The Benthic Exotic Species of the Black Sea: Blood Cockle
(*Anadara inaequivalvis*, Bruguiere, 1789: Bivalve) and Rapa Whelk
(*Rapana thomasi*, Crosse, 1861: Mollusc)

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**Abstract:** The Black Sea is in transition from a freshwater to a marine environment and has a very low biodiversity. Therefore, it appears to be particularly vulnerable and easy target for many exotic species. Anthropogenic introductions of exotic species into the Black Sea began in the 19th century, but accelerated during the second half of the century. There are about 36 kinds of introduced species in Black and Azov seas now and some of them had already severe damage to part or whole ecosystem, while some may have limited or neutral impacts. Current status of two exotic benthic species presented here: Rapa Whelk, *Rapana thomasi* and blood-cockle, *Anadara inaequivalvis*. Most dramatic changes to benthic ecosystem of the Black Sea has taken place after introduction of predatory gastropod Rapa whelk from Far East (Sea of Japan) to the Black Sea in 1940s and has since spread to the Aegean and Adriatic Seas. The second species blood-cockle is a filtering feeding bivalve introduced 20 years ago, but not so well-known since its invasion ability and impact on ecosystem seems to be not very devastating. Particularly rapid distribution and increased biomass of Rapa Whelk caused severe damage to narrow benthic ecosystem. It has direct (predation on bivalves) and indirect (fishing with dredges) negative impacts on the ecosystem. Annual Rapa whelk catches from Turkey and Bulgaria reached totally 13,000 ton year⁻¹. This study presents updated information on spatial distribution, habitats preferences, population structures, ecological and economical impacts of two exotic species; Rapa whelk and blood-cockle.

**Keywords:** Black Sea, exotic species, invasive species Rapa whelk, *R. thomasi*, blood cockle, *Anadara inaequivalvis*

**INTRODUCTION**

The Black Sea was characterized until the mid 1980s as a highly productive ecosystem at all trophic levels. However, the system rapidly degraded during early 1990s due to multi-factor actions including pollution, changes in river discharge, over-fishing, eutrophication, climate change and anthropogenic introduction of exotic species. Accidental or intentional introduction of exotic species into the Black Sea started in the 19th century, but the major impacts were observed during the second half of the current century. The Black Sea, with semi-enclosed brackish water environment and its decreased diversity, has been target of opportunistic invasions by temperate and subtropical species (Sigancova, 1998). Among nearly 30 exotic species currently occurring in the Black Sea, 6 had significant impact on its ecosystem and fisheries.

These are ctenophore *Mnemiopsis leidyi*, the molluscs, *Rapana thomasi*, *Mya arenaria* and *Anadara inaequivalvis*, crustacean, *Rhitheonopeus harrisi* and the fish *Mugil soiuy*, *M. arenaria* and *R. harrisi* have not widely distributed along the Turkish coast.

Rapa whelk or sea snail, *Rapana thomasi* (syn. *Rapana venosa*), is originated from the Sea of Japan. It was first recorded from the Black Sea in Novorossisk Bay in 1946. It is supposed that like most exotic species it was also carried in ballast waters and introduced (Bilecik, 1975; Duzgunes et al., 1988). Since, veliger larvae of sea snail has pelagic larval phase, human activities facilitated transportation and spread of the species (Cesari and Mizan, 1993). The biology (biometric parameters, reproduction and food consumption) (Hou, 1990, 1991), salinity tolerance during the early development stages of the growth (Mann et al., 1999) and

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distribution (Rinaldi, 1985; Koutsoubas and Vouletsiadou-Kouloura, 1990; Harding, 2003) were studies around the world. Distribution (Bilek, 1975), assessment of stocks during early 1990 (Duzgunes et al., 1992; Prodanov et al., 1995), prey and predator relationships (Konsulova, 1992; Savini and Anna, 2006), growth rate (Prodanov et al., 1995; Sahin et al., 2005) and reproductive characteristics were studied in the Black Sea (Emiral, 1997, 2003). The carnivorous Rapa whelk has been considered as an important fisheries source but stocks have been exploited by dredging and exported to Far East countries since it is lack domestic consumption in Turkey. The amount of Whelk production by fishing of Turkey and some countries in Black Sea was given in Table 1 (Emiral, 2003).

