A Resurvey of the Freshwater Gastropods within South Dakota's Prairie Couteau Region

Species stability, Sampling & Metapopulation dynamics

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Abstract

A resurvey of fresh water snails was performed on twenty-eight water bodies originally sampled in 2005. All sample sites were within the Prairie Couteau ecoregion of South Dakota. Individual water bodies were found to be dynamic in regard to species presence and absence; 23 of 28 sites were found to have different species composition between 2005 and 2011. Though species presence and absence was found to be different at most of the water bodies sampled, species occurrence is not very dynamic when considering the entire region. Throughout the twenty-eight sites one additional species was found while one species discovered previously was not detected.

Analysis of changes in species presence and absence either via sampling error or metapopulation modeling were performed. Metapopulation theory explains the results of the second survey better than sampling error but only when it comes to local species extinctions. Specific observations at several water bodies, however, point to sampling dynamics being a factor as well.

The lack of much change in the regional richness between 2005 and 2011 suggest two things, first, that the region has not experienced any dramatic change that affect fresh water snails species in the six years since it was last sampled. Second, that a single stop at multiple sites is an affective way to determine species richness within a region. This method, however, may miss the mark on species specificity at individual water bodies.

Introduction

Freshwater snails play a vital role in the ecology of aquatic systems occupying a central part of the ecological food web. Most snails feed on periphyton and in turn are eaten by a number of invertebrate and vertebrate species particularly waterfowl (Swanson & Duebbert, 1989; Dillon, 2000). Snails are responsible for much of the energy throughput in aquatic systems (Newbold et al, 1983; Richardson et al, 1988; Brown, 2001). Due to their importance in primary production, snails seem to be a major influence on wetland growth and destruction under changing environmental conditions (Silliman et. al, 2005).

Snails also host the early life stages of a variety of parasites from the annoying to the deadly such as the trematode that causes 'duck-itch' and the trematode that causes Schistosomiasis (Dillon, 2000). Though clearly the importance of snails transcend a single focus, little is known about the stability of snails in South Dakota or indeed this region - or most of North America for that matter (Dillon, 2000). Most 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). Valid taxonomic up-to-date information for most States is absent (Dillon, 2000). In South Dakota our knowledge of species distribution of snails comes primarily from just a few studies (Over, 1915, 1915a; Over, 1928; Henderson, 1927).

Freshwater gastropods are more imperiled than understood and they are in a conservation crisis that will remain unacknowledged unless challenged directly. The non-marine mollusks collectively are thought be one of the most threatened groups of organisms (Lydeard et al, 2004). More specifically freshwater gastropods head the list of most threatened species by some analysis (Allan and Castillo, 2007) and the conservation challenges have been outlined (Lysne et al, 2008).

Since freshwater gastropods have not been well studied many questions remain regarding their distribution, conservation status and in many species even basic life-history traits. In addition snail species, being small, often abundant, easily found and manipulated also provide good model organisms for ecological studies.

Understanding more about snail distribution, abundance and biodiversity aids finding answers to fundamental ecological questions of population stability. The

persistence of a species may also be used as a measure of wetland health. In this situation some fundamental questions about their stability can be garnered by a simple resurvey of previous sample sites.

Herein we resurvey twenty-eight water bodies that were first sampled in 2005. All samples sites are within the EPA designated level IV ecoregion known as the Prairie Couteau, an elevated region of dense wetlands in the northeast corner of South Dakota. EPA designated ecoregions are based on the maps by Omerik (1987, 1995)

When resurveying sites after a series of years, given no dramatic environmental change, the expectation is that the same species would be represented. Changes to the expected species could be the result of several things. First, the sampling method may not be comprehensive. This would likely result in differences between re-detection of species based on species size (smaller species more likely to escape detection) or based on water body size (larger water bodies are more difficult to sample fully).

A second possibility is that differences in species composition are due to local extinctions and subsequent colonization as per metapopulation theory. A metapopulation is a group of local populations that are connected together via gene flow. Under this theory smaller populations may go extinct and be subsequently repopulated due to migration from neighboring populations. The concept is most connected to Levins (1969, 1970), who first used the term and described in mathematically, but the idea has been around much longer and one early study in this regard was on freshwater snails (Boycott, 1928). Analysis of species within regions based on metapopulation theory may be a valuable method to study species conservation (Hanski and Simberloff, 1997) since the theory deals with species persistence. Metapopulation theory, though popular from a theoretical perspective, is difficult to test via field studies due to the inability to distinguish absences due to sampling effort or bias from true local extinctions (Clark and Rosenzweig, 1994).

Here we look at this resurvey data briefly as a metapopulation analysis and also analyze it for potential changes due to sampling bias. The metapopulation analysis is done here using the most basic model of Levins (1969, 1970), without the assumptions of similar sized populations, by comparing predicted and actual species changes (as extinction or colonization).

Methods

This survey in 2011 was conducted on the same sites using the same methods as was done in a 2005 survey. All sample sites are water bodies within the Prairie Couteau ecoregion, an approximately 300 by 150 km plateau located in northeast South Dakota. In 2005 thirty-three sites were sampled, in 2011 twenty-eight of those sites were resurveyed. Except in regard to the total number of species, all analysis used here consider just the twenty-eight sample sites that were consistent between the two years.

The sampling procedure used was a timed weighted effort method: Sampling was done until 30 minutes had elapsed until a new species of snail was found. Snails were found by visual examination of shorelines, bottom substrate, vegetation, detritus and shallow water structures. Shoreline waters and structures were swept with a small hand net and dip net. Live specimens and shells were collected at each site. Shells were housed in storage jars while live specimens were preserved in 95% ethanol and stored in glass jars.

Statistical Analysis

The number of species of each size class and the water body size classes for missing and additional species were compared between 2005 and 2011 via contingency tables. These analysis were used as a test on whether the pattern of species occurrence was different in the two sampling years based on species size and then again on water body size.

Metapopulation analysis were done following some of the methods outlined well by Gotelli and Taylor (1999), though abbreviated herein due to the data coming from just two years of sampling (2005 and 2011). For each species with a value above zero in 2005, extinction and colonization probabilities were calculated. The extinction probability is found by:

Sites occupied in 2005 not occupied in 2011 / # Sites occupied in 2005

The colonization probability is found by:

Sites occupied in 2011 not occupied in 2005 / # Occupied in 2005

A regression analysis was performed on the combination of all species using the fraction of occupied sites and, first, the extinction probabilities and, second, the colonization probabilities. This is a test of the null hypothesis, that the slope of a regression lines comparing the fraction of occupied sites versus the probability of extinction and versus the probability of colonization, should be zero.

All statistical analyses were done using Prism 5.0 (2007).

Taxonomic Note:

This report utilizes updated taxonomy following the recommendations of the Freshwater Gastropods of North America (FWGNA) project (fwgna.org). The major and only real comprehensive guides to fresh water snails in North America number the species richness at over 500 (Burch and Tottenham, 1980; Burch, 1982; Burch, 1988). Species taxonomy, however, appears ever changing and some, mostly, recent works have made great strides in clarifying the overzealous nature of new species additions to North American gastropods over the last 100 years. This huge array of species listed as being present in North America has been overstated. These works include morphologic analysis (Hubendick, 1951, Hubendick, 1955), molecular analysis: (Walther et al 2006; Wethington and Lydeard, 2007, Walther et al 2010), and traditional mating experiments (Wethington and Dillon, 1993; Dillon et al 2002; Dillon and Wethington, 2002). Using the family Physidae as an example; from what was once thought to be over forty species, research has shown that the Physidae of North America consist of only about ten species (Dillon et al 2002; Wethington and Lydeard, 2007). This clarification will greatly clear up species identification problems while at the same time causing confusion due to the large number of synonyms. For this last reason the last table included here (Table 3) provides a list of the species used in this report and common synonyms.

Results

Summary results for twenty-eight sites sampled in 2011 are listed in Table 1 and Table 2 along with comparisons to sampling of sites in 2005. Ten species were found in 2005 and ten species were also found in 2011. From the 28 sites sampled in both years, 23 sites were found with different species composition. The number of records of *Physa gyrina* increased in 2011 (Table 2) compared to 2005, as did the records of *Aplexa elongata*. In addition one species, *Valvata tricarinata*, was present in 2011 while not being found in 2005. All other species were found in fewer sites in 2011 than in 2005 with one species (*Lymnaea humilis*) not being found at all.

Sample Bias

Figure 1 shows the species records divided by each of four size classes for each year and the differences between years. Chi Square analysis of different size classes between 2005 and 2011 show no significant difference ($P = 0.26$) illustrating that the number and proportion of species found between 2005 and 2011 are similar regardless of species size.

Figure 2 shows the records of missing or additional species per site based on the size of the water body. The proportion of sites with missing species and those with additional species are similar – with Chi Square analysis indicating no significant difference ($P = 0.95$).

Meta-population analysis

Predicted extinction and colonization rates following simple metapopulation modeling is shown in Figure 3. Figure 4 shows the results of species extinction and colonization probabilities calculated from the current data from two sampling years. Regression analyses show a significant negative slope ($P = 0.0018$, $\beta = -1.2$) of the extinction probability with a high coefficient of determination ($R_2 = 0.77$). The colonization probability slope is not significantly different than zero ($P = 0.8$, $\beta = -0.09$) and shows a very low coefficient of determination ($R_2 = 0.009$).

Discussion

This resurvey for fresh water snails was done in an attempt to evaluate the persistence and therefore the stability of fresh water snails. When sampling multiple sites within a region there is good detection of regional species present. One additional species found while one species was not found. Single stop at multiple sites within a region is an affective way to determine species composition within a region but may miss the mark on species specificity at individual water bodies.

The expectation on resurveying the same sample sites is that the same species will be present (and absent). If the presence/absence of species is different there may be several reasons for this. Species may actually be present but overlooked in the sampling. For this same reason species may be located that were not discovered in initial sampling. A second possible reason is that species, following metapopulation theory, go locally extinct and water bodies are repopulated – either from a 'source' location or consistently between different water bodies. Reasons for local extinctions may be due to short term or longer-term environmental change. In one historical study on fresh water snails done in English wetlands, the local extinctions in later years of study were attributed to a prolonged drought that struck the region (Boycott, 1928). Each of these potential reasons for changes to the sampling result is dealt with below. In both years, 2005 and 2011 ten species of snail were found in the Prairie Couteau region, though one species was not found and one was added (Table 1). Though overall species richness remained the same, the species occurrences were different in 23 of the 28 sites sampled. Table 2 illustrates the overall difference in species records.

Sampling Analysis

If sampling error is the cause of species differences we might expect to see some general patterns that indicate this. First we may see differences in detect ability of species based on their size. Smaller snail species in particular would be missed. When species are broken down by into size classes (figure 1) its apparent that overall numbers of each class are slightly lower in 2011. The Chi Square analysis, however, indicates no significant differences exist. The graph does illustrate that the same distribution pattern of species in regards to size is shown in 2011 compared to 2005 (large species are the least

represented, with tiny species next and the greatest number of medium sized species records are indicated for both years).

Second we might expect to see a pattern of species detection based on water body size. Large size water bodies are expected to be more difficult to sample and thus species detection should be lower. The number of sites with missing species compared to sites with additional species is not significantly different via Chi Square analysis. The pattern of sites with missing species and additional also look very similar (Figure 2).

Metapopulation Analysis

This resurvey may be more a test of sampling methods than of metapopulation dynamics, however, the metapopulation analysis – such as can be done with a comparison between two years – indicates an extinction pattern similar to that predicted by models. Having only two years of data does limit the robustness of this analysis.

Assuming these metapopulation changes are valid an open question still exists on whether we see true extinction and re-colonization of species or other effects that just appear so. For example a likely pattern of events is that year-to-year fluctuations in environmental conditions in turn cause fluctuations that limit or increase populations. Thus species are not actually wiped out (locally extinct) but are just much more difficult or easy to detect due to changes in population numbers. If this is the case the line between sampling bias and metapopulation modeling is blurred even more.

Flooding:

Though the analysis herein suggests that metapopulation modeling and not sampling bias best explain species record differences between years, the flooded conditions throughout the region in 2011 did affect the sampling at some sites, two examples below:

One good example can be shown via Dry Wood Lake. In 2011 high water prevented sampling from the marshy areas sampled in 2005. The subsequence sampling area had very little emergent vegetation and many difference in species detection: Not found were *Lymnaea stagnalis* (which prefers large marshy areas), *Helisoma trivolvis*, and *Lymnaea humilis*. In addition two species not previously found were present; *Gyraulus deflectus* and *Valvata tricarinata*. (*Valvata tricarinata* had not been found in the Prairie Couteau region at all before this).

It was also the case that shells were not as apparent at most sites, high water having effectively moved shorelines. Species richness counts in some larger lakes were affected. For example at Grasswood Lake, where the 2011 shoreline was effectively within the parking lot, few shells were found in 2011. Large arrays of shells along the beach were the indicators of much of the species presence in 2005.

