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Short Communication

Population estimate of Chinese mystery snail (*Bellamya chinensis*) in a Nebraska reservoir

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Abstract

The Chinese mystery snail (*Bellamya chinensis*) is an aquatic invasive species in North America. Little is known regarding this species' impacts on freshwater ecosystems. It is believed that population densities can be high, yet no population estimates have been reported. We utilized a mark-recapture approach to generate a population estimate for Chinese mystery snail in Wild Plum Lake, a 6.47-ha reservoir in southeast Nebraska. We calculated, using bias-adjusted Lincoln-Petersen estimation, that there were approximately 664 adult snails within a 127 m^2 transect (5.2 snails/m^2). If this density was consistent throughout the littoral zone (<3 m in depth) of the reservoir, then the total adult population in this impoundment is estimated to be 253,570 snails, and the total Chinese mystery snail wet biomass is estimated to be 3,119 kg (643 kg/ha). If this density is confined to the depth sampled in this study (1.46 m), then the adult population is estimated to be 169,400 snails, and wet biomass is estimated to be 2,084 kg (643 kg/ha). Additional research is warranted to further test the utility of mark-recapture methods for aquatic snails and to better understand Chinese mystery snail distributions within reservoirs.

Key words: mark-recapture; invasive snail; freshwater ecosystem; small impoundment

Introduction

The Chinese mystery snail (*Bellamya* [=*Cipangopaludina*] *chinensis* (Reeve, 1863)), native to Asia, is an invasive species in North American freshwater ecosystems that has established populations in at least 27 states and some, if not all, of the Great Lakes (Johnson et al. 2009; Jokinen 1982; Solomon et al. 2010; USGS 2012). The ecological impacts of Chinese mystery snail invasion are largely unknown, though Chinese mystery snails negatively affect native snails in experimental mesocosms (Johnson et al. 2009). Additionally, Chinese mystery snails may influence nitrogen: phosphorus (N:P) ratios differently than native snails, suggesting potential effects on algal communities (Johnson et al. 2009). Although population estimates have not been previously reported, Chinese mystery snails can occur at very high (up to 38 snails/m^2) densities (Branson 1977; Johnson et al. 2009; Solomon et al. 2010).

It is important to understand population dynamics of introduced species because of links between population processes and ecological effects. Aquatic snails present a challenge for estimating population size. The method most commonly used is counting all snails within m^2 plots. This method is time consuming and fails to account for differences in detectability, which may substantially affect population estimates. A mark-recapture technique has been tested for estimating the density of another large-sized aquatic snail, the apple snail (*Pomacea paludosa* (Say, 1829)), in Florida freshwater marshes (Darby et al. 1997).

Figure 1. Chinese mystery snails marked with paint on the nuclear and penultimate whorls. Photograph by M. Hellman.

Given the potential impacts of invasive freshwater snail species and questions regarding the enumeration of snail populations, we utilized a mark-recapture technique to (a) determine its appropriateness for Chinese mystery snails and similar species and to (b) estimate the population of Chinese mystery snails within a Nebraska reservoir. We also developed estimates of density and biomass from the population estimate. This is the first known demonstration of applying mark-recapture techniques to generate a population estimate for the invasive Chinese mystery snail.

Material and methods

Sampling scheme

Sampling occurred on 8 and 15 September 2011 at Wild Plum Lake, Lancaster County, Nebraska, approximately 27 km southwest of Lincoln. The reservoir has an area of 64,700 m^2 and is shallow (<5 m). We sampled a belt transect that was located on the western side of the reservoir and not immediately adjacent to the boat launch. This is important to note because Chinese mystery snail distributions within reservoirs may be influenced by the presence and location of boat launches (Solomon et al. 2010). The habitat featured submergent vegetation and a silty bottom substrate.

The belt transect was approximately 11.5 m wide and extended out from the shoreline approximately 11 m, for a total sampled area of 127 m^2. Transect width was determined by the number of persons present at the initial sampling event; samplers spread out such that extended arms met fingertip to fingertip (approximately 1.7-m width per person). The transect length was limited by the depth that samplers could reach habitable substrate to search for snails. The deepest depth sampled was approximately 1.46 m.