Blood-cockle Anadara inaequivalvis (Syn. Anadara cornea Reew, 1841) is another benthic species introduced into the Black Sea accidentally. It's known that from Acreidae family has been fished intensively in the southeast Asian countries (FAO, 2000; Broom, 1985). It’s been determined that the species has a great distribution around the world (Lazzari and Rinaldi, 1981; Boonuang and Fanekarn, 1987; Narasimham, 1988). Various biocological aspects of the blood-cockle and species from genus Anadara have been studied around the world; e.g., growth rate and fishing of Anadara ovalis on the Virginia seashore in America (Alexander, 1993), egg productivity and larval growth of Anadara trapezia in Australia (Cruz, 1984, 1987; Nell et al., 1994), growth, mortality and production of the species of Anadara granosa, Anadara cornea (S. inaequivalvis), Anadara modera and Anadara senlis during reproduction season in India, Malaysia and Senegal (Kayombo, 1993; Debenay and Tack, 1994).

The blood-cockle was transferred from Indo-Pacific region into Adriatic and Aegean and Black Sea through ballast waters during late 1970s. It was first time recorded by Russian scientists on the Bulgaria coast in 1981 and initial data from the Black Sea and its distribution were published after several years (Zolotaryov et al., 1987). Scientific name of the species was accepted as Anadara cornea after consultation with British Natural Science Museum (Sahin et al., 1999). Currently S. inaequivalvis seems to be preferred scientific name for the species (CIESM, 2007). Moreover, growth parameters, age composition, population structure and reproduction period along the north-eastern Black Sea coast of Turkey were studied by Sahin (1999, 2006).

Main objectives of the study are to present updated data on spatial distribution, habitats preferences, population structures, ecological and economical impacts of two exotic species in the Black Sea; Rapa whelk (R. thomaisana) and blood-cockle (A. inaequivalvis).
age classes ranged between 0 and 5 years, while growth parameters were estimated as $L_\infty = 103.97$ mm, $k = 0.345$, $t_0 = -0.310$ and $W_\infty = 213.52$ g. Sex ratio (male to female) was 1:1.6 and the smallest matured individual was 32 mm. Spawning in Rapa whelk stock in the Black Sea takes place between June and July and recruitment starts in September (Emiral, 1997, 2003; Sahin et al., 2005).

Mean length and weight values of blood-cockle in the eastern Black Sea region were reported as $39.28 \pm 0.261$ mm and $24.84 \pm 0.372$ g, respectively. Maximum measured length was 85 mm found at around 15 m on the coast of Giresun. The equation of length-weight relation was calculated as $W = 0.0002 \times L^{3.08}$. The oldest individual was found to be 7 years old. The growth parameters have been estimated as $L_\infty = 89.30$ mm, $k = 0.238$, $t_0 = -0.454$ and $W_\infty = 166.47$ g. Histological studies indicated that the ratio of male to female was almost equal (1.04:1). The size at first maturity was assessed as 20 mm and reproductive period lasts from June to September, while recruitment starts in August (Sahin, 1999; Sahin et al., 2006).

**DISCUSSION**

Carnivorous Rapa whelk was one of most remarkable introductions into Black Sea ecosystem, while bivalve blood-cockle was also significant, but not as effective as
the former (Duzgunes et al., 1992; Prodanov and Konsulova, 1995; Emiral, 1997; Sahin, 1999). Both species have found almost ideal living conditions in the Black Sea in terms of abiotic and biotic parameters.