Sampling Efficiency

More time consuming sampling techniques would be expected to be better at gathering the species richness of a region. Time and money, or course, restrict sampling. This resurvey illustrates that single visits to each of several water bodies within a region is a good way to garner fresh water snail species richness for the region. This was the case even when the sampling conditions differed greatly from 2005 to 2011. In 2011, as mentioned above, flooding was rampant throughout the region making it difficult and sometimes impossible to sample specific water bodies and specific locations at particular water bodies.

Other Agents of change:

The results presented here suggest no dramatic changes in species composition of the region took place since the last survey six years before. Any changes that occurred appear specific to a water body and did not affect the whole region – this can be see in the similar nature of overall species occurrences (Table 2). Though a species may have been found missing from a water body that same species was often detected at another water body where it was previously not found.

Though the lack of dramatic changes seen in this study suggest a relatively stable region some agents of change may still be at work or still be a threat to local fauna. Long-term change such as global climate alteration will undoubtedly effect species distributions; the specific nature of that change is unknown and worthy of study. Non-native species, particularly non-native snails, are potential agents of change as well. Of particularly interest are those non-natives that have exploding populations when introduced into a new region thus becoming invasive. No species of fresh water snail known to be non-native were discovered in this resurvey.

Acknowledgements

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Tables & Figures

Table 1. Comparisons of species found in 2005 and 2011 within water bodies of the Prairie Couteau region of South Dakota.

	2005	**2011**
Sites Sampled	33	28
Species Found	10	10
Missing Species Compared to 2005		1
Additional Species Compared to 2005		1

Table 2. The number of sample sites in which each of eleven species of fresh water snail was found within 28 sample locations in 2005 and 2011.

Species	**Site Presence 2005**	**Site Presence 2011**
Lymnaea elodes	22	21
Physa gyrina	20	23
Helisoma trivolvis	13	10
Aplexa elongata	9	10
Gyraulus deflectus	8	5
Promenetus exacuous	6	3
Lymnaea stagnalis	5	1
Lymnaea caperata	4	3
Lymnaea humilis	3	0
Physa acuta	3	1
Valvata tricarinata	0	1
Total Records	**93**	**78**

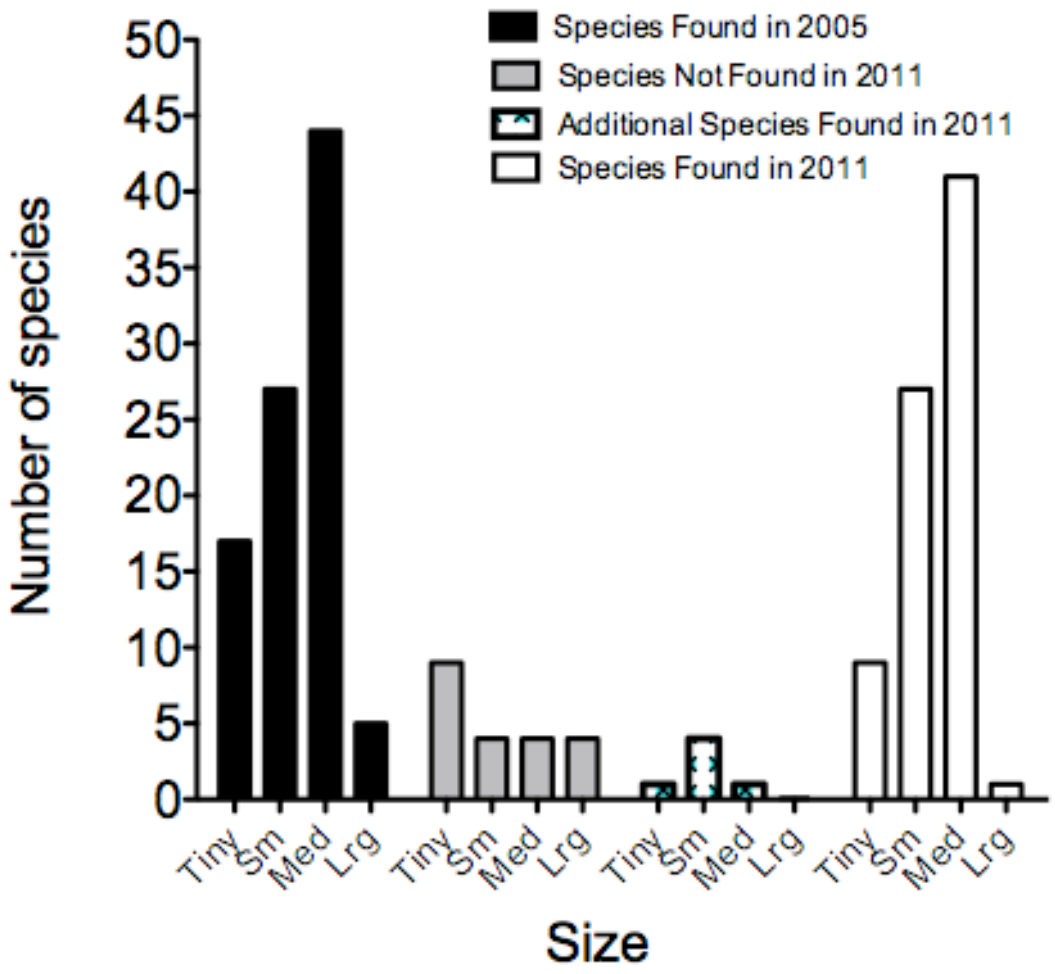
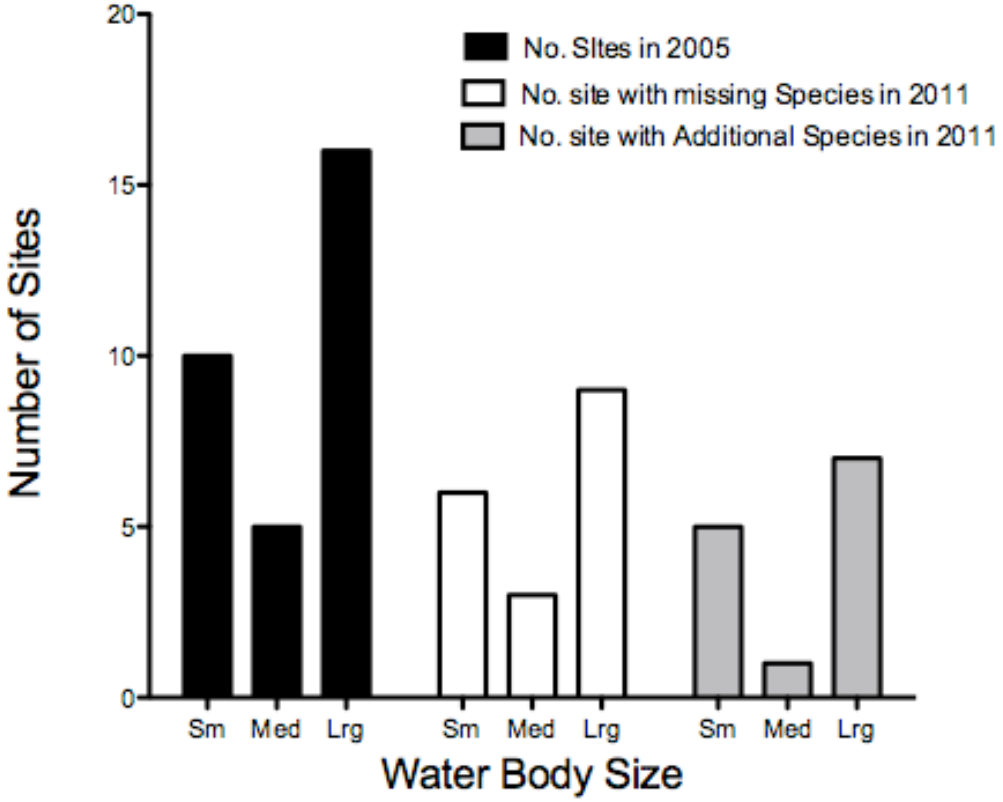


Figure 1. The number of species records based on species size in 2005 (black bars) compared to 2011 (open bars). Also shown are species of each size class not found (grey bars) and additional species in each size class (open bars with hatch marks).



Figures 2. The number of sites in each of three size classes; small, medium and large. Value from 2005 (black bars) compared to site size class with missing (open bars) and additional species (grey bars) in 2011.

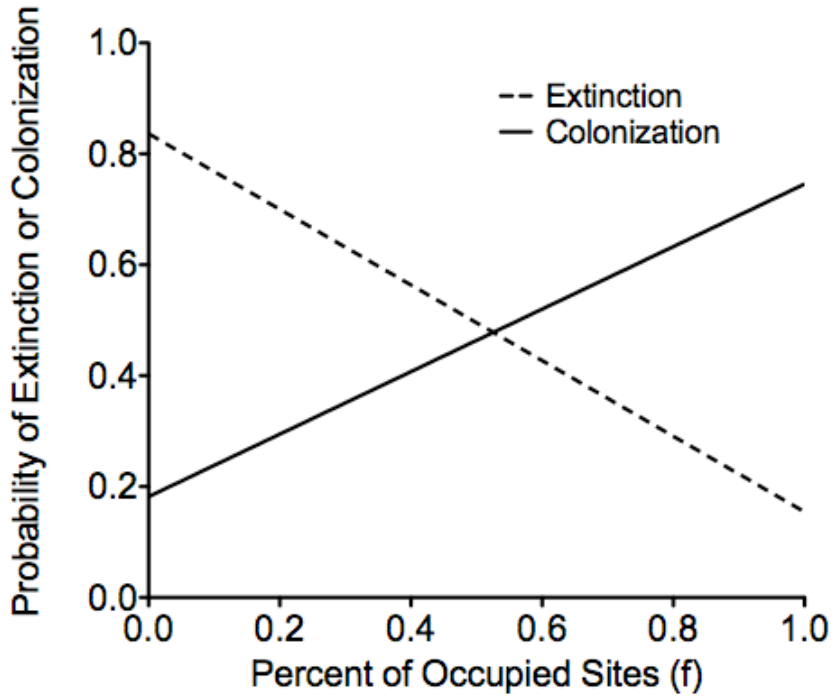


Figure 3. Predicted extinction rates (dotted line) and colonization rates (solid line) based on the fraction of occupied sites in simple metapopulation theory.

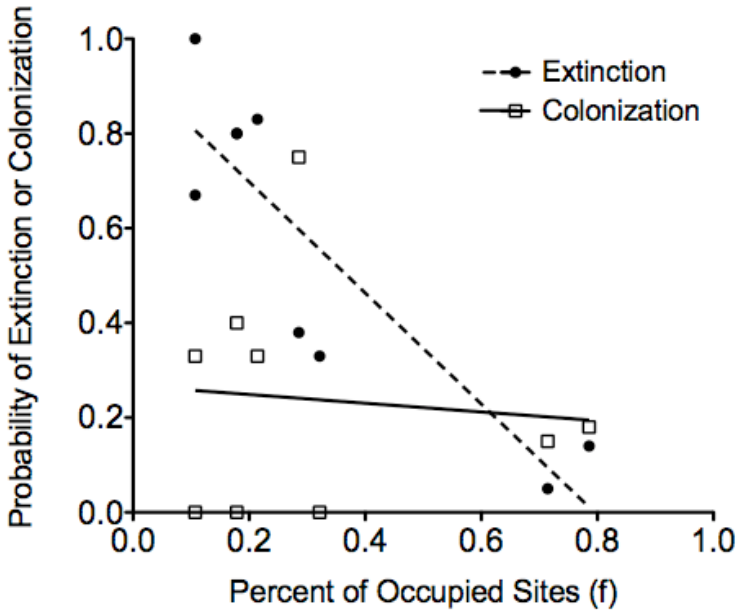


Figure 4. Extinction rates (dotted line) and colonization rates (solid line) based on the fraction of occupied sites. Data is calculated from fresh water snails in South Dakota between two sampling years (2005 and 2011).

Table 3. List of species from South Dakota collected in 2011 and some of the possible synonyms used historically.

Nomen Used here	Possible Synonyms
Lymnaea elodes	Sometimes the genus *Stagnicola* is used
Physa gyrina	*P. ancillaria, P. lordi*, many others Sometimes genus *Physella*
Helisoma trivolvis	Sometimes the genus *Planorbella*
Aplexa elongata	*Aplexa hypnorum*
Gyraulus deflectus	Appears stable
Promenetus exacuous	Appears stable
Lymnaea stagnalis	Appears stable
Lymnaea caperata	*Stagnicola caperata,* Sometimes the genus *Galba*
Lymnaea humilis	*Fossaria obrussa, L. modicella, L. parva, L. dalli*
Physa acuta	*P. heterostropha, P. integra, P. virgata.* Sometimes the genus *Physella*
Valvata tricarinata	Appears stable