Short Communication

Reproductive ecology of the invasive whelk *Rapana venosa* Valenciennes, 1846, in the southeastern Black Sea (Gastropoda: Muricidae)

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The reproductive ecology of the invasive whelk *Rapana venosa* Valenciennes, 1846 (Gastropoda: Muricidae) was examined in Surmene, southeastern Black Sea, Turkey, using monthly samples of individuals collected by dredging from November 1999 to October 2000. The observed sex ratio (F : M) was 1 : 1.6; mean shell length at sexual maturity was 40 mm. Changes in the ovary and testis indices indicated that spawning mainly occurred between June and early August in the southeastern Black Sea.

Keywords: Black Sea, *Rapana venosa*, reproductive ecology, sex ratio.

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Introduction

The veined Rapa whelk *Rapana venosa*, a native of Asian waters, was introduced into the Black Sea in the 1940s, the first recorded observation being in Novorossiysky Bay. It is considered unlikely that *R. venosa* was introduced through ballast water, given the transit time from the native range and general lack of shipping traffic along these routes through wartime hostilities. A more likely route of introduction is with oysters from the Sea of Japan (Drapkin, 1963). It has since spread along the Caucasian and Crimean coasts, into the Sea of Azov, and along the coastlines of Romania, Bulgaria, and Turkey, and has subsequently appeared in the Aegean and Adriatic (Koutsoubas and Voultsiadou-Koukoura, 1990; Bombace *et al.*, 1994). In 1998, it was reported from Chesapeake Bay, USA (Harding and Mann, 1999) and recently has spread to the coasts of northwest Europe: Brittany (Camus, 2001) and the Netherlands (Nieweg *et al.*, 2005).

Currently the gastropod is one of the most commercially important whelks in the eastern Black Sea off Turkey. It has been fished intensively by dredge or diving in the southeastern Black Sea since the early 1980s, though there is still no domestic consumption in Turkey. All the whelks caught are exported to Asia, specifically Japan and China.

Several aspects of the biology of the species have been documented to date: distribution (Bilecik, 1975; Düzgünes *et al.*, 1992), egg-capsule deposition and the reproductive cycle (Westcott *et al.*, 2001; Chung *et al.*, 2002; Mann *et al.*, 2006; Saglam and Düzgünes, 2007), and feeding (Savini *et al.*, 2002; Seyhan *et al.*, 2003). To date, however, nothing has been published on the general reproductive ecology, specifically the sex ratio, size at sexual maturity, and gonadosomatic index of *R. venosa* in the southeastern Black Sea. This study therefore reports on its reproductive ecology in the Black Sea, including the sex ratio, its size at sexual maturity from morphometric data, and its annual reproductive cycle as determined from ovary and testis indices.

Material and methods

Samples of *R. venosa* were collected by dredge (length 3.8 m; height 0.6 m; mesh size 40 mm) off Surmene–Camburnu, Trabzon, Turkey (40°55′22.5″N 40°11′09.0″E), at depths of 20–25 m. Sampling was monthly from November 1999 to October 2000, but was not possible in December 1999 or September 2000 owing to inclement weather. Monthly, some 50 whelks were selected randomly from the collections. Shell length was measured with a Vernier caliper to the nearest millimetre or 0.1 mm, and total weight with a digital scale to a precision of the nearest gramme. For each animal, the shell was cracked in a vice and the total wet tissue weight determined after draining on a paper towel, then dissected to determine the weight of the organs. The ovary and the testis were discernible from the digestive gland and were dissected out and weighed. Ovary and testis indices were calculated by expressing the respective organ weight as a percentage of the somatic weight (total weight minus the weight of the ovary or the testis, respectively). Sex was determined by the presence or absence of a penis. Size at maturity of each sex was determined from the relationship between ovary or testis weight and the shell length. The hypothesis of equal representation of both sexes in the population under study was tested using a Chi-squared test (Zar, 1984).

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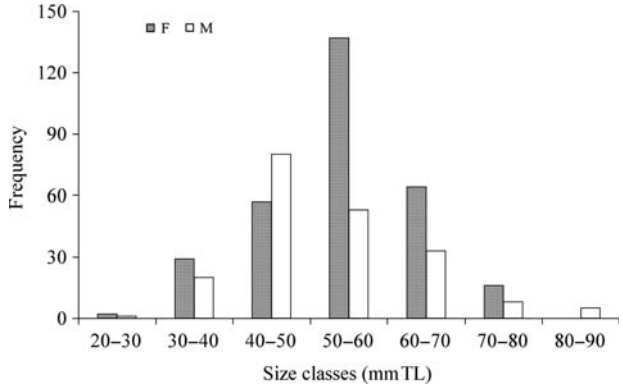


Figure 1. Length frequency distribution of the whelks caught in the southeastern Black Sea (F, females; M, males; TL, total length).

Results

The shell length of females ranged from 21.8 to 79 mm (mean 52.7 ± 0.8 mm) and of males from 29 to 90 mm (mean 55.6 ± 0.8 mm; Figure 1). Of the 497 whelks collected, 194 (39%) were females and 303 (61%) were males, the male-to-female ratio being significantly different from unity ($\chi^2 = 23.91$; d.f. $= 1$; $p < 0.001$).

Female and male sexual maturity was determined morphologically based on the size of the reproductive organs. The relationship between ovary weight and shell length, based on 173 of the females, showed that ovaries generally increased in size rapidly at a shell length of 40 mm in November 1999 and October 2000 (Figure 2). The relationship for males based on 222 animals revealed a similar rapid increase at around the same shell length (Figure 2). All whelks of >40 mm shell length were mature.

An annual cycle in ovary and testis indices was observed. The ovary index increased from a low in January to peak (7.52) in June, then decreased to a statistically lower value (2.70) in August ($p < 0.01$). The decrease between June and August demonstrated that spawning was between those months. The index was lowest in August 2000. The mean gonadosomatic indices of females were higher than those of males all year around ($p < 0.05$; Figure 3). The testis index increased significantly in June (to 3.06) and July (to 3.70) 2000, then decreased to a low of 1.63 in August. Both indices therefore followed a similar seasonal trend, with higher values in summer and lower values in winter (Figure 3).

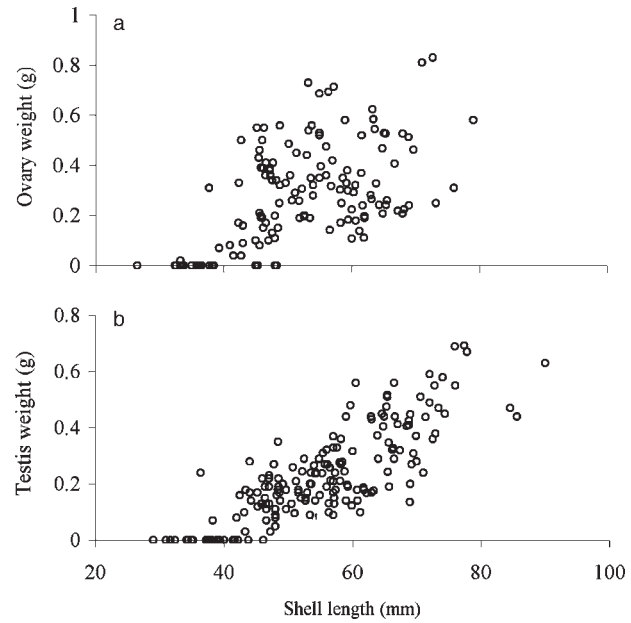


Figure 2. Relationship between (a) ovary and (b) testis wet weight and shell length of *R. venosa* in the Black Sea.

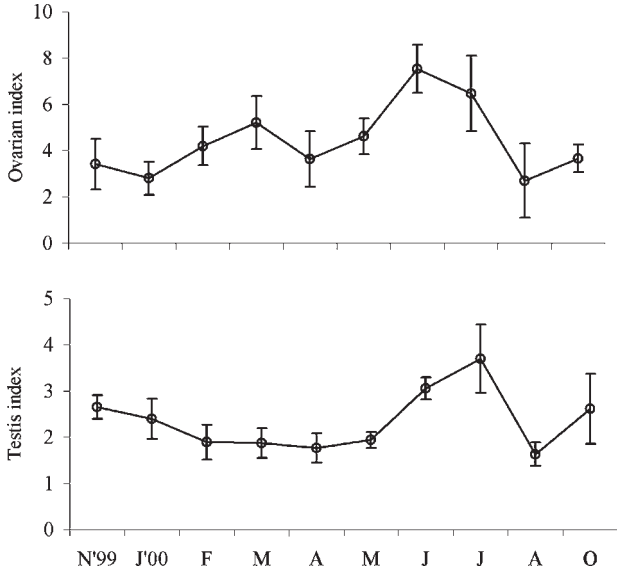


Figure 3. Mean ovary and testis indices for (top) female and (bottom) male whelks, *R. venosa*, in the Black Sea, November 1999–October 2000. Vertical bars indicate the 95% confidence limits.

Discussion

The sex ratio of the whelks in this study (F:M) in the Black Sea was 1:1.6, considerably different from the equal ratios (1:1) reported by Chung *et al.* (2002) from west coast of Korea and by Mann *et al.* (2006) from Chesapeake Bay, USA. The variations among the three areas may have been the consequence of sample collection methods, sampling intervals, and the sizes of the whelks examined. Chung *et al.* (2002) used samples collected monthly by dredge off the west coast of Korea, and Chesapeake Bay samples were collected opportunistically through the Virginia Institute of Marine Science (VIMS) bounty programme from many locations and using different gear types. Chung *et al.* (2002) presented the data for all sizes (31–169 mm) of whelks collected monthly, but Mann *et al.* (2006) reported that all the whelks used in their study were >70 mm shell length and that the sampling intervals depended on fishing activity rather than regular monthly sampling.

As in many other marine molluscs, the gonad development of *R. venosa* had an annual periodicity during the reproductive season, with a sharp decrease in the gonad index of female whelks between July and late August. This result is supported by laboratory observations, where egg deposition was between June and August (Saglam and Düzgünes, 2007). Similarly, Cesari and Mizzan (1993) reported egg deposition of *R. venosa* only during summer at temperatures >18°C (18–23°C) in the Venice lagoon, Italy. Chung *et al.* (2002) reported spawning of

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R. venosa on the west coast of Korea from late May to early August and in the Ariake Sea, Japan, from June to August. The slight discrepancy in the spawning period between these studies is likely related to differences in geographic area and annual water temperatures.

The highest values of GSI for both sexes were during the months with the warmest water temperature in Chesapeake Bay (Mann *et al*., 2006), and in this study in July (males) and June (females). The GSI values for the Korean whelks relied on the measurements of gonad thickness in relation to the diameter of the posterior appendage, including the gonad and the digestive gland (Chung *et al*., 2002), and for Chesapeake Bay on the combined weight of the gonads and the digestive glands (Mann *et al*., 2006), rather than on the gonad weight only (i.e. without the digestive gland), as used in this study. The slight geographic differences may therefore be methodological or reflect real differences between the native (Korean) and the invading populations in Turkey and the United States.

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