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Research Article

Preliminary estimates of consumption rates of *Rapana venosa* (Gastropoda, Muricidae); a new threat to mollusk biodiversity in the Río de la Plata

Andrea Lanfranconi, Ernesto Brugnoli and Pablo Muniz*

Oceanografía y Ecología Marina, IECA, Facultad de Ciencias, UdelaR, Iguá 4225, Montevideo 11400, Uruguay

E-mail: pmmaciel@fcien.edu.uy *(PM)*, andrea.lanfranconi@gmail.com *(AL)*, ebo@fcien.edu.uy *(EB)*

**Corresponding author*

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Abstract

The veined whelk *Rapana venosa* (Valenciennes, 1846) is an active, Asian, invasive mollusk predator that has been present along the coastal zone of Maldonado, Uruguay since 2004. The feeding rate of *R. venosa* on native mussels was estimated in a laboratory experiment. A flume with a constant water flow was used, in which the mean (± SD) temperature was 25.4 ± 1.8 °C, the mean (± SD) salinity was 18.5 ± 1.6, and a 15:9 light-dark schedule was followed. Each experimental trial lasted 9 days and a constant prey supply was maintained. Three size classes of predators and three size classes of prey (*Brachidontes rodriguezii* and *Mytella charruana*), were used. For all sizes of predator combined, the average (± SD) absolute consumption rate was 0.88 ± 0.3 g day^{-1}, and the relative consumption rate was 0.057 ± 0.034 g g^{-1} day^{-1}. No significant differences were found between the number of prey and total grams consumed among the three size categories of snails. However, for the relative consumption rate, small snails consumed significantly greater (0.10 g g^{-1} day^{-1}) amounts than intermediate and large snails (0.04 and 0.02 g g^{-1} day^{-1} respectively). All sizes of snails consumed significantly more intermediate- than small-sized mussels. This study provides important knowledge for future research to assess the impact of this invasive species on native bivalve resources.

Key words: exotic invasive species; *Mytella charruana*; *Brachidontes rodriguezii*; coastal zone; Uruguay

Introduction

The veined whelk *Rapana venosa* (Valenciennes, 1846) (Gastropoda, Muricidae) is a large carnivorous whelk native from Asia (Tsi 1983, Chung et al. 1993). Veined whelks show wide thermal and salinity tolerances (Chung et al. 1993; ICES 2004), fast growth, high fertility (ICES 2004; Harding et al. 2007a), a planktonic phase ranging from 14 to 80 days (Mann and Harding 2000), plus tolerance to water pollution and hypoxia (Zolotarev 1996). These traits have made this organism a successful invader. The veined whelk is a voracious predator (Savini et al. 2002) with serious negative effects on native mollusc populations (Drapkin 1963; Zolotarev 1996; Giberto et al. 2006) including economically important oysters, mussels and clams (Harding and Mann 1999; Harding et al. 2007a,b; Savini et al. 2002; Savini and Occhipinti-Ambriogi 2006).

Since 1947, *R. venosa* has spread to coastal waters in Asia (Drapkin 1963), Europe (Zolotarev 1996; Goulletquer 2000; Kerckhof et al. 2006), and North America (Harding and Mann 1999). In South America, it was first recorded in 1998 in the Río de la Plata (Scarabino et al. 1999; Pastorino et al. 2000). Since then, it has spread about 300 km eastward along the Uruguayan coast to its current known distribution limit, the beaches of Maldonado Department (Lanfranconi et al. 2009; Carranza et al. 2010). Several species of mytilids inhabit the Uruguayan coast (Maytia and Scarabino 1979; Scarabino 2006), and the blue mussel *Mytilus edulis platensis* (d´Orbigny, 1842) represents the country's principal mollusc resource. According to Defeo et al. (2009) the blue mussel fishery is "fully exploitated". Recent work shows that the veined whelk is now active predator of mussels in Río de la Plata (Lanfranconi et al. 2009; Carranza et al. 2010; Giberto et al. 2006, 2011).

In view of the potential ecological and commercial importance of the invasion of the Río de la Plata estuary by *R. venosa*, the aim of

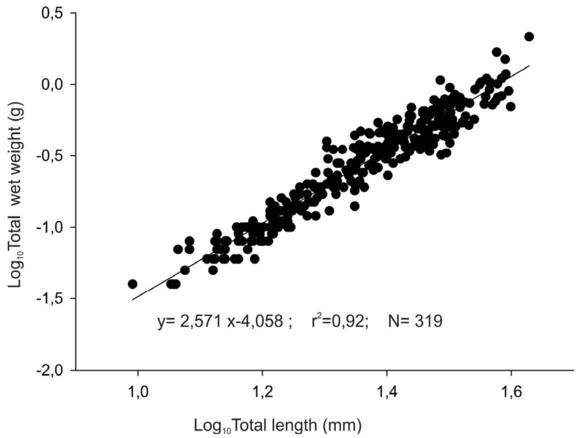

Figure 1. Common relationship between total tissue wet weight (g) and total length (mm) and for the two species of mussels (*Brachidontes rodriguezii* and *Mytella charruana*) used in the experiments.

this study was to quantify, under controlled laboratory conditions, the consumption rate of *R. venosa* using two mytilid species common to the Río de la Plata. These results are a first step in assessing the potential impact of *R. venosa* on the blue mussel resource.

Methods

Feeding experiments were conducted using a flume, which consists of a main, rectangular, acrylic chamber (140 cm long × 10 cm wide × 20 cm high) designed to circulate water at a constant rate via a speed-controlled pump. To simulate the natural circadian rhythm, 15–9 light-dark cycle was provided using fluorescent lighting. The flume was divided into four equal size (35 cm long × 10 cm wide) compartments, and one snail was placed within each compartment. The compartments were separated by a screen that permitted water circulation, but prevented the snails or mussels from moving between the compartments. In each compartment, stones were used to mimic the natural environment of *R. venosa*. Based on a pilot study, it was necessary to monitor the level of ammonia and dissolved oxygen in the water daily and the water in the flume was replaced every 48 hours to maintain original conditions. The water was taken every week directly from the Buceo´s beach (34º54'56.02" S; 56º08'51.17" W) and the unfiltered water was transported to the laboratory for use in the experiment. Once collected, the snails were kept in tanks in the laboratory under identical conditions to those in the flume. Upon initiating the experiment, salinity and temperature were measured daily using a YSI 5947 Multi-parameter meter (YSI Inc., Yellow Springs, OH, USA).

Study organisms

Predator: *Rapana venosa*

During September 2008, 33 veined whelks were collected manually by scuba diving off the east coast of Rio de la Plata (Playa Hermosa, Maldonado: 34°50'38" S; 55°18'09" W). We measured the snails' total length (TL ± 1 mm) (maximum distance from spire to siphonal canal) using calipers and total tissue wet weight (ToWW to 0.1 g) using a digital scale. For the experiment, we used 4 small (40–49 mm TL), 5 intermediate (60–69 mm TL), and 3 large (80–89 mm TL) snails.

Snails not being used in an experimental trial were kept in tanks under identical experimental conditions. After completion of the experiments, each snail was killed and wet weight of the tissue was recorded.

Prey: *Brachidontes rodriguezii* and *Mytella charruana*

Brachidontes rodriguezii (d´Orbigny, 1842) and *Mytella charruana* (d´Orbigny, 1842) were collected manually from the Buceo beach (160 of each species). Total length (TL) (mm) and tissue wet weight (TiWW) (g) were measured for all individuals and the weight-length relationship did not differ significantly (ANCOVA, $P > 0.05$) between species, yielding a common weight-length relationship (Figure 1) that allowed us to use the two mussel species interchangeably in the experiments. To test for possible prey size preferences, we grouped separated the mussels into three size-classes: small (Sm 15–19 mm TL), intermediate (Im 20–30 mm TL), and large (Lg 31–40 mm TL). All mussel individuals were kept in tanks in the laboratory under identical conditions to those in the flume.

Experimental design

Because we only had four compartments in the flume, three consecutive experimental runs had to be performed (November-December 2008). For each experimental run, one snail from each size category as selected and placed in a compartment, and one from one of the three

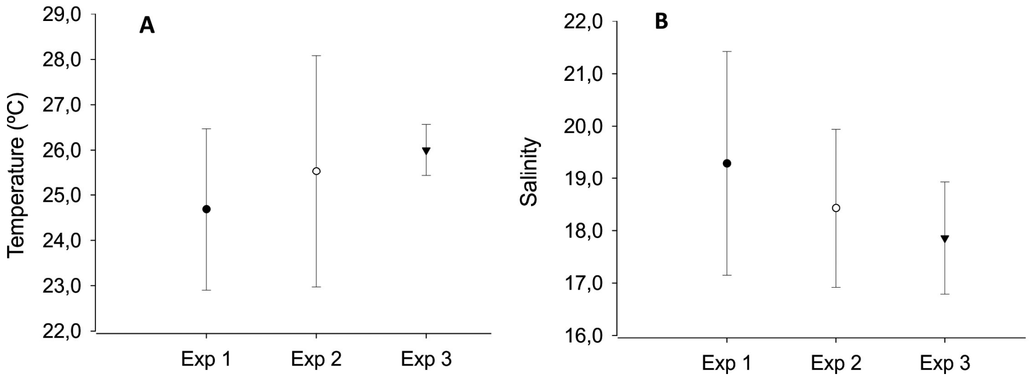

Figure 2. A) Daily range of temperature and B) salinity for the three experimental runs. Black points indicated the mean value during the 9 days of each experiment.

categories was selected randomly to fill the fourth compartment (except for the "Large" class for which only 3 individuals were available). Each experimental run lasted 9 days. The snails were not offered food for the first two days to standardize hunger levels among snails (Savini et al. 2002; Savini and Occhipinti-Ambrogi 2006). To ensure the relatively constant availability of prey in all sizes, each snail was offered 9 mussels per day, three of each size class. The compartments were examined each morning to identify and quantify the prey consumed. Mussels that had been consumed were replaced with individuals of the same size.

Data analysis

Differences in daily temperature and salinity readings among the 3 experiments were tested for using Kruskal-Wallis tests because the assumptions of normality and homoscedasticity needed for parametric analysis were not met.

Daily consumption rates were calculated as an average of the 12 snails used in the experiment, taking into account the number of prey, the total grams consumed (absolute rate), and total grams consumed relative to the tissue wet weight of each snail (relative rate). To test for differences in consumption rates between the three size classes of snails, a Kruskal-Wallis test was used because data did not meet the assumptions for parametric analyses.

Preference for prey size by snails of the different size classes was analyzed using a two-way ANOVA with the number of prey consumed for each snail as the response variable (the data were normally distributed). Scheffé's a posteriori test was used to identify which means differed. All statistical analyses were conducted with an a priori level of significance of $\alpha = 0.05$ using the software Statistical 7.0 (Statsoft Inc., Tulsa OK, USA).

Results

Environmental parameters

During the 27 days of experiments, the average (± SD) temperature was 25.4 (± 1.8) °C and the average salinity was 18.5 (± 1.6). Due to the wide variation in the daily measurements (Figure 2 A, B), there were no significant differences ($P > 0.05$) in mean of temperature and salinity between experimental runs.

Consumption rates

A total of 220 mussels were consumed by the snails over the 3 experimental trials. Considering each experiment separately, the maximum consumption by a snail was 29 prey items and the minimum 4 prey items (during 7 days). On average (± SD), each snail consumed 2.0 ± 0.8 prey per day.

During the whole experiment a total of 95.5 grams were consumed by the 12 snails (range 1.7 to 12.2 g per snail per 7 days; Figure 3). On a daily basis, the average (± SD) was 0.88 (± 0.3) g day^{-1} (range 0.19 to 1.35 g day^{-1}). As relative consumption, the average (± SD) was 0.057 (± 0.034) g g^{-1} day^{-1}. On average (considering the 12 snails) each snail consumed a 5.7% of its body wet weight per day.

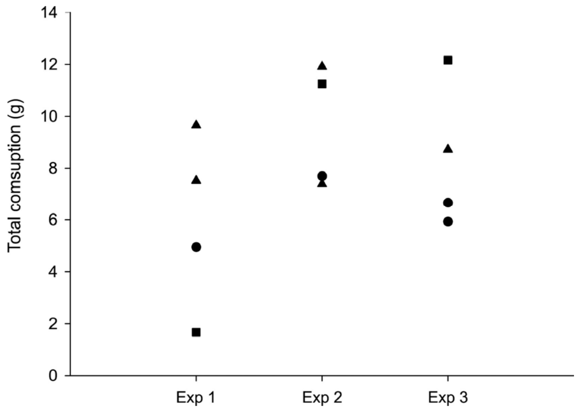

Figure 3. Total amount of prey in grams consumed during the seven days of each experiment. Each point represents a different snail; square: large size, triangle: medium and circle: small size.

Table 1. Total number of prey consumed for each snail size class.

Snail category	**Mussel size class**		
	Small	Intermediate	Large
Small	8	29	20
Intermediate	22	47	38
Large	13	24	19
Total	43	100	77

No significant differences were found between the total number of prey consumed among the three size categories of snails (KW, P>0.05; Figure 4A). No significant differences were found between the number of total grams consumed during 7 days among the three size categories of snails (KW, P>0.05; Figure 4B). However, for the relative consumption rate a significant difference was found between small and large snails (KW, P<0.05) (Figure 4C).

Related to prey preference, intermediate mussels (20–30 mm TL) were most commonly consumed by snails of all three size classes, while small mussels (<20 mm TL) were the least common (Table 1). There was no significant difference in the numbers of prey consumed between snail size class (ANOVA, $F_{2,38} = 1.38$, P = 0.27) but there was a significant difference in sizes consumed (ANOVA, $F_{2,125} = 4.54$, P = 0.020), regardless of predator size. Consumption of intermediate-sized mussels was significantly greater than of small-sized mussels (Scheffe's test, P = 0.015) with no significant difference (P = 0.19) between numbers of small- and large-sized mussels consumed.

