficult to be certain that these species are not present in Nebraska when up–to–date sampling is lacking. Thus, this list acts as an incentive for current surveys and further analysis. Species richness of Nebraska freshwater snails is lower than that of adjacent Iowa, which was recently reviewed and shown to house 47 species historically (Stewart 2006). Though not as diverse as Iowa, Nebraska's 31 freshwater snail species include members from nine families. The majority of species (22) in Nebraska are pulmonate snails from the families Lymnaiedae, Physidae, and Planorbidae. At least four species appear to be abundant throughout Nebraska based on the number of historical listings and county distribution. These species are *Lymnaea elodes*, *Aplexa elongata*, *Physa gyrina*, and *Physa acuta.* All of these most abundant snails are pulmonates within the Heterobranchia.

Based on the number of records and localities I suspect eight species of being rare in Nebraska; *Cincinnatia integra*, *Probythinella emarginata*, *Lymnaea stagnalis*, *Ferrissia fragilis*, *Gyraulus crista*, *Pleurocera acuta*, *Pomatiopsis lapidaria*, and *Valvata sincera*. Some species, for example *Lymnaea stagnalis*, though rare in Nebraska appear to be at the edge of their range and more common in the broader region.

Though a conservation assessment of freshwater gastropods of North America has recently been completed (Johnson *et al.* 2013) the lack of attention to freshwater gastropods in general reduces the ability to provide worthwhile analysis of each species. This recent conservation assessment relies on historic data and also places some species within a region based on their presence in adjacent regions or states and not specific locality records. In addition, the absence of recent records means rare species are difficult to distinguish from species erroneously listed. It is clear that field surveys are needed to clarify species in need of conservation and validate presence or extirpation.

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Table 2.1. Thirty–one species of freshwater gastropod recently or historically present in Nebraska. The non–indigenous *Bellamya chinensis* appears as a relative newcomer.

Family	Species	No. Site records
Amnicolidae	*Amnicola limosus*	5
Hydrobiidae	*Cincinnatia integra*	1
Hydrobiidae	*Probythinella emarginata*	1
Lymnaeidae	*Lymnaea bulimoides*	4
Lymnaeidae	*Lymnaea caperata*	8
Lymnaeidae	*Lymnaea catascopium*	4
Lymnaeidae	*Lymnaea elodes*	23
Lymnaeidae	*Lymnaea humilis*	12
Lymnaeidae	*Lymnaea stagnalis*	1
Physidae	*Aplexa elongata*	18
Physidae	*Physa acuta*	38
Physidae	*Physa gyrina*	63
Physidae	*Physa jennessi*	3
Physidae	*Physa pomilia*	15
Planorbidae	*Ferrissia fragilis*	1
Planorbidae	*Ferrissia rivularis*	6
Planorbidae	*Gyraulus circumstriatus*	5
Planorbidae	*Gyraulus crista*	1
Planorbidae	*Gyraulus deflectus*	3
Planorbidae	*Gyraulus parvus*	5
Planorbidae	*Helisoma anceps*	7
Planorbidae	*Helisoma trivolvis*	12
Planorbidae	*Planorbula armigera*	3
Planorbidae	*Promenetus exacuous*	5
Planorbidae	*Promenetus umbilicatellus*	5
Pleuroceridae	*Pleurocera acuta*	1
Pomatiopsidae	*Pomatiopsis lapidaria*	1
Valvatidae	*Valvata sincera*	2
Valvatidae	*Valvata tricarinata*	7
Viviparidae	*Bellamya chinensis*	1
Viviparidae	*Campeloma decisum*	10

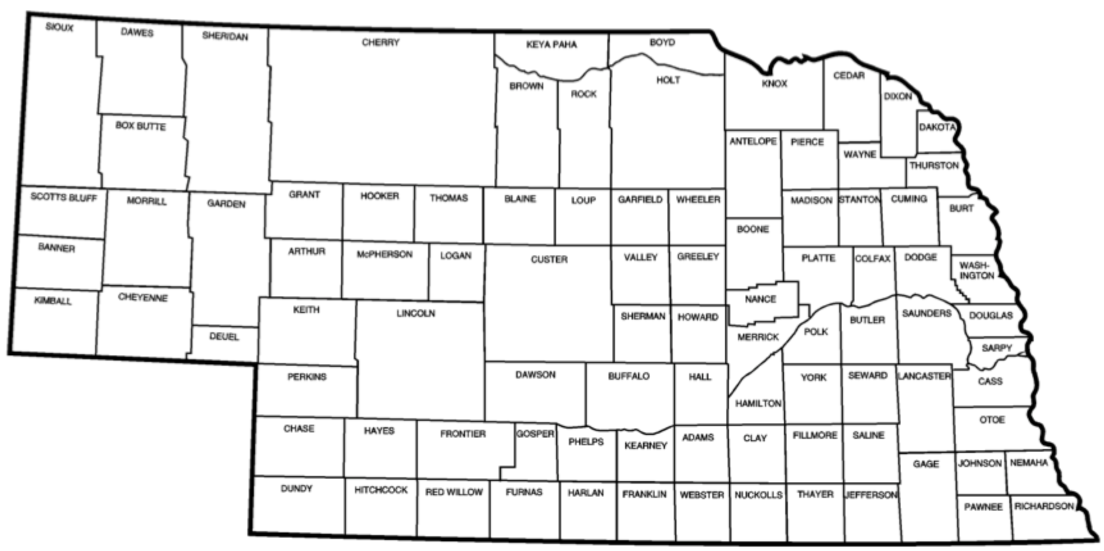

Figure 2.1. Nebraska's 93 counties

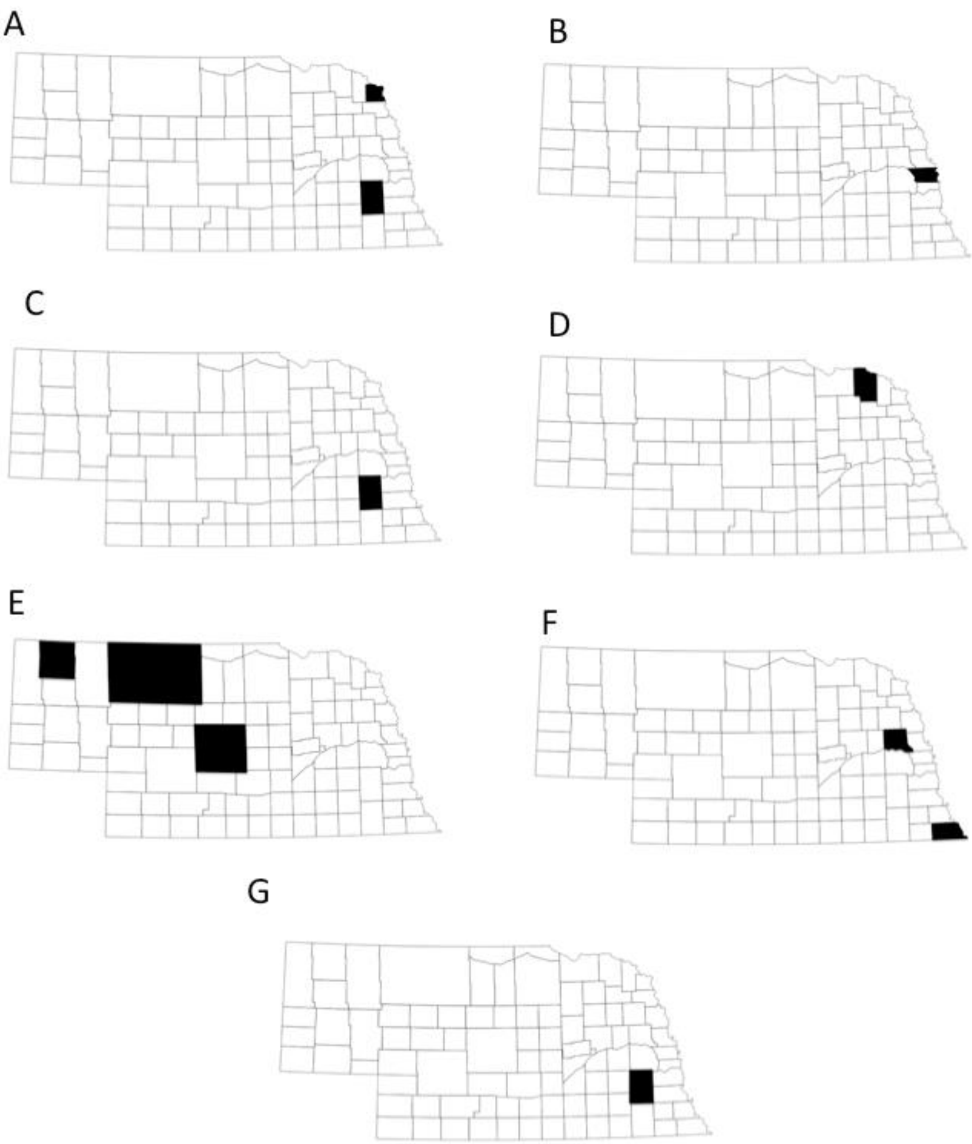

Figure 2.2. County level location for **A,** *Amnicola limosus*, **B,** *Cincinnatia integra*, **C,** *Probythinella emarginata*, **D,** *Valvata sincera*, **E**, *Valvata tricarinata*, **F,** *Campeloma decisum*, and **G,** *Bellamya chinensis*. Shading indicates counties where taxa have been documented in Nebraska

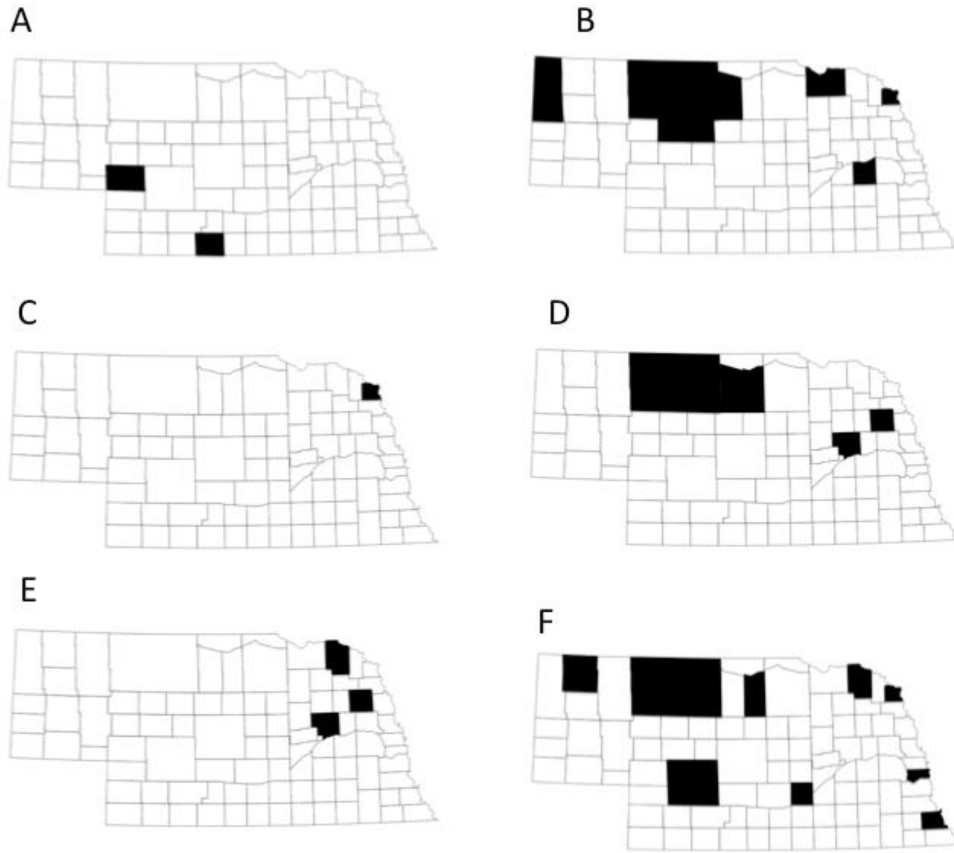

Figure 2.3. County level location for **A,** *Lymnaea bulimoides,* **B,** *Lymnaea humilis,* **C,** *Lymnaea stagnalis,* **D,** *Lymnaea caperata*, **E**, *Lymnaea catascopium,* and **F,** *Lymnaea elodes*. Shading indicates counties where taxa have been documented in Nebraska.

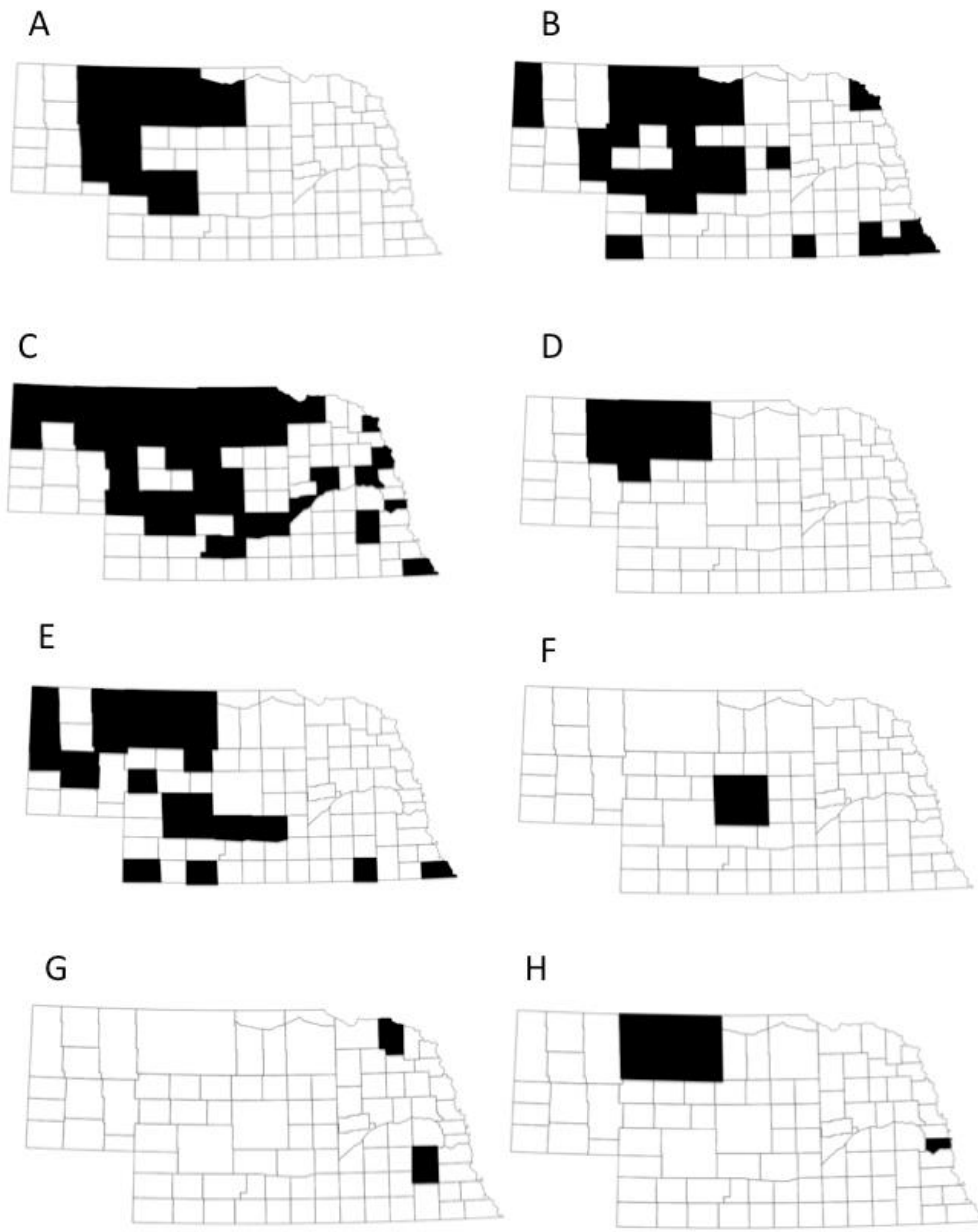

Figure 2.4. County level location for **A,** *Aplexa elongata*, **B,** *Physa acuta*, **C,** *Physa gyrina*, **D,** *Physa jennessi*, **E**, *Physa pomilia*, **F,** *Ferrissia fragilis*, **G,** *Ferrissia rivularis*, and **H,** *Gyraulus deflectus*. Shading indicates counties where taxa have been documented in Nebraska.

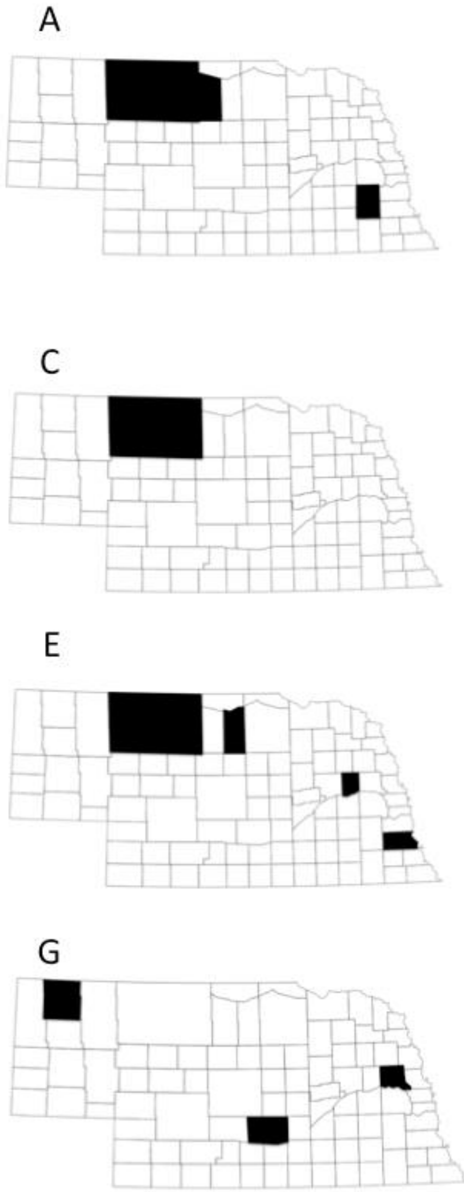

Figure 2.5. County level location for **A,** *Gyraulus circumstriatus,* **B,** *Gyraulus parvus,* **C,** *Gyraulus crista,* **D,** *Planorbula armigera,* **E**, *Promenetus exacuous,* **F,** *Promenetus umbillicatellus,* **G,** *Helisoma anceps,* and **H,** *Helisoma trivolvis*. Shading indicates counties where taxa have been documented in Nebraska.

CHAPTER THREE: SPECIES COMPOSITION OF SOUTH DAKOTA'S FRESHWATER GASTROPODS A REVIEW OF HISTORICAL RECORDS

Freshwater snails are important components of aquatic systems. Snails consume periphyton and play a role in the breakdown of leaf litter (Dillon 2000, Brady and Turner 2010). Snails are eaten by a variety of invertebrate and vertebrate species, particularly fishes and waterfowl (Osenberg 1989, Brönmark and Vermaat 1998, Swanson and Duebbert 1989, Dillon 2000, Tiemann *et al*. 2011). Competitive and more complex interactions are between freshwater snails and tadpoles (Brönmark *et al*. 1991; Smith *et al*. 2012). Complex interaction also exists among snails, fish, and epiphyton (Brönmark and Vermaat 1998). A large amount of energy throughput in aquatic systems is via snails (Newbold *et al*. 1983, Richardson *et al*. 1988, Brown 2001). Snails also host the early life stages of a variety of trematode parasites (Dillon 2000). Despite this central ecosystem role, information about the distribution, incidence, and abundance of aquatic snails is lacking.

In South Dakota, specific information on the distribution of aquatic gastropods comes primarily from just a few studies (Over 1915a, Over 1915b, Over 1928, Henderson 1927), which contain little specific locality data. Recent work on South Dakota freshwater gastropods is sparse (Hershler 1996, Stephen and Winkler 2007) or focused on fossil species (Jass *et al*. 2002). South Dakota is not an anomaly; current information on freshwater snail distribution across the U.S. is missing for many states. Most of the information about freshwater snail distribution in North America comes from The Freshwater Snails of North America guide, which lists over 500 species of freshwater snail for in North America (Burch 1989). A recent conservation assessment attempts to evaluate the conservation status of each species in each State and Province of North America (Johnson *et al*. 2013). These works are invaluable resources on freshwater snails but are large in scope and the presence of some species is included based on regional range and not specific collection data. Knowledge of freshwater snail presence and conservation status for most regions is in need of refinement.

Systematic work, particularly on the families Ancylidae and Physidae, have shown that the number of species historically listed as being present in North America has been overstated (Hubendick 1951, Dillon *et al*. 2002, Walther *et al*. 2006, Wethington and Lydeard 2007, Walther and Burch 2010). Historically the Ancylidae have been plagued with inadequate generic and species level descriptions (Basch 1963) but the works of Walther *et al*. (2006) and Walther and Burch (2010) conclude that just a two species of Ferrissia and one of Laevepex inhabit North America. The large number of Physidae species listed for North America by Burch (1989) is reduced to ten to twelve species (Dillon *et al*. 2002, Wethington and Lydeard 2007). It’s apparent that there is a need to produce region–specific lists of freshwater snails, merging the many synonyms. While these systematic studies have allowed a great deal of clarification of species names, the taxonomy of freshwater gastropods has long been in a state of flux, and authors still use a variety of names for the same species.

A list of fresh water gastropod species is produced herein based on the historical literature and museum collections updated with taxonomic revisions. Regional studies from the adjacent states of Iowa, Nebraska, North Dakota and Wyoming are used to identify regional species incidence. However, as in South Dakota, current surveys are almost nonexistent for these states. The studies for Iowa (Stewart 2006) and Nebraska

(Stephen 2015) are historical reviews. This list, in turn, will act as a starting point for surveys to assess the present geographic distribution and conservation status of freshwater snails of South Dakota.

METHODS

Study Region

South Dakota has an area of approximately 199,400 km3 extending from 30 N to 45 N latitude and 97 W to 104 W longitude (USGS 2009). South Dakota's climate consists of hot summers and cold winters (July average highs range from 32 to 38^{o}C while January average lows range from 1 to –12oC (PRISM 2014). Annual precipitation ranges from more than 60 cm in the eastern part of the state to 40 cm in the dryer west. South Dakota has tall grass, mixed grass, and short grass prairies and contains eight level III ecoregions with three of these; the Northwest Great Plains, the Northwestern Glaciated Plains and the Northern Glaciated Plains making up most of the area of the state (Bryce *et al*. 1998). Agricultural cropland is concentrated in the Northern Glaciated Plains in the eastern portion of the state. The state has fourteen 3rd level Hydrologic units. Most of the state ultimately drains into the Missouri river but the extreme northeast region drains via the Upper Red river and finally into Hudson Bay (USGS 2009).

Species presence records were obtained from published literature and online museum collections. There are not many studies of South Dakota freshwater snails; information comes from just a few sources (Over 1915*a*, Over 1915*b*, Over 1928, Henderson 1927). The Florida Museum of Natural History (FLMNH), Illinois Natural History Survey Mollusk Collection (INHS), The Academy of Natural Sciences of Drexel University (formally The Academy of Natural Sciences Philadelphia) (ANS), and

Harvard Museum of Comparative Zoology (MCZ) online catalogs were searched for records of freshwater snails from South Dakota. The Academy of Natural Sciences of Drexel University (ANS), and Harvard Museum of Comparative Zoology (MCZ) have records from South Dakota.

All species listed were scrutinized to assess the likelihood of identification errors based on the species presence in other states within the region; no museum specimens were examined. The primary works examined from each state were North Dakota (Cvancara 1983), Nebraska (Stephen 2015), Wyoming (Beetle 1989), and Iowa (Stewart 2006). Updating and merging of species names were done by following taxonomic specific works of families as follows: Planorbidae (Hubendick and Rees 1955); Physidae (Dillon *et al*. 2002, Dillon and Wethington 2004, Wethington and Lydeard 2007); Lymnaeidae (Hubendick 1951, Remigio 2002, Correa *et al*. 2010); Ancylidae (Walther *et al*. 2006, Walther *et al*. 2010). Where no recent studies have been completed I follow the comprehensive guide by Burch (1989). A brief narrative description, including synonyms used in South Dakota studies, is produced for every species considered to be historically or currently present in South Dakota. I mapped county locality for each species with specific county locality data (Figures 3.2 – 3.5). I discuss regional species that may inhabit South Dakota but I did not include them in column 1 (Table 3.1) unless specific records exist of their presence within the state. I follow the taxonomy adopted by the Freshwater Gastropods of North America project (Dillon *et al*. 2006), which differs somewhat from names used in a recent conservation work (Johnson *et al*. 2013). To enable comparison both names are included in Table 3.1.

RESULTS

My literature and online review of the freshwater snails of South Dakota returned 214 records and names of 54 freshwater snail species. I reduced these 54 to 25 valid species primarily by grouping synonyms (Table 1). Synonyms for each species listed are those used historically within South Dakota. My list includes the non–indigenous species, *Melanoides tuberculatus*, not listed in any historic study but more recently observed in rivers fed by warm water springs in southwest South Dakota (Anderson 2004). Details for each species are organized by family below.

Amnicolidae and Hydrobiidae – The families Amnicolidae, Hydrobiidae and the Pomatiopsidae (the last not represented by any species herein) have overlapping descriptions and a history of misidentifications (Burch 1989). These families all contain tiny conical snails. The family Amnicolidae was often placed as a subfamily of Hydrobiidae: however, recent molecular work separates the families into separate clades (Wilke *et al*. 2001, Bouchet and Rocroi 2005). Though some clarity in the number of species is provided by the lumping of many nominal species of Probythinella into two, historic listings are still unclear. Some historic listings of *Amnicola cincinnatiensis* are actually *Probythinella emarginata* whereas others are *Cincinnatia integra* (Hershler 1996).

Amnicola limosus (Mud Amnicola). This small snail was listed in historical studies both by Over (1915b) and Henderson (1927). Listings are from Brookings, Clay and Codington counties. Regionally it appears common, observed in all neighboring states examined (Cvancara 1983, Beetle 1989, Stewart 2006, Stephen 2015).

Amnicola walkeri (Canadian Duskysnail). This tiny snail was listed only by Over (1928) from Marshall County. No records of this species exist from adjacent states and it is out of range in South Dakota (Burch 1989). I treat this record as a misidentification.

Cincinnatia integra (Midland Siltsnail). Synonym: *Amnicola cincinnatiensis*. This small 5 mm snail was listed in historical studies both by Over (1915b) and Henderson (1927) from Brookings, Moody and Spink counties. The Museum of Comparative Zoology also has records of this species from Turtle River in Spink County (MCZ 2013). This species is recorded regionally from Nebraska (Stephen 2015), Iowa (Stewart 2006) and North Dakota (Cvancara 1983).

Probythinella emarginata (Delta Hydrobe). Synonyms: *Amnicola emarginata*, *Probythinella lacustris*. This tiny 2–3 mm snail is listed by two historical surveys from Codington, Clay, Moody and Roberts counties, and Lake Campbell, which is in Brookings County (Over 1915b; Henderson 1927). Burch (1989) placed it in South Dakota following Hibbard and Taylor (1960). The only regional listing is from Iowa (Stewart 2006). A recent systematic treatment recognizes a single species *Probythinella emarginata* among many synonyms (Hershler 1996).

Lymnaeidae – There is wide systematic and taxonomic confusion among this family. Often placed in different genera according to size with the smallest placed into *Galba* or *Fossaria*, *Stagnicola* used for medium sized snails and *Lymnaea* used for the largest (Burch 1989; Johnson *et al*. 2013). Dillon *et al*. (2006) suggests placing them all under the same genus *Lymnaea*. Confusion also exists among the many synonyms within this family, an area ripe for more molecular analysis. Most of the small Lymnaeids were synonimized by Hubendick (1951) under *Lymnaea humilis* including *L. parva* listed in South Dakota by Over (1915b). It seems likely that *Lymnaea elodes* is the conspecific elongate morph of *Lymnaea catascopium* as suggested by a gene tree of this family (Correa *et al*. 2010). Until this possibility is confirmed I retain *L. elodes* as one species and *Lymnaea catascopium* as a separate species. Another species listed historically is *Lymnaea palustris*, which is restricted to Europe. I include *Lymnaea palustris* as a synonym of *L. elodes* following Burch (1989). I could not resolve one species, *Lymnaea tyroni*, listed historically by Over (1915b).

Lymnaea bulimoides (Prairie Lymnaea). Synonyms: *Lymnaea cokerelli*, *Lymnaea techella*. Over (1915b, 1928) list this species from Harding County and generally over the State. The Academy of Natural Sciences (ANS) collection includes records from Harding, Pennington and Corson counties. The Museum of Comparative Zoology collections include a record of this species without a specific locality (MCZ). Regionally this species is listed from Nebraska and Wyoming (Hibbard and Taylor 1960, Beetle 1989). Given the taxonomic uncertainty, Stewart (2006) placed all historical listings of the small Lymnaeids (including *L. bulimoides*) together under *L. humilis*.

Lymnaea caperata (Wrinkled Pondsnail). Synonym: *Stagnicola caperata.* This species is listed by Over (1915b) and Henderson (1927) as well as Hibbard and Taylor (1960). It is considered common throughout South Dakota (Over 1915b). Henderson (1927) lists three localities: Lake Campbell, Spring Creek, and Stony Butte in Brookings, Todd and Lyman counties respectively. Hibbard and Taylor (1960) list localities from Perkins, Pennington and Lake counties. Museum collections include records from the additional counties of Clay, Corson, and Butte (ANP 2014). Though apparently abundant in South Dakota this species is sometimes considered under sampled due to its presence in temporary wetlands (Jokinen 1992). Regional records are from Nebraska, North Dakota, and Iowa (Stephen 2015, Cvancara 1983, Stewart 2006).

Lymnaea catascopium (Woodland Pondsnail). Synonyms: *Galba apicina, Limnaea catascopium*. This snail is placed in South Dakota with a single record from Stanley County as *Galba apicina* (Baker 1911) following Binney (1865) who actually listed it as *Limnaea catascopium*. Baker thought this was a misidentified and altered it (Baker 1911). In addition to this problematic identification this species may be shown to be conspecific to *L. elodes* and several other medium size marsh snails (Correa *et al*. 2010). There are no regional listings of *Lymnaea apicina* but *Lymnaea catascopium* is recorded from Wyoming (Beetle 1989) and Iowa (Stewart 2006).

Lymnaea elodes (Marsh Pondsnail)**.** Synonyms*: Stagnicola elodes, Lymnaea palustris*. Historical listings of this species are from two authors and two museum collections. Counties with records are Brookings, Clay, Corson, Deuel, Hamlin, Harding, Jones, Lyman, Moody, and Perkins (Over 1915, Henderson 1927, ANS, MCZ). Over (1915) also listed this species as "over the state". There are regional records from each of the adjacent states of North Dakota, Wyoming, Iowa, and Nebraska (Cvancara 1983, Beetle 1989, Stewart 2006, Stephen 2015).

Lymnaea humilis (Golden Lymnaea)**.** Synonyms: *Lymnaea obrussa, Lymnaea parva*. This snail is listed historically in the state by Over (1915b) and the one museum collection (ANP). Records are from Butte, Corson, Clay, Deuel, Edmunds, Fall River, Harding, Lincoln, Pennington, and Perkins counties. Due to taxonomic uncertainly this nomen is used by some authors to encompass all tiny to small Lymnaeids (Stewart 2006).

Regional listings of this species are from Nebraska, North Dakota, Wyoming, and Iowa (Stephen 2015, Cvancara, 1983, Beetle 1989, Stewart 2006).

Lymnaea stagnalis (Great Pondsnail)**.** This species has consistent naming and no synonyms exist. This snail was listed only by Over (1915b) from Deuel county. This species is considered common in northern North America from large water bodies (Burch 1989). Listed regionally from a single location in Nebraska (Aughey 1877), it appears more common in North Dakota (Cvancara 1983) and northern Iowa (Stewart 2006).

Physidae – Many nominal species of this family have been merged due to recent research using both traditional mating experiments (Dillon *et al*. 2002, Dillon and Wethington 2004) and molecular data (Wethington and Lydeard 2007). These works have reduced the possible 40 species of Physidae in North America to perhaps eleven. The two most abundant members of this family, *Physa gyrina* and *Physa acuta*, take on most of the nominal species. I follow the taxonomy suggested by Wethington and Lydeard (2007) and use a two–genus system of *Physa* and *Aplexa* for this family. One species listed historically, *Physa humerosa*, not examined in recent systematic studies is placed under the subgenus Costatella by Burch (1989). All other species in this subgenus are merged into *Physa acuta* (Wethington and Lydeard 2007) therefore I consider this a synonym of *P. acuta* below. *Physa warreniana* is not considered valid by Burch (1989) and has been treated as a subspecies of *P. sayi* (Walker 1906, Wu 2004–2005), which in turn is a synonym of *P. gyrina* (Wethington and Lydeard 2007). One species, *Physa crandilli*, listed by Over (1915b) I could not resolve.

Aplexa elongata (Lance Aplexa). Synonym: *Aplexa hypnorum*. This species was listed by a single historical study from Deuel County (Over 1915b). This species is common throughout the region being observed in Nebraska, North Dakota, Wyoming, and Iowa (Stephen 2015, Cvancara 1983, Beetle 1989, Stewart 2006).

Physa acuta (Bladder Physa)**.** Synonyms: *Physa ancillaria, Physa humerosa. Physa walkeri.* Over (1915b) recorded this snail from three counties Spink, Codington, and Lawrence while Henderson (1927) recorded one site, Rapid Creek in Pennington County The Museum of Comparative Zoology (MCZ) also houses specimens from Rapid Creek and the Academy of Natural Sciences of Drexel University (ANS) has records from Union and Washabaugh counties: Washabaugh County no longer exists being split and merged into Jackson, Pennington and Shannon counties. This species appears common regionally being observed in North Dakota, Wyoming, Iowa, and Nebraska (Cvancara 1983, Beetle 1989, Stewart 2006, Stephen 2015).

Physa gyrina (Tadpole Physa). Synonyms: *Physa sayi, Physa warreniana, Physella gyrina*. This snail is listed by Over (1915b) as abundant over the entire state. Specific records are from Deuel, Harding, Pennington, and Perkins counties (Over 1915, Henderson 1927). Museum collections contain records from the additional counties of Brookings, Clay, Codington, Custer, Fall River, Lawrence, Stanley, Union, Yankton, and the former county of Washabaugh (ANS, MCZ). This is a common species being listed in all regional states examined, North Dakota, Wyoming, Iowa, and Nebraska (Cvancara 1983, Beetle 1989, Stewart 2006, Stephen 2015).

Physa jennessi (Obtuse Physa). Synonym: *Physa skinneri*. There is a single museum record of this species from Deuel County (ANS). Regional observations are from Wyoming and Nebraska (Beetle 1989, Stephen 2015).

Planorbidae – This is the most specious family of freshwater snails (Strong *et al*. 2005). For the taxonomy of this group I follow the Freshwater Gastropods of North America project, which follows Hubendick and Rees (1955). Some recent molecular systematic work has delved into a limited number of species in this family (Albrecht *et al*. 2007), but the most complete treatment is morphological (Hubendick and Rees 1955). Two species of historically listed planispiral snails, *Planorbis vermicularis* and *Sementina crassilabris*, remain unresolved. Both species are listed by Over (1915b). The fresh–water limpets, formerly in the family Ancylidae, are now placed within the Planorbidae (Bouchet and Rocroi 2005). Recent work has reduced the many possible historical species of fresh water limpets thought to inhabit North America to just three valid species throughout the entire U.S. (Walther *et al*. 2006, Walther and Burch 2010). One species listed historically, *Ferrissia tarda,* I could not resolve (Over 1928). The MCZ lists a specimen of genus *Ancylus* (now *Ferrissia*), from the Vermillion River, without other details (MCZ 2014).

Ferrissia rivularis (Creeping Ancylid). Synonyms: *Ferrissia parallela*, *Ancylus parallelus*. This is a small freshwater limpet. Listings of this species are from two studies from Deuel and Marshall counties (Over 1915b, 1928). This limpet is abundant in Iowa (Stewart 2006), and it was observed at more than 40 sites in North Dakota (Cvancara 1983). It is also recorded from at least four counties in Wyoming (Beetle 1989). It is possible that the unresolved species *Ferrissia tarda*, and the MCZ record of *Ancylus* is this species.

Gyraulus crista (Nautilus Ramshorn). Synonym: *Segmentina cristyi*. This species is listed by Over (1915b) from a single “small pond” in Deuel county. Regionally records of this species are from the northern adjacent states of North Dakota and Wyoming plus a single record from Nebraska (Cvancara 1983, Beetle 1989, Taylor 1960). This species is abundant in the northern U.S. and Canada (Burch 1989).

Gyraulus deflectus (Flexed Gyro). Synonyms: *Planorbis deflectus*, *Planorbis hirsutus*. This species is listed by two studies by Over (1915b, 1928). Counties listed are Deuel, Clay, Perkins, and Marshall and two former counties Washington and Washabaugh, which have been sliced up or merged into Jackson, Pennington and Shannon counties. Regionally this species is recorded from just Nebraska and Iowa (Aughey 1877, Stewart 2006).

Gyraulus parvus (ash gyro). Synonym: *Planorbis parvus.* This species is listed by Over (1915b) and one museum collection (ANS) from Brookings, Clap, Deuel, Hamlin, Harding, Lincoln, Moody, and Pennington counties. Regionally it appears common with listings from all the neighboring states examined here, North Dakota, Wyoming, Iowa, and Nebraska (Cvancara 1983, Beetle 1989, Stewart 2006, Stephen 2015).

Helisoma anceps (Two–ridged Ramshorn). Synonym: *Planobula antrosa*. This species is listed in only one historical study as being observed over the state (Over 1915b). Museum records list this species from Perkins County and the former county of Washabaugh (ANS). This species is considered abundant in riverine systems (Burch

1989). Regionally it appears common with records from in North Dakota, Wyoming, Iowa and Nebraska (Cvancara 1983, Beetle 1989, Stewart 2006, Stephen 2015).

Helisoma trivolvis (marsh ramshorn). Synonym: *Planorbis trivolvis*. Two studies list this species (Over 1915b, Henderson 1927). Records of this species also appear in the museum collections (ANS, MCZ). Over (1915b) considered them common over the state. Specific counties with records are Brookings, Clay, Deuel, Hamlin, Jones, Lyman, Pennington, Perkins, Stanley, and the former county Wasabaugh (ANS, MCZ, Henderson 1927). Regional records exist from all adjacent states examined (Cvancara 1983, Beetle 1989, Stewart 2006, Stephen 2015).

Planorbula armigera (Thick–lipped Ramshorn). Synonym: *Planorbis exacuus.* This snail is listed by a single study and one museum collection from Deuel and Edmunds counties (ANS, Over 1915b). This species is common regionally being observed in all adjacent states examined (Cvancara 1983, Beetle 1989, Stewart 2006, Stephen 2015).

Promenetus exacuous (Sharp Sprite)**.** Synonym: *Planorbis exacuus.* This snail is listed by a single study and one museum collection from Deuel and Edmunds counties (ANS, Over 1915b). This species is common regionally being observed in all adjacent states examined (Cvancara 1983, Beetle 1989, Stewart 2006, Stephen 2015).

Promenetus umbilicatellus (umbilicate sprite)**.** Synonym: *Planorbis umbilicatellus.* This is snail is listed historically in South Dakota from Corson and Perkins County (ANS, Over 1915b). This species is also included on a map with (two sites in the northeast and one in the northwest) made from museum records but specific locality information is not included (Hibbard and Taylor 1960, Fig 8 page 112).

Regionally it is listed from Iowa (Stewart 2006), North Dakota (Cvancara 1983), and Wyoming (Beetle 1989). The Iowa listing is historical and is from a single unspecified location (Stewart 2006). Burch (1989) lists *P. umbilicatellus* in Colorado but recent surveys failed to find it or the congeneric *P. exacuous* (Harrold and Guralnick 2010).

Thiaridae – The Thiaridae are a tropical family common in the aquarium trade. Some members of this family, including *Melanoides tuberculatus*, are parthenogenic (Burch 1989).

Melanoides tuberculatus (Red–rimmed Melania). Synonym: *Melanoides tuberculata*. This species is not listed in historical studies and is non–indigenous to South Dakota. This tropical species is known from just one area of South Dakota, the warm water streams around the town of Hot Springs in the southern Black Hills (Anderson 2004). This species is also observed in Colorado where it is similarly confined to warm springs (Harrold and Guralnick 2010).

Valvatidae – Species within this family are considered common in northern North America (Clarke 1981, Jokinen 1992). The southern extent of their range is not well clarified but extends beyond South Dakota; *Valvata tricarinata* was observed in Nebraska (Gugler 1969).

Valvata tricarinata (three–ridged Valvata). Synonym: *Valvata winnebagoensis*. This species was observed in South Dakota by two researchers (Over 1915b, Henderson 1928). There are also records from two museums (ANS, MCZ). Specific records are from Brookings, Codington, Corson, Deuel, Hamlin, Marshall, Moody, and Roberts counties. Regionally it appears common with records from North Dakota (Cvancara 1983), Nebraska (Gugler 1969) and Iowa (Stewart 2006). This species is not listed in Wyoming but there are records of the congeneric *Valvata sincera* (Beetle 1989).

Viviparidae – The Vivipariade are large ovoviviparous snails common in the northeast U.S. Historically several species within this family are recorded in adjacent Nebraska (Aughey 1877); however, only the range of *Campeloma decisum* is considered to be within this region (Burch 1989).

Campeloma decisum (pointed campeloma). Synonym: Campeloma integrum. Records of this species are from Clay County and the Vermillion River (Over 1915b). The species is present in large lakes and slow-moving rivers and may be under sampled since it burrows in the substrate (Jokinen 1983). In North America it's considered common from South Dakota to the east coast (Burch 1989). Regional listings are from Iowa and Nebraska (Stewart 2006, Stephen 2015).

DISCUSSION

Historical records list 54 species names for freshwater gastropods within South Dakota. I reduce these nominal species to 25 valid species including one recent non–indigenous addition (Table 1). Four additional species appear to be likely South Dakota inhabitants, either historically or currently, though I could not find any records. Reducing the number of species from the historical list is primarily due to systematic revisions that lump species. Nineteen of the twenty–five species listed are pulmonates. This high pulmonate incidence is due to their ability to thrive in ephemeral wetlands throughout the state, which are particularly abundant in northeast of South Dakota.

Seventeen species appear abundant throughout South Dakota and the region based on the number of historical and regional listings. Common pulmonates are *Lymnaea bulimoides, Lymnaea caperata, Lymnaea elodes, Lymnaea humilis, Lymnaea stagnalis, Aplexa elongata, Physa gyrina, Physa acuta, Gyraulus deflectus, Gyraulus parvus, Helisoma anceps, Helisoma trivolvis,* and *Promenetus exacuous*. Common non–pulmonates are *Cincinnatia integra*, *Amnicola limosa*, and *Valvata tricarinata*.

Excluding the non–indigenous species *Melanoides tuberculatus*, Six species appear to have extremely limited distribution within South Dakota, all being observed in a single site and/or county; *Lymnaea catascopium*, *Lymnaea stagnalis*, *Aplexa elongata*, *Physa jennessi*, *Gyraulus crista*, and *Promenetus exacuous*. *Physa jennessi* and *Gyraulus crista* appear rare in the broader region.

Lymnaea catascopium, indeed the Lymnaiedae in general, is in a problematic taxonomic and systematic position. In South Dakota a single records accounts for both *Lymnaea catascopium* and *Lymnaea apicina*. *Lymnaea catascopium* might also be conspecific to *Lymnaea elodes* (Correa *et al.* 2010) and this is likely the case for *Lymnaea apicina* as well. Considering these three species I expect only *Lymnaea elodes* is actual present in South Dakota and the single record of *L. catascopium/apicina* is misidentified. This family is known for a large amount of phenotypic plasticity (Brown 1985, Wullschleger and Jokela 2002, Bronmark *et al*. 2011) and I suspect that detailed molecular analysis of this family will reveal far fewer valid species than currently recognized. *Lymnaea stagnalis,* a large conspicuous snail, appears to be near the southern extent of its range in South Dakota. In Nebraska there is a single record of this species from the northeastern part of the state (Aughey 1877). However, in North Dakota this snail accounts for 18 records in ten counties (Cvancara 1983) and six records of this species are listed for Wyoming (Beetle 1989). Historic records suggest this species was common in northern Iowa but has since been reduced in abundance (Stewart 2006). *Aplexa elongata* appears present in all adjacent states examined. In North Dakota there are records for 14 sites in 13 counties. There are 5 county records from Iowa (Stewart 2006), in Wyoming records are from 10 counties and Yellowstone National Park (Beetle 1989), and in Nebraska there are 18 records from 9 counties (Stephen 2015). It is apparent that this species is more abundant in the region than historic records from South Dakota suggest. *Physa jennessi* first listed in the region as *Physa skinneri* was not listed in earlier studies under that name since it was not described until 1954 (Taylor 1954). The species appears to be a synonym of *Physa jennessi* (Wethington and Lydeard 2007), which was described earlier by Dall (1919) but perhaps thought restricted to Alaska and Canada. In addition, this species is small and may be confused with young of other Physidae. *Gyraulus crista* appears rare within the region with records from just four sites within North Dakota (Cvancara 1983), two county records from Wyoming (Beetle 1989), and a single record from Nebraska (Taylor 1960). This species is more common to the north being abundant in central Canada (Prescott and Curteanu 2004). Regionally *Promenetus exacuous* appears more abundant than in South Dakota. Regional records include nine counties in Iowa (Stewart 2006), 17 counties in North Dakota (Cvancara 1983), and five specific county records from Nebraska with the suggestion that they are observed in “all streams” of the state (Aughey 1877). Wyoming also has two county records and the species is present within Yellowstone National Park (Beetle 1988).

I discovered no specific locality data for four species (*Ferrissia fragilis*, Gyraulus circumstriatus, *Pomatiopsis lapidaria*, and *Valvata sincera*) listed as being in South Dakota by a recent conservation review of the freshwater snails of North America (Johnson *et al.* 2013). Each of these species is listed regionally in at least some adjacent states and therefore the presence in South Dakota is probable. The limpets suffer from inadequate generic descriptions (Basch 1963), which led to historic confusion. This problematic area has recently been clarified with molecular data lumping most of the nominal species into just three species throughout the entire U.S. (Walther *et al*. 2006, Walther and Burch 2010). This modern clarification, however, doesn't help clear up unresolved historic names within South Dakota. There is a single listing of the genus *Ancylus* from MCZ and the unresolved species *Ferrissia tarda* from Roberts County – each of which could be *Ferrissia fragilis*. Records for *F. fragilis* are from each of the adjacent states of Kansas, Iowa, Colorado, and Nebraska (Leonard 1959, Stewart 2006, Harrold and Guralnick 2010, Stephen 2015), and thus it is likely present in South Dakota. Records of *Pomatiopsis lapidaria* are from Kansas, Iowa, and Nebraska (Leonard 1950, Stewart 2006, Stephen 2015) thus it also appears to be a likely South Dakota inhabitant. This species appears to require spring water habitats (Angelo *et al*. 2002) which limits its distribution. *Valvata sincera*, observed in the adjacent states of Wyoming, Colorado, and Nebraska (Beetle 1989, Harrold and Guralnick 2010, Stephen 2015) is another likely candidate for presence in South Dakota though it doesn't appear abundant in any of the adjacent states. In fact, three of these possible inhabitants of South Dakota, *Ferrissia fragilis*, *Pomatiopsis lapidaria*, and *Valvata sincera* are considered rare and are listed as species of conservation concern in some states (Smith 1984, KSDWPT 2009).

Based on historical records and regional literature at least four species of freshwater snail are rare in South Dakota and should be objects of local conservation concern. Three of these species appear more common further north. I speculate on the rarity of species, but the scarcity of historical records makes confident evaluation of species conservation status impossible. Current surveys are needed to evaluate the geographic range, species diversity hotspots, critical habitat, and overall conservation status of freshwater snail species within South Dakota.

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Table 3.1. Freshwater snail species historically listed in South Dakota. The second column shows 25 species of freshwater gastropods based on my current review. The far right column shows 34 species (species in a single row I treat as synonyms) listed for South Dakota by a recent conservation study of North American freshwater gastropods (Johnson *et al.* 2013).

Family	Species (Used in this Review)	# Records / # Counties (Historic Comments)	Species Listed in Conservation Study (Expected synonyms are combined in one row)
Amnicolidae	*Amnicola limosus*	3 / 3	*Amnicola limosus*
Hydrobiidae	*Cincinnatia integra*	3 / 2	*Cincinnatia integra*
Hydrobiidae	*Probythinella emarginata*	5 / 5	*Probythinella emarginata*
Lymnaeidae	*Lymnaea bulimoides*	8 / 3 (Over State)	*Galba bulimoides, G. cockerelli*
Lymnaeidae	*Lymnaea caperata*	17 / 8 (Common over	*Stagnicola caperata*
Lymnaeidae	*Lymnaea catascopium*	1 / 1	*Stagnicola apicina, Stagnicola catascopium*
Lymnaeidae	*Lymnaea elodes*	16 / 10 (Over State)	*Stagnicola elodes*
Lymnaeidae	*Lymnaea humilis*	30 / 10	*Galba dalli, G.modicella, G. obrussa, G. parva*
Lymnaeidae	*Lymnaea stagnalis*	1 / 1	*Lymnaea stagnalis*
Physidae	*Aplexa elongata*	1 / 1	*Aplexa elongata*
Physidae	*Physa acuta*	10 / 5 (Rare over State)	*Physella integra*
Physidae	*Physa jennessi*	1 / 1	*Physa skinneri*
Physidae	*Physa gyrina*	35 / 14 (Abundant over State)	*Physella gyrina, Physella virgata*
Planorbidae			*Ferrissia fragilis*
Planorbidae	*Ferrissia rivularis*	4 / 2	*Ferrissia rivularis*
Planorbidae			*Gyraulus circumstriatus*
Planorbidae	*Gyraulus crista*	1 / 1	

Planorbidae	*Gyraulus deflectus*	6 / 6	*Gyraulus deflectus*
Planorbidae	*Gyraulus parvus*	11 / 8	*Gyraulus parvus*
Planorbidae	*Helisoma anceps*	6 / 2 (Common over State)	*Helisoma anceps*
Planorbidae	*Helisoma trivolvis*	17 / 8 (Common over State)	*Planorbella trivolvis, P. subcrenata*
Planorbidae	*Planorbula armigera*	7 / 4	*Planorbula armigera, P. campestris*
Planorbidae	*Promenetus exacuous*	3 / 2	*Promenetus exacuous*
Planorbidae	*Promenetus umbilicatellus*	5 / 2	*Promenetus umbilicatellus*
Pomatiopsidae			*Pomatiopsis lapidaria*
Thiaridae	*Melanoides tuberculatus*	1 / 1	
Valvatidae			*Valvata sincera*
Valvatidae	*Valvata tricarinata*	8 / 8	*Valvata tricarinata*
Vivipariadae	*Campeloma decisum*	2 / 1	

Figure 3.1. Map of South Dakota’s 66 counties.

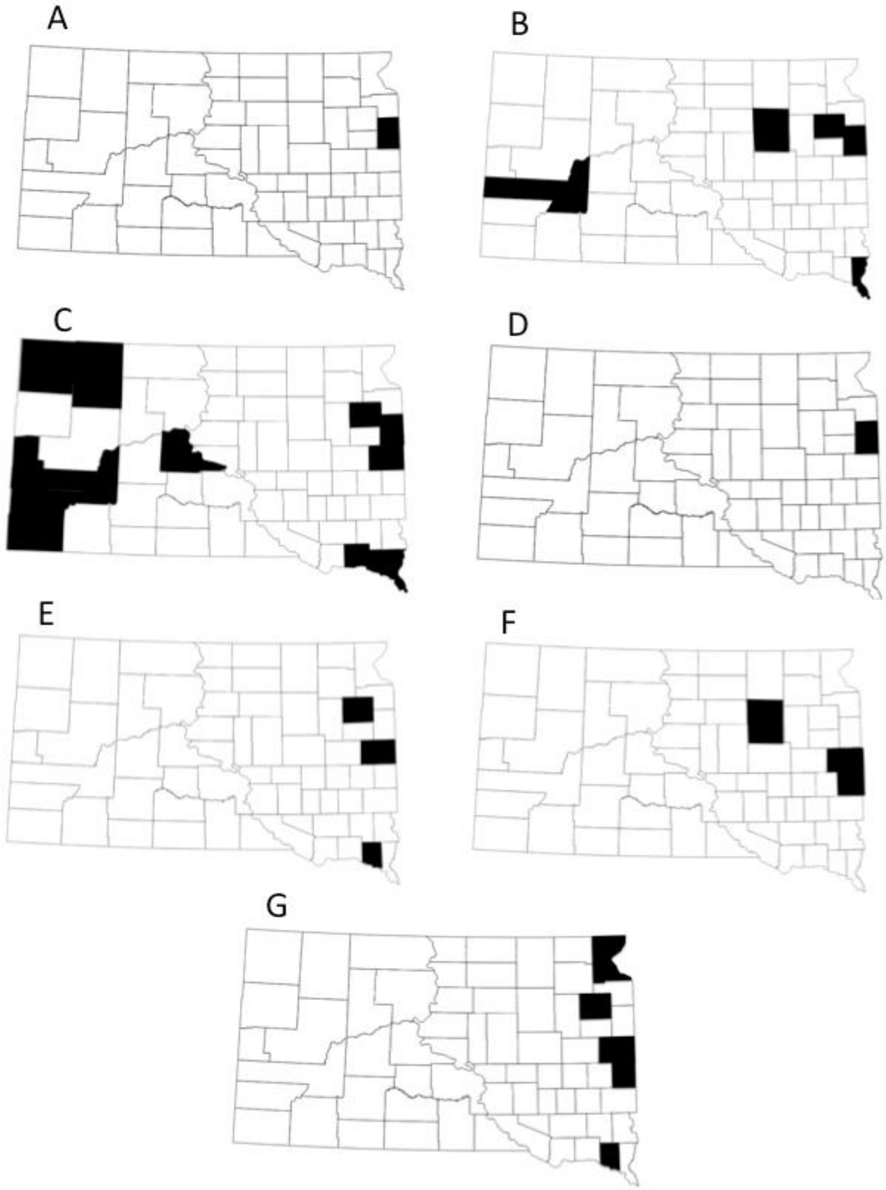

Figure 3.2. County level locations for (A) *Aplexa elongata*, (B) *Physa acuta*, (C) *Physa gyrina*, (D) *Physa jennessi*, (E) *Amnicola limosus*, (F) *Cincinnatia integra* and (G) *Probythinella emarginata*. Shading indicates counties where taxon has been observed in South Dakota.

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Figure 3.3. County level locations for (A) *Lymnaea bulimoides*, (B) *Lymnaea caperata*, (C) *Lymnaea catascopium*, (D) *Lymnaea elodes*, (E) *Lymnaea humilis*, and (F) *Lymnaea stagnalis*. Shading indicates counties where taxon has been observed in South Dakota.

Figure 3.4. County level locations for (A) *Ferrissia rivularis,* (B) *Gyraulus crista*, (C) *Gyraulus deflectus,* (D) *Gyraulus parvus*, (E) *Helisoma anceps,* and (F), *Helisoma trivolvis*. Shading indicates counties where taxon has been observed in South Dakota.

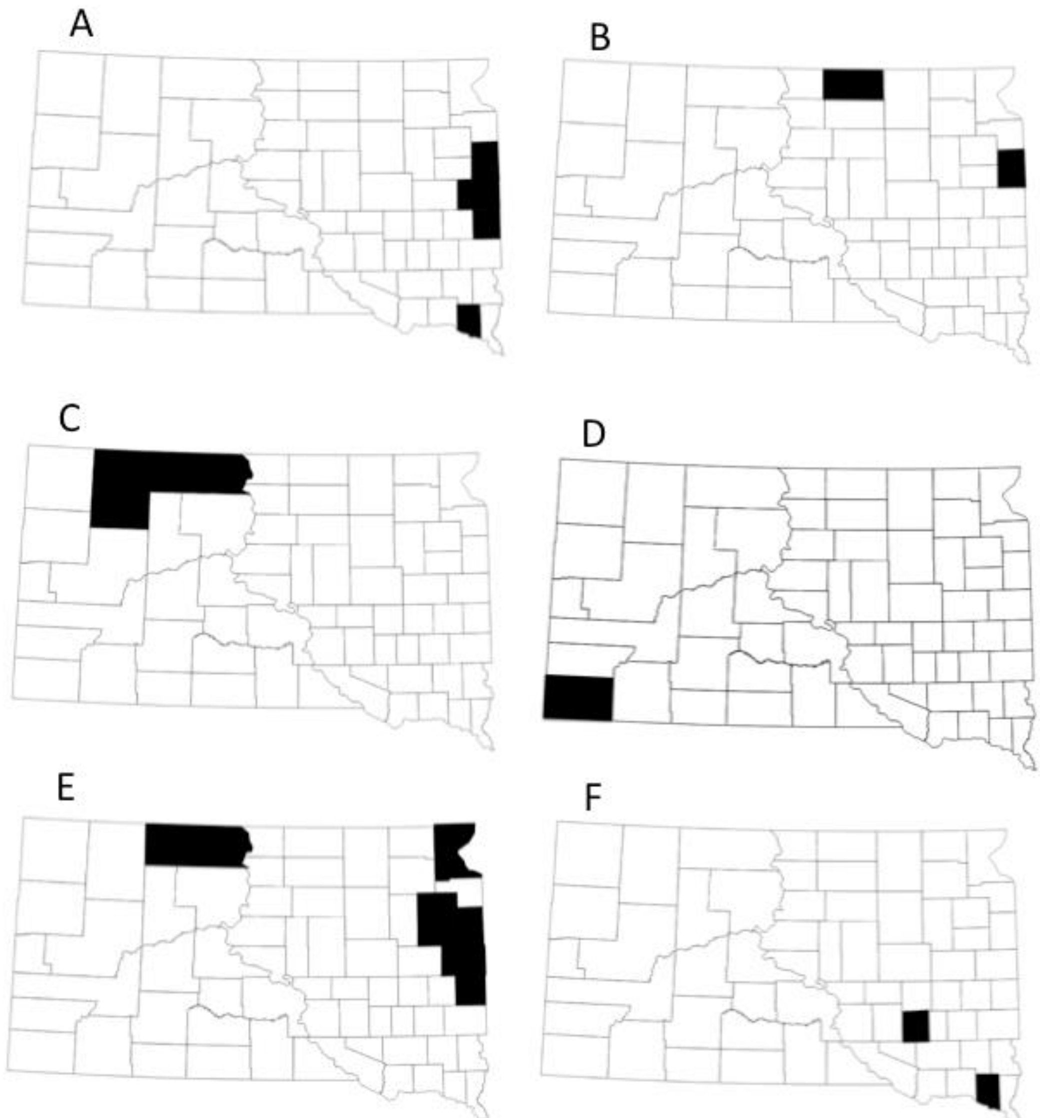

Figure 3.5. County level locations for (A) *Planorbula armigera*, (B) *Promenetus exacuous*, (C) *Promenetus umbilicatellus*, (D) *Melanoides* tuberculatus, (E) *Valvata tricarinata*, and (F) Campeloma *decisum*. Shading indicates counties where taxon has been observed in South Dakota.

