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RAPA WHELK *RAPANA VENOSA* (VALENCIENNES, 1846) PREDATION RATES ON HARD CLAMS *MERCENARIA MERCENARIA* (LINNAEUS, 1758)

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ABSTRACT The recent discovery of adult veined rapa whelks *Rapana venosa* (Valenciennes, 1846) in the Lower Chesapeake Bay, U.S.A. offers cause for both ecological and economic concern. Adult rapa whelks are large predatory gastropods that consume bivalves including commercially valuable species such as hard clams, *Mercenaria mercenaria* (Linnaeus, 1758). Laboratory feeding experiments were used to estimate daily consumption rates of two sizes of whelks feeding on two size classes of hard clams. Large rapa whelks (shell length, SL >101 mm) are capable of consuming up to 2.7 g wet weight of clam tissue daily, equivalent to 0.8% of their body weight. Small whelks (60–100 mm SL) ingest an average of 3.6% of their body weight per day.

KEY WORDS: rapa whelk, *Rapana venosa*, hard clam, *Mercenaria mercenaria*, predation, Chesapeake Bay

INTRODUCTION

The veined rapa whelk, *Rapana venosa*, (Valenciennes 1846; Gastropoda: Muricidae) was discovered in the Hampton Roads region of the Chesapeake Bay, USA, in the summer of 1998 (Harding & Mann 1999). The species is native to the Sea of Japan, Yellow Sea, East China Sea and the Bohai Sea (Tsi et al. 1983) but was introduced to the Black Sea in the 1940's (Drapkin 1953) and has since spread to the Aegean Sea (Koutsoubas & Voultsiadou–Koukoura 1990) and the Adriatic Sea (Ghisotti 1974). Recently a female specimen together with egg masses was found in the Rio del Plata, an estuary between Argentina and Uruguay in South America (Pastorino et al. 2000).

The predatory activity of rapa whelks in the Black Sea is considered by Zolotarev (1996) to be the prime reason for the decimation of native Black Sea oyster, scallop and mussel populations. Given this history, there is both ecological and economic concern for the future of shellfish stocks in the Hampton Roads region of the Chesapeake Bay. Hard clam, *Mercenaria mercenaria*, populations are of particular concern in that the Hampton Roads region supports a substantial local commercial hard clam fishery. Laboratory feeding experiments were used to quantify daily feeding rates for two size classes of adult rapa whelks offered hard clams.

MATERIALS AND METHODS

Twelve adult rapa whelks, collected from the lower Chesapeake Bay, USA, between March and May 2000, were separated into two different size classes: small (60–100 mm shell length (SL), the maximum dimension from the apex of the spire to the end of the siphonal canal) and large (101–160 mm SL). Rapa whelks were maintained individually in 60 × 40 × 30 cm plastic net cages submerged in a shallow flume (250 × 70 × 30 cm) with a constant flow of unfiltered York River water as described in Savini (2001). The bottom of each cage was covered with 15 cm of clean hard sand substrate. Rapa whelks were starved for 48 hours prior to the addition of hard clams (prey) to each enclosure. Each whelk was given five small (50–70 mm maximum dimension, hereafter shell height, SH) and five large (71–100 mm SH) hard clams as potential prey. Clams were arranged in the experimental cages so that whelks initially had the same probability of encountering each size of prey (i.e., whelks at the center of a circle with clams of alternating size classes spaced evenly around the circumference).

The experimental flume was covered with a fixed plastic net to prevent escape of the whelks and maintained on a 14/10 h natural light/dark schedule. Water temperature and salinity data were collected daily from the flume for the 38 day duration of the experiment (June 11 to July 18, 2000). Experimental cages were examined daily and the empty shells of all prey were removed and measured. Clams that were consumed were replaced daily with clams of similar dimensions thus maintaining constant prey availability.

A size range (30–100 mm SH) of fifty hard clams was selected from the pool of potential prey items and used to create size-weight relationships for the prey. Individual hard clams were measured (SH, mm) and weighed (g) prior to the removal of soft tissue. Clam soft tissue was weighed (wet weight, g) to the nearest 0.1 g.

Data Analyses

Significance levels for all statistical tests were established at $P = 0.05$ *a priori*. Bartlett's test for homogeneity of variance and the Ryan-Joiner test for normality were used prior to analyses. When appropriate, Fisher's test was used for post-hoc multiple comparisons.

Feeding Rates

The numbers of clams consumed by each size class of whelks during the entire experimental period were compared using a one-way ANOVA with individual whelk as a factor. The number of clams consumed satisfied the assumptions of homogeneity of variance and normality without transformation. Daily feeding rates were calculated for each whelk by dividing the total number of clams consumed during the experimental period by the duration of the experiment (38 days).

Consumption on a Weight-Weight Basis

Clam wet and dry tissue equivalents consumed by whelks were compared using a two-way ANOVA with whelk size class and

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individual whelk as factors. Tissue equivalent data satisfied the assumptions of homogeneity of variance and normality without transformation.

RESULTS

Average water temperature during the experimental period was 26°C (±1°C). Average salinity was 21 ppt (±1 ppt). During the 38 day experiment, the six small whelks ate a total of 19 clams while the six large whelks consumed a total of 15 clams. There was no significant difference in the total number of clams eaten by small and large whelks (ANOVA, $F = 0.67$; $P > 0.05$). Small rapa whelks did not show any clear size preference when offered hard clams as prey (Fig. 1) although small whelks consumed a total of 11 small clams and 8 large clams. It should be noted that 5 of the 11 small clams were consumed by one individual. Large rapa whelks consumed large clams more frequently than small clams (4 small clams vs. 11 large clams; see Fig. 1).

Clam Size-Weight Relationships

Clam tissue wet and dry weights were plotted in relation to shell height and used to calculate shell height-wet tissue weight relationships for hard clam prey. These relationships were used to calculate wet tissue equivalents for each clam consumed by an individual whelk and were described with the following equations:

$$\text{Log (CWWgt)} = -3.93 + 2.77 * (\text{Log SH}); \quad R^2 = 0.96$$

where CWWgt is clam tissue wet weight (g) and SH is clam shell height.

Rapa Whelk Size-Weight Relationships

Rapa whelk tissue wet weight was plotted in relation to shell length and used to calculate a shell length–wet tissue weight relationship for whelk predators. This relationship is based on 150 animals (80–165 mm SL) collected from lower Chesapeake Bay, USA between October 1999 and July 2000 (Harding and Mann, unpublished data):

$$\text{WWWgt} = 6.4908 * e(0.0229 * \text{SL}), \quad R^2 = 0.69$$

where WWWgt is whelk tissue wet weight (g) and SL is whelk shell length (mm).

On the basis of tissue wet weight, large whelks consumed significantly more prey flesh tissue than small whelks (ANOVA, $F = 4.45$, $P < 0.05$). Individual small whelks ate proportionately more hard clam tissue on a clam wet weight: whelk wet weight basis than large whelks (Fig. 2). Maximum daily clam consumption rates of 5.6% of body wet weight were recorded for small whelks as compared to 1.6% of body wet weight for large whelks.

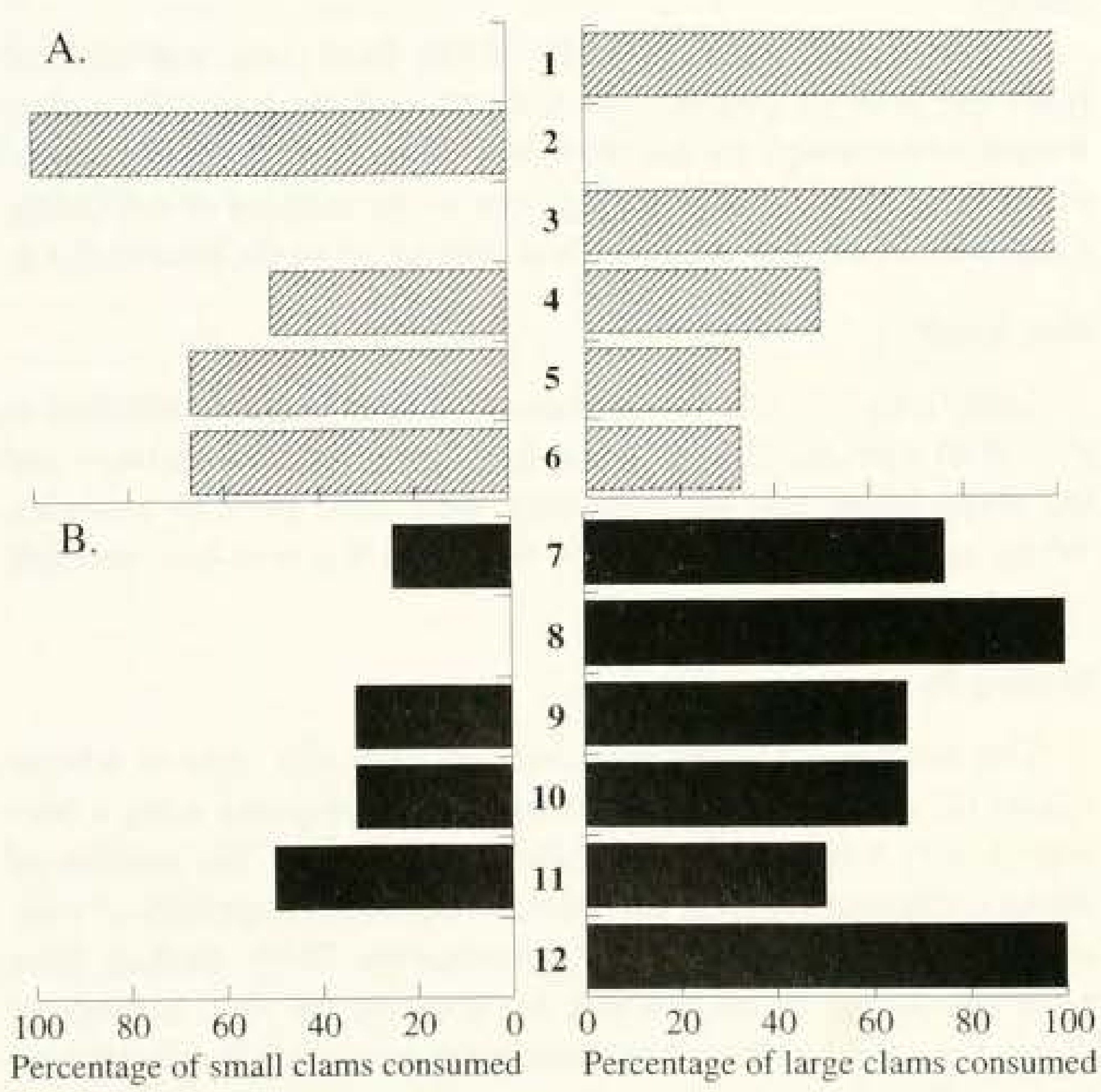

Figure 1. Percentage of small (50–70 mm SH) and large (71–100 mm SH) hard clams eaten in each experimental cage by each rapa whelk during the whole experimental period (June 11 to July 18, 2000). A) N. 1–6 = small whelks (60–100 mm SL), B) N. 7–12 = large whelks (101–160 mm SL).

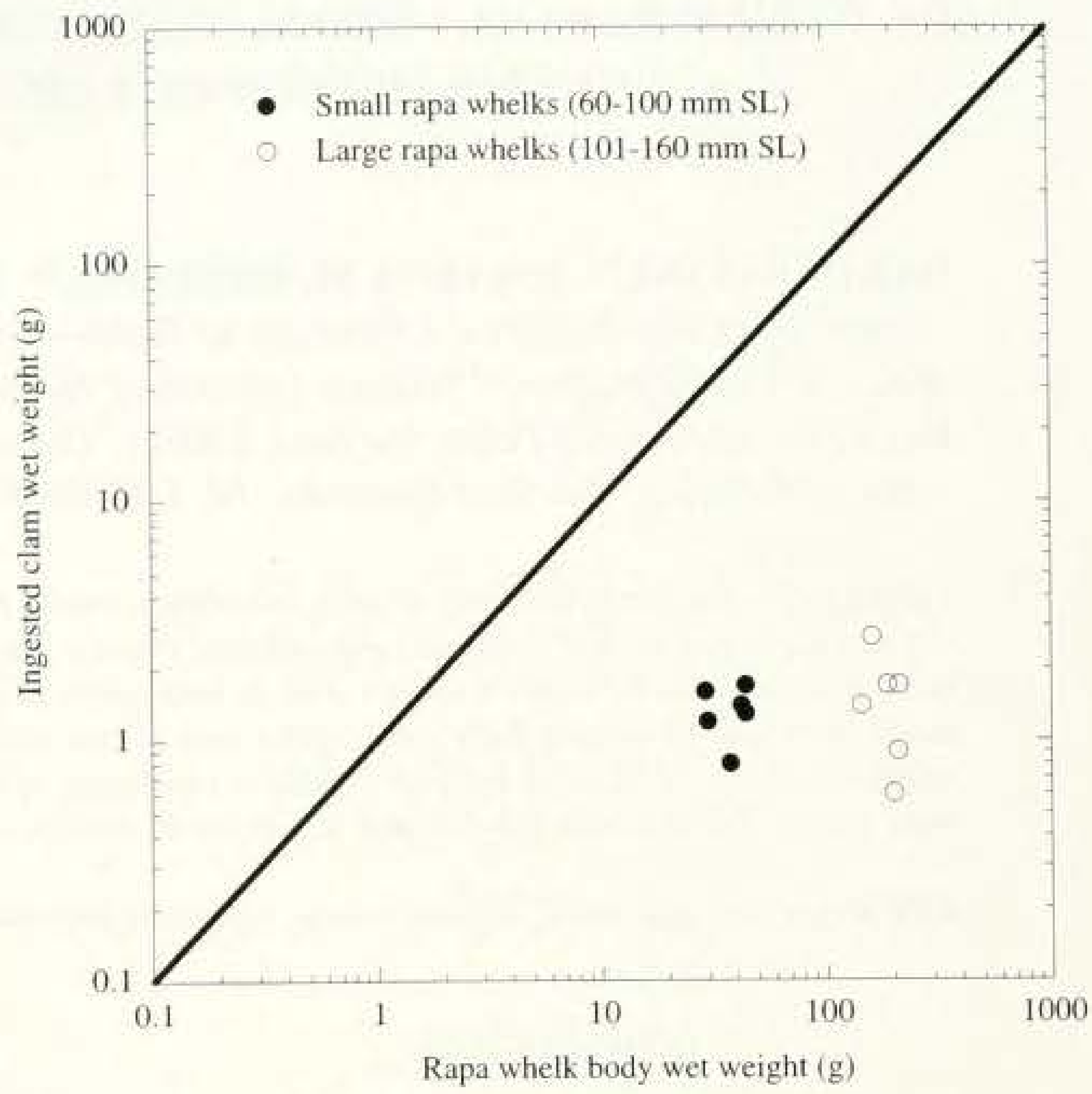

Figure 2. Daily ingested clam wet weight (g) in relation to rapa wet weight (g) observed in laboratory feeding experiments during June and July, 2000. The solid diagonal line represents clam consumption equal to the body weight of the predator (whelk) or a 1:1 consumption relationship on a prey wet weight: predator wet weight basis. Points above the line indicate prey consumption at a rate greater than one while points below the line indicate daily consumption rates less than the body weight of the predator.

DISCUSSION

Large rapa whelks (101–160 mm SL) are able to consume up to 2.7 grams of clam tissue (wet weight) per day or 0.8% of their body weight per day at water temperatures of approximately 26°C. In contrast, small rapa whelks (60–100 mm SL) ingested an average 3.6% of their body weight every day, which is more than four times that observed for larger rapa whelks at similar water temperatures on a weight-specific basis. Edwards and Huebner (1977) suggest that temperature affects feeding rate in the moon snail *Polinices* by increasing predators' metabolic rate, and thus the requirement for a larger amount of food. The present investigation was conducted during warmer months and is probably indicative of the maximum feeding activity of rapa whelks. There is considerable variation in reported ingestion rates for predatory gastropods with values up to 25% of its body weight per day reported for the moon snail, *Polinices duplicatus* (Thorson 1971).

The hard clam fishery in the lower Chesapeake Bay is already in decline. Hard clam landings during 1999 were less than 10% of landings during 1973 (Virginia Marine Resources Commission, Newport News, VA). The observed decline in hard clam stocks may be related to increased anthropogenic impacts on the Chesapeake Bay ecosystem in the past 20 years including overfishing, water pollution and disease. Habitat changes are considered the major threats to estuarine ecosystem (Smith et al. 1999). The superimposition of a novel invading predator on this already stressed population has clear ecological and economic implications.

Virnstein (1977), found that particularly in Chesapeake Bay, densities of infaunal species are not controlled by competitive interactions for food or space but mainly by the action of predators. If the introduction of *Rapana venosa* into the lower Chesapeake Bay results in a large scale successful invasion, rapa whelks could have a serious negative impact on the density and distribution of the native hard clam population in the lower Chesapeake Bay. At this time we do not have a good estimate of the resident population of rapa whelks in the Chesapeake Bay but is possible to use our data for a hypothetical calculation to estimate potential impact of the whelk on the clam population. The rapa whelk distribution in the Chesapeake Bay, which extends from the mouth of the Rappahannock River in the North, to the Chesapeake Bay Bridge tunnel in the southeast and to the Lafayette River in the south (Harding & Mann 1999, Mann & Harding 2000), is within the historic distribution of *M. mercenaria* (Roegner & Mann 1991). The 1999 summer fishing season for hard clams in the lower Chesapeake Bay produced a harvest of 27388 kg or approximately 3,040,000 individual clams. Based on the predation rates observed in this study, a population of 1000 rapa whelks in the lower Bay could reduce this yield by between 0.3 to 0.9%.

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