Blood-cockle prefers a substratum structure to hide itself easily and so, it increases its survival and filter feeding. Therefore, they became dense near coasts and river mounts. It is known that Anadara sp. can survive in very shallow waters and even when sea water withdraws in tide (Seed, 1975; Morton, 1980; Broom, 1982; Boornuang and Fanekarn, 1987). However, they can be hardly found waters less than 3 m depths in the Black Sea. This is mainly because the substratum in shallow waters of the Black Sea is mostly consisted of gravels and coarse sand particles. The studies indicate that growth performance seems to be better in the Black Sea than in other coastal waters and oceans (Sahin, 1999; Sahin et al., 1999). For example, lack of competition for space and food is among the major factors for better growth in the Black Sea. The species forms quite dense stocks in particular places where there is no any fishing activity yet. Blood-cockle is not consumed in Turkey, but many people consume it in other counties and future demands may trigger blood-cockle fishing in the Black Sea and it can be a new fisheries resource for coastal communities.

The distribution of Rapa whelk in the Black Sea starts almost from coast line and goes up to 90 m depths. Most dense schools can be found around 30 m, where their major food organisms, bivalves occur (Rinaldi, 1985; Koutsoubas and Koukoura-Koukoura, 1990; Konsulova, 1992; Duzgunes et al., 1992; Cesari and Mizan, 1993; Harding, 2003). The species seems to have no substratum preference. It is present on rocky, sandy, clay and similar habitats, due to either continuously searching for food or feeding on existing prey. By doing vertical migration it only goes to certain depths in winter when the seasonal water temperature may drop down 7-9°C (Rinaldi, 1985; Koutsoubas and Koukoura-Koukoura, 1990; Duzgunes et al., 1992). In spite of lack of reliable data on age structure of the Black Sea population, according to size distribution and maximum sizes of individuals caught, it is possible to assess that growth performance seems to slower than that of original stocks in Pacific Ocean and Japan Sea (Emiral, 1997). Rapa whelk, which was found in 1962 in Turkish coast first time has formed important commercial stock. It is not consumed in domestic market, but as a result of demands from the Far Eastern countries, commercial fishing started in 1985. At the beginning mean size of catch was 65 mm; it has decreased to 57 mm since then (Duzgunes et al., 1992; Emiral, 1997; Sahin et al., 2005). It has been providing important income source particularly for small scale coastal fishermen. Since, the continental shelf of the southeastern Black Sea is very narrow and both its benthic fauna and flora have been affected to a serious extent, fishing for Rapa whelk with dredge has been forbidden and also size (length) limitation has been imposed by considering the first size of maturity. In spite of these limitations, mean size in stocks has continued to decline. This might be due to multiple factors including excessive reproduction and recruitment, lack of natural predators, limited food sources and competition for food. From the ecologically point of view there is no doubt that R. thomastiana caused considerable deleterious effects and should be controlled or managed properly. Therefore, recently studies have concentrated on alternative fishing methods and management strategies.

Although, both species can also be considered alternative aquaculture species, it is difficult to expect any development particularly for Rapa whelk due to its feeding habit. Unfortunately, the species is a top predator on the benthic ecosystem of the Black Sea and it is an important disadvantage for the simple food web since there are no any predators, which will form natural balance in the system. This situation affects not only benthic but also pelagic organisms depending benthic to in important extent. Considering the blood-cockle as a candidate for aquaculture its main limitations are the market, suitable site for culture and again natural food source.

Rapa whelk is still accidentally transported and introduced into coastal waters around the world. Recently, it has been introduced and colonized in the Chesapeake Bay Region (USA) (Harding, 2003). Therefore, it has been classified as invader species (Harding, 2003; Mann et al., 2006). Although, basic studies on these species have been performed in the Black Sea, their distribution and population characteristics haven’t been stated in FAO (2000) reports and publications.

CONCLUSION

Currently, the Black Sea ecosystem is accommodating around 30 exotic species from temperate and subtropical waters. These species and their impacts can be classified as benