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Fecundity of the Chinese mystery snail in a Nebraska reservoir

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The Chinese mystery snail (*Bellamya chinensis*) is a non-indigenous, invasive species in freshwater ecosystems of North America. We provide fecundity estimates for a population of these snails in a Nebraska reservoir. We dissected 70 snails, of which 29 were females. Nearly all female snails contained developing young, with an average of 25 young per female. Annual fecundity was estimated at between 27.2 and 33.3 young per female per year. Based on an estimated adult population and the calculated fecundity, the annual production for this reservoir was between 2.2 and 3.7 million young.

Keywords: *Bellamya chinensis*; freshwater snail; non-indigenous species; invasive species; annual fecundity

Introduction

Mystery snails, *Bellamya chinensis* and *Bellamya japonica* are non-indigenous aquatic species in North America. These large Asian snails were introduced into North America in the 1890s and are now established in more than 25 states (Jokinen 1982) and continue to spread (Solomon et al. 2010). Though some impacts of mystery snails have been investigated (Johnson et al. 2009; Solomon et al. 2010), the ecological effects of mystery snails on invaded ecosystems are essentially unknown.

To assess impacts of non-indigenous species on invaded systems, basic life-history information of the invading species is needed. Life-history information is incomplete or absent for many freshwater snail species (Jokinen 1992), including the mystery snails. Specifically, measures of growth, development, and fecundity are critical for assessing ecological impacts. Fecundity in particular is associated with high nuisance risk in non-indigenous mollusks (Keller et al. 2007).

Some measures of the reproductive capability of mystery snails have been reported. Similar to other snails within the family Viviparidae, Chinese mystery snails exhibit internal fertilization and give birth to live young (Jokinen 1982; Dillon 2000). Wood (1892) reported that adult snails purchased at a San Francisco Chinese market contained between 12 and 18 embryonic snails inside, although as many as 116 embryos have been found in

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a single female collected in Pennsylvania (Crabb 1929). The most complete life-history analysis is from a population from the Ottawa River of Canada, where average fecundity was 32 embryos per female with most snails carrying young during July, August, and September (Stanczykowska et al. 1971). Variations in the fecundity of populations are likely related to seasonal and/or latitudinal temperature differences (Dillon 2000).

Herein we analyze the number of embryos in a population of Chinese mystery snails from a Nebraska reservoir found to have high population density. This information will aid in estimating population growth and the impacts this species has on aquatic ecosystems.

Taxonomic note

The taxonomic position of the oriental mystery snails is somewhat unclear; we follow Smith (2000). This analysis of differences between *Bellamya* species concludes that *B. chinensis* and *B. japonica* are similar but distinct species. Several features indicate the species examined here is the Chinese mystery snail *B. chinensis*. Large adults (over 35 mm) have no carina, and developing young have a depressed embryonic whorl. Synonyms for this species include *Cipangopaludina chinensis, Cipangopaludina malleatus,* and *Viviparus malleatus* (Smith 2000).

Methods

Chinese mystery snails were collected in September 2011 from Wild Plum Lake, an approximately 6.5 ha multipurpose reservoir of the Salt Creek watershed, 28 km southwest of Lincoln in Lancaster County, Nebraska, USA. Snails were collected as part of a population study along an 11 by 11.5 m wide belt transect that extended from the shoreline to 1.46 m in depth. Seventy snails, approximately one-third of those collected, were set aside and stored in 70% ethanol for later examination. Stored snails were dissected and sex determined by the presence or absence of testes. Tentacles were examined to confirm sex determination; males have a longer, thicker right tentacle with a blunt curved end (Smith 2000). Sex ratios were compared using a chi-squared test to determine if they differed from 1:1. Embryos were extracted from ripe females, counted, and their length measured. Linear regression was used to determine potential relationships between the number or size of embryos and length of adult females. Length of embryos and adults was measured across the greatest dimension or from the tip of the spire to the lip of the aperture. Extracted embryos were placed into one of two categories: yolk or complete shell. Annual fecundity and production of young were then estimated for the population at Wild Plum Lake. Annual fecundity, f_{yr}, was estimated from the mean brood size, f_b, and estimates of the brooding period, t_b, in months, based on one year, t_{yr}:

$$f_{yr} = f_b \times t_{yr}/t_b.$$

Results

Forty-one of the 70 adults examined were male. The sex ratio did not differ from 1:1 (chi-square $= 2.057$, $p = 0.15$). Ripe females comprised 21 of the 29 females found in the sample. Ripe females contained 525 embryos, an average of 25 (standard error (SE)

Table 1. Relative proportions of adult genders, length (in millimeters, with standard error of the mean and range) and developing young found in 70 Chinese mystery snails from Wild Plum reservoir, Nebraska.

	Number (%)	Length (mm)
Males	41 (59%)	41.2 ± 1.1 (30.0–55.6)
Females	29 (41%)	41.0 ± 1.4 (28.5–57.1)
Ripe females	21 (30%)	42.2 ± 1.6 (31.2–57.1)
Embryos	525	
Yolk	377	2.6 ± 0.05 (1.0–5.5)
Shelled	148	3.9 ± 0.11 (2.0–7.0)
Number of females with stages of developing young		
Yolk and shelled young	5 (24%)	
Just yolk	14 (67%)	
Just shelled young	2 (9%)	

= 6.8) per female. Embryos were found at different stages of development and size: 377 were yolk capsules and 148 of the embryos were shelled. The size of yolk capsules, taken at the widest diameter, ranged from 1 to 5.5 mm with an average of 2.6 mm. Shelled embryos ranged from 2 to 7 mm in length with an average of 3.9 mm. Five female snails were found with embryos at both developmental categories (yolk capsules and complete shells) (Table 1).

There was a positive relationship between female body length and the number of developing embryos ($p = 0.0009$; $r^2 = 0.44$) (Figure 1). A single 54 mm long female contained 133 developing embryos. The largest female was 57 mm long and had 44 embryos. The smallest female was 31 mm in length and had four embryos. The size of embryos was also positively related to female adult length but the strength of the association was weak ($p = 0.07$; $r^2 = 0.15$; Figure 2).

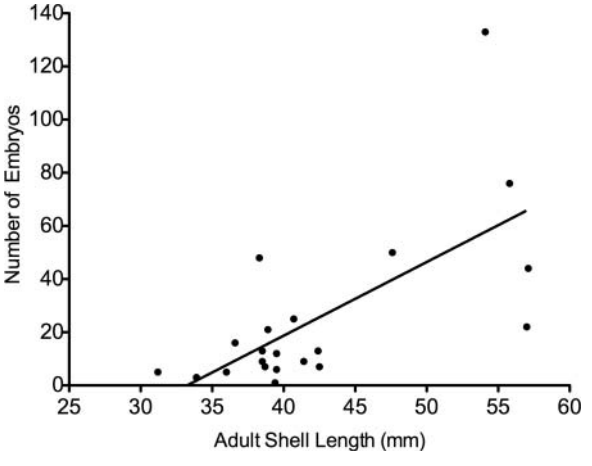

Figure 1. The number of brooded embryos as a function of adult shell length of ripe adult female *Bellamya chinensis*. Estimated linear regression line shown ($Y = -92.06 + 2.77X$; $p = 0.0009$; $r^2 = 0.44$).

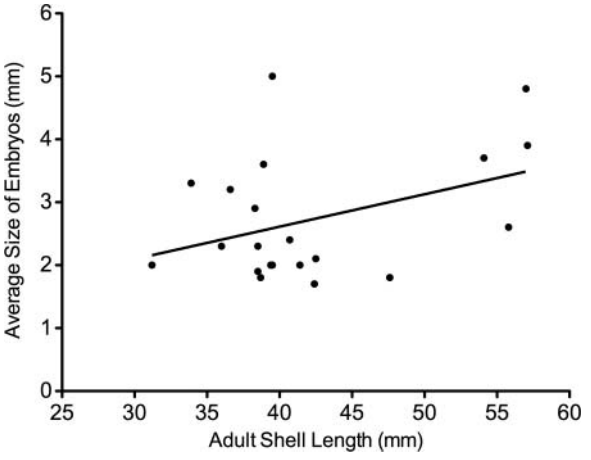

Figure 2. The size of brooded embryos as a function of adult shell length of ripe adult female *Bellamya chinensis*. Estimated linear regression line shown ($Y = 0.55 + 0.05X$; $p = 0.07$; $r^2 = 0.15$).

Fecundity estimate

The period of brooding for *B. chinensis* is unknown but another large snail within this family, the Banded mystery snail, *Viviparus georgianus*, has a brood period of about 10 months (Jokinen et al. 1982; Rivest and Vanderpool 1986). Ten months is used as the median value and annual fecundity is estimated for the Chinese mystery snail for 9, 10, and 11 months of brooding. The average number of embryos per female, and the expected brood time, indicates each female will produce 27.2 to 33.3 young per year. The adult female population estimate of 84,500–112,500 in Wild Plum Lake, based on a capture-recapture study (Chaine et al. 2012), and multiplied by the average production for each female translates into a current yearly production of 2.2 to 3.7 million young.

Discussion

Ripe female Chinese mystery snails contained developing embryos of more than one size and stage of development. This continuous reproductive strategy is found in some of the members of the Viviparidae (Jakubik 2007), although others have a single batch of eggs released once per year (Jokinen et al. 1982). Female Chinese mystery snails can produce a large number of young. One snail in this study contained 133 developing embryos. An earlier study reported 116 embryos in one female (Crabb 1929). In the present study, females of sizes 31 to 57 mm were found to contain embryos. Larger females have larger numbers of brooding embryos (Figure 1) and thus produce more embryos per year. The size of developing embryos also increased with the length of the female, but the relationship was weak explaining little variance (Figure 2). The relationships to female size were consistent with the results of Stanczykowska et al. (1971) who found that with increasing female size, the number but not the size of embryos increased.

Fecundity and population growth

Given the number of developing embryos within female Chinese mystery snails the expected population growth of a newly invaded water body would be overwhelming in

the absence of density-dependent forces to limit growth. Overwhelming population growth could occur even though the fecundity recorded here is low among species of freshwater snails, many of which produce 100s to 1000s of young per year (Keller et al. 2007). Though some effects of Chinese mystery snails on invaded systems have been documented the full impact of invasions by this species are not well known (Solomon et al. 2010). A large amount of the energy throughput in aquatic systems involves snails (Newbold et al. 1983; Richardson et al. 1988; Brown 2001). Considering the large size of Chinese mystery snails, the effects of a vast increase in biomass due to explosive population growth is expected to have dramatic effects on the energy flux in aquatic systems.

Reproductive mode

Semelparity is found in some species of snail within the Viviparidae. *Viviparus subpurpureus* brood young over winter and die after releasing the young in spring, while *Campeloma decisum* have two breeding periods one in their second and one in their third year (Brown et al. 1989). Chinese mystery snail females are able to produce young within their first year and reach a maximum age of 5 years (Stanczykowska et al. 1971). The estimated lifespan, the size range of adults housing embryos, and the different stages of developing embryos suggest that these snails produce over an extended period and have more than a single release of brooded young, thus iteroparity is the apparent reproductive strategy of Chinese mystery snails. Given that nearly all the females collected here contained developing young it seems likely that females produce young nearly every year until death. This reproductive pattern and the average young per female suggest that explosive population growth is possible in ecosystems invaded by this species.

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