CHAPTER 4: CURRENT GEOGRAPHIC DISTRIBUTION OF THE FRESHWATER GASTROPODS OF NEBRASKA AND SOUTH DAKOTA

Although important, the current geographic distribution and conservation status of freshwater snails in most of North America is desperately lacking. Most of the information about freshwater snail distribution in North America comes from the guide by Burch (1989). Valid up–to–date information for most states doesn't exist (Stewart and Dillon 2004, Stewart 2006), though some inventories have been completed, including New York and Connecticut (Jokinen 1992, Jokinen 1983) and several southeastern states (Dillon 2006). Knowledge of the distribution of freshwater gastropods in Nebraska and South Dakota come primarily from six historical studies (Tryon 1868, Aughey 1877, Walker 1906, Over 1915a, Over 1915b, Over 1928, Henderson 1927). Samuel Aughey, who lists the largest number of species for Nebraska (Aughey 1877), was the first "keeper of the cabinet" in what would become the University of Nebraska State Museum. Unfortunately, his work in other areas has been criticized as being unreliable (Bolick 1993, Hoke 2000). Questions remain as to the species historically present within Nebraska and South Dakota and different lists have been proposed (Johnson *et al.* 2013, Stephen 2015, Chapter 3). Given these uncertainties, the overall goals of this study are to inventory and provide analysis of the presence and distribution of freshwater snails within the prairie states of Nebraska and South Dakota.

<u>Distribution</u>

Most common freshwater gastropods are eurytrophic, although some exceptions have been identified: *Valvata sincera* appears to favor oligotrophic waters, while *Amnicola limosus*, *Lymnaea stagnalis*, and *Planorbula armigera* tend to be present under mesotrophic conditions (Clarke 1979). Freshwater snails have a broad tolerance for environmental perturbation and common species are present in environments altered by pollutants (Harman 1974). Available calcium, and related variables such as pH and alkalinity, is the one major limiting factor to freshwater snail presence (Dillon 2000). Some species have a limited tolerance to other chemical variables (Pip 1986). For example, *Lymnaea caperata* is absent in waters without sulphate, and *Lymnaea megasoma* seems to favor low phosphorus levels (Pip 1986). There appears to be some differentiation between presence/absence of species within the genus *Helisoma* when sulphate and dissolved organic matter are combined (Pip 1987). These apparent preferences in chemical variable may be attributable to broader habitat differences such as water body type. Most species are present throughout a wide range of chemical composition and with little connection to natural values of these substances (Pip 1986). Besides calcium and related variables, the distribution of freshwater snails may be influenced more by geographic features than chemical attributes but freshwater mollusk populations in general have a high level of ecological overlap (Dillon 2000).

Large–scale geographic factors are often used to describe species distributions. For example, species ranges are usually in terms of latitude, with northern or southern limits (Burch 1989). Smaller scale features such as the type of water body also play a role. *Ferrissia rivularis* and species within the family Pleuroceridae tend to be present in rivers where flowing water is present because of their need for high oxygen levels (Jokinen 1992). Species are also listed with apparent habitat restrictions or habitat preferences, for example, *Lymnaea elodes* is know as a ‘marsh’ snail, however it is also present in other water body types (Burch 1989). Species richness, but not the presence of a particular species, is influenced by pond area (Brönmark 1985, Jokinen 1987). Hydrologic conditions also play a role in species distribution with several species known to aestivate while other species cannot tolerate ephemeral conditions (Jokinen 1992, Dillon 2000). Competition may influence species assemblages among snails though (Pyron *et al*. 2009).

Regional analysis of freshwater snails could provide data enabling the evaluation of the conservation status of species. Threats to gastropod fauna including loss of habitat, competition by invasive species, such as the New Zealand mudsnail and Chinese mystery snail, and climate change. Non–marine mollusks collectively are thought to be one of the most threatened groups of organisms (Lydeard *et al.* 2004). Freshwater snails, specifically, head the list of endangered groups in some analyses (Allan and Castillo 2007, Lysne 2008). An assessment of the conservation status of freshwater snails of North America has been recently completed (Johnson *et al*. 2013). Johnson *et al*. (2013) is primarily based on historic data, as up–to–date sampling is absent for much of the region. Recent sampling is necessary to provide worthwhile conservation statuses for freshwater snail species.

First, I provide a list of freshwater snails for the region based on recent surveys. My second goal is the evaluation of species similarities across the region and the identification of habitats with high species richness. My third goal is to evaluate the distribution of specific freshwater snail species based on the geographic features, ecoregion, water body type, hydrologic condition, latitude and longitude. My final goal is to evaluate species assemblages for evidence of habitat-based presence/absence or competition among species or morphologic types.

METHODS

I surveyed freshwater snails throughout Nebraska and South Dakota between 2006 and 2014. In addition, sixty–eight samples from Nebraska, which were collected primarily by Steve Schianost from 2001 to 2010, were obtained from the Nebraska Game and Parks Commission. These specimens were collected by net and hand opportunistically. In this dataset, two water bodies overlapped with my own sample sites. When this was the case only information from my sample site was used in data analyses.

I primarily targeted areas of Nebraska and South Dakota that contained high densities of water bodies. I also choose sample sites from the historic literature; this included haphazard sampling in regions where specific locality data was not noted. Finally, I targeted waters of the region that were comparatively unique, such as streams fed by cold water and diverse water bodies within ecoregions not previously sampled.

In areas with a high density of water bodies I choose sample sites systematically each day while driving through the area. Every fifth water body was sampled after a random starting point. I altered this method when sampling within the Crescent Lake Wildlife Refuge and the Black Hills National Forest. In these areas I chose samples sites systematically from a map prior to entering the region as part of the requirement to sample these Federal lands. The Nebraska Game and Park Commission samples were collected opportunistically.

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. This method is expected to emphasize discovery of uncommon species compared to random sampling techniques.

Each sample site was visited once for a single sampling period.

Study Area

Nebraska and South Dakota contain nine level III EPA ecoregions (Chapman *et al.* 2001) and includes areas of high water body density, often referred to as wetland complexes, such as the lakes region of the Nebraska Sand Hills, the Rainwater Basin Plains (LaGrange *et al.* 2005), and the Wet Meadow and Marsh Plains in Nebraska. In South Dakota areas of high water body density include the Prairie Coteau, within the Northern Glaciated Plains (NGLP), part of the prairie potholes region, and the Middle Rockies region (MR) (Chapman *et al.* 2001). I sampled aquatic habitats within all nine level III ecoregions that encompass Nebraska and South Dakota (Chapman *et al.* 2001). The nine ecoregions are; Western Cornbelt Plains (WCBP), Central great Plains (CGP), the Northwest Great Plains (NWGrP), The Nebraska Sand Hill Plains (NSHP), Northwestern Glaciated Plains (NWGlP), Northern Glaciated Plains (NGLP), Middle Rockies (MR), Lake Agassiz Plain (LAP), and the Western Cornbelt Plains (WCBP). I had a single sample site from the Lake Agassiz Plain and information from this site was not used in any analysis herein. I obtained information from the U.S. Fish and Wildlife Service Wetlands Mapper (FWS 2013) for each sampled water body. This information included water body type, palustrine, lacustrine, riverine, or reservoir (lacustrine habitats that have been dammed or channelized); and hydrologic condition permanent, semi–permanent, or temporary. GPS coordinates were taken at the point of entry at each water body sampled.

Species Identification

Snail identification is problematic for some species. Individual snails from each sample site were first divided by gross morphological characteristics. I examined at least three individuals, when available, from each morphologic type using a hand lens or microscope to clarify species determinations made in the field. Unless a distinct morphological difference was apparent, I assumed all specimens from a gross morphologic group were the same species. Contrasting identification characteristics are used for species of Physidae by different authors (Wu 2004–2005, Dillon *et al*. 2006). I identified Physidae species as *Physa acuta* when a distinct shoulder was present and as *Physa gyrina* when whorls partially overlapped, this follows the characteristics used by Dillon *et al*. (2006). Externally *Physa acuta* and *Physa pomilia* are morphologically similar and I did not find any distinct difference that enabled me to identify any Physidae as *Physa pomilia*. Some specimens were sub–fossils, or were very small, making identification challenging. If I lacked confidence in identification to the species level, I recorded only the genera. Specimens categorized in this way were not used in statistical analysis.

Statistical Analysis

I determined species richness for each ecoregion, water body type, hydrologic conditions and region of high water body density. I used these values to calculate species similarity measures among ecoregions, among water body types, and among hydrologic conditions. I used Sørensen similarity index[1] to produce values between zero, no similarity, and one, total similarity.

[1]($C_S = 2 \text{ x } S_{1,2} / S_1 + S_2$)

Where $S_{1,2}$ is the number of shared species and S_1 and S_2 the number of total species at each site being compared. I correlation species richness to sampling effort. Species accumulation curves were rarefied to allow comparisons between geographic covariates with different sampling efforts and to combat possible correlation to sampling effort. Sites without snails were not used in these analyses.

I used Non–metric multidimensional scaling (NMS) using Bray–Curtis distances to visualize co–occurring species or species clusters via graphs. I also used NMS to check whether different morphological groups clustered together. Species were divided into 10 morphological groups 1. small–gilled (2 species), 2. large–gilled (1 species), 3. small–right handed (1 species), 4. medium–right handed (1 species), 5. large–right handed (2 species), 6. small–left handed (1 species), 7. large–left handed (3 species), 8. small–planorbid (3 species), 9. large planorbid (2 species), and 10. Limpet (1 species).

To test for competitive interactions between species pairs, species co-occurrence patterns were compared to simulated null model datasets (Gotelli and Graves 1996). Co–occurrence indices produced were the number of checkerboard species, checkerboard scores, and the unique number of species pairs. Only species present at more than five sample sites were included in these analyses.

I used R to perform data analyses (R Development Core Team 2012) with the exception of co–occurrence indices where I used EcoSim 7 (Gotelli and Entsminger 2001). I used the R package *vegan* for rarefaction and NMS cluster analysis. Graphical analysis was done in Graphpad Prism (2008).

RESULTS

Throughout Nebraska and South Dakota, I sampled 262 water bodies yielding 635 records of freshwater gastropods (Table 4.1). An approximate location of each sample site within each state is shown in Figures 1a and 1b. I observed no snails at eight sites. Sites where I observed snails contained from 1–6 species with an average of 2.4 species per site. I identified twenty freshwater snail species in eight families. Three records of the genus *Physa* were not determined to the species level. Of the nine level III EPA ecoregions sampled, one, the Lake Agassiz Plain (LAP), had only a single sample site; this sample site is not used in any analyses herein. All other ecoregions provided at least 11 sample sites with the greatest number of sites, 63, from the Northern Glaciate Plain (NGLP). There were 139 palustrine, 54 riverine, 44 reservoirs, and 25 lacustrine water bodies. The majority of sites, 121, were permanent, 89 were semi–permanent, and 52 were temporary water bodies. Of the eight sample sites where I did not find snails, three were reservoirs (Sutherland Reservoir, Lake Gardner, and Angostura Reservoir), one within each of the CGP, NWGrP, and MR ecoregions; three were palustrine sites within the NSHP ecoregion, and a fourth palustrine site was within the Northern Glaciated Plains (NGLP). A single riverine site within the CGP ecoregion was also absent of snails.

<u>Species Summation</u>

The most encountered species in this study was *Physa gyrina*, occuring at 160 sites. *Helisoma trivolvis*, occured at 110 sites, and was the next most common species encountered. Five species, the two most common and *Lymnaea caperata*, *Lymnaea elodes*, and *Gyraulus parvus*, were present in all eight ecoregions that had more than a single sample site.

I documented seven species at five or fewer sites. These species were *Amnicola limosus, Lymnaea bulimoides, Planorbula armigera, Ferrissia* rivularis, *Campeloma* *decisum* and the two non–indigenous species *Melanoides tuberculatus* and *Bellamya chinensis*. The two non–indigenous species have limited geographic distribution: *Melanoides tuberculatus* was observed exclusively in riverine systems that are fed by warm water springs in and around Hot Springs, South Dakota. *Bellamya chinensis* was observed in southeastern Nebraska within the WBCP ecoregion, only within reservoirs.

Besides the non–indigenous snails, several species also have limited geographic distribution. *Lymnaea bulimoides* was observed at three sites and only in Nebraska within the CGC ecoregion and then within the smaller level IV ecoregion of the Rainwater Basin Plains. *Lymnaea stagnalis* was observed at six sites all in the level IV ecoregion of the Prairie Coteau of South Dakota, which is within the level III ecoregion the Northern Glaciated Plains. Another species exclusive to South Dakota was *Amnicola limosus*, observed at only two sites in lacustrine environments in eastern South Dakota. *Ferrissia rivularis* was observed at just three sites but had a broader geographic distribution, with two sites in western South Dakota's MR ecoregion and one site in western Nebraska's WHP ecoregion. All sites for *F. rivularis* had moving water being either riverine or palustrine systems near areas of rapid water flow. *Campeloma decisum*, observed at five sites, was observed in the eastern portion of the region only within the WCBP primarily in riverine systems.

<u>Species Richness</u>

Species richness of snails within EPA level III ecoregions ranged from 6 to 14. The LAP ecoregion, where only one site was sampled, is excluded. Species richness, along with the number of sample sites and species records for each ecoregion are shown in Table 4.2. The regions with the greatest number of samples sites, NGLP with 63 sites, also had the greatest species richness of 14. The regions with the fewest samples sites, NWGrP and NWGlP, each with eleven sample sites, also had the lowest richness. Species richness is positively correlated to the number of sampling sites ($r = 0.86$; $p = 0.006$) among ecoregions.

Among water body types riverine systems have the lowest richness of 11 while palustrine wetlands had the highest richness of 15 (Table 4.3, top). Lacustrine and reservoirs each had a richness of 12. Lacustrine habitats had the fewest number of samples sites while palustrine sites had the greatest number. The correlation between species richness and water body type was not significant ($r = 0.88$; $p = 0.12$).

Species richness among hydrologic condition, (permanent, semi–permanent, and temporary) is highest in permanent water bodies (Table 4.3, bottom). Species richness is correlated to the number of sample sites, permanent sites made up the greatest number of sample sites, 119, and temporary sites were the least frequent with 49. Correlation between species richness and the number of sample sites was not significant ($r = 0.98$; $p = 0.12$).

Areas with a high density of water bodies show the most distinct correlation of species richness to number of sample sites (Table 4.4). The region with the greatest number of sample sites was the Prairie Coteau, which had the highest species richness of 13. This was followed by a richness of 8 from the Middle Rockies region. The seventeen sites within the Rainwater Basin revealed 7 species. The twelve sites within the sand hills lakes region had 6 species whereas the ten sites within sand hills east region (the Wet Meadow and Marsh Plain) held 7 species. A positive correlation between species richness and the number of sample sites was present ($r = 0.99$; $p = 0.001$).

The highest species similarities among all pairs of ecoregions were between the Western High Plains (WHP) and the non–adjacent Western Corn Belt Plains (WCBP) (0.80), and between the Nebraska Sand Hill Plain (NSHP) and the adjacent Western High Plains (WHP)(0.76) (Table 4.5, Figure 4.2). The Western High Plains (WHP) and the non–adjacent Western Corn Belt Plains (WCBP) and the WHP and Northwestern Great Plains (NWGrP) had similarly high similarities (both were 0.75). The non–adjacent Middle Rockies (MR) and WHP also display a high similarity value (0.74). The lowest similarities (0.47 to 0.50) were between the Northwestern Glaciated Plain and four other regions, the NSHP, the CGP, WCBP, and the WHP (Table 4.5, Figure 4.2).

Palustrine and lacustrine systems have the highest species similarity while lacustrine and riverine had the lowest among water body types (Table 6). Among hydrologic conditions permanent and semi–permanent sites show the greatest similarity, while the least similar are permanent compared to temporary sites (Table 7). Species similarities between areas of high wetland density showed relatively low values (Table 8). The highest value of 0.63 was between the Rain Water Basin (RWB) and the Sandhills lakes region (SHL). The lowest of 0.47 was between the SHL and the Middle Rockies (MR).

<u>Rarefaction</u>

Direct comparisons of species richness among regions, water body types or hydrologic conditions may be biased due to correlation between richness and sampling effort. To address this bias, I rarefied species accumulation curves to interpolate species richness to smaller sample sizes. These same species accumulation curves can be used to extrapolate to larger sample sizes or, in the absence of an asymptote, at least suggest whether more species are likely to be present (Colwell *et al*. 2012).

Rates of new species are estimated in species accumulations curves for each of four comparisons; ecoregions, areas of high water body density, water body types, and hydrologic condition (Figures 4.3 to 4.6). The Northern Glaciated Plains (NGLP), the Nebraska Sand Hill Plains (NSHP), the Central Great Plains (CGP) and the Western Cornbelt Plains (WCBP) each have at least 30 samples sites and at this sampling effort. The NGLP had the greatest richness followed by the NSHP, though standard deviations overlap (Figure 4.3a). The region with the lowest richness was the WCBP. The NGLP and the NSHP showed the most rapid species accumulation even at the lowest sampling efforts. The rarefied species accumulation curves for these four regions reached clear asymptotes before the point of comparison at 30 sample sites. (Figure 4.3a).

Among the four ecoregions with low sampling effort (MR, NWGlP, WHP, and NWGrP), each region has at least 11 sample sites (Figure 4.3b). The greatest richness among these regions was the MR, which has overlapping standard deviations with the NWGlP, and WHP, which, in turn have overlapping standard deviations with the lowest richness region the NWGrP. Among these four regions, the lines representing the NWGlP and NWGrP appear to have reached clear asymptotes while the MR and WHP do not (Figure 4.3b). This indicates that the MR and WHP regions are likely to hold more species than my sampling indicates.

Species accumulation curves among water body types sampled shows palustrine sites have highest species richness and riverine sites shows the lowest (Figure 4.3). Standard deviations overlap and thus the expectation is each water body type houses about 11 species. However, the curves for palustrine and riverine systems do not reach clear asymptotes and this indicates that more species may be present in these water body types.

Permanent water bodies show the greatest richness, while temporary water bodies show the lowest richness. Permanent water bodies are expected to have about 16 species while temporary should have about 10 species. The species accumulation curve for permanent water bodies does not show a clear asymptote and thus more species are likely to be present in permanent water bodies.

Among water body complexes, the Prairie Coteau (PC) of South Dakota has the greatest species richness of 10; the Middle Rockies (MR) region has the second highest estimated richness but standard deviations overlap (Figure 4.6). The Rainwater Basin and the western Sandhills (SH west) have overlapping standard deviations at the low end of estimated richness, 6 and 7 respectively. The eastern Sandhills (SH east), also known as the Wet Meadow and Marsh Plain, has an estimated richness of 8 species.

Sample Effort Correlation

Sampling effort and species richness is correlated (Table 4.9). Ecoregions and high–density region show significant correlations between sampling effort and species richness. Once values are rarefied these relationships are less pronounced (Table 4.9, column 3) though water body type and hydrologic condition show correlation between sampling effort and max richness asymptotes. When the same comparison is made using the lowest sampling effort among compared covariates, a significant correlation is shown only under hydrologic condition (Table 4.9, column 4), which showed no initial correlation.

Cluster Analysis

Species presence and morphologic type (morph) presence via non–metric Multidimensional scaling (NMS) shows few co–occurrence clusters (Figure 4.7, top). Species that cluster closely are *Lymnaea elodes* and *Promenetus exacuous*. A slightly broader cluster includes *Aplexa elongata*. These three species are known as marsh snails as is *G. parvus*. *Gyraulus parvus* was observed primarily in temporary marshes while the other three species were present in semi–permanent or permanent marshes. Two morph clusters are suggested by the graphical analysis of species–morphs, 1. Small gilled snails and large planorbids, and 2. Small planorbids, large right–handed snails, and small left–handed snails. These are marked with circles in Figure 4.7 (bottom).

A graph of the number of species vs. morphologic types suggests specific morphs are not necessarily observed together but different morphs are present together (Figure 4.8). This figure illustrates the number of occurrences of species and morphologic groups. Where the bars are equal it indicates that the same number of species as morphologic group are present. Sites with more than one species contain about the same number of species as morphologic types. This may indicate that competition among species morphs is one factor in determining species assemblages. Co–occurrence indices between pairs of species, also suggest competition influences species assemblages. Checkerboard species pairs: 102. Observed > Expected (P= 0.000001). Checkerboard (C–Score): 431 Observed > Expected (P= 0.03). Number of combinations: 104. Observed < Expected (P= 0.000001).

CONCLUSIONS

This benchmark survey of the freshwater snails of Nebraska and South Dakota provides the most up–to–date distribution records of freshwater snails for the region. I observed twenty species in sample sites spanning eight ecoregions, four water body types, and three hydrologic conditions. My records include two non–indigenous species. No species are endemic to the region.

The five most encountered species are also the most widespread species, being present in each of the eight major ecoregions sampled. These are *P. gyrina, H. trivolvis, L. elodes, G. parvus* and *L caperata*. Widespread species influence species similarity indexes between regions and habitats. This accounts for the high values (.80 – 0.75) between pairs of regions (Table 4.5, Figure 4.2). A standout for low similarity among regions is the NWGlP, which has the lowest similarity to other regions (Table 4.5, Figure 4.2). Riverine systems are least simliar in species to the other systems as are temporary water bodies so habitat does influence species presence. Among wetland complexes the Nebraska Sand Hills and Prairie Coteau are most similar in species makeup, likely due to the high number of palustrine wetlands within each, reinforcing the connection of habitat to species presence.

Species richness is correlated to sampling effort and attempts to mediate this were done via rarefaction of species accumulation curves. The highest rarefied richness values among the level III ecoregions are the Northern Glaciated Plains (NGLP) and the Nebraska Sand Hill Plains (NSHP). These regions contain high numbers of water bodies. The lowest richness is in Northwest Great Plains (NWGrP), which covers the majority of the western half of South Dakota. This region of the state has few water bodies and the lowest rainfall for the state (Chapman *et al*. 2001). Among specific regions of high water body density, the Prairie Coteau (PC) and the Middle Rockies

(MR) have the highest richness. This study suggests species richness is not greatly influenced by water body type though species accumulation curves suggest more species are present in palustrine and riverine systems. Among hydrologic conditions, permanent water bodies hold more species. Worldwide freshwater gastropods biodiversity is greatest among springs, large rivers, ancient oligotrophic lakes and moonsonal wetlands (Strong *et al.* 2008). Species richness in general may be more influenced by the diversity of the habitat itself (Brönmark, 1985) and most freshwater snail species appear to inhabit wide geographic ranges and water body types,

The reason for the complete absence of snails is apparent in six of the eight sites where no snails were detected. In the Sutherland reservoir in Nebraska, 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 discover them. Similar reasons explain the lack of snails in Angostura reservoir in South Dakota, the reservoir had recently been drained for maintenance and water levels were still rising when sampling was done. The three–palustrine sites within the NSHP that housed no snails were alkaline water bodies with pH values above 10. High pH values (above 10) was also the case in Lake Gardner in NW South Dakota, where no snails were observed. I observed no discrete reason for the absence of snails in the last two sites, one was a palustrine site in the MR region of South Dakota and one a riverine site, the Medicine Bow River, in the CGP in SW Nebraska,

<u>Species Conservation</u>

Seven species, *Bellamya chinensis* (5), *Campeloma decisum* (5), *Lymnaea bulimoides* (3), *Ferrissia rivularis* (3), *Amnicola limosus* (2), *Planorbula armigera* (2), *and Melanoides* *tuberculatus* (2) were observed at five of fewer (less than 2%) of sample sites. These species are rare and more susceptible to extinction These rare species should be the focus of conservation efforts, with the exception of the two non–indigenous species *Bellamya chinensis* and *Melanoides tuberculatus*. In addition, some of these species are limited in their distribution. The distribution of *L. bulimoides* is restricted; I observed them only within the Rainwater Basin Plain (RWB) a level IV EPA ecoregion (Bryce *et al.* 1998). *Lymnaea stagnalis*, though observed at more sample sites, was also limited geographically, observed within the level IV ecoregion of the Prairie Coteau, which is within the larger level III EPA ecoregion the Northern Glaciated Plain. Due to their limited geographic range, they are more susceptible tl extinction from changes in climate or habitat loss (Pimm *et al*. 2014). Though not limited to a single level IV EPA ecoregion, two species, *A. limosus* and *P. armigera*, were observed at just two sites. Another rare species, *F. rivularis,* was located at just three sites. This species requires high oxygen levels and inhabits well–aerated regions such as fast flowing streams (Jokinen 1992). This may limit its effective habitat, especially due to nutrient runoff from the agricultural dominated landscape of the region. Nutrient runoff causes eutrophication, which in turn causes depressed oxygen levels. This tiny snail may be easily overlooked, however, I discovered other species within this size range (*A. limosus*, *L. humilis, L. bulimoides*) throughout the region.

Species with limited distribution within South Dakota and Nebraska does not mean they are rare in North America. *Lymnaea Stagnalis* appears to be more abundant to the North and Northeast. It was the second most abundant Lymnaeid in a study of pulmonates, observed at 18% of the study sites, in Minnesota (Laursen 1989). *Lymnaea* *stagnalis* also appears common in and around the Great Lakes region (Clarke 1973, Burch 1989). *Lymnaea bulimoides*, observed only in the south-central part of Nebraska, may be more common to the South in Kansas (Leonard 1959). However, without current inventories, this cannot be established. *Campeloma decisum*, observed in two reservoirs and three riverine systems all within the WCBP ecoregion, is considered a river snail (Burch 1989), so reservoir habitation is somewhat surprising. However, with only five total records, conclusions on its distribution are difficult. In addition, this species is often considered to be under–sampled due to its deep–water habitat and burrowing behavior (Burch 1989). I concentrated on shallow water habitats during my sampling and thus I expect this species is more widespread.

Snail presence and biodiversity are influenced by many factors. Two factors of interest not evaluated here are predators and shoreline vegetation. Fathead minnows decrease invertebrate abundance, including snails (Zimmer *et al.* 2000). Shoreline vegetation and the diversity of macrophytes increase gastropod diversity (Brönmark 1985, Lewis and Magnuson 2000). Though neither predator presence nor the absence of vegetation has been tied to the presence or absence of specific species. Further studies comparing predator presence and shoreline vegetation diversity among water bodies may aid determination of species presence.

Species Assemblages

Analysis via non–metric multidimensional scaling shows some evidence of species clusters (Figure 6, top). The strongest cluster is *L. elodes* and *P. exacuous*. A larger cluster includes these two species and *A. elongata*. Is this co–occurrence due to the lack of competition or preference for similar habitats? All three of these species are described as marsh snails (Burch 1989), so habitat preference appears to be underlining this cluster.

Clusters of morphologically different species may reveal evidence of competition. Two morphological clusters are apparent in Figure 6 (bottom). 1. Small gilled snails and large planorbids, 2. Small planorbids, large right–handed snails and small left–handed snails. Beside these two clusters, there is no strong support for specific morphologic type clusters. The graph of the number of species and number of morphologic types is more informative (Figure 4.7). This simpler view connects the number of species and morphologic types suggesting specific morphs are not necessarily observed together but different morphs are observed together. Different morphs co–occur, perhaps due to competition between similar morphologic types. Significant checkerboard species scores; species C–scores, the number of checkerboard species, and the number of species combinations, show significant deviation from random (Null) models ($P<0.05$). Together these indicate competition is a factor influencing species assemblages among freshwater snails.