Samplers searched for snails by hand at shallower depths and with flat-bottomed dip-nets (roughly 6-mm mesh - small enough to capture most size groups) when it was too deep to hand sample to the bottom substrate. Samplers moved in 1-m increments (bands) from shore, moving forward once all samplers along the transect had thoroughly searched their immediate vicinity and collected all snails detected. Samplers continued outward from the shore until they could no longer reach the bottom with dip-nets to search for snails.

During the first sampling event, we captured and marked snails (Figure 1). Two types of paint were used, a general hardware store grade multi-purpose red enamel and a white porcelain appliance touch-up paint. All snails received two marks, one of each color. The tip of the shell, or nuclear whorl, was coated with one color of paint and a round spot of the other color was painted onto the penultimate whorl. Marked snails were then released in the center of the 1-m band from which they were captured, leaving a 4.25-m buffer on either side (Figure 2).

The second sampling event was conducted one week later. The same area was resurveyed in a similar fashion to the first occasion. The number of marked and unmarked snails captured was recorded.

Population analysis

For the transect area sampled, the bias-adjusted Lincoln-Petersen estimation method proposed by Chapman (Seber 1982; Williams et al. 2002) was used to determine a population estimate, variance and 95% confidence interval. The population estimate was calculated as:

$$\tilde{N} = \frac{(n_1 + 1)(n_2 + 1)}{m_2 + 1} - 1,$$

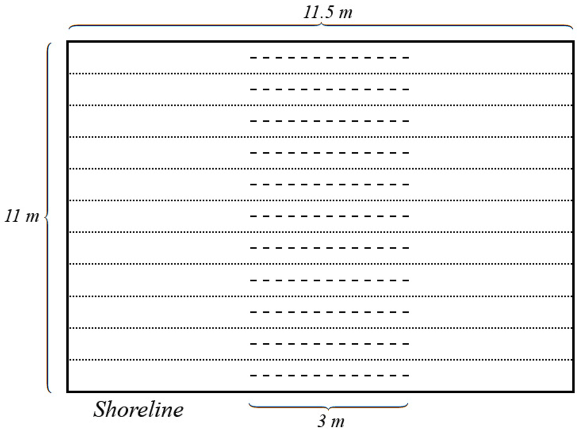

Figure 2. Snails were sampled within a belt transect that was 11.5-m wide and extended 11 m from shore. The transect was searched in 1-m increments (bands – between dotted lines) going away from the shore. Marked snails were returned to the center of the 1-m band from which they were captured and spread out over 3 m (dashed line), leaving a 4.25-m buffer on either side.

where n_1 and n_2 represent the number of individuals caught on the first and second occasions and m_2 represents individuals marked on the first occasion and recaptured on the second occasion. Variance for the population estimate, $\hat{\text{var}}(\tilde{N})$, was calculated as:

$$\hat{\text{var}}(\tilde{N}) = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)}$$

The 95% confidence interval, CI, was calculated as:

$$\text{CI} = \tilde{N} \pm 1.96\sqrt{\hat{\text{var}}(\tilde{N})}.$$

The population estimate was converted to a density estimate (snails/m^2; snails/ha). The transect population and density estimates were extrapolated to the reservoir for areas within the maximum expected inhabited depth of 3 m (USGS 2012) and then, conservatively, to areas within the deepest depth sampled. From the reservoir population estimates, wet biomass data was used to estimate total biomass.

Results and discussion

During the first sampling event, we captured 232 snails (n_1), which were marked and released. During the second sampling event, we captured 213 snails (n_2), comprised of 74 marked (m_2) snails and 139 unmarked snails. A total of 371 unique individuals were encountered during the study.

The population estimate for the sampled transect area (127 m^2) of Wild Plum Lake, derived using bias-adjusted Lincoln-Petersen estimation, was 664 snails (5.2 snails/m^2; 52,283 snails/ha). The variance of this estimate was 2,562 and the lower and upper bounds of the 95% confidence interval were 565 and 763, respectively. This is the first reported population estimate for the Chinese mystery snail, *Bellamya chinensis*.

Lincoln-Petersen estimation relies on three assumptions: (1) the population was closed during the time frame of the study (no births, deaths, immigration, or emigration), (2) marks were not lost or missed, and (3) all individuals were equally likely to be captured. We are confident that no marks were lost during the week between sampling occasions because painted marks on Chinese mystery snails remain for months (Chaine et al., unpublished data). Snails were handled and closely examined during the second sampling event, so it is unlikely that a mark would have been missed. We did not find any snails smaller than 11.3 mm. This suggests that we likely missed the younger age groups. Therefore, our estimate only pertains to the adult population and is a conservative estimate of the overall population. For snails ≥11.3 mm, it is reasonable to assume that sampling was conducted such that all individuals present in the sampling area would have an equal likelihood of being captured.

The assumption of closure may have been violated. Although Chinese mystery snails are capable of traveling more than 6 m in 7 d, the median distance travelled for 130 snails was 1.8 m in 7 d (Chaine et al., unpublished data). Thus, snails could have moved during the interval between sampling events, but only those snails near the edge of the transect were likely to have immigrated and emigrated. We have no reason to suspect that the rates of immigration or emigration were unbalanced. Marked snails were released into the middle of the transect area, >4.25 m from the edge. Without adequate analysis of Chinese mystery snail movement patterns, it is impossible to determine the probability that the closure assumption was substantially violated, and thereby biasing the population estimate. However, we believe that a mark-recapture approach remains valid for Chinese mystery snails.

As we did not capture the smallest size groups, we do not consider the possibility of closure violation as a result of births. We assume that there were not enough deaths during the one week interval between sampling to bias the result. It should also be noted that although the greatest depth sampled was less than the expected maximum inhabited depth of 3 m (USGS 2012), samplers found few snails near the deep edge of the belt transect. This implies population estimation was unaffected by not sampling to the full expected depth range of the species. However, extrapolating the transect estimate to all areas within the maximum expected inhabited depth of 3 m (USGS 2012) likely overestimates the adult population size.

The belt transect area sampled comprised a relatively minor portion of the available snail habitat at Wild Plum Lake, and we only detected individuals ≥11.3 mm. Given that within the transect we captured 371 unique individuals and estimated the population to be 664 adult Chinese mystery snails (5.2 snails/m2; 52,280 snails/ha), this reservoir likely has a high-density population and correspondingly high biomass of Chinese mystery snails. Even without knowledge of specific ecological impacts, an extremely high snail biomass can reasonably be assumed to influence water chemistry and food webs (Hall et al. 2003).

To accurately estimate the population of an entire lake or reservoir, further research is needed to determine how snails are distributed within a given water body, relative to factors such as substrate, vegetation and depth. Although extrapolation to the reservoir is speculative, a biomass estimate for the reservoir based on the transect density and wet biomass data from Wild Plum Lake (Chaine et al., unpublished data) provides insight into the potential ecological impact of Chinese mystery snail invasion. At least 75% of the reservoir (Nebraska Game and Parks Commission 2012) is within the maximum expected inhabited depth for Chinese mystery snails (3 m) (USGS 2012). Applying the transect density (52,280 snails/ha) to 75% of the entire reservoir (4.85 ha), the total adult Chinese mystery snail population was estimated to be 253,570 snails. At a wet biomass average of 12.3 g/snail (wet weight [shell included]), this population size corresponds to an estimated biomass of 3,119 kg (643 kg/ha) for the reservoir. Given that we found few snails at the deep end of our transect, we also produced an extrapolation covering only the area of Wild Plum Lake within the depth we sampled (1.46 m) to avoid potential overestimation. About 50% of the reservoir contains this depth (Nebraska Game and Parks Commission 2012). Applying the transect density (52,280 snails/ha) to 50% of the entire reservoir (3.24 ha), the total adult Chinese mystery snail population was estimated to be 169,400 snails. At a wet biomass average of 12.3 g/snail (wet weight [shell included]), this population size corresponds to an estimated biomass of 2,084 kg (643 kg/ha) for the reservoir. In comparison, a study of fish populations from 38 lakes worldwide found only one species of fish with a biomass greater than 643 kg/ha, with the rest of the species no more than 248 kg/ha (Downing and Plante 1993). This suggests that Chinese mystery snails comprise a sizable portion of the animal biomass in the reservoir.

This is a first attempt at using a mark-recapture technique to estimate the population size of Chinese mystery snails. Repeated trials testing the methods outlined in this study and longer studies with more than two sampling events could contribute to our understanding of the Chinese mystery snail population within this reservoir and in other invaded water bodies throughout the United States of America. Further research is also necessary to understand how population abundance varies with habitat characteristics.

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