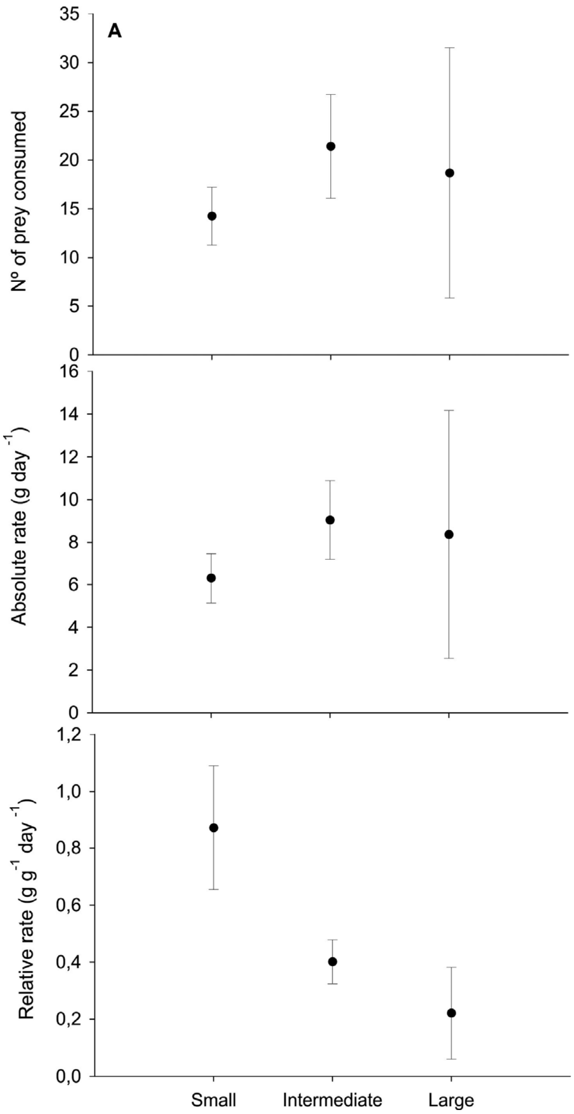

Figure 4. Range in the total consumption (during the nine days of each experiment) for each snail size category, expressed as A) number of prey, B) absolute rate (g day^{-1}) and C) relative rate (g g $^{-1}$ day^{-1}).

Discussion

Variability in the amount and frequency of the number of prey items consumed per day suggests that the rate of consumption is naturally variable among snails. This variability is probably determined by a series of factors that affect each individual, such as the general state of health, stressors, life history or the physical condition of each organism (Randall et al. 1997). Morton

(1994) estimated a handling time of 1–5 hours for prey of 33–35 mm TL using *R. venosa* as predator. The result of our experiment is within this range as the maximum number of prey consumed was 6 (3.1 g) in 24 hours, which is equivalent to 4 hours to consume a mussel.

Comparison of absolute consumption (g per snail per day) is complicated by differences in both predator size and water temperature. At the higher end, Savini et al. (2002) described an absolute daily consumption rate of 1.5 g (wet weight) of the clam *Mercenaria mercenaria* by *R. venosa* individuals of 101–160 mm TL maintained at an average temperature of 26°C and Savini and Occhipinti-Ambrogi (2006) found that *R. venosa* of 104 mm TL consumed on average 1.2 g day^{-1} in wet weight during a field caging study. More recently, Giberto et al. (2011) reported a consumption rate of 0.68 g day^{-1} for a snail of 70 mm shell width maintained at 20°C. The results obtained in this study, 0.88 g day^{-1} for an average specimen of 65 mm TL and water temperature of 25°C, are consistent with the published studies.

While the actual number of prey eaten by differing size-classes of veined whelk did not differ (Savini et al. 2002; this study), the results when expressed on a per capita basis indicated small snails consumed more than large snails. These results are consistent with those of Savini et al. (2002) and Giberto et al. (2011).

In terms of preferred prey size, veined whelks consume more intermediate- than large- or small-sized bivalves (Savini and Occhipinti-Ambrogi 2006; this study). To better quantify the size-selectivity response of the full size range of veined whelks, it would be useful to repeat this experiment using both a broader range of snail sizes, as well as a larger sample size for each snail category.

Stramonita haemastoma (Linnaeus, 1767) is a native snail of the Muricidae family, has similar characteristics to *R. venosa*, and coexists with this invasive species on the coast of the department of Maldonado (Lanfranconi et al. 2009; Scarabino et al. 2006). These snails also eat bivalves; consequently, these two species could be competing for the same resource. A study by Alyakrinskaya (2002) found that, given the choice between mussels and oysters, *S. haemastoma* prefers consuming mussels. Kenneth (1987) found similar consumption rates for *S. haemastoma* individuals (35 to 55 mm TL) as those reported here for *R. venosa* (6 prey per day or 4 hours for a mussel of 27 mm TL) while Rilov et al. (2004) describe a handling time between 3 and 16 hours for the bivalve prey, *Brachidontes pharaonis* (P. Fischer, 1870) (25–30mm TL). Reproductively, Harding et al. (2007a) conclude *R. venosa* has a greater reproductive potential than *S. haemastoma*, given the larger adult size, longer life expectancy, and higher estimated fertility. The sum of these characteristics raises the question as to whether *R. venosa* is dominant over *S. haemastoma* and whether it could displace the species from the Uruguayan coastal zone. It would be interesting to explore whether real competition exists between these two species by comparing the method of attack and handling time of prey and also the possibility these two predators prey upon each other.

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