There is a wide literature debating the best way to evaluate evidence for competition since the checkerboard species idea was proposed (Diamond 1975, Connor and Simberloff 1979, Harvey *et al.* 1983, Gotelli and Graves 1996). If competition organizes species, then it is expected that different morphologic types form assemblages; the same specific species would not necessarily cluster each time. One idea that accounts for differences in species assemblages in different water bodies, is that the first of a (morphologic) type to reach the locale gets the advantage and thus tends to keep others of that type from establishing a hold (Pimm 1991). A confounding aspect of the reason for assemblages suggested here, is that food preferences and life history data are missing for many species of freshwater snail, and this data would do much to inform the competition hypothesis of assemblages.

<u>Non–indigenous species</u>

The non–indigenous species *Bellamya chinensis* and *Melanoides tuberculatus* were observed within distinct regions. For *B. chinensis* their greater incidence within the WCBP ecoregion may be explained by a correlation to anthropogenic factors such as population centers and water bodies with boat ramps due to their human aided mode of introduction (Solomon *et al.* 2010). However, similar to its confamiliar *C. decisum*, this is a deeper water species than most native snails, and thus its presence may go undetected. *Melanoides tuberculatus* is a tropical species, and its persistence in Fall River in South Dakota is due to the warm water springs that allow these snails to escape freezing winter temperatures.

SUMMARY

This is the first effort to assess the statewide presence of freshwater snails in Nebraska and South Dakota in many years. The most complete species list of Nebraska freshwater gastropods was published more than 100 years ago from data collected during the 1861 Hayden Survey of the West (Aughey 1877). Unfortunately, some of Samuel Aughey's work has been criticized as being unprecise (Bolick 1993, Hoke 2000) and errors may be present in his list of freshwater snails. South Dakota's most comprehensive study is from the early 1900's (Over 1915). Thus, the time was ripe to reassess gastropod species of the region.

It is expected that the current study did not realize the full extent of freshwater snail species biodiversity currently present throughout this region. One region stands out as holding the greatest freshwater gastropod diversity in the region, the Prairie Coteau (PC) within the Northern Glaciated Plain (NGLP) of South Dakota (Figures 5 and 2). Another area of high biodiversity is the Middle Rockies (MR) of South Dakota. Species accumulation curves of these regions also show no clear asymptote as does curves of permanent water bodies and palustrine habitats. Thus, further sampling in permanent marsh habitats within the Prairie Coteau and Middle Rockies regions of South Dakota is likely to increase the total number of species observed.

Several species are of conservation concern due to their being observed at few samples sites and/or having limited distribution across the region. I observed *Ferrissia rivularis* at very few sites and only in flowing waters. I observed *Lymnaea bulimoides* at few sites and only within the Rainwater Basin Plain, a level IV ecoregion. A similar pattern is shown with *L. stagnalis,* this species is observed at few sites and is limited to a smaller level IV ecoregion. *Amnicola limosus,* though not limited to a single level IV ecoregion, is present at just two sites. I do not include the deeper water snail *C. decisum* among my species of concern. Though this species is not very abundant in this study, I expect it to be more widespread throughout the region once deeper waters are sampled more effectively.

Most species are not connected to a specific geographic covariate; those species that are connected include, *L. caperata*, which I observed only in temporary wetlands, *Helisoma anceps*, present primarily in riverine systems, and *V. tricarinata* observed in reservoirs. In addition, latitudinal limitations appear in several species; for example *L. stagnalis* is tied to higher latitudes whereas *L. bulimoides* is observed only at lower latitudes within my study region.

Habitat and competition influence species presence. Checkerboard species scores and graphical analysis of species and morphs suggest competition has a strong influence on freshwater snail species assemblages in the aquatic habitats of the prairie region.

The study of freshwater snails should allow other fruitful avenues of research. Freshwater snail species ecophenotypes could be studied between ecoregions or water body types. The presence of two invasive snail species will contribute to studies on the influence of these snails on the local snail fauna and community ecology in general. In addition, freshwater gastropods are readymade for evolutionary studies; gene flow studies, for example, underscored by recent findings of snails surviving the guts of migratory birds (Van Leeuwen *et al.* 2011, Wada *et al.* 2011), could be conducted between areas of waterfowl migration.

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Table 4.1. Twenty freshwater gastropod species ranked by incidence collected during surveys throughout Nebraska and South Dakota. Non–indigenous species are marked with an asterisk. Three records of individuals in the genus *Physa* not identified to species are not included.

Species	Nebraska Records	South Dakota Records	Total
Physa gyrina	91	69	160
Helisoma trivolvis	71	39	110
Lymnaea elodes	39	60	99
Gyraulus parvus	28	40	68
Lymnaea caperata	23	15	38
Physa acuta	30	4	34
Aplexa elongata	13	19	32
Lymnaea humilis	15	4	19
Promenetus exacuous	——	16	16
Valvata tricarinata	5	10	15
Helisoma anceps	4	6	10
Physa jennessi	2	4	6
Lymnaea stagnalis	——	6	6
Campeloma decisum	3	2	5
*Bellamya chinensis**	5	——	5
Lymnaea bulimoides	3	——	3
Ferrissia rivularis	3	——	3
Planorbula armigera	1	1	2
Amnicola limosus	——	2	2
*Melanoides tuberculata**	——	2	2

Table 4.2. Alpha diversity of freshwater snails among the eight level III EPA ecoregions of Nebraska and South Dakota.

Level III Ecoregion	Species Richness (Alpha diversity)	Number of Sample Sites	Species Records
NW Glaciated Plains	6	11	31
NW Great Plains	7	11	28
Middle Rockies	8	12	23
Western High Plains	10	20	35
Central Great Plains	10	42	90
W. Corn Belt Plains	10	58	123
Nebraska Sand Hills Plains	11	47	102
N Glaciated Plains	14	63	203

Table 4.3. Alpha diversity of freshwater snails and sample information within water bodies of Nebraska and South Dakota.

Water body type or hydrologic condition	Species Richness (Alpha diversity)	Number of Sample Sites	Species Records
Riverine	11	53	122
Lacustrine	12	25	64
Reservoir	12	48	114
Palustrine	15	138	335
Temporary	13	53	125
Semi–permanent	16	90	218
Permanent	17	121	292

Table 4.4. Alpha diversity and sample information of water bodies in areas of high water body density within Nebraska and South Dakota.

Region	Species Richness (Alpha diversity)	# Sample Sites	Species Records
Sandhills – Lakes region (NE)	6	12	32
Sandhills –marsh plain (NE)	7	10	26
Rainwater Basin (NE)	7	17	38
Middle Rockies (SD)	8	12	22
Prairie Couteau (SD)	13	30	196

Table 4.5. Similarity Indexes for freshwater snails between pairs of EPA ecoregions South Dakota and Nebraska. The ecoregions are Central Great Plains (CGP), Northwestern Great Plain (MWGrP), Nebraska Sand Hill Plain (NSHP), Northwestern Glaciated Plain (NWGlP), Northern Glaciated Plain (NGLP), Middle Rockies (MR, and Western Corn Belt Plain (WCCBP).

Ecoregion	CGP	NWGrP	NSHP	NWGlP	NGLP	MR	WCBP
WHP	0.67	0.75	0.76	0.50	0.58	0.74	0.80
CGP		0.59	0.73	0.47	0.67	0.53	0.67
NWGrP			0.71	0.62	0.60	0.63	0.59
NSHP				0.47	0.72	0.60	0.67
NWGlP					0.60	0.53	0.50
NGLP						0.61	0.75
MR							0.63

Table 4.6. Similarity Indexes for freshwater snail species observed among water body types in South Dakota and Nebraska.

	Lacustrine	Reservoir	Riverine
Palustrine	0.81	0.74	0.62
Lacustrine		0.75	0.43
Reservoir			0.61

Table 4.7. Similarity Indexes for freshwater snail species observed among hydrologic conditions in Nebraska and South Dakota.

	Semi–permanent	Temporary
Permanent	0.85	0.73
Semi–permanent		0.76

Table 4.8. Similarity Indexes for freshwater snail species between regions with a high density of water bodies within Nebraska and South Dakota. The regions are Rainwater Basin Plains (RWB), Middle Rockies (MR), Wet Meadow and Marsh Plain (WMMP), Sand Hills Lakes Region (SHL), and Prairie Coteau (PC).

	MR	WMMP	SHL	PC
RWB	0.56	0.60	0.63	0.61
MR		0.56	0.47	0.57
WMMP			0.53	0.52
SHL				0.48

Table 4.9. Relationship between sampling effort and species richness in freshwater snails observed in Nebraska and South Dakota, four geographic indices shown. Columns are indices before any rarefaction (Column 2), after rarefaction at maximum richness (Column 3) and rarefied richness values at the comparisons point of lowest sampling effort (Last Column). Pearson Correlation Coefficients (r) and p–values are shown.

	Species richness	Rarefied species richness, maximum alpha (asymptote)	Rarefied species richness at the lowest sampling effort (# sample sites)
Ecoregion III	r = 0.86; P = 0.006	r = 0.73; P = 0.036	r = 0.89; P = 0.10 (11) r = 0.83; P = 0.16 (30)
Water body	r = 0.88; P = 0.126	r = 0.97; P = 0.02	r = 0.82; P = 0.17 (25)
Hydrologic Condition	r = 0.98; P = 0.124	r = 0.99; P = 0.04	r = 1.0; P = 0.004 (48)
High–density regions	r = 0.99; P = 0.001	r = 0.59; P = 0.29	r = 0.61; P = 0.26 (10)

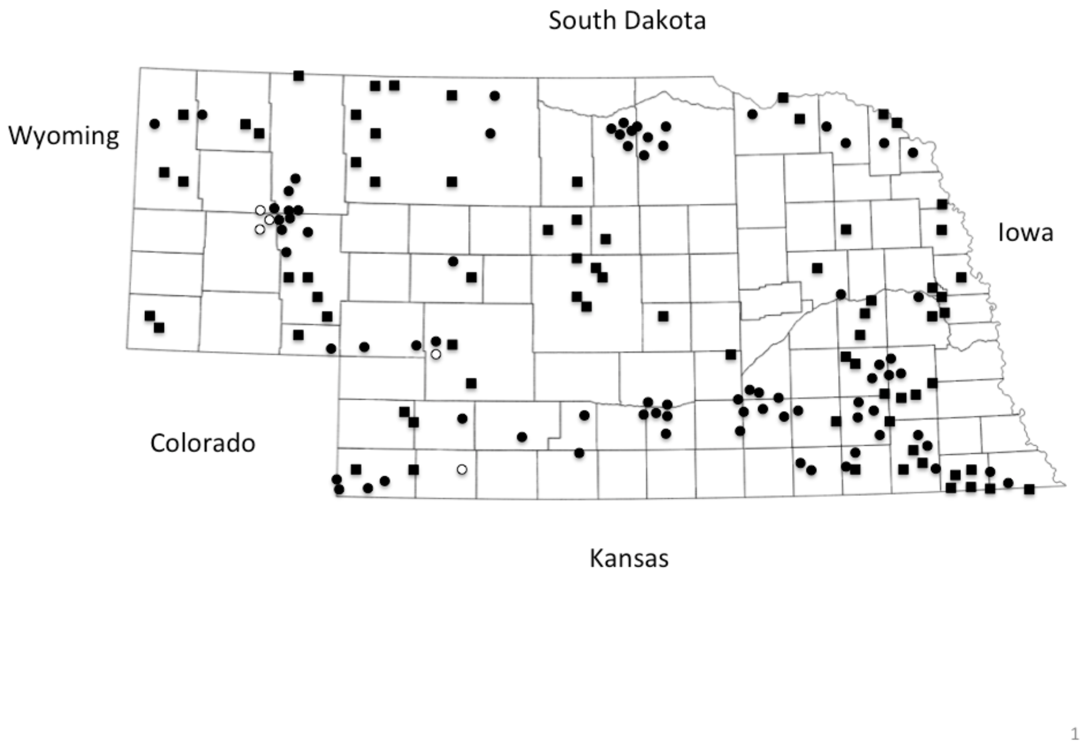

Figure 4.1a. Approximate locations of freshwater snail sample sites within Nebraska. Closed circles are my sample sites. Closed squares are sample sites from the Nebraska Game and Parks Commission. Open circles are sample sites where no snails were observed.

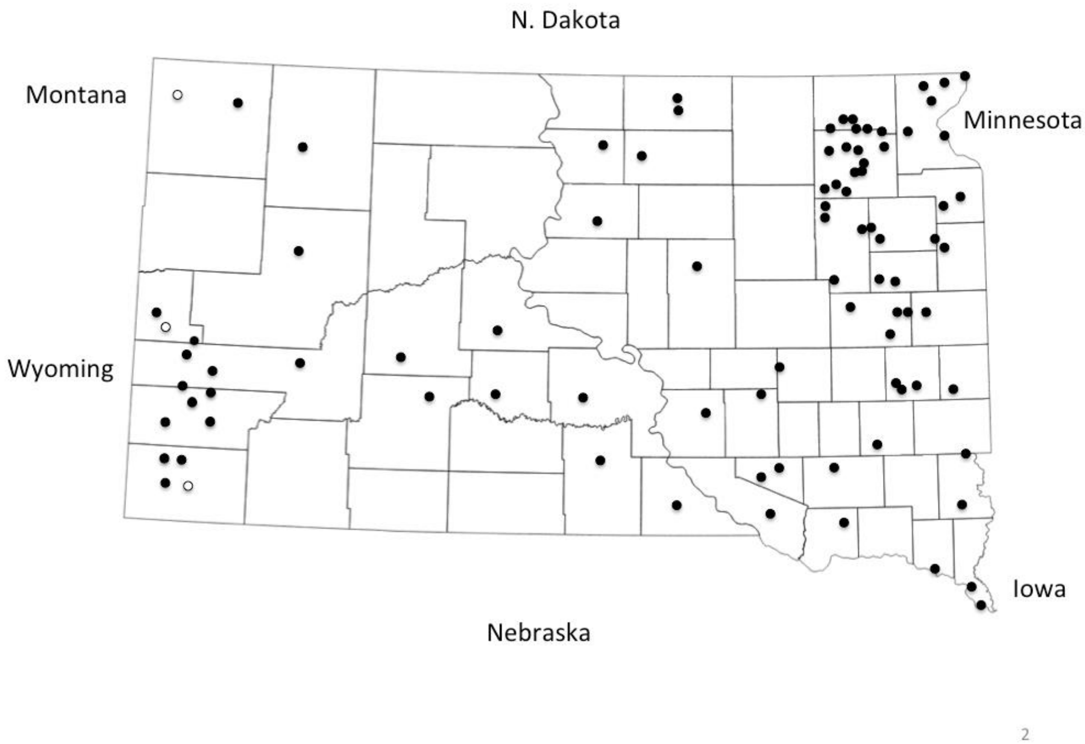

Figure 4.1b. Approximate locations of sites where freshwater snails were sampled within South Dakota. Open circles are samples sites where no snails were observed.

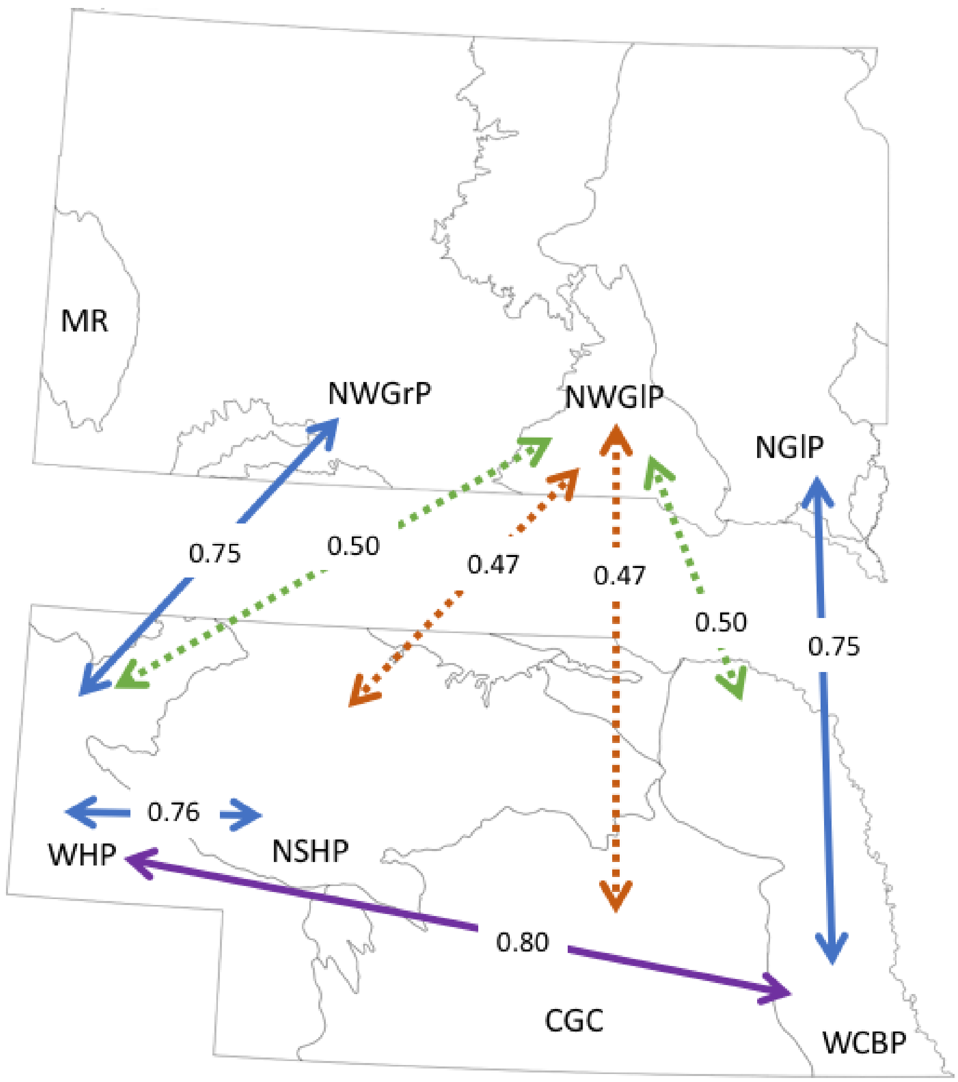

Figure 4.2. Freshwater snail species similarities using Sørensen index, among paired EPA ecoregions of Nebraska and South Dakota. The highest similarities are between the Western High Plains and the Western Corn Belt Plains, and the Western High Plains and Nebraska Sand Hill Plains, the Western High Plains and Northwestern Great Plains, and Western Corn Belt Plains and Northern Glaciated Plains, solid lines. Dotted lines are the lowest four similarities, these are pairs between each of the large ecoregions of Nebraska and the Northwestern Glaciated Plains of South Dakota, dotted lines. Similarity values are shown on the line connecting regions

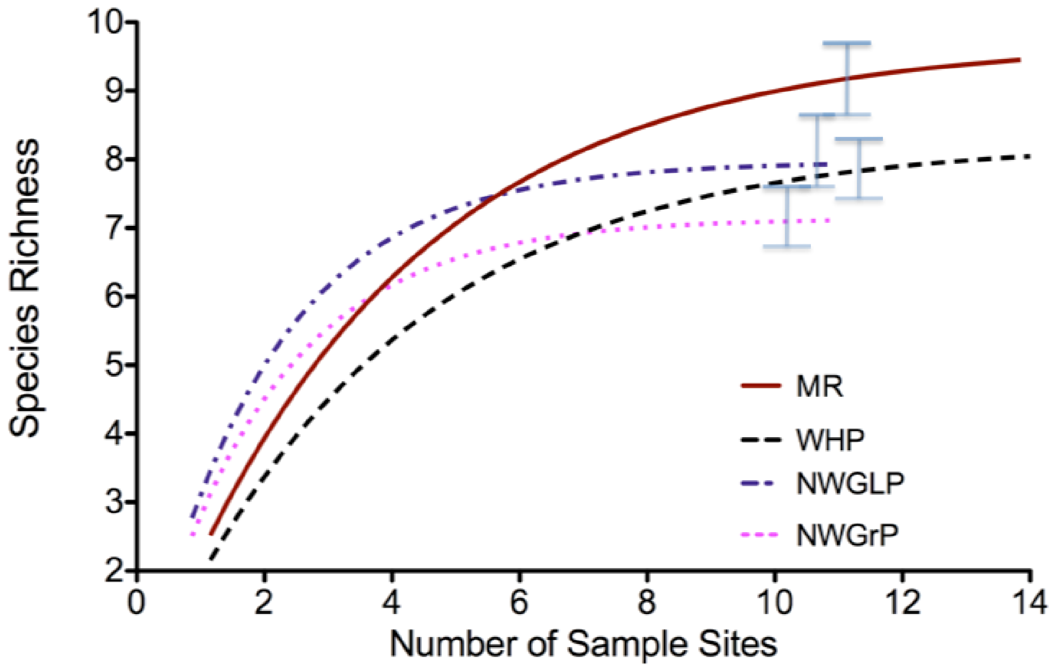

Figure 4.3a. Species accumulation curves showing species richness of freshwater snails among ecoregions within Nebraska and South Dakota. Standard deviations (offset to prevent overlap) are shown at the point where all regions have the same number of sample sites.

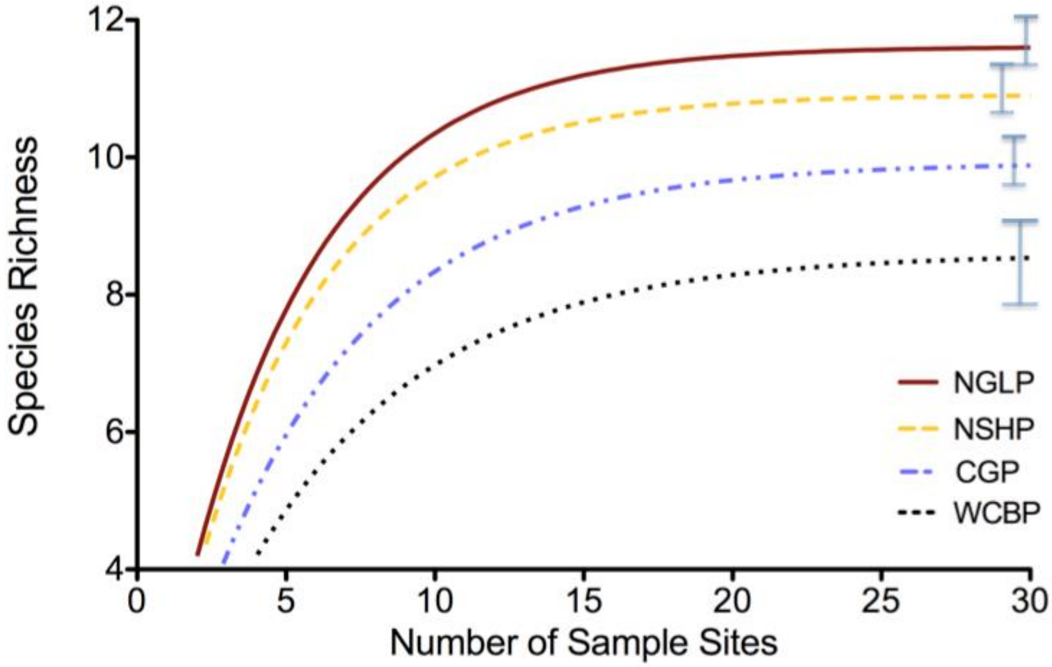

Figure 4.3b. Species accumulation curves showing species richness of freshwater snails among ecoregions within Nebraska and South Dakota. Standard deviations (offset to prevent overlap) are shown at the point where all regions have the same number of sample sites.

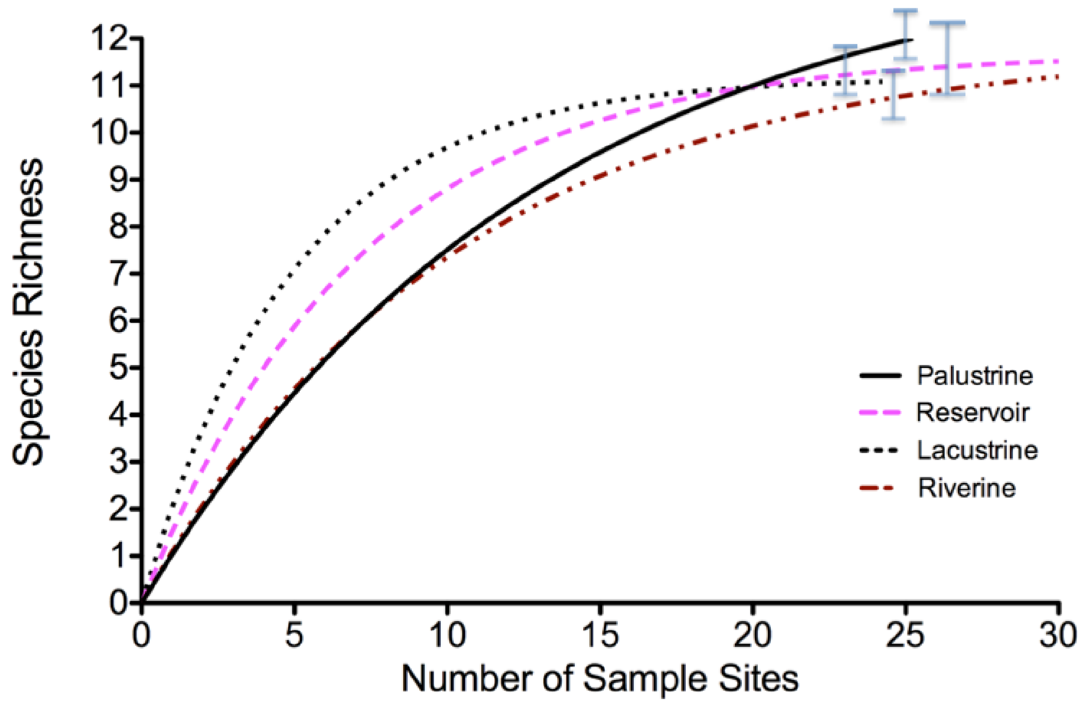

Figure 4.4. Species accumulation curves comparing species richness of freshwater snails among water body types within Nebraska and South Dakota. Standard deviations (offset to prevent overlap) are shown at the point where all water body types have the same number of sample sites.

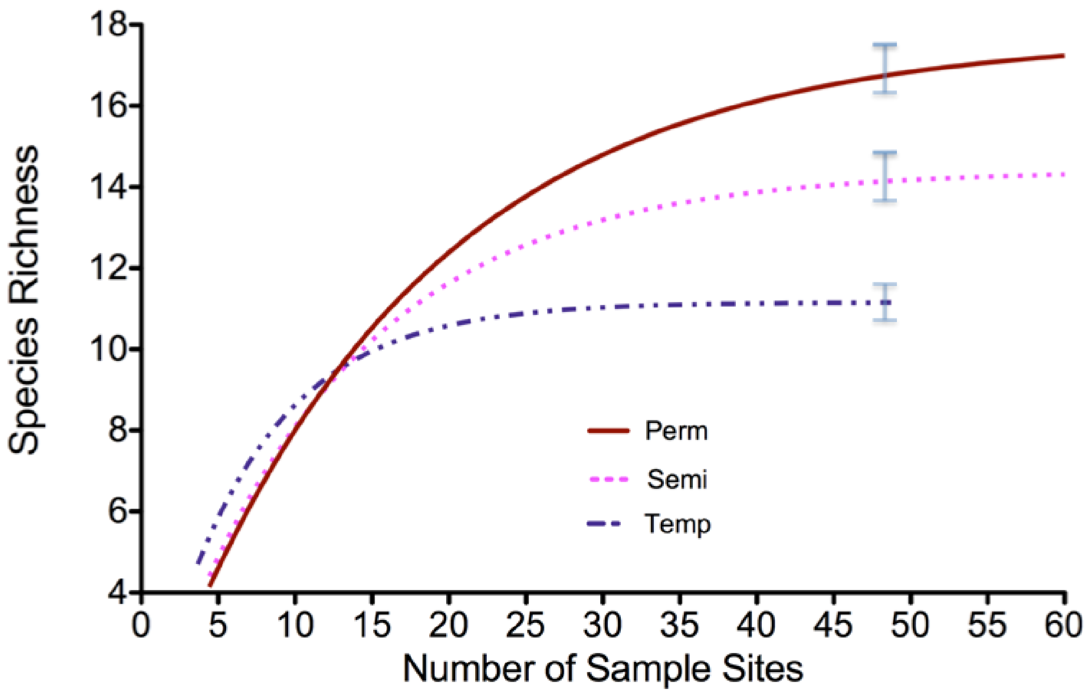

Figure 4.5. Species accumulation curves comparing species richness of freshwater snails among hydrologic conditions within Nebraska and South Dakota. Categories are, Perm (Permanent), Semi (Semi–permanent), Temp (temporary) based on U.S. Fish and Wildlife Service criteria. Standard deviations are shown at the point where all water body conditions have the same number of sample sites.

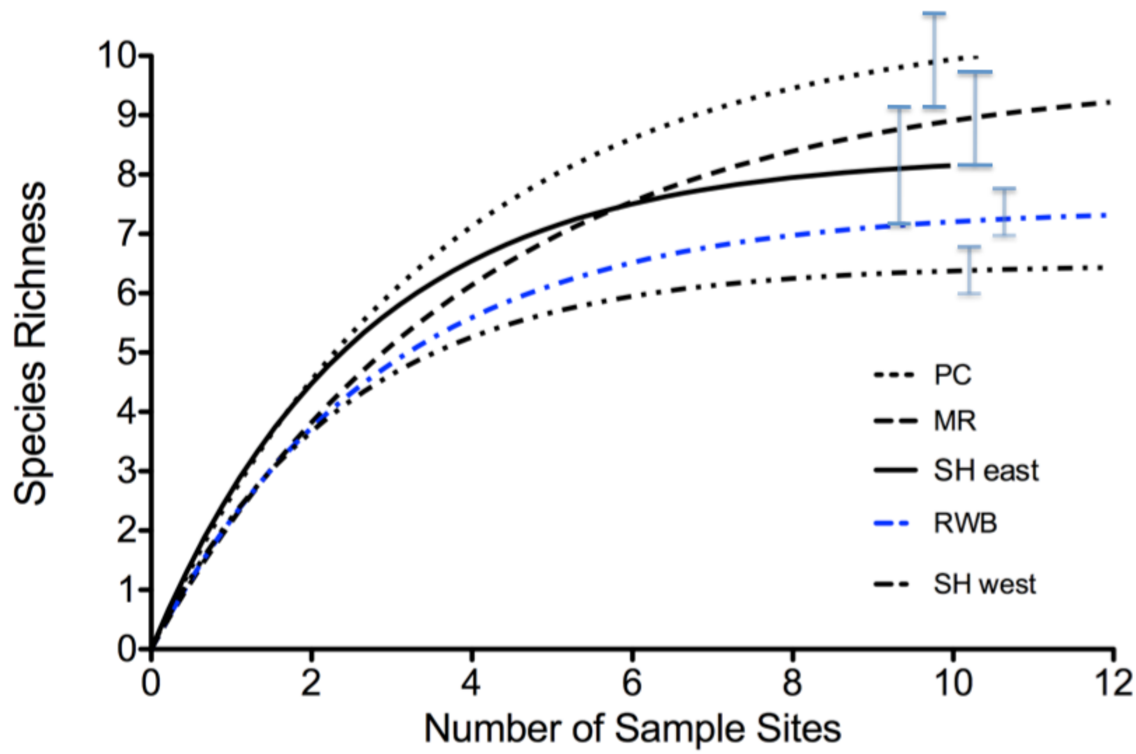

Figure 4.6. Species accumulation curves comparing species richness of freshwater snails among areas of high water body density within Nebraska and South Dakota. PC (Prairie Coteau), MR (Middle Rockies), SH east (Eastern Sand Hills lakes), SH west (Western Sand Hills lakes), RWB (Rainwater Basin). Standard deviations (offset to prevent overlap) are shown at the point where all regions have the same number of sample sites (10).

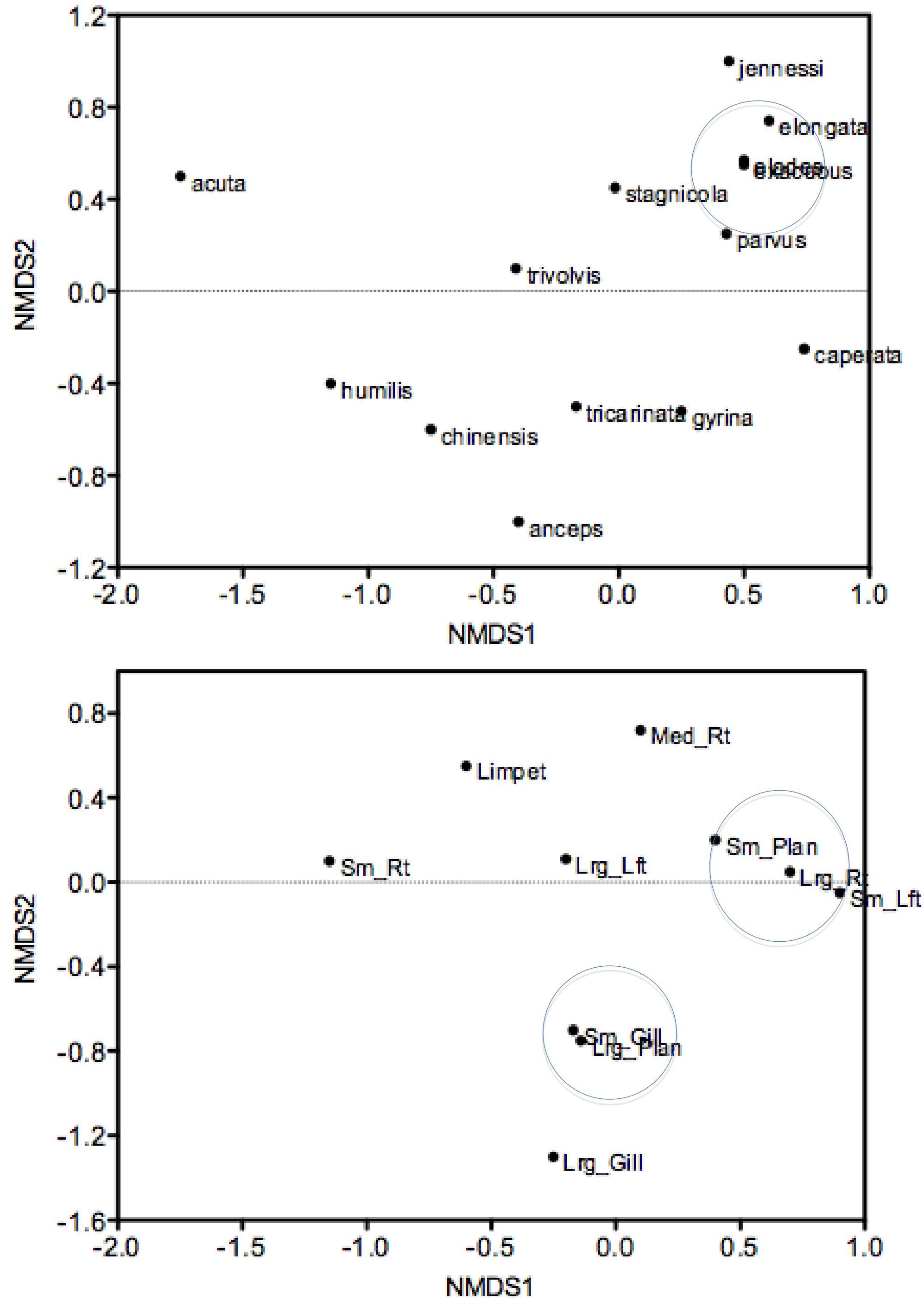

Figure 4.7. Cluster analysis of freshwater snail species (top) and morphologic type (bottom) using non–metric multidimensional scaling. Suggested clusters are shown with circles.

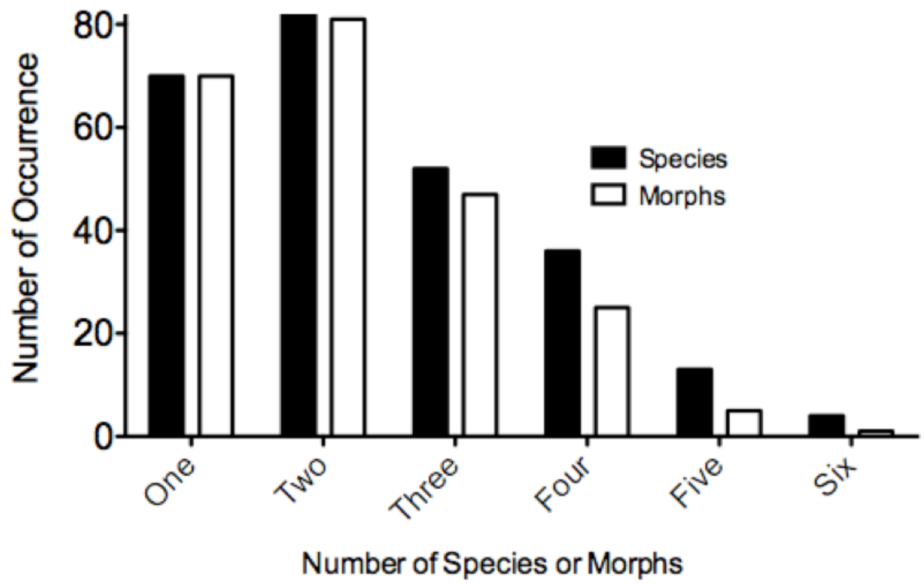

Figure 4.8. The number of occurrences (sites) where species and morphologic groups of freshwater snails observed in Nebraska and South Dakota. Dark bars are the number of species and Light bars indicate species–morphs. Where the bars are equal it indicates that the same number of species as morphologic groups are present. Sites with more than one species contain about the same number of species as morphologic types.

CHAPTER FIVE: CONSERVATION STATUS OF FRESHWATER GASTROPODS OF NEBRASKA AND SOUTH DAKOTA

Aquatic invertebrate fauna, including freshwater snails, have high extinction rates; a modeling of these rates 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). More than forty percent of freshwater snail species are negatively affected by human activity (Neves *et al.* 1997). 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). Many species of freshwater snails 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 United States (Régnier *et al*. 2009). These losses may already have altered ecosystems because loss of species alters ecosystem services such as the flow–through of energy and resilience (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). Not only does agriculture influence water quality but much of aquatic habitat loss is due to conversion to agriculture (USGS 1996). In Nebraska and South Dakota this loss includes about 35% of the original wetland area (USGS 1996).

Our current knowledge of freshwater snails places them in conservation danger;

athough worldwide the conservation status of the majority of gastropod taxa is unknown (Strong *et al*. 2008). Some areas of the world have yet to be even superficially surveyed (Lydeard *et al*. 2004). Hot spots of new species of freshwater snails are springs, large river systems, ancient lakes, and Monsoonal wetlands, primarily in Africa and Asia (Strong *et al*. 2008). However, even within North America, information on species presence, habitat use, and geographic distribution is absent for many freshwater species (Brown *et al*. 2008, Lysne *et al*. 2008). The need for surveys and distributional trends of freshwater gastropods is urgent (Lydeard *et al*. 2004, Wilson, 2005, Lysne *et al*. 2008).

Currently neither Nebraska nor South Dakota state agencies list any freshwater gastropods as species of conservation concern (NGPC 2013, SDGFP 2013). Since no comprehensive study of freshwater snails has ever been conducted in South Dakota or Nebraska this lack of listings of freshwater snail species is due to the absence of data not the absence of species in need. Though 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. In addition the study by Johnson *et al*. (2013) 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) and this remains the most powerful predictor of past extinctions (Pimm and Jenkins 2010). Abundance patterns of species often assume a competitive aspect based on resources within a community being divided among species. Models of the partitioning of species as a way to explain relative species abundance include the broken stick model (MacArthur 1957) and expansions of this model such as sequential niche fragmentation (Tokeshi 1990, 1993). Sequential niche fragmentation fits the relative abundance of species well (Gaston 1994). Using a pie analogy for the allocation of resources – the first species takes a big piece (approximately half of the pie), the next takes one half of the rest, the next one half of the rest and so on. The overall pattern of this model suggests a minimal structure of biological communities observed in freshwater snail communities (Dillon 2000). In this pattern of niche allocation a few species are in high abundance and the decreasing fraction of resources continue to be divided among the remaining species (Tokeshi 1990, 1993). In addition, geographic distribution, and habitat specificity are considerations when evaluting species rarity and thus conservation status (Rabinowitz 1981). The data collected and used here are species incidence, defined as the number of water bodies that house a specific species, and not species abundance, which is typically used (Gaston 1994, Dillon 2000).

By first using species incidence records and then taking into account geographic distribution, and habitat specificity, I evaluate species throughout the region and assign each a conservation status. I include information about species listed in historic studies but not observed in current surveys. Though low species incidence and other factors indicate imperiled species, searching for species not observed recently should also be a focus of conservation action.

Once a conservation status is established for each species I briefly explore the possible reason for species rarity. Considering the broken stick model mentioned above; what allows one species to take ½ of the stick while another is left with the short end? This difference between rare and common species is the subject of a review (Kunin and Gaston 1997). The authors outline eight potential differences between rare and common species: Rare species tend to 1. rely on self–fertilization or asexual reproduction, 2. put less energy into reproduction, 3. have low dispersal capabilities, 4. have low levels of genetic polymorphism, 5. have low competitive ability, 6. be a resource specialist, 7. be at higher trophic levels, and 8. have large body size. This is an extensive list and full evaluation is beyond the scope of this study. However, I explore known differences between the rarest snails and more common snails observed in my recent survey in regard to reproduction, feeding, and habitat. This analysis is brief due to the limited knowledge of life history and habitat use for many freshwater snail species (Brown *et al*. 2008, Lysne *et al*. 2008).

METHODS

The recent data used here comes from the same surveys from chapter 4 from South Dakota and Nebraska. Historical species lists are based on the literature and museum collections and follow the taxonomic changes from early chapter (Chapter 2, Chapter 3).

Species incidence (the number of sites that housed a specific species) was analyzed for both the two-state region, and each state separately, using a quartile model method (Gaston 1994, Dillon *et al.* 2013). The number of species was partitioned into quartiles with the two lowest incidence quartiles divided between the lowest 5% incidence, considered rank 1, and one step higher, the next lowest 20%, considered rank 2. Subsequent ranks; 3, 4, and 5, account for 25% each of the remaining species incidences. If species had the same incidence, for example, each observed at three sample sites, they were not separated into difference ranks even if that meant unequal quartiles.

Once ranked each species was evaluated on the breadth of distribution, specificity of habitat, and regional rarity.

Each species was placed into one of these seven conservation ranks, as developed by The Nature Conservancy and NatureServe (Master *et al*. 2009), as follows: SU – Unable to evaluate. (taxonomically suspect or historical identification error). SH – Possibly extirpated (historical listing only), S1 – Critically imperiled regionally because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation. S2 – Imperiled regionally because of rarity or factor(s) making it vulnerable. S3 – Uncommon in region. S4 – Apparently secure in region. S5 – Demonstrably secure in region.

RESULTS

The estimated conservation rank of each species of freshwater snail observed is based primarily on quartile ranking of species incidence, but includes geographic occurrence, habitat specificity, and the expected rarity in the broader region (Table 5.1)

I place three species, *Ferrissia rivularis*, *Amnicola limosus*, and *Planorbula armigera*, under the imperiled conservation status, S2, due to their low incidence. Based soley on incidence, no species is initially placed in S1 status. However, *Lymnaea bulimoides*, though within the same S2 category-based quartile intially, I move to S1 status (critically imperiled) due to its limited geographic range, limited habitat, and its rarity in the broader region.

By comparing historical species records to recent surveys, I place species missing entirely under the *possibly extirpated* category SH. This process is not straight forward as misidentified and unresolved species names appear common in the literature (Burch

1989). I place nine species into the SH category due to their historical presence within the prairie regions of Nebraska and South Dakota. These species are *Cincinnatia integra, Probythinella emarginata, Ferrissia fragilis, Gyraulus circumstriatus, Gyraulus crista, Gyraulus deflectus, Promenetus umbilicatellus, Pleurocera canaliculata,* and *Pomatiopsis lapidaria.* I place two species, *Lymnaea catascopium* and *Valvata sincera*, in the SU category due the likelihood of historical misidentification. More information on these 'missing' species is needed to clarify their historic presence in the region as well as determine if they might still be present. Below I list ecological and life history data, when known, of the eleven species designated with a conservation status of SH or SU. Snails are listed alphabetical by species under each family heading.

DISCUSSION

In evaluating the rarity of freshwater snails of the region I have encountered several difficulties. Simply listing as rare possibly extirpated, and therefore a conservation concern, those species that were recorded historically but were 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. In Nebraska particularly, I suspect several errors in historic listings from the work of Samuel Aughey (Aughey 1877). The accuracy of Samuel Aughey's work in other fields has faced criticism (Bolick 1993, Hoke 2000). Aughey's work on freshwater snails is the largest list of species from Nebraska (Aughey 1877). The first confounding principle can be alleviated by more survey data but the last two place doubt on the validity of some of the historical species and are more difficult to clarify.

Several methods may be useful in classifying the conservation status of freshwater snails, but the number of species only listed in historic records is troubling and beyond a quantitative method. I divide species into conservation status categories based on their quartile incidence (Figure 5.1, Table 5.1). Disregarding the non-indigenous species, four species initially fall into the imperiled category S2 using this method. No species initially falls into S1, the most critical status because species observed in the same number of sample sites are not divided between quartiles, three species have incidences of 2. I believe, however, *L. bulimoides* warrants movement from its initial S2 status into S1 due to its limited distribution, limited habitat, and regional rarity.

Within the two-state region I observed nine species that are only listed historically, status SH: *Cincinnatia integra, Probythinella emarginata, Ferrissia fragilis, Gyraulus circumstriatus, Promenetus umbilicatellus, Gyraulus crista, Gyraulus deflectus, Pleurocera canaliculata and Pomatiopsis lapidaria.* I rank two other species, *Lymnaea catascopium* and *Valvata sincera*, as SU, due to likely historical misidentifications. I list historical distribution and life history data for each historical species not observed in the current survey in Appendix D.

Though I provide a conservation rank to species not observed in my current surveys identification problems persist beyond those ranked as SU. I list *Lymnaea catascopium* rank SU because it has a single historical record I find doubtful, it may be confused with *Lymnaea elodes*. It also is likely that *Valvata sincera*, ranked as SU and recorded by the same author as *Lymnaea catascopium* (Aughey 1877), is misidentified. Other species share the possibility of identification errors: *Gyraulus parvus* is nearly morphologically identical to *Promenetus umbilicatellus* and *Gyraulus circumstriatus*.

These species are thus candidates for identification errors and perhaps are also conspecific (an area ripe for molecular phylogenetic analysis). Two other species, *Cincinnatia integra* and *Probythinella emarginata*, have known historical misidentifications (Hershler 1996) and therefore I find it likely that only one and not both of these species either were or are present in the region.

Due to morphological similarity I do not distinguish between *Physa pomilia* and *Physa acuta*. Thus, *Physa pomilia*, placed in Nebraska by Wu (2004 – 2005), does not appear anywhere on this list. This lack of confidence in identification extends to their historic presence in the region. Species with the Physidae are not the only snails where confusion or mixing species with synonyms is easy: Some freshwater snail species have morphological features that make them distinctive, however, particularly in the Lymnaeidae and Pleuroceridae, phenotypic plasticity is apparent (Brown 1985, Wullschleger and Jokela 2002, Bronmark *et al*. 2011, Dillon *et al.* 2013). Morphological differences may be due to differences in parasites, nutrients load, predators, and water quality/conditions. Very little work has been done in this regard within the Planorbidae but at least one work suggests that some of the features that differentiate ‘species’ within this family may be ecophenotypic as well (Spyra and Strezelec 2013).

I altered the conservation category of *Lymnaea bulimoides*, to S1, critically imperiled, as an indication of its susceptibility to extirpation due to its limited range and habitat, several other species may also be at greater risk than my categorization suggests. For example, *Ferrissia rivularis* is present in only one habitat, as is the even more abundant *Lymnaea caperata*. These species are more risk of extirpation due to their limited habitat (cold water streams or temporary palustrine habitats in this case).

Estimated conservation statuses for the broader region are higher for most species than local status. For example, *Campeloma decisum,* ranked S3, appears very abundant in the northeastern US (Burch 1989, Dillon *et al*. 2006). *Ferrissia rivularis* is also more common to the North and East of South Dakota and Nebraska (Burch 1989). *Amnicola limosus* and *P. armigera* are widespread species across North America (Burch 1989). Species at or near the edge of their range in Nebraska or South Dakota are expected to appear more imperiled locally than throughout the broader region. One species that does not appear more common in the broader region is *Lymnaea bulimoides.*

Vast differences in species incidence and the conservation concern for rare species sparks an interest in what makes a species rare. Rare species might be poor competitors, be specialist feeders, or have traits that require them to live in a specific restricted habitat, use asexual reproduction pathways, have lower reproductive effort, and disperse poorly (Kunin and Gaston 2012). Among freshwater snails' life history and other data are missing for many species, therefore comparing traits of common species to those of rare species is challenging. However, I have detailed any known trait for the five most common and five least common (excluding non–indigenous) species in my survey that might pertain to their rarity or commonness.

Among the five most common freshwater snails in this study *Physa gyrina,* is a habitat generalist, and in known to be 'weedy' producing many young quickly. *Helisoma trivolvis* is also 'weedy' but has more restricted habitat (Burch 1989). The next most common snail, *Lymnaea elodes,* has an apparent preference for marsh habitats but adjusts its size (morphology) and fecundity based on the quality of food resources; this flexibility might explain its broad distribution (Jokinen 1992). *Gyraulus parvus* is present in a broad set of habitats but has low fecundity, laying 1–7 eggs at a time (Jokinen 1992). However, development is fast and newly hatched eggs can produce their own young within 6 weeks (Krull 1931). The fifth most common species is *Lymnaea caperata*, which has the most restrictive habitat; temporary wetlands (Chapter 5). Given its broad distribution I expect it has high fecundity or another trait that promotes its high incidence, however life history data is absent for this species (Jokinen 1992).

The five least common species are, *Campeloma decisum*, *Ferrissia rivularis*, *Planorbula armigera*, *Amnicola limosus, and Lymnaea bulimoides*. *Campeloma decisum* is primarily observed in rivers and populations tend to have few males and are often parthenogenic (Jokinen 1992). *Ferrissia rivularis* and *Amnicola limosus* stand out as the least fecund, each species producing only a single egg at a time (Jokinen 1992, Dillon and Herman 2009). These snails also have gills and require waters with high oxygen levels (Jokinen 1992) greatly limiting their habitat within the prairie region. *Planorbula armigera* is primarily in temporary habitats and probably only produces eggs one per year (Jokinen 1992). No life history, or much data at all, exist for *Lymnaea bulimoides* and so I can only speculate why it is one of the rare snails in this study.

The most common species are expected to have high fecundity, be generalist feeders, and have few specific habitat requirements. On at least a cursory level these factors appear to be the reason for the common or rare appearance of freshwater snails in the region. However, this is far from an exhaustive look and many other factors of rare species such as genetic polymorphisms are beyond the scope of this conservation analysis. Even for aspects of snail biology that I have briefly evaluated there is missing data. Life history data are very limited for most freshwater snails, some species have no life history information at all and data for other species, when present, often comes from a single study and is therefore region specific.

I believe 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 (Jokinen 1992). Oxygen levels tend to be depleted by adjacent agriculture (EPA 2002). Another threat to local species is species invasions. Two freshwater snail species are recent invaders to the region. In Nebraska the Chinese mystery snail, *Bellamya chinensis*, is in reservoirs in the southeastern part of the state (Chaine *et al*. 2012). In South Dakota the red–rimmed melania, *Melanoides tuberculatus*, is in or near warm water springs around the town of Hot Springs, South Dakota (Anderson 2004). These and other invasive species may pose a threat to local fauna through competition, though the negative effects of these two species on local fauna appear low. *Melanoides tuberculata* is an unlikely to spread because it is a tropical species and only survives in a region of South Dakota due to the warm water springs. The Chinese mystery snail, *Bellamya chinensis*, appears primarily in reservoirs in Southeast Nebraska a habitat already greatly altered.

My analysis of conservation status of species of freshwater snail uses recent surveys from Nebraska and South Dakota from 265 samples sites and compares the results to historical listings for these states. The conservation status of species I list herein is tentative, but overall it appears that the number of imperiled species is high. The large number of species listed SH (possible extirpated, historical) underscores the need to collect more survey data that allows clarification of the conservation status of freshwater snails in the region. These surveys should include targeted searches for rare species as well as species listed historically but not observed by my recent surveys.

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Table 5.1. Evaluation of the conservation status of freshwater gastropod species observed throughout Nebraska and South Dakota. Column two shows rankings based on quartile analysis of species incidence with adjustments made for *L. bulimoides* based on criteria in columns 5 and 6. The least critical conservation status is S5, proceeding down to the most critical ranking of S1. Species listed historically but not discovered in recent surveys are included as rank SH. Historical species suspected of being misidentified are listed SU. Non–indigenous species are included but are not ranked.

Species	Conservation Status	Species Incidence	Quartile Rank	Limited Distribution (Single ecoregion)	Limited Habitat (Single type)
Physa gyrina	S5	160	5		
Helisoma trivolvis	S5	110	5		
Lymnaea elodes	S5	99	5		
Gyraulus parvus	S5	68	5		
Lymnaea caperata	S4	38	5		Yes
Physa acuta	S4	34	4		
Aplexa elongata	S4	32	4		Yes
Lymnaea humilis	S4	19	4		
Promenetus exacuous	S4	16	4		
Valvata tricarinata	S3	15	4		Yes
Helisoma anceps	S3	10	3		
Physa jennessi	S3	6	3		
Lymnaea stagnalis	S3	6	3	Yes	Yes
Campeloma decisum	S3	5	3		
Bellamya chinensis		5	3		
Ferrissia rivularis	S2	3	2		Yes
Planorbula armigera	S2	2	2		
Melanoides tuberculatus		2	2		
Amnicola limosus	S2	2	2		

Lymnaea bulimoides	S1	3	2	Yes	Yes
Cincinnatia integra	SH	0	NA		
Ferrissia fragilis	SH	0	NA		
Gyraulus crista	SH	0	NA		
Gyraulus deflectus	SH	0	NA		
Pleurocera canaliculata	SH	0	NA		
Pomatiopsis lapidaria	SH	0	NA		
Gyraulus circumstriatus	SH	0	NA		
Promenetus umbilicatellus	SH	0	NA		
Probythinella emarginata	SH	0	NA		
Lymnaea catascopium	SU	0	NA		
Valvata sincera	SU	0	NA		

CHAPTER 6: SUMMARY

An understanding of the presence and distribution of freshwater snails across North America suffers from many limitations. There is a large amount of historical and current systematic and taxonomic confusion in regard to freshwater snail species. Throughout North America we also suffer from a lack of recent species inventories. Nebraska and South Dakota are not exceptions to this lack of information; this region has little current inventory data and also has a few historical studies. In addition, these historical studies often include only a cursory amount of locality data. This dissertation summarizes the historical data and improves upon the deficient information regarding the presence and geographic distribution of freshwater gastropods in Nebraska and South Dakota. Finally, I provide a list of species and conservation status of each.

Chapters 2 and 3 examine the historical inventories of the states of Nebraska (Chapter 2) and South Dakota (Chapter 3). Analyses of these historical data reduce the snail species expected to be present in each state by using systematic studies that reveal synonymies and by comparing regional data that exposes misidentifications. My analysis reduces the species historically within Nebraska from 81 to 30. In South Dakota I reduce the nominal species from 51 to 24. The reduction of species names is not clear cut and further analysis is warranted. Due to phenotypic plasticity and lack of detailed species descriptions among snails I expect future work to further reduce the species deemed valid for this region.

Chapter 4 presents a current survey of the freshwater snails within the two–state region. This survey provides a baseline data set of species presence for Nebraska and

South Dakota. This data set is used to analyze species distribution based on geographic covariates across the two states. Snail biodiversity among geographic regions is revealed, as is the species similarity among regions. Areas of high species biodiversity are the Prairie Coteau and Middle Rockies regions of South Dakota. Among the ecoregions of Nebraska species composition is similar and western Nebraska is similar in species composition to the western South Dakota Middle Rockies region. The regions that have the most divergent species composition are the Northern Glaciated Plains (eastern South Dakota) and the Northwest Great Plains (western South Dakota). The presence of some species is linked to habitat and/or geographic condition though most species have a broad distribution. Species with limited habitat or distribution include *L. caperata*, confined to temporary wetlands, *L. bulimoides*, confined to The Rainwater Basin area, and *L. stagnalis* confined to the Prairie Coteau region. Checkerboard species analysis aids in explaining species presence. This analysis suggests that competition is at least partially responsible for species assemblages and distribution of freshwater snails.

In chapter 5 I utilize the modified historical lists and the current survey data to scrutinize each species within Nebraska and South Dakota and suggest a conservation status for each. Method to determine conservation status differ, I use a modification of an analyses suggested by others following the quartile distribution of the incidence of freshwater snails (Gaston 1994, Dillon *et al*. 2006). Using this method, three species, *Amnicola limosus*, *Planorbula armigera*, and *Ferrissia rivularis* are classified as imperiled, status S2. *Lymnaea bulimoides* is the only species I list under the most critical local conservation status category, S1, critically imperiled. Though slightly more abundant than two species I add *L. bulimoides* to the S1 category due to its limited geographic distribution and limited habitat. *Lymnaea bulimoides* also appears rare in the broader region. I list nine species as SH (historically present but possible extinct). This large group of ‘missing’ snails is of concern and more survey data is needed to evaluate whether species have gone extinct from this region.

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APPENDIX A: HISTORICAL RECORDS OF FRESHWATER GASTROPODS OF NEBRASKA

X = Name not valid, unknown synonymy, ** = valid species but out of range, ID error.

Recognized Species: Following the taxonomy of Dillon *et al.* 2006.	Literature Listing	Reference	County	Locality
Family Amnicolidae				
Amnicola limosus	*Amnicola limosa*	Aughey 1877	Cedar	Bow River
Amnicola limosus	*Amnicola limosa*	Aughey 1877		Elkhorn River
Amnicola limosus	*Amnicola limosa*	Aughey 1877		Blue River
Amnicola limosus	*Amnicola limosa*	Aughey 1877		Nemaha River
Amnicola limosus	*Amnicola limosa*	Walker 1906	Lancaster	City of Lincoln
***Lyogyrus granum*	*Amnicola granum*	Aughey 1877		Nemaha River
Family Hydrobiidae				
Cincinnatia integra	*Amnicola cincinnatiensis*	Tyron 1868	Douglas	City of Omaha
Probythinella emarginata	*Probythinella lacustris*	Hibbard and Taylor 1960	Lancaster	Salt Creek in Lincoln
Family Lymnaeidae				
***Acella haldemani*	*Limnaea gracilis*	Aughey 1877	Cedar	Bow River
***Acella haldemani*	*Limnaea gracilis*	Aughey 1877		Elkhorn River
Lymnaea bulimoides	*Stagnicola bulimoides techella*	Hibbard and Taylor 1960	Furnas	Medicine Creek
Lymnaea bulimoides	*Stagnicola cockerelli*	Hibbard and Taylor 1960	Keith	Ogallala
Lymnaea bulimoides	*Lymnaea bulimoides*	MCZ, date UNK	Keith	Ogallala
Lymnaea bulimoides	*Lymnaea cokerelli*	MCZ, date UNK	Keith	Ogallala
Lymnaea caperata	*Lymnaea caperata*	Walker 1906	Cuming	
Lymnaea caperata	*Lymnaea caperata*	Walker 1906	Cherry	
Lymnaea caperata	*Stagnicola caperata*	Taylor 1960	Cherry	Sand Hills pond
Lymnaea caperata	*Stagnicola caperata*	Taylor 1960	Cherry	Creek near Simeon
Lymnaea caperata	*Stagnicola caperata*	Taylor 1960	Cherry	Lake off US 83 20 m. n. of Thedford
Lymnaea caperata	*Stagnicola caperata*	Taylor 1960	Brown	Drainage ditch (temp) sec 34 NW corner
Lymnaea caperata	*Stagnicola caperata*	Taylor 1960	Rock	Drainage ditch HW 20 2.8 m. e. of Bassett
Lymnaea caperata	*Lymnaea caperata smithsonia*	MCZ, date UNK	Platte	Platte City
Lymnaea catascopium	*Limnaea catascopium*	Aughey 1877	Cedar	Bow River
Lymnaea catascopium	*Limnaea emarginata*	Aughey 1877	Cedar	Bow River
Lymnaea catascopium	*Limnaea pallida*	Aughey 1877	Cedar	Bow River
Lymnaea catascopium	*Lymnaea sumassi*	MCZ, date UNK		Platte City (Platte Center in Platte county or North Platte?)
*** Lymnaea columella*	*Limnaea columella*	Aughey 1877	Dakota	Smith's Lake
Lymnaea elodes	*Stagnicola elodes*	Freeman and Perkins 1992	Lincoln	Platte River
Lymnaea elodes	*Stagnicola elodes*	Freeman and Perkins 1992	Hall	Platte River backwaters
Lymnaea elodes	*Stagnicola elodes*	Freeman and Perkins 1992	Sarpy	Platte River backwaters
Lymnaea elodes	*Stagnicola elodes*	Freeman and Perkins 1997	Cherry	Niobrara River
Lymnaea elodes	*Stagnicola elodes*	Freeman and Perkins 1997	Dawes	Niobrara River
Lymnaea elodes	*Limnaea elodes*	MCZ, date UNK		Grindstone Creek
Lymnaea elodes	*Limnaea reflexa*	MCZ, date UNK	Nemaha	Whiskey Run
Lymnaea elodes	*Limnaea reflexa*	Aughey 1877	Dakota	Smith's Lake
Lymnaea elodes	*Limnaea reflexa*	Walker 1906	Buffalo	
Lymnaea elodes	*Lymnaea reflexa*	Walker 1906	Sarpy	. City of Bellevue
Lymnaea elodes	*Limnaea umbrosa*	Aughey 1877	Dakota	Smith's Lake
Lymnaea elodes	*Limnaea palustris*	Aughey 1877		All streams of Nebraska
Lymnaea elodes	*Lymnaea palustris*	Walker 1906	Cherry	
Lymnaea elodes	*Lymnaea palustris elodes*	MCZ, date UNK		Agate
Lymnaea elodes	*Stagnicola palustris*	Taylor 1960	Cherry	Sand Hills pond
Lymnaea elodes	*Stagnicola palustris*	Taylor 1960	Cherry	Creek near Simeon
Lymnaea elodes	*Stagnicola palustris*	Taylor 1960	Cherry	Red Deer Lake
Lymnaea elodes	*Stagnicola palustris*	Taylor 1960	Cherry	Lake, west side HW 83, 20 m. n. of Thedford
Lymnaea elodes	*Stagnicola palustris*	Taylor 1960	Rock	Drainage ditch 20 m. w. of Bassettt
Lymnaea elodes	*Limnaea haydeni*	Aughey 1877	Cedar	Bow River
Lymnaea elodes	*Limnaea haydeni*	Aughey 1877		Elkhorn River
Lymnaea elodes	*Limnaea haydeni*	Aughey 1877		Elk Creek
Lymnaea elodes	*Limnaea haydeni*	Aughey 1877		Logan Creek
Lymnaea humilis	*Limnaea humilis*	Aughey 1877		All streams of Nebraska
Lymnaea humilis	*Fossaria obrussa*	Taylor 1960	Brown	Calamus River
Lymnaea humilis	*Fossaria obrussa*	Taylor 1960	Cherry	Fort Niobrara NWR
Lymnaea humilis	*Fossaria obrussa*	Taylor 1960	Hooker	Middle Loup, 5 m. e. of Mullen
Lymnaea humilis	*Fossaria obrussa*	Taylor 1960	Thomas	Middle Loup, Thedford
Lymnaea humilis	*Fossaria dalli*	Taylor 1960	Cherry	Niobrara River, .5 m. w. of HW 20
Lymnaea humilis	*Fossaria dalli*	Taylor 1960	Brown	Seepage along stream 2.5 m. s. of Long Pine
Lymnaea humilis	*Fossaria obrussa*	Freeman and Perkins 1997	Knox Co.	Niobrara River
Lymnaea humilis	*Fossaria obrussa*	Freeman and Perkins 1997	Sioux	Niobrara River
Lymnaea humilis	*Limnaea desidiosa*	Aughey 1877		All streams of Nebraska.
Lymnaea humilis	*Lymnaea desidiosa*	Walker 1906	Sioux	Monroe Canyon
Lymnaea humilis	*Lymnaea desidiosa*	MCZ, date UNK	Butler	David City
X	*Limnaea kirkladiana*	Aughey 1877	Cedar	Bow River
Lymnaea stagnalis	*Limnaea stagnalis*	Aughey 1877	Dakota	Smith's Lake
Family Physidae				
Aplexa elongata	*Aplexa hypnorum*	Aughey 1877		All quiet waters of the state.

Aplexa elongata	*Bulinus hypnorum*	Walker 1906	Cherry	
Aplexa elongata	*Bulinus distortus*	Aughey 1877		Nemaha River
Aplexa elongata	*Aplexa hypnorum*	Taylor 1960	Brown	Ditch sec 34, nw corner
Aplexa elongata	*Aplexa hypnorum*	Taylor 1960	Rock	Ditch along HW 20 2.8 m. w. Bassett
Aplexa elongata	*Aplexa hypnorum*	MCZ, date UNK	Lincoln	North Platte, along Great Pacific RR line
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Arthur	Three Mile Lake.
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Arthur	3 m N. of Arthur.
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Cherry	Middle Loup HW 61.
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Cherry	Middle Loup n. of Hyannis
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Garden	n. of Oshkosh.
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Grant	Creek 2.5 m S. of Collins Lake.
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Grant	HW 61 13 m s of NE 2 and 61
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Keith	Ditch HW 61 18.5 m S. of Arthur
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Rock	Ditch HW 20 8.5 m w of Newport
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Rock	Spring Valley Park, HW 20
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Sheridan	Roadside seep, HW 2 at Crescent Lake Entrance
Aplexa elongata	*Aplexa elongata*	Wu 2004–2005	Sheridan	Creek at HW 250, 3.2 m S of Rushville
Physa acuta	*Physa heterostropha*	Aughey 1877		All the streams of Nebraska
Physa acuta	*Physa anatina*	Walker 1906	Lincoln	Three co. two rivers, listed below, no specifc sites:
Physa acuta	*Physa anatina*	Walker 1906	Washington	Roca
Physa acuta	*Physa anatina*	Walker 1906		Platte river
Physa acuta	*Physa anatina*	Walker 1906	Cedar	
Physa acuta	*Physa anatina*	Taylor 1960	Cherry	Fort Niobrara NWR pond
Physa acuta	*Physa anatina*	Taylor 1960	Brown	Stream 2.5 m. s. of Long Pine near Long Pine Creek
Physa acuta	*Physa anatina*	Taylor 1960	Brown	Calamus Rriver
Physa acuta	*Physa anatina*	Taylor 1960	Thomas	Middle Loup 1 m. e. Seneca
Physa acuta	*Physa heterostropha*	Wu 2004–2005	Cherry	Roadside ditch HW 61, 9.1 m. n. Hyannis
Physa acuta	*Physa heterostropha*	Wu 2004–2005	Cherry	Gordan Creek HW 61, 31.5 m. s. Merriman
Physa acuta	*Physa heterostropha*	Wu 2004–2005	Logan	South Loup River at HW 70, Arnold
Physa acuta	*Physa heterostropha*	Wu 2004–2005	Rock	North fork Elk River at HW 137
Physa acuta	*Physa acuta*	Wu 2004–2005	Dakota	Tributary of Elk Creek at HW 20 and HW 12 Junction
Physa acuta	*Physa acuta*	Wu 2004–2005	Gage	Big Indian Creek at HW 77
Physa acuta	*Physa acuta*	Wu 2004–2005	Greeley	North Loup River at HW 22
Physa acuta	*Physa acuta*	Wu 2004–2005	Keith	Pond at S. Platte River HW 61
Physa acuta	*Physa acuta*	Wu 2004–2005	Nemaha	Little Nemaha River at HW 67
Physa acuta	*Physa acuta*	Wu 2004–2005	Pawnee	North fork of Big Nemaha River at HW 4
Physa acuta	*Physa anatina*	Wu 2004–2005	Dixon	Tributary of Lime Creek at HW 12
Physa acuta	*Physa anatina*	Wu 2004–2005	Dundy	N. Fork Republican River at fork
Physa acuta	*Physa anatina*	Wu 2004–2005	Dundy	Indian Creek at HW 61
Physa acuta	*Physa anatina*	Wu 2004–2005	Grant	Dismal River 12.2 m. e. & 17.9 m. n. of Arthur
Physa acuta	*Physa anatina*	Wu 2004–2005	Lincoln	Puddle, N. Platte River at Airport Rd.
Physa acuta	*Physa anatina*	Wu 2004–2005	Lincoln	Red Willow Creek at HW 23
Physa acuta	*Physa anatina*	Wu 2004–2005	Lincoln	Creek at Interstate 80 3.5 m. w. of exit 164 (Hersey exit)
Physa acuta	*Physa anatina*	Wu 2004–2005	Nuckoll	Little Blue River at HW 14
Physa acuta	*Physa anatina*	Wu 2004–2005	Richardson	N. Fork Big Nemaha River at HW 75
Physa acuta	*Physa anatina*	MCZ, date UNK	Sioux	Pond at Agate
Physa acuta	*Physa halei*	Wu 2004–2005	Custer	Arnold Lake at Arnold Lake State Rec Area
Physa acuta	*Physa halei*	Wu 2004–2005	Dundy	Rock Creek Rec Area
Physa acuta	*Physa halei*	Wu 2004–2005	Garden	Coldwater Creek at HW 26, 0.6 m. e. of Lisco
Physa acuta	*Physa virgata*	Wu 2004–2005	Cheyenne	Lodegpole Creek at HW 19
Physa acuta	*Physa virgata*	Wu 2004–2005	Custer	Arnold Lake at Arnold Lake State Rec Area
Physa acuta	*Physa virgata*	Wu 2004–2005	Rock	North Fork Elk River at HW 137
Physa acuta	*Physa whitei*	Wu 2004–2005	Cherry	Fort Niobrara NWR, spirng pond
Physa acuta	*Physa whitei*	Wu 2004–2005	Cherry	Snake River at HW 61 23.9 m. s. Merriman
Physa gyrina	*Physa gyrina*	Aughey 1877		All tributaries of Missouri River
Physa gyrina	*Physa gyrina*	Walker 1906	Sarpy	City of Bellevue
Physa gyrina	*Physa gyrina*	Taylor 1960	Cherry	Sand Hills pond
Physa gyrina	*Physa gyrina*	Taylor 1960	Cherry	Creek near Simeon
Physa gyrina	*Physa gyrina*	Taylor 1960	Cherry	Creek at junction of Alkali Lake rd and dirt road 4.4 m. w. of HW 83
Physa gyrina	*Physa gyrina*	Taylor 1960	Cherry	Red Deer Lake
Physa gyrina	*Physa gyrina*	Taylor 1960	Cherry	Lake along HW 83 20 m. n. of Thedford
Physa gyrina	*Physa gyrina*	Taylor 1960	Brown	Ditch Sec 10, nw corner
Physa gyrina	*Physa gyrina*	Taylor 1960	Rock	Ditch along HW 20 2.8 m. w. of Thedford
Physa gyrina	*Physa gyrina*	Taylor 1960	Rock	Ditch along HW 20 2.3 m. e. of Thedford
Physa gyrina	*Physa gyrina*	Taylor 1960	Thomas	Stock tank along HW 2 1 m. w. of Seneca

Physa gyrina	*Physa gyrina*	Taylor 1960	Thomas	Middle Loup River Thedford
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1992	Sarpy	Platte River, Sarpy Co.
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1992	Platte	Loup River, Platte Co.
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1992	Platte/Merrick	Silver Creek, Platte Co./Merrick Co.
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1992	Hall	Platte River, Hall Co.
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1992	Buffalo	Platte River, Gibbon
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1992	Hall	Platte River, Hall Co.
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1992	Hall / Buffalo	Platte River, Hall and Buffalo Co.
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1992	Gosper / Phelps	Platte River, Border Gosper and Phelps Co.
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1992	Lincoln	State Fish Hatchery, Lincoln Co..
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1992	Lincoln	N. Platte River, Lincoln Co.
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Dawes	Box Butte Reservoir
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Dawes	Box Butte Reservoir, 2nd site
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Cherry	Cornell Dam
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Cherry	Powderhorn Valley
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Cherry	Merriman
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Sheridan	Rushville NW
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Sioux	Agate
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Dawes	Box Butte Reservoir, 3rd site
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Knox	Verdigre, NE
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Holt	Naper SW
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Boyd	Monowi
Physa gyrina	*Physella gyrina*	Freeman and Perkins 1997	Knox	Niobrara
Physa gyrina	*Physa gouldi*	Wu 2004–2005	Brown	Calamus River at HW 7
Physa gyrina	*Physa gouldi*	Wu 2004–2005	Brown	Willow Creek at HW 183
Physa gyrina	*Physa gouldi*	Wu 2004–2005	Burt	Ditch HW 75 2.9 m s. Tekamah
Physa gyrina	*Physa gouldi*	Wu 2004–2005	Cherry	Roadside Pond, HW 83 145 m n. Thedford
Physa gyrina	*Physa gouldi*	Wu 2004–2005	Cherry	Minnechaduza Creek HW 83 12 m n. Valetine
Physa gyrina	*Physa gouldi*	Wu 2004–2005	Dodge	Elkhorn River at HW 91
Physa gyrina	*Physa gouldi*	Wu 2004–2005	Lincoln	Medicine Creek pond, HW 23, Somerset
Physa gyrina	*Physa gouldi*	Wu 2004–2005	Sheridan	Creek at HW 250, 3.2 m s. Rushville
Physa gyrina	*Physa saffordi*	Wu 2004–2005	Blaine	N. Loop River at HW 7 (his spelling of loop)
Physa gyrina	*Physa saffordi*	Wu 2004–2005	Keyapaha	East of Holt Creek at HW 183
Physa gyrina	*Physa saffordi*	Wu 2004–2005	Richardson	Roadside marsh at HW 8, 4.5 m. w. Falls City
Physa gyrina	*Physa saffordi*	Wu 2004–2005	Rock	Roadside ditch HW 20, 8.5 m. w. Newport
Physa gyrina	*Physa warreniana*	Wu 2004–2005	Arthur	Swan lake
Physa gyrina	*Physa warreniana*	Wu 2004–2005	Sheridan	Pine Creek at HW 250
Physa gyrina	*Physa warreniana*	Wu 2004–2005	Sheridan	Smith Lake at HW 270
Physa gyrina	*Physa warreniana*	Wu 2004–2005	Sheridan	Willy Lake at HW 2
Physa gyrina	*Physa warreniana*	Wu 2004–2005	Sioux	Pond at Agate
Physa gyrina	*Physa warreniana*	MCZ, date UNK	Sioux	Pond at Agate
Physa gyrina	*Physa warreniana*	MCZ, date UNK	Custer	S. Loup River, Georgetown
Physa gyrina	*Physa ancillaria*	Aughey 1877		Elkhorn River
Physa gyrina	*Physa ancillaria*	Aughey 1877		Nemaha River
Physa gyrina	*Physa ancillaria*	Aughey 1877		Loup River
Physa gyrina	*Physa ancillaria*	Walker 1906	Cherry	Details ??
Physa gyrina	*Physa ancillaria*	Wu 2004–2005	Cherry	Pond at Fort Niobrara NMR
Physa gyrina	*Physa ancillaria*	Wu 2004–2005	Grant	Collins Lake
Physa gyrina	*Physa lordi*	Aughey 1877		Loup River
Physa gyrina	*Physa lordi*	Aughey 1877		Wood Rivers
Physa gyrina	*Physa sayi*	Walker 1906	Lancaster	City of Lincoln
Physa gyrina	*Physa virginea*	Aughey 1877	Dakota	Smith's Lake
Physa jennessi	Physa skinneri	Wu 2004 –2005	Cherry	HW 83 14 m. n. Thedford
Physa jennessi	Physa skinneri	Wu 2004 –2005	Grant	HW 2, 48.5 m e of Lakeside
Physa jennessi	Physa skinneri	Wu 2004 –2005	Sheridan	Willy Lake HW2
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Arthur	Swan Lake 12.2 m. e. & 10.9 m.n. of Arthur
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Buffalo	Windmill Rec Area, Lake, Gibbon
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Buffalo	Pond at Kearney Fort Rest Area, Interstate 80, 3.5 m. w. of Kearney Exit.
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Cherry	Minnechaduza Creek at HW 83
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Dawson	0.6 m. w. of Cozad on HW 80
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Dundy	North Fork of Republican River at Parks
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Dundy	Arikaree River at HW 34
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Jefferson	Little Blue River HW 136
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Lincoln	Creek at Interstate 80, 3.5 m. w. of Hersey exit (184)
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Morrill	Pimpkin Creek at HW 385
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Red Willow	Red Willow Creek at HW 34
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Richardson	Roadside pens and marsh at HW 8, 4.5 m. w. of Falls City

Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Scotts Bluff	Sheep Creek at HW 29
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Sheridan	Niobrara River at HW 250, 11 miles s. of Rushville
Physa pomilia	*Physa pomilia*	Wu 2004 –2005	Sioux	Tributary of Warbonnet Creek at end of paved HW 29, 8.3 m. n of Harrison
X	*Physa smithsoniana*	MCZ, date UNK	Buffalo	Fort Kearney, Wood River
Family Planorbidae				
Ferrissia fragilis	*Ancylus shimekii*	Walker 1906	Custer	Town of Calloway
Ferrissia rivularis	*Ancylus rivularis*	Aughey 1877	Cedar	Bow River
Ferrissia rivularis	*Ancylus rivularis*	Walker 1906	Lancaster	Dead Man's Run (Lincoln)
Ferrissia rivularis	*Ancylus caurinus*	Aughey 1877		Logan River
Ferrissia rivularis	*Ancylus caurinus*	Aughey 1877		Elkhorn River
Ferrissia rivularis	*Ancylus caurinus*	Aughey 1877		Nemaha River
Ferrissia rivularis	*Ancylus caurinus*	Aughey 1877		Blue River
X	*Ancylus tardus*	Walker 1906	Lancaster	Town of Lincoln
***Laevepex fuscus*	*Ancylus diaphanous*	Aughey 1877	Cedar	Bow River
Gyraulus crista	*Armiger crista*	Taylor 1960	Cherry	Creek at junction of paved & dirt road to Alkali Lake, 4.4 m. w. of HW 83
Gyraulus circumstriatus	*Gyraulus circumstriatus*	Taylor 1960	Cherry	Sand Hills pond, Junction of HW 83 & HW 30 then s. 7.4 m.
Gyraulus circumstriatus	*Gyraulus circumstriatus*	Taylor 1960	Cherry	Temp creek, ne. of Simeon
Gyraulus circumstriatus	*Gyraulus circumstriatus*	Taylor 1960	Brown	Seepage along creek 2.5 m. s. of Long Pine
Gyraulus circumstriatus	*Gyraulus circumstriatus*	Taylor 1960	Brown	Calamus River, .5 m. w. of HW 20
Gyraulus circumstriatus	*Gyraulus circumstriatus*	Hibbard and Taylor 1960	Lancaster	Lincoln
Gyraulus deflectus	*Gyraulus deflectus*	Perkins and Freeman 1992	Sarpy	Platte River
Gyraulus deflectus	*Planorbis deflectus*	Aughey 1877		All streams of eastern Nebraska
Gyraulus deflectus	*Gyraulus deflectus*	Taylor 1960	Cherry	Fort Niobrara NWR reservoir
Gyraulus parvus	*Planorbis parvus*	Aughey 1877		All streams of Nebraska
Gyraulus parvus	*Planorbis parvus*	Walker 1906	Dodge	Omaha
Gyraulus parvus	*Planorbis parvus*	Walker 1906	Lancaster	Lincoln
Gyraulus parvus	*Gyraulus parvus*	Taylor 1960	Cherry	Fort Niobrara NWR reservoir
Gyraulus parvus	*Gyraulus parvus*	Taylor 1960	Cherry	Sand Hills pond, HW 83 7.4 m. s. of HW 20
Gyraulus parvus	*Gyraulus parvus*	Taylor 1960	Cherry	Creek at Junction of Alkali Rd. and HW 83
Gyraulus parvus	*Gyraulus parvus*	Taylor 1960	Cherry	Red Deer Lake
Gyraulus parvus	*Gyraulus parvus*	Taylor 1960	Rock	Drainage ditch HW 20 2.8 m. w. of Bassett
Gyraulus parvus	*Gyraulus parvus*	Taylor 1960	Rock	Pond along HW 20 2.3 m. e. of Bassett
Helisoma anceps	*Planorbis bicarinatus*	Tyron 1868	Dodge	City of Omaha
Helisoma anceps	*Planorbis bicarinatus*	Aughey 1877		All streams of eastern Nebraska
Helisoma anceps	*Helisoma anceps*	Taylor 1960	Cherry	Fort Niobrara NWR
Helisoma anceps	*Helisoma anceps*	Freeman and Perkins 1997	Cherry	Niobrara River
Helisoma anceps	*Helisoma anceps*	Freeman and Perkins 1997	Dawes	Niobrara River
Helisoma anceps	*Helisoma anceps*	MCZ, Date UNK	Buffalo	Gibbon
Helisoma anceps	*Helisoma anceps*	MCZ, Date UNK	Buffalo	Wood River 10 m n.e. of Fort Kearney
Helisoma trivolvis	*Planorbis trivolvus*	Tyron 1868	Dodge	City of Omaha
Helisoma trivolvis	*Planorbis trivolvis*	Aughey 1877	Cedar	Bow River
Helisoma trivolvis	*Planorbis trivolvis*	Walker 1906	Sarpy	Bellevue
Helisoma trivolvis	*Planorbis trivolvis*	Walker 1906	Lancaster	Lincoln
Helisoma trivolvis	*Helisoma trivolvis*	Taylor 1960	Cherry	Fort Niobrara NWR pond
Helisoma trivolvis	*Helisoma trivolvis*	Taylor 1960	Cherry	Red Deer Lake
Helisoma trivolvis	*Helisoma trivolvis*	Taylor 1960	Rock	Ditch along Hw 20 2.8 m. w. of Bassett
Helisoma trivolvis	*Helisoma trivolvis*	Taylor 1960	Rock	Ditch along Hw 20 2.3 m. e. of Bassett
Helisoma trivolvis	*Planorbella trivolvis*	Freeman and Perkins 1992	Sarpy	Platte River
Helisoma trivolvis	*Planorbella trivolvis*	MCZ, Date UNK	Nemaha	Whiskey Run
Helisoma trivolvis	*Helisoma trivolvis*	MCZ, Date UNK	Buffalo	Gibbon
Helisoma trivolvis	*Helisoma trivolvis*	MCZ, Date UNK	Buffalo	Wood River 10 m n.e. of Fort Kearney
Planorbula armigera	*Sementina armigera*	Aughey 1877	Cedar	Bow River
Planorbula armigera	*Sementina armigera*	Aughey 1877		Loup River
Planorbula armigera	*Planorbula armigera*	Taylor 1960	Cherry	Niobrara River oxbow 0.5 m. w. HW 20
Promenetus exacuous	*Planorbis exacutus*	Aughey 1877		All streams of eastern Nebraska
Promenetus exacuous	*Promenetus exacuous*	Taylor 1960	Cherry	Creek 4.4 m. w. of Alkali Lake Rd.
Promenetus exacuous	*Promenetus exacuous*	Taylor 1960	Rock	Pond along HW 20, 2.3 m. e. Bassett
Promenetus exacuous	*Promenetus exacuous*	Hibbard and Taylor 1960	Colfax	Lake MacPherson s. of Richland
Promenetus exacuous	*Promenetus exacuous*	Hibbard and Taylor 1960	Otoe	Nebraska City
Promenetus umbilicatellus	*Promenetus umbilicatellus*	Taylor 1960	Cherry	Sand Hills pond, HW 83 7.4 m. s. of HW 20
Promenetus umbilicatellus	*Promenetus umbilicatellus*	Taylor 1960	Cherry	Lake along HW 20 n. of Thedford
Promenetus umbilicatellus	*Promenetus umbilicatellus*	Taylor 1960	Brown	Ditch, Sec 34 nw corner
Promenetus umbilicatellus	*Promenetus umbilicatellus*	Hibbard and Taylor 1960	Cheyenne	Sidney
Promenetus umbilicatellus	*Promenetus umbilicatellus*	Hibbard and Taylor 1960	Lancaster	Near Lincoln
X	*Planorbis albus*	Aughey 1877	Cedar	Bow River
X	*Planorbis albus*	Aughey 1877		Logan River
***Planorbella campanulata*	*Planorbis campanulatus*	Aughey 1877	Cedar	Bow River
X	*Planorbis glabratus*	Aughey 1877		Nemaha River
*** Planorbella multivolvis*	*Planorbis multivolvis*	Aughey 1877	Cedar	Bow River
Family Pleuroceridae				

***Leptoxis carinata*	*Anculosa carinata*	Aughey 1877		Nemaha River
***Leptoxis carinata*	*Anculosa carinata*	Aughey 1877		Blue River
***Leptoxis carinata*	*Anculosa carinata*	Aughey 1877		Elkhorn River
Pleurocera canaliculata (acuta)	*Goniobasis neglectum*	Aughey 1877		Blue River
***Elimia semicarinata*	*Goniobasis larvaeformis*	Aughey 1877		Nemaha River
***Elimia semicarinata*	*Goniobasis occulata*	Aughey 1877		Nemaha River
***Elimia semicarinata*	*Goniobasis semicarinata*	Aughey 1877		Nemaha River
***Elimia semicarinata*	*Goniobasis semicarinata*	Aughey 1877		Blue River
Family Pomatiopsidae				
Pomatiopsis lapidaris	*Pomatiopsis lapidaris*	Aughey 1877		Missouri Bluffs
X	*Pomatiopsis lustrica*	Aughey 1877		Eastern Nebraska
Family Valvatidae				
Valvata sincera	*Valvata sincera*	Aughey 1877	Cedar	Bow River
Valvata sincera	*Valvata sincera*	Aughey 1877		Elkhorn River
Valvata tricarinata	*Valvata tricarinata*	Aughey 1877		Papillion River
Valvata tricarinata	*Valvata tricarinata*	Aughey 1877		Elkhorn River
Valvata tricarinata	*Valvata tricarinata*	Taylor 1960	Cherry	Fort Niobrara NWR
Valvata tricarinata	*Valvata tricarinata*	Gugler 1969	Custer	Arnold Lake
Valvata tricarinata	*Valvata tricarinata*	Freeman and Perkins 1997	Cherry	Niobrara River
Valvata tricarinata	*Valvata tricarinata*	Freeman and Perkins 1997	Dawes	Niobrara River
Valvata tricarinata	*Valvata tricarinata*	MCZ, Date UNK	Custer	Loup River, Georgetown
Family Viviparidae				
Campeloma decisum	*Melantho decisa*	Aughey 1877		All streams of Nebraska
Campeloma decisum	*Melantho ponderosa*	Aughey 1877		Elkhorn River
Campeloma decisum	*Melantho ponderosa*	Aughey 1877		Blue River
Campeloma decisum	*Vivipara contectoides*	Aughey 1877		Nemaha River
Campeloma decisum	*Vivipara integra*	Tyron 1868	Dodge	City of Omaha
Campeloma decisum	*Vivipara integra*	Tyron 1868	Richardson	Big (Great) Nemaha River at Falls City
Campeloma decisum	*Vivipara intertexta*	Aughey 1877		Papillion River
Campeloma decisum	*Vivipara intertexta*	Aughey 1877		Nemaha River
Campeloma decisum	*Vivipara subpurpurea*	Aughey 1877		Blue River
Campeloma decisum	*Vivipara subpurpurea*	Aughey 1877		Nemaha River
Bellamya chinensis	*Bellamya chinensis*	Chaine et. al. 2013	Lancaster	Wild Plum Reservoir

APPENDIX B: HISTORICAL LISTINGS OF FRESHWATER GASTROPODS OF SOUTH DAKOTA

X = Name not valid, unknown synonymy.

MCZ = the Museum of Comparative Zoology. ANS = The National Hist

Family	Recognized Species: Following Dillon *et al.* (2006).	Literture Listing	Reference	County	Locality
Amnicolidae	Amnicola limosa	Amnicola limosa	Over 1915	Codington	
Amnicolidae	Amnicola limosa	Amnicola limosa	Over 1915	Clay	
Amnicolidae	Amnicola limosa	Amnicola limosa	Henderson 1927	Brookings	Lake Campbell
Amnicolidae	Amnicola walkeri	Amnicola walkeri	Over 1928	Marshall	
Hydrobiidae	Cincinnatia integra	Amnicola cincinnatiensis	Over 1915	Spink	Turtle River
Hydrobiidae	Cincinnatia integra	Amnicola cincinnatiensis	Henderson 1927	Brookings	Lake Campbell
Hydrobiidae	Cincinnatia integra	Amnicola cincinnatiensis	Henderson 1927	Moody	
Hydrobiidae	Cincinnatia integra	Amnicola cincinnatiensis	MCZ (no year)	Spink	Turtle River
Hydrobiidae	Probythinella emarginata	Amnicola emarginata	Over 1915	Codington	
Hydrobiidae	Probythinella emarginata	Amnicola emarginata	Over 1915	Clay	
Hydrobiidae	Probythinella emarginata	Amnicola emarginata	Henderson 1927	Brookings	Lake Campbell
Hydrobiidae	Probythinella emarginata	Amnicola emarginata	Henderson 1927	Moody	
Hydrobiidae	Probythinella emarginata	Probythinella lacustris	Hibbard and Taylor 1960	Roberts	Lake Traverse
Lymnaeidae	Lymnaea bulimoides	Lymnaea cokerelli	Over 1915		Over the state
Lymnaeidae	Lymnaea bulimoides	Lymnaea techella	Over 1915	Harding	
Lymnaeidae	Lymnaea bulimoides	Lymnaea bulimoides cockerelli	MCZ (no year)		Water hole
Lymnaeidae	Lymnaea bulimoides	Lymnaea bulimoides techelda	ANS (no year)		
Lymnaeidae	Lymnaea bulimoides	Lymnaea bulimoides cockerelli	ANS 1912)	Harding	Spring Hole east Short Pines
Lymnaeidae	Lymnaea bulimoides	Lymnaea bulimoides cockerelli	ANS 1914	Pennington	Water hole btwn Pennington Cty and Reservation east of Sheep Mountain
Lymnaeidae	Lymnaea bulimoides	Lymnaea bulimoides cockerelli	ANS 1915	Corson	Missouri River
Lymnaeidae	Lymnaea bulimoides	Lymnaea bulimoides techella	ANS (no year)		Little Missouri River
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	Over 1915		Common over the state
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	ANS 1910	)	
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	ANS (no year)	Brooking	
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	ANS 1913	Clay	South Vermillion RIver
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	ANS 1914	Clay	Vermillion RIver
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	ANS 1915	Corson	Missouri River
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	ANS 1915	Corson	Missouri River
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	ANS 1913	Pennington	Spring hole Tepee Gulch
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	ANS (no year)	Butte/Harding	water holes in Perkins
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	ANS (no year)	Perkins	Spring holes
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	Henderson 1927	Brookings	Caputa
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	Henderson 1927	Brookings	Lake Campbell
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	Henderson 1927	Moody	Spring creek
Lymnaeidae	Lymnaea caperata	Lymnaea caperata	Henderson 1927	Moody	Stony Butte, water hole
Lymnaeidae	Lymnaea caperata	Stagnicola caperata	Hibbard and Taylor 1960	Perkins	Springhole
Lymnaeidae	Lymnaea caperata	Stagnicola caperata	Hibbard and Taylor 1960	Pennington	0.5 m. s. of Quinn
Lymnaeidae	Lymnaea caperata	Stagnicola caperata	Hibbard and Taylor 1960	Lake	Lake Herman
Lymnaeidae	Lymnaea catascopium	Galba apicina	Baker 1911	Stanley	Grindstone Creek
Lymnaeidae	Lymnaea elodes	Lymnaea elodes	Over 1915	Clay	
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	Over 1915		Over the state
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	Henderson 1927	Brookings	Lake Oakwood
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	Henderson 1927	Lyman	Stony Butte
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	Henderson 1927	Hamlin	Hayti
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	Henderson 1927	Brookings	Lake Campbell
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	Henderson 1927	Moody	Claremont
Lymnaeidae	Lymnaea elodes	Stagnicola palustris elodes	MCZ 1965	Jones	2 mi. W of Murdo, Brunskill Ranch
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	ANS 1902	Butte/Harding	water holes in Perkins

Lymnaeidae	Lymnaea elodes	Lymnaea palustris	ANS 1915	Clay	Slough
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	ANS No year	Perkins	Cash P.O.
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	ANS 1915	Corson	Missouri River
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	ANS (no year)	Brookings	
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	ANS (no year)	Brookings	
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	ANS 1912	Harding	Spring at elevation East Short Pine Hills
Lymnaeidae	Lymnaea elodes	Lymnaea palustris	ANS (no year)	Deuel	
Lymnaeidae	Lymnaea humilis	Lymnaea humilis	Over 1915	Deuel	
Lymnaeidae	Lymnaea humilis	Lymnaea humilis	Over 1915	Clay	
Lymnaeidae	Lymnaea humilis	Lymnaea humilis	Over 1915	Butte	
Lymnaeidae	Lymnaea humilis	Lymnaea humilis	Over 1915	Perkins	
Lymnaeidae	Lymnaea humilis	Lymnaea humilis	Over 1915	Harding	
Lymnaeidae	Lymnaea humilis	Lymnaea obrussa	Over 1915		Black Hills
Lymnaeidae	Lymnaea humilis	Lymnaea parva	Over 1915	Perkins	
Lymnaeidae	Lymnaea humilis	Lymnaea parva	Over 1915	Deuel	
Lymnaeidae	Lymnaea humilis	Lymnaea desidiosa	ANS (no year)	Edmunds	
Lymnaeidae	Lymnaea humilis	Lymnaea h modicella	ANS (no year)		Little Missouri at Camp Cook
Lymnaeidae	Lymnaea humilis	Lymnaea h modicella	ANS (no year)		Pelham Ranch
Lymnaeidae	Lymnaea humilis	Lymnaea h modicella	ANS (no year)		Reva Gap
Lymnaeidae	Lymnaea humilis	Lymnaea h modicella	ANS (no year)	Butte	Belle Fourche River
Lymnaeidae	Lymnaea humilis	Lymnaea h modicella	ANS (no year)	Harding	7 miles north of Camp Crook
Lymnaeidae	Lymnaea humilis	Lymnaea h modicella	ANS (no year)	Harding	Spring hole in East Short Pines
Lymnaeidae	Lymnaea humilis	Lymnaea h modicella	ANS (no year)	Harding	West Short Pines
Lymnaeidae	Lymnaea humilis	Lymnaea modicella	ANS (no year)		
Lymnaeidae	Lymnaea humilis	Lymnaea modicella	ANS (no year)		Reva
Lymnaeidae	Lymnaea humilis	Lymnaea modicella	ANS (no year)	Deuel	Hidewood Creek
Lymnaeidae	Lymnaea humilis	Lymnaea obrussa	ANS 1915	Corson	Missouri RIver
Lymnaeidae	Lymnaea humilis	Lymnaea obrussa	ANS 1912		Spearfish
Lymnaeidae	Lymnaea humilis	Lymnaea obrussa	ANS (no year)	Deuel	Hidewood Creek
Lymnaeidae	Lymnaea humilis	Lymnaea obrussa	ANS 1914	Fall River	Fall River Hot Springs
Lymnaeidae	Lymnaea humilis	Lymnaea obrussa	ANS 1914	Pennington	Pond I mile s of Imlay
Lymnaeidae	Lymnaea humilis	Lymnaea obrussa	ANS 1914	Pennington	Spring hole at Mystic
Lymnaeidae	Lymnaea humilis	Lymnaea parva	ANS (no year)		Antelope Creek
Lymnaeidae	Lymnaea humilis	Lymnaea parva	ANS 1913	Clay	Dry Creek south of Vermillion
Lymnaeidae	Lymnaea humilis	Lymnaea parva	ANS (No year)	Deuel	Bates Creek
Lymnaeidae	Lymnaea humilis	Lymnaea parva	ANS (No year)	Deuel	
Lymnaeidae	Lymnaea humilis	Lymnaea parva	ANS 1916	Lincoln	Sioux River 5 miles south of Canton
Lymnaeidae	Lymnaea stagnalis	Lymnaea stagnalis	Over 1915	Deuel	
Lymnaeidae	Lymnaea stagnalis	Lymnaea stagnalis	ANS (No year)	Deuel	Spombill Slough, 5 mi. NE of Clear Lake
	X	Lymnaea tryoni	Over 1915	Deuel	
	X	Lymnaea haydeni	ANS (no year)		Big Sioux River
	X	Lymnaea lancelata	ANS (no year)		Big Sioux River
Physidae	Aplexa elongata	Aplexa hypnorum	Over 1915	Deuel	
Physidae	Physa acuta	Physa ancillaria	Over 1915	Codington	
Physidae	Physa acuta	Physa humerosa	Over 1915	Spink	

Physidae	Physa acuta	Physa walkeri	Over 1915	Spink	Turtle River
Physidae	Physa acuta	Physa integra	Henderson 1927	Pennington	Rapid Creek
Physidae	Physa acuta	Physa integra	MCZ (no year)	Pennington	Rapid Creek, nr. Rapid City
Physidae	Physa acuta	Physella integra	ANS (no year)		Little Missouri Rover, north of Camp Crook
Physidae	Physa acuta	Physella integra	ANS (no year)	Deuel	Adney Creek
Physidae	Physa acuta	Physella integra	ANS (no year)	Deuel	No locale
Physidae	Physa acuta	Physella integra	ANS 1915	Union	Brule Creek
Physidae	Physa acuta	Physella integra	ANS 1914	Washabaugh	Turtle Creek near Eastman P.O.
Physidae	Physa gyrina	Physa gyrina	Over 1915		Abundant over state
Physidae	Physa gyrina	Physa sayi	Over 1915	Perkins	
Physidae	Physa gyrina	Physa sayi	Over 1915	Harding	
Physidae	Physa gyrina	Physa sayi	Over 1915	Deuel	
Physidae	Physa gyrina	Physa sayi	Henderson 1927	Pennington	Dark Canyon
Physidae	Physa gyrina	Physa sayi	Henderson 1927		Seavey's Lake
Physidae	Physa gyrina	Physa sayi	Henderson 1927	Pennington	Rapid Creek
Physidae	Physa gyrina	Physa sayi	Henderson 1927	Pennington	Caputa
Physidae	Physa gyrina	Physa sayi	Henderson 1927	Pennington	Black Hawk
Physidae	Physa gyrina	Physa gyrina	MCZ	Yankton	Yankton, Marne Creek
Physidae	Physa gyrina	Physa warreniana	MCZ	Union	Elk Point
Physidae	Physa gyrina	Physa warreniana	MCZ	Codington	Lake Kampeska
Physidae	Physa gyrina	Physella gyrina	ANS (no year)		
Physidae	Physa gyrina	Physella gyrina	ANS (no year)		
Physidae	Physa gyrina	Physella gyrina	ANS 1912		
Physidae	Physa gyrina	Physella gyrina	ANS 1912		Reva Gap
Physidae	Physa gyrina	Physella gyrina	ANS (no year)	Brookings	Sioux River
Physidae	Physa gyrina	Physella gyrina	ANS 1914	Clay	Vermillion River
Physidae	Physa gyrina	Physella gyrina	ANS 1914	Custer	Water hole, Black Hills, Mayo
Physidae	Physa gyrina	Physella gyrina	ANS 1912	Deuel	Degenoar Bridge 9.27.07, near Cleak Lake
Physidae	Physa gyrina	Physella gyrina	ANS (no year)	Deuel	
Physidae	Physa gyrina	Physella gyrina	ANS 1914	Fall River	Fall River, Hot Springs
Physidae	Physa gyrina	Physella gyrina	ANS (no year)	Harding	7 miles north of Camp Crook
Physidae	Physa gyrina	Physella gyrina	ANS 1912	Harding	Spring Hole, West Short Pines
Physidae	Physa gyrina	Physella gyrina	ANS (No year)	Lawrence	Spreafish
Physidae	Physa gyrina	Physella gyrina	ANS 1914	Pennington	1 miles south of Imlay
Physidae	Physa gyrina	Physella gyrina	ANS 1914	Pennington	Kettle Springs, Rapid Creek
Physidae	Physa gyrina	Physella gyrina	ANS 1914	Pennington	1 miles south of Imlay
Physidae	Physa gyrina	Physella gyrina	ANS (no year)	Perkins	Antelope Creek
Physidae	Physa gyrina	Physella gyrina	ANS 1912	Perkins	Near Antelope Creek
Physidae	Physa gyrina	Physella gyrina	ANS 1914	Stanley	Pond near Interior
Physidae	Physa gyrina	Physella gyrina	ANS 1914	Washabaugh	Bear Creek
Physidae	Physa gyrina	Physella gyrina	ANS 1914	Washabaugh	Red Water Creek
Physidae	Physa gyrina	Physella gyrina	ANS 1914	Washabaugh	Turtle Creek near Eastman P.O.
Physidae	Physa gyrina	Physella vinosa	ANS 1912	Codington	Near Watertown, Lake Kanapeska (sp)

Physidae	Physa jennessi	Physa skinneri	ANS 1912	Deuel	Pond north of Altamont
Physidae	X	Physa crandalli	Over 1915	Lawrence	Fish hatchery ponds
Planorbidae	Ferrissia rivularis	Ferrissia rivularis	Over 1928	Beadle	Lake Byron
Planorbidae	Ferrissia rivularis	Ferrissia parallela	Over 1928	Marshall	
Planorbidae	Ferrissia rivularis	Ferrissia parallelus	Over 1915	Deuel	
Planorbidae	X	Ferrissia tarda	Over 1928	Roberts	
Planorbidae		Ancylus	MCZ (no year)		Vermillon River
Planorbidae	Gyraulus crista	Segmentina chirstyi	Over 1915,	Deuel	
Planorbidae	Gyraulus deflectus	Planorbis deflectus	Over 1915??	Clay	
Planorbidae	Gyraulus deflectus	Planorbis deflectus	Over 1915	Perkins	
Planorbidae	Gyraulus deflectus	Planorbis deflectus	Over 1915	Deuel	
Planorbidae	Gyraulus deflectus	Planorbis deflectus	Over 1915	Washington (old cty sliced into Jackson, Pennington and Shannon)	
Planorbidae	Gyraulus deflectus	Planorbis deflectus	Over 1915	Washabaugh (old county –merged into Jackson)	
Planorbidae	Gyraulus deflectus	Planorbis hirsutus	Over 1928	Marshall	
Planorbidae	Gyraulus parvus	Planorobis parvus	Over 1915	Deuel	
Planorbidae	Gyraulus parvus	Planorobis parvus	Over 1915	Pennington	
Planorbidae	Gyraulus parvus	Planorobis parvus	Over 1915	Clay	
Planorbidae	Gyraulus parvus	Planorobis parvus	Over 1915	Harding	
Planorbidae	Gyraulus parvus	Planorobis parvus	Henderson 1927	Hamlin	Hayti
Planorbidae	Gyraulus parvus	Planorobis parvus	Henderson 1927	Brookings	Lake Campbell
Planorbidae	Gyraulus parvus	Planorobis parvus	Henderson 1927	Moody	Lake Campbell
Planorbidae	Gyraulus parvus	Gyraulus parvus	ANS (no year)		Antelope Creek
Planorbidae	Gyraulus parvus	Gyraulus parvus	ANS (no year)		Vermillion River
Planorbidae	Gyraulus parvus	Gyraulus parvus	ANS 1915		Missouri River
Planorbidae	Gyraulus parvus	Gyraulus parvus	ANS 1916	Lincoln	Sioux River
Planorbidae	Helisoma anceps	Planorbis antrosus	Over 1915		Over the state
Planorbidae	Helisoma anceps	Helisoma anceps	ANS (no year)		
Planorbidae	Helisoma anceps	Helisoma anceps	ANS 1892		Pine Ridge Reservation
Planorbidae	Helisoma anceps	Helisoma anceps	ANS 1909	Perkins	Antelope Creek
Planorbidae	Helisoma anceps	Helisoma anceps	ANS 1914	Washabaugh	Red Water Creek
Planorbidae	Helisoma anceps	Helisoma anceps	ASN 1914	Washabaugh	Spring hole near Turtle Creek
Planorbidae	Helisoma trivolvis	Planorbis trivolvis	Over 1915		Common over state
Planorbidae	Helisoma trivolvis	Planorbis trivolvis	Henderson 1927	Brookings	Lake campbell
Planorbidae	Helisoma trivolvis	Planorbis trivolvis	Henderson 1927	Brookings	Lake Oakwood
Planorbidae	Helisoma trivolvis	Planorbis trivolvis	Henderson 1927	Lyman	Stony Butte
Planorbidae	Helisoma trivolvis	Planorbis trivolvis	Henderson 1927	Hamlin	Hayti
Planorbidae	Helisoma trivolvis	Planorbis trivolvis	Henderson 1927	Pennington	Caputa
Planorbidae	Helisoma trivolvis	Helisoma trivolvis	MCZ 1965	Jones	2 mi. W of Murdo, Brunskill Ranhc
Planorbidae	Helisoma trivolvis	Planorbis trivolvis macrostomus	MCZ 1908		Devil's Lake
Planorbidae	Helisoma trivolvis	Planorbis tumidus	Over 1915	Perkins	Colorado bk synonym with trivolvis
Planorbidae	Helisoma trivolvis	Planorbis tumidus	Over 1915	Deuel	Colorado bk synonym with trivolvis
Planorbidae	Helisoma trivolvis	Planorbella trivolvis	ANS (no year)		
Planorbidae	Helisoma trivolvis	Planorbella trivolvis	ANS (no year)		Lake Badus
Planorbidae	Helisoma trivolvis	Planorbella trivolvis	ANS (no year)		Near Gradn River
Planorbidae	Helisoma trivolvis	Planorbella trivolvis	ANS 1914	Clay	Vermillion River
Planorbidae	Helisoma trivolvis	Planorbella trivolvis	ANS (no year)	Perkins	Antelope Creek
Planorbidae	Helisoma trivolvis	Planorbella trivolvis	ANS (no year)	Perkins	Spring hiles, S.N. 1/4, 15–16–12
Planorbidae	Helisoma trivolvis	Planorbella trivolvis	ANS (no year)	Perkins	SW 27–16–12 Antelope Creek
Planorbidae	Helisoma trivolvis	Planorbella trivolvis	ANS 1916	Stanley	Pond on "Scotty" Philips Buffalo Ranch
Planorbidae	Helisoma trivolvis	Planorbella trivolvis	ASNS 1914	Washabaugh	Spring hole near Turtle Creek
Planorbidae	Planorbula armigera	Sementina armigera	Over 1915	Clay	
Planorbidae	Planorbula armigera	Sementina armigera	Over 1915	Deuel	
Planorbidae	Planorbula armigera	Planorbula armigera	Henderson 1927	Brookings	Lake Campbell
Planorbidae	Planorbula armigera	Planorbula armigera	Henderson 1927	Moody	
Planorbidae	Planorbula armigera	Planorbella armigera	ASN (no year)		Vermillion River
Planorbidae	Planorbula armigera	Planorbella armigera	ANS (no year)	Brookings	

Planorbidae	Planorbula armigera	Planorbella armigera	ANS (no year)	Deuel	
Planorbidae	Promenetus exacuous	Planorbis exacuus	Over 1915	Deuel	Near Altimont
Planorbidae	Promenetus exacuous	Promenetus exacuous	ANS.(No year)	Edmunds	
Planorbidae	Promenetus exacuous	Promenetus exacuous	ANS (no year)	Edmunds	
Planorbidae	Promenetus umbilicatellus	Planorbis umbilicatellus	Over 1915	Perkins	
Planorbidae	Promenetus umbilicatellus	Promenetus umbilicatellus	Hibbard and Taylor 1960		No specifics – just shown on map
Planorbidae	Promenetus umbilicatellus	Promenetus umbilicatellus	Hibbard and Taylor 1960		No specifics – just shown on map
Planorbidae	Promenetus umbilicatellus	Promenetus umbilicatellus	Hibbard and Taylor 1960		No specifics – just shown on map
Planorbidae	Promenetus umbilicatellus	Promenetus umbilicatellus	ANS 1915	Corson	Missouri River
Planorbidae	X	Planorbis vermicularis	Over 1928	Roberts	Jim Creek
Planorbidae	X	Sementina crassilabris	Over 1928	Roberts	Jim Creek
Planorbidae	X	Planorbula campestris	ANS (no year)	Deuel	Central part
Thiaridae	Melanoides tuberculatus	Melanoides tuberculatus	Anderson 2004	Fall River	Cascade Creek
Valvatidae	Valvata tricarinata	Valvata tricarinata	Over 1915	Codington	
Valvatidae	Valvata tricarinata	Valvata tricarinata	Over 1915	Deuel	
Valvatidae	Valvata tricarinata	Valvata tricarinata perconfusa	Henderson 1927	Brookings	Lake Campbell
Valvatidae	Valvata tricarinata	Valvata tricarinata	Henderson 1927	Moody	Lake Campbell
Valvatidae	Valvata tricarinata	Valvata tricarinata	Henderson 1927	Hamlin	Hayti
Valvatidae	Valvata tricarinata	Valvata tricarinata	MCZ		
Valvatidae	Valvata tricarinata	Valvata winnebagoensis	MCZ	Roberts	Lake Traverse
Valvatidae	Valvata tricarinata	Valvata tricarinata	ANS 1915	Corson	Missouri River
Viviparidae	Campeloma decisum	Campeloma integrum	Over 1915	Clay	Vermillion River
Viviparidae	Campeloma decisum	Campeloma subsolidum	Over 1928	Davidson	

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APPENDIX C: SAMPLES SITES FOR THE CURRENT SURVEY OF FRESHWATER SNAILS WITHIN NEBRASKA AND SOUTH DAKOTA.

Site No	Waterway	Ecoregion III Name	Water body Type	Hydro	Latitude	Longitude
1	Holmes Lake	WCBP	Reservoir	Perm	40.7848	–96.6207
2	Jack Sinn SWMA	WCBP	Palustrine	Temp	40.04616	–96.56424
3	Pfizer Wetlands	WCBP	Palustrine	Temp	40.83388	–96.72132
4	Burchard Lake	WCBP	Reservoir	Perm	40.16485	–96.31073
5	Verlyn Beethe Prairie pond	WCBP	Palustrine	Semi	40.23331	–96.17923
6	Pawnee Prairie Pond #6	WCBP	Palustrine	Semi	40.0317	–96.32378
7	Lin Saline Wetlands Nat Cen	WCBP	Palustrine	Temp	40.8252	–96.7263
8	Osage SWMA pond	WCBP	Palustrine	Temp	40.4111	–96.228
9	Humbolt Lake Park pond	WCBP	Palustrine	Semi	40.1587	–95.9467
10	Olive Creek Lake	WCBP	Reservoir	Perm	40.57871	–96.84699
11	Ditch, near Waverly Oxbow of Salt Creek	WCBP	Palustrine	Semi	40.92118	–96.54015
12	Rock Creek	WCBP	Riverine	Perm	41.04296	–96.56358
13	L. Salt Fork preserve, Nat Cons	WCBP	Palustrine	Temp	40.9595	–96.72096
14	Spring Creek Prairie pond	WCBP	Palustrine	Semi	40.6926	–96.852
15	Unk Pond, beaver dam	WCBP	Palustrine	Temp	41.01234	–96.58383
16	Verdon Lake	WCBP	Reservoir	Perm	40.14651	–95.72418
17	Roadside pond, Rt 8	WCBP	Palustrine	Semi	40.0737	–95.6929
18	Day Memorial Park pond	WCBP	Palustrine	Semi	40.86938	–96.14603
19	Wheeping Water creek	WCBP	Riverine	Perm	40.86925	–96.14733
20	Eight Mile Creek pond	WCBP	Palustrine	Perm	40.98765	–95.98308
21	Farm pond	WHP	Palustrine	Semi	40	–97
22	Hedgefield Reservoir SRA	CGP	Reservoir	Perm	40.60215	–96.568
23	Rose Creek SWMA, pond	WHP	Palustrine	Semi	40.0759	–97.2183
24	New Wetland, Adj to Jack Sinn	WCBP	Palustrine	Semi	40.042	–96.5645
25	Marsh, Adj to Crescent Lake	NSH	Palustrine	Semi	41.71512	–102.39072
26	Marsh, Hackberry Lake adj	NSH	Palustrine	Semi	41.73887	–102.42016
27	Unk Marsh	NSH	Palustrine	Perm	41.7821	–102.49723
28	Wooded Marsh, Goose Lake adj	NSH	Palustrine	Temp	41.77419	–102.44952
29	Island Lake	NSH	Lacustrine	Perm	41.7241	–102.4101
30	Marsh, Goose Lake adj	NSH	Palustrine	Semi	41.7856	–102.4654
31	Roadside marsh	NSH	Palustrine	Temp	41.7812	–102.5197
32	Unk Marsh	NSH	Palustrine	Temp	41.74019	–102.37375
33	Marsh, Entrance Smith Lake SWMA	NSH	Palustrine	Semi	42.4105	–102.4493
34	Marsh, West Smith Lake SWMA	NSH	Palustrine	Semi	42.4109	–102.44941
35	Smith Lake, Smith Lake SWMA	NSH	Reservoir	Perm	42.4105	–102.4493
36	Marsh, roadside	NSH	Palustrine	Semi	42.29563	–102.43049
37	Ballards Marsh	NSH	Palustrine	Semi	42.57421	–100.53644
38	Roadside marsh	NSH	Palustrine	Semi	42.14258	–98.72891
39	Flooded Field	NSH	Palustrine	Temp	42.11752	–98.70117
40	Roadside marsh	NSH	Palustrine	Semi	42.08858	–98.6778
41	Roadside marsh	NSH	Palustrine	Semi	42.11755	–98.69558
42	Railside Cattail Marsh	NSH	Palustrine	Semi	42.08868	–98.60352
43	Goose Lake	NSH	Lacustrine	Perm	42.11444	–98.57018
44	Pintail WPA	CGP	Palustrine	Semi	40.78569	–97.95911
45	Nelson WPA	CGP	Palustrine	Semi	40.75671	–97.93983
46	Harvard WPA	CGP	Palustrine	Semi	40.61032	–98.18414
47	Schuck WPA	CGP	Palustrine	Temp	40.45575	–97.99519
48	Meadowlark WPA	CGP	Palustrine	Semi	40.47205	–97.99552
49	Moger WPA	CGP	Palustrine	Semi	40.48134	–97.99199
50	Hultine WPA (Fed)	CGP	Palustrine	Semi	40.61184	–97.96326
51	Lange WPA	CGP	Palustrine	Temp	40.56341	–97.84384
52	Real WPA	CGP	Palustrine	Temp	40.66933	–97.57097
53	County Line WPA	CGP	Palustrine	Semi	40.69873	–97.54646
54	Sinninger WPA	CGP	Palustrine	Semi	40.71313	–97.53193
55	Hidden Marsh SWMA	CGP	Palustrine	Temp	40.7075	–97.4799
56	Sacramento WPA	CGP	Palustrine	Semi	40.4221	–98.9762
57	Gleason WPA	CGP	Palustrine	Temp	40.4296	–98.9924
58	Railside marsh	CGP	Palustrine	Temp	40.65744	–97.2546
59	Farm pond (private)	CGP	Palustrine	Semi	40.7327	–97.18493
60	Republican River	CGP	Riverine	Perm	40.21682	–100.49706
61	Roadside Ditch	CGP	Palustrine	Temp	40.12986	–101.20348
62	Swanson Res.	CGP	Reservoir	Perm	40.17509	–101.09927
63	S. Platte River	WHP	Riverine	Temp	40.14789	–101.23481
64	S. Platte River	WHP	Riverine	Temp	41.11721	–101.35619
65	Sutherland Canal	WHP	Riverine	Temp	41.10652	–101.32038

66	S. Platte River	CGP	Riverine	Temp	41.74801	–101.00225
67	Hershey SWMA	CGP	Reservoir	Perm	41.1343	–100.99363
68	S. Platte River	WHP	Riverine	Temp	41.08554	–101.888
69	S. Platte River	WHP	Riverine	Temp	41.1196	–101.71402
70	Wilkinson SWMA	CGP	Palustrine	Semi	41.5049	–97.4944
71	Pond on Hooper Memorial Park	WCBP	Palustrine	Perm	41.6144	–96.5487
72	Smith Falls stream	NWGrP	Riverine	Perm	42.8888	–100.315
73	Republican River	WHP	Riverine	Perm	40.04146	–101.72023
74	Rock Creek Lake	WHP	Reservoir	Perm	40.08653	–101.76313
75	Wild Plum	WCBP	Reservoir	Semi	40.615	–96.9023
76	Pond on Wiebel Property	WHP	Palustrine	Semi	42.1	–104
77	Pond in Agate Fossil Beds	WHP	Palustrine	Semi	42.2	–104.1
78	Pond on TNC Cherry Ranch	WHP	Palustrine	Semi	42.9	–104.2
79	Calamus Reservoir	NSH	Reservoir	Perm	41.88283	–99.28583
80	Winters Creek Lake	WHP	Lacustrine	Perm	41.95653	–103.52563
81	Ansley City Park Lake	CGP	Reservoir	Semi	41.29225	–99.38693
82	Stagecoach Reservoir	WCBP	Reservoir	Perm	40.60092	–96.63648
83	Iron Horse Trail Lake	WCBP	Reservoir	Perm	40.04622	–96.09643
84	Unamed pond	CGP	Palustrine	Semi	41.01467	–96.96967
85	Unamed to Turkey Creek	WCBP	Riverine	Semi	40.13108	–96.16755
86	Cedar Creek	WCBP	Riverine	Perm	40.23618	–96.6725
87	Pawnee City Park	WCBP	Reservoir	Semi	40.10432	–96.16277
88	Oliver Reservoir	WHP	Reservoir	Perm	41.2214	–103.81098
89	West Branch Turkey Creek	WCBP	Riverine	Perm	40.09452	–96.22652
90	Big Nemaha River	WCBP	Riverine	Perm	40.01285	–95.46347
91	Rock Creek State Lake	WHP	Reservoir	Perm	40.0899	–101.76143
92	Farm pond	WCBP	Palustrine	Semi	41.72717	–96.27017
93	Farm pond	WCBP	Palustrine	Semi	40.46743	–96.8048
94	No Separate site #94					
95	So. Branch Middle Loup River	CGP	Riverine	Semi	42.09647	–101.53487
96	Frye Lake	NSH	Palustrine	Semi	40.0899	–101.76143
97	Chappell City Lake	WHP	Reservoir	Perm	41.08298	–102.46622
98	Platte River	WHP	Riverine	Perm	40.993	–100.38942
99	Mud Creek	CGP	Riverine	Perm	41.041944	–98.989722
100	Buckskin Hills Lake	WCBP	Reservoir	Perm	42.6272	–96.9256
101	Box Butte Reservoir	NSH	Reservoir	Temp	42.46102	–103.1329
102	Czechland Lake	WCBP	Reservoir	Perm	41.31778	–96.83667
103	Lodgepole Creek	WHP	Riverine	Semi	41.2315	–103.838
104	*No Separate site #104*					
105	Niobrara River	NSH	Riverine	Temp	42.45673	–103.06937
106	South Loup River	CGP	Palustrine	Semi	41.49812	–100.50395
107	Middle Loup River	NSH	Palustrine	Perm	41.97825	–100.62208
108	Blue Creek	NSH	Palustrine	Perm	41.56262	–102.27942
109	Cottonwood Lake outlet	NSH	Palustrine	Semi	42.92365	–101.6741
110	North Platte River	NSH	Riverine	Semi	41.29983	–102.07702
111	Pawnee Creek	WCBP	Riverine	Perm	41.0009	–96.2907
112	Salt Creek	WCBP	Riverine	Perm	40.65302	–96.8041
113	Mud Creek	CGP	Riverine	Semi	41.34915	–99.50353
114	Mill Creek	WCBP	Riverine	Perm	40.99975	–96.16115
115	Plum Creek	WCBP	Palustrine	Semi	40.90262	–97.08748
116	Rose Creek	CGP	Riverine	Perm	40.08013	–97.2181
117	Timber Point Lake	WCBP	Reservoir	Temp	41.16313	–96.96355
118	North Aowa Creek	WCBP	Riverine	Temp	42.62995	–96.91808
119	Middle Loup River	NSH	Palustrine	Semi	41.7518	–99.7712
120	Leander Creek	NSH	Palustrine	Perm	42.89844	–101.81522
121	Unnamed Lake	NSH	Lacustrine	Perm	42.0316	–101.3504
122	Red Willow Creek (2)	CGP	Palustrine	Perm	40.64748	–100.96085
123	Big Sandy Creek	CGP	Palustrine	Temp	40.30721	–97.75537
124	Swanson Reservoir	CGP	Reservoir	Temp	40.1517	–101.0652
125	Dry Creek	NSH	Palustrine	Temp	42.91999	–101.67978
126	South Twin Lake	NSH	Lacustrine	Temp	41.7126	–102.53595
127	Leander Creek	NSH	Riverine	Semi	42.8733	–101.8689
128	Carver Creek	NSH	Palustrine	Perm	42.40752	–101.55719
129	Sicily Creek	WCBP	Palustrine	Semi	40.15363	–96.79616
130	Klein Fish Farm ponds	WHP	Palustrine	Perm	41.976	–103.81072
131	Beaver Creek	CGP	Riverine	Semi	40.84977	–97.46398
132	Middle Loup River	CGP	Riverine	Semi	41.49143	–99.23895
133	Cedar Creek	WCBP	Riverine	Temp	40.23618	–96.6725
134	Unnamed to E Br Muddy Creek	CGP	Palustrine	Semi	40.62496	–99.97853
135	Middle Channel Platte River	CGP	Riverine	Temp	40.79184	–98.46233
136	Unnamed to Beaver Creek	CGP	Palustrine	Perm	41.4533	–97.69748

137	Minnechaduza	NSH	Palustrine	Semi	42.99068	–100.91043
138	Tracy Creek	WCBP	Palustrine	Semi	41.7239	–97.4262
139	Island Lake	NSH	Lacustrine	Temp	41.7267	–102.39957
140	Unnamed to Verdigre Creek	NSH	Riverine	Perm	42.52566	–98.05334
141	Dry Creek	NSH	Palustrine	Semi	42.97907	–101.8269
142	Red Willow Creek	CGP	Palustrine	Temp	40.7217	–101.0274
143	Lodgepole Creek	WHP	Riverine	Semi	41.2259	–103.9019
144	Arkansas Flats	NSH	Palustrine	Temp	42.48929	–101.70719
145	Walnut Creek	WCBP	Riverine	Semi	41.14431	–96.06806
146	Unnamed to South Papillion Creek	WCBP	Riverine	Semi	41.1735	–96.1493
147	Buffalo Creek	WCBP	Riverine	Perm	41.0474	–96.1385
148	Unnamed to Bazile Creek	WCBP	Palustrine	Perm	42.37943	–97.85659
149	Niobrara River	NSH	Riverine	Perm	42.52837	–103.92837
150	Mud Creek	WCBP	Riverine	Semi	40.23256	–96.60997
151	Big Sandy Creek	CGP	Riverine	Semi	40.30711	–97.75462
152	Big Creek	NSH	Palustrine	Semi	42.3173	–100.8417
153	Missouri Bluffs	WCBP	Palustrine	Temp	40.24739	–95.5202
154	Roadside Marsh	NSH	Palustrine	Temp	42.17569	–98.65972
155	Roadside Marsh	NSH	Palustrine	Temp	42.16127	–98.65972
156	Roadside Marsh	NSH	Palustrine	Temp	42.11768	–98.66602
157	Bow River	WCBP	Riverine	Perm	42.77865	–97.14608
158	Blyburg Lake	WCBP	Palustrine	Semi	42.29711	–96.41776
159	Wildwood Golf Course pond	WCBP	Palustrine	Perm	40.67323	–95.87955
South Dakota sites begin here starting at site #300						
300	Unnamed pond	NGlP	Palustrine	Semi	43.97966	–96.96936
301	Lake Madison	NGlP	Lacustrine	Perm	43.98013	–97.06947
302	Unnamed pond	NGlP	Palustrine	Semi	43.97283	–97.03771
303	Unnamed ditch	NGlP	Palustrine	Temp	44.26331	–97.12921
304	Oakwood Lake	NGlP	Lacustrine	Perm	44.42551	–96.96934
305	Unnamed pond	NGlP	Palustrine	Temp	44.4255	–97.07907
306	Lake Kampeska	NGlP	Lacustrine	Perm	44.94363	–97.17115
307	Grass Lake	NGlP	Palustrine	Perm	45.0723	–97.3567
308	Unnamed pond	NGlP	Palustrine	Semi	45.07244	–97.35359
309	Horseshoe Lake	NGlP	Lacustrine	Semi	45.24787	–97.5229
310	Unnamed pond	NGlP	Palustrine	Semi	45.38197	–97.51985
311	S. Waubay Lake	NGlP	Lacustrine	Perm	45.394	–97.44881
312	Unnamed pond	NGlP	Palustrine	Temp	45.40303	–97.48916
313	Unnamed pond	NGlP	Palustrine	Perm	45.50046	–97.55124
314	Unnamed pond	NGlP	Palustrine	Perm	45.50104	–97.59245
315	Unnamed lake	NGlP	Lacustrine	Perm	45.51501	–97.6712
316	Unnamed marsh	NGlP	Palustrine	Perm	45.59411	–97.66989
317	Unnamed pond	NGlP	Palustrine	Temp	45.64552	–97.53226
318	Unnamed lake	NGlP	Lacustrine	Semi	45.61712	–97.4919
319	Unnamed lake	NGlP	Lacustrine	Semi	45.61771	–97.40162
320	WPA east pond	NGlP	Palustrine	Temp	44.89092	–96.71258
321	WPA west pond	NGlP	Palustrine	Semi	44.89095	–96.71778
322	Unnamed pond	NGlP	Palustrine	Semi	45.10312	–97.77079
323	Unnamed lake	NGlP	Lacustrine	Perm	45.10422	–97.77089
324	Unnamed ditch	NGlP	Palustrine	Semi	45.21712	–97.77901
325	Unnamed pond	NGlP	Lacustrine	Perm	45.26726	–97.57181
326	Unnamed pond	NGlP	Palustrine	Semi	45.54242	–97.1613
327	Dry Wood Lake	NGlP	Lacustrine	Perm	45.59321	–97.18547
328	Lake Marsh	NGlP	Lacustrine	Perm	44.66236	–97.21954
329	Mickelson GPA	NGlP	Palustrine	Semi	44.60166	–96.96369
330	Unnamed ditch	NGlP	Palustrine	Temp	44.60176	–96.96369
331	Spirit Lake	NGlP	Lacustrine	Semi	44.48433	–97.61712
332	Unnamed marsh	NGlP	Palustrine	Semi	44.58746	–97.63713
333	Beaver Creek lake	NGlP	Palustrine	Perm	43.03427	–97.67559
334	Weiger Slough GPA	NGlP	Palustrine	Temp	43.36631	–97.75776
335	Unk WPA	NGlP	Palustrine	Temp	43.86429	–98.44005
336	Long Lake ditch	NGlP	Palustrine	Temp	43.99603	–98.21098
337	Jones Lake	NGlP	Palustrine	Perm	44.47434	–98.94508
338	Lake Dudley	NGlP	Palustrine	Perm	44.67609	–98.28366
339	Alkali Lake Prot Area	NGlP	Palustrine	Perm	45.14262	–98.68407
340	Proud GPA	NGlP	Palustrine	Semi	45.54613	–98.4897
341	Renziehausen GPA	NGlP	Palustrine	Perm	45.79151	–97.98944
342	Willow Dam GPA	NGlP	Palustrine	Perm	45.76344	–98.43721
343	Fairfax Lake	NWGlP	Palustrine	Perm	43.04964	–98.88062
344	Lake Sixteen	NWGlP	Palustrine	Perm	43.72064	–98.85502
345	Corsica Lake	NWGlP	Reservoir	Perm	43.40952	–98.29827

346	Lake Dante	NWGlP	Lacustrine	Perm	43.06721	–98.17678
347	Lake Alcazar	NWGlP	Reservoir	Perm	43.32206	–98.34109
348	Potts Dam GPA	NWGlP	Reservoir	Perm	44.92882	–99.77823
349	Alkali Lake	NWGlP	Reservoir	Perm	45.74253	–99.13903
350	Unk Lake	NWGlP	Reservoir	Perm	45.39827	–99.64689
351	Spring Lake WPA	NWGlP	Reservoir	Perm	45.44733	–99.85286
352	Unk Roadside Marsh	NWGlP	Palustrine	Semi	45.75198	–99.14976
353	Unk Pond SGPA	NWGrP	Palustrine	Semi	43.34321	–99.77608
354	Byre Lake	NWGrP	Reservoir	Perm	43.92945	–99.83715
355	Murdo Dam GPA	NWGrP	Reservoir	Perm	43.92141	–100.7258
356	KOA CG Lake	NWGrP	Reservoir	Perm	43.89018	–101.14775
357	Hayes Lake	NWGrP	Reservoir	Perm	44.37012	–101.01243
358	Lake Waggoner	NWGrP	Reservoir	Perm	44.07633	–101.65173
359	Unk Pond	NWGrP	Palustrine	Semi	44.10744	–102.8436
360	Durkee Lake	NWGrP	Reservoir	Perm	44.9872	–102.05856
361	Owen Lake	NWGrP	Reservoir	Perm	45.46261	–102.3957
362	Pond Creek pond	NWGrP	Palustrine	Perm	45.45496	–103.02226
363	Horseshoe Lake	WCBP	Lacustrine	Perm	42.63391	–96.53231
364	Lake Lakota	WCBP	Lacustrine	Perm	43.20537	–96.56003
365	Burbank Lake	WCBP	Lacustrine	Perm	42.72545	–96.8605
366	LaBolt Lake	NGlP	Lacustrine	Perm	45.05418	–96.69033
367	Kaufman WPA	NGlP	Palustrine	Perm	45.09316	–96.47524
368	Roadside ditch, adjacent to Fonder/Okeson WPA	NGlP	Palustrine	Semi	45.60176	–96.97878
369	Cottonwood Slough 1	NGlP	Palustrine	Semi	45.74679	–96.88036
370	Cottonwood Slough 2	NGlP	Palustrine	Semi	45.78852	96.82112
371	Clubhouse Lake	LAP	Lacustrine	Perm	45.8929	–96.61885
372	Cascade Spring	MR	Riverine	Perm	43.3347	103.55172
373	Cold Brook Reservoir	MR	Reservoir	Perm	43.45817	–103.4904
374	Gates Park Lake	MR	Reservoir	Perm	43.75818	–103.626
375	Sunday Gulch GPA pond	MR	Reservoir	Perm	43.88966	–103.58655
376	Sheridan Lake	MR	Reservoir	Perm	43.96933	103.47921
377	Pactola Reservoir	MR	Reservoir	Perm	44.07331	–103.48472
378	Strawberry Picnic grounds pond	MR	Palustrine	Perm	44.31121	–103.69228
379	James River	NGlP	Riverine	Perm	44.59867	–98.23964
380	Big Sioux River	NGlP	Riverine	Perm	44.33007	–96.88813
381	Big Sioux River	NGlP	Riverine	Perm	43.91527	96.66822
382	W F Vermillion River	NGlP	Riverine	Perm	43.55783	–97.37034
383	James River	NGlP	Riverine	Perm	43.05183	–97.40756
384	Big Sioux River	NGlP	Riverine	Perm	40.80647	–96.67112
385	James River	NGlP	Riverine	Perm	40.80617	–96.66612
386	Fall River	MR	Riverine	Perm	43.3354	–103.5514
387	Kidney Springs	MR	Riverine	Perm	43.4585	–103.4904
388	Hot Brook	MR	Riverine	Perm	43.7585	–103.6267
389	Unk, lrg marsh	NGlP	Palustrine	Perm	45.54068	–97.16168
390	Tiny Unk marsh	NGlP	Palustrine	Temp	45.58744	–97.14159
391	Unk, cattail marsh	NGlP	Palustrine	Perm	43.9789	–96.98933
392	Unk, cattail marsh	NGlP	Palustrine	Perm	44.4237	–96.967
393	Barry Keal Memorial Wetland	NGlP	Palustrine	Perm	44.4612	–97.03122
394	Unk, cattail marsh	NGlP	Palustrine	Temp	44.57284	–97.0266
395	Unk, cattail marsh	NGlP	Palustrine	Temp	44.69515	–97.55256
396	Unk, cattail marsh	NGlP	Palustrine	Perm	45.2686	–97.61117
397	GM, Big Sioux River	WCBP	Riverine	Perm	40.80644	–96.67112
	Sites w/o Snails below					
	Unk wetland	NSH	Palustrine	Semi		
	Unk wetland	NSH	Palustrine	Semi		
	Unk wetland	NSH	Palustrine	Semi		
	Sutherland Reservoir	CGP	Reservoir	Perm		
	Medicine (Bow) creek	CGP	Riverine	Perm		
	Lake Gardner	NWGlP	Reservoir	Perm		
	Angostura Reservoir	MR	Reservoir	Perm		
		MR	Reservoir	Perm		

APPENDIX D: DISTRIBUTIONAL AND LIFE HISTORY DATA ON FRESHWATER SNAIL SPECIES LISTED HISTORICALLY BUT NOT OBSERVED IN THE RECENT SURVEYS OF SOUTH DAKOTA AND NEBRASKA.

Family Hydrobiidae

Cincinnatia integra (Say, 1821). Synonyms: *Amnicola integra, Paludina integra*. This is a tiny snail of about 4 mm. The shell is dextral and conical with 5–6 whorls. The spire is elongate, whorls are distinct and shouldered. Historically recorded for Nebraska and South Dakota (Tryon 1868, Over1915b; Henderson 1927). Regional records are from Iowa (Stewart 2006) and North Dakota (Cvancara 1983). It is at the western edge of its range according to sites mapped by Hershler and Thompson (1996), which lists a single site along the Missouri river. These snails are restricted to permanent waters (Burch 1989). They inbed with the substrate in lakes and slow streams and inhabit mesotrophic lakes in Canada (Berry 1943, Clarke 1979). In North Dakota they inhabit large and small streams and permanent lakes (Cvancara 1983). This species feeds on diatoms (Berry 1943). It is likely that this species has been misidentified historically. Thomas Say's original description of *Paludina integra* (Say, 1821) provided little detail and no figure. In addition, no specimens are available as the original material has been lost. See Hershler and Thompson (1996) and Hershler, (1996) for a more complete evaluation of these snails. This species is morphologically similar to *Lyogyrus granum* and *Probythinella emarginata*.

Probythinella emarginata (Kuster, 1852). Synonym: *Probythinella lacustris*. Common name: Delta hydrobid. This is a small snail < 5 mm. Shell is globose and has 4–5 whorls with a flattened apex. Sutures are deep, and the peristome is continuous sometimes detached. Historic records are from South Dakota (Over 1915b, Henderson 1927) with a more recent single site record from Nebraska (Hibbard and Taylor 1960). This species is on the Kansas Species in Need of Conservation (SINC) list with a single known population (Angelo *et al*. 2002). Regional records also exist for Iowa (Stewart 2006). It is observed among vegetation in permanent streams (Clarke 1981). In Kansas it appears limited to spring fed streams (KSDWPT 2009). It tends to inhabit deeper water, greater than 3m, particularly in the southern portion of its range (Clarke 1981, Jokinen 1992). Eaten in abundance by Whitefish in the Great Lakes (Jokinen 1992), the diet of this species is primarily diatoms (Berry 1943). This species is morphologically similar to *Lyogyrus granum* and *Cincinnatia integra*.

Family Lymnaeidae

Lymnaea catascopium (woodland pondsnail). Synonyms: *Galba apicina*, *Limnaea catascopium*. This is a medium sized snail reaching 15 mm. Shell is conical and thick. This species was recorded in Nebraska from Bow River with notes that only a single specimen was observed (Aughey 1877). In South Dakota there is also a single record as *Galba apicina* (Baker 1911) following Binney (1865) who listed it as *Limnaea catascopium*. Baker thought this was a misidentified and he altered it (Baker 1911). In addition to this problematic identification, this species may be shown to be conspecific to *L. elodes* and several other medium size marsh snails (Correa *et al*. 2010). There are no regional listings of *Lymnaea apicina* but records of *Lymnaea catascopium* are from Wyoming (Beetle 1989) and Iowa (Stewart 2006). Despite these records I still believe the listing of this species within Nebraska and South Dakota is an error.

Family Planorbidae

Ferrissia fragilis (Tyron, 1863). This is a small snail reaching up to 4 mm. Shell shape is broadly conical (conical Asian hat; limpet). The shell apex is elevated and acute not at the midline but instead below and to the right. This species has a single historic record from Custer County Nebraska (Walker 1906). Regionally present in Kansas, North Dakota, Iowa, Colorado, and Missouri. (Leonard 1959, Cvancara 1983, Stewart 2006, Harrold and Guralnick 2010, Wu *et al*. 1997). Inhabiting in streams and on aquatic vegetation or detritus (Jokinen 1992). Some minimum level of dissolved oxygen seem to be required for populations of this species as they are not present in warm reservoirs or stagnant waters, or in water that is artificially enriched or polluted. (Dillon 2006). They eat a diatom rich diet (Dillon 2000). Generation times can be as little as six weeks in laboratory populations – adults lay eggs as singletons (Dillon and Herman 2009)

Gyraulus circumstriatus (Tryon, 1866). This small snail has a planispiral shell up to 5 mm in diameter. Its 4–5 whorls slowly increase in diameter. The top and bottom of this shell are almost identical (this feature is suppose to distinguish this species from the nearly identical *Gyraulus parvus* where the top and bottom are different). Historic records are from five sites in Nebraska (Taylor 1960, Hibbard and Taylor 1960). Regional records are from Kansas, North Dakota, Wyoming and Iowa (Leonard 1959, Cvancara 1983, Beetle 1989, Stewart 2006). Inhabit quiet waters including temporary ponds (Jokinen 1992). Probably produce young multiple times per season in most of its range (Jokinen 1992).

Gyraulus crista (Linneaus, 1758). Synonym: *Armiger crista*. Common name: Nautilus ramshorn or star gyro. This is a tiny planispiral snail with a maximum length of 3 mm. Identification should be straightforward due to distinct transverse ridges projecting from the shell. Historically this species is listed from South Dakota and Nebraska (Over 1915b, Taylor 1960). Records are from Clay and Deuel counties without specific localities. This is a northern species with regional records from North Dakota and Wyoming (Cvancara 1983, Beetle 1989). It appears common in some areas of Canada (Prescott and Curteanu 2004). It inhabits quiet waters among vegetation (Burch 1989). This species may be overlooked due to its tiny size. Nebraska seems to be the southern extent of its range. I can find no life history data for this species.

Gyraulus deflectus (Say, 1824). Synonym: *Gyraulus hirsutus*. Common name: flexed gyro. This is a small planispiral snail with a maximum length of about 8 mm. The shell of this species has “hairs” along the long axes of the whorls, which are formed by the periostracum. Historically this species is listed from both South Dakota (Over 1915b, 1928) and Nebraska (Aughey 1877). Regionally this species is present in Missouri and Iowa (Wu *et al.* 1997, Stewart 2006). This species isn’t restricted to a particular habitat (Burch 1989, Prescott and Curteanu 2002). This species is more common to the north and east (Clarke 1981, Burch 1989) and is abundant in central Canada (Prescott and Curteanu 2004). This species has a bivoltine life cycle in Connecticut (Jokinen 1992).

Promenetus umbilicatellus (Cockerell 1887). Synonyms: Common name: Umbilicate sprite. This species is small with a diameter of < 5 mm. The thin shell is planispiral with round whorls and a deep funnel–shaped umbilicus. The first two whorls are slightly immersed in a mostly flattened spire. Listed in South Dakota from Perkins County (Over 1915b) and 3 mapped sites without specifics (Hibbard and Taylor 1960, Fig 8 page 112). Nebraska records are from Cherry, Brown, Cheyenne and Lancaster counties (Taylor 1960, Hibbard and Taylor 1960). Regionally it is listed from Iowa (Stewart 2006), North Dakota (Cvancara 1983), and Wyoming (Beetle 1989). Recent surveys in Colorado failed to find it or the congeneric *P. exacuous* (Harrold and Guralnick 2010). Continental range is Alaska to New Mexico and east to New York (Burch 1989). In Canada this species is centrally located within the prairie regions but is uncommon (Clarke 1981, Lipitzki 2001). Habitat is temporary ponds, marshes and intermittent streams (Clarke 1981). I can find no life history data for this species.

<u>Family Pleuroceridae</u>

Pleurocera canaliculata (Say 1821). Synonyms: *Pleurocera acuta*, *P. pyrenellum*. Common name: Silty hornsnail or Sharp hornsnail. This is a large snail reaching over 30 mm. Shell is auger shaped and often contains wine colors whorls often with a band of yellow. Operculum is paucispiral, chitinous and red colored (Baker 1928, Dazo 1965). This species is riverine and is reported to burrow into the sediment (Burch 1989), however, other reports have it inhabiting rivers with rocky substrate (Tiemann and Cummings 2005). Regionally it is observed in Kansas, Missouri and Iowa (Leonard 1959, Wu *et al*. 1997, Stewart 2006). This species is listed on the Kansas species in need of conservation (SINC) list as threatened (KSDWPT 2009). This species is dioecious (separate sexes) and females may lay eggs daily during April and

May. Eggs are deposited on hard substrate in masses of 1–19 contained within a gelatinous matrix (Dazo 1965). Females reproduce each year starting the second year of its several year lifespan (Dazo 1965). The diet of this species is primarily green algae (desmids), red algae, diatoms, and decaying vegetation (Jokinen 1992).

Family Pomatiopsidae

Pomatiopsis lapidaria (Say 1817). Synonyms: Common name: This snail is small, 6 mm, with a conical shell with 5 whorls. This species is amphibious observed on moist soils on riverbanks and also in deep water (Dewitt 1952). In Kansas this species is listed as endangered (KSDWPT 2009). It is considered rare in Iowa (Stewart 2006). In Missouri it is widespread but still uncommon due to habitat restrictions (Wu *et al*. 1997). The species is dioecious with an approximate lifespan of 2 years. Reproduction occurs after the first year (Davis 1967).

Family Valvatidae

Valvata sincera (Say, 1824). Synonym: *Valvata lewisi*. Common name:

mossy valvata. This snail has a tightly coiled shell with a moderately elevated spire, (depressed trochiform). This is a tiny snail that reaches just 3 mm. Coiling is dextral and it has a round, horny, multispiral operculum. This species is reported from the Bow and Elkhorn rivers in the northeast part of Nebraska (Aughey 1877) but is not recorded from historic records from South Dakota. Burch (1989) places this species as ranging south to South Dakota, therefore it appears Nebraska is the southern edge of its range, or the Nebraska records are misidentifications. Listings of this species in the adjacent states of Iowa and Colorado are all due to historic records (Stewart 2006, Harrold and Guralnick 2010). This snail is observed to the north and east and into

Canada but is not considered common (Clarke 1981, Lepitzki 2001, Prescott and Curteanu 2004). This snail is on the endangered species list in Massachusetts (Smith 1984). In Canada it inhabits deep waters of lakes, ponds, and slow-moving streams (Clarke 1981). As with so many species listed herein, life history data is absent for this species. Given the single author recording this species, the snails' small size, and similar morphology to *Valvata tricarinata* I believe the listing of this species within Nebraska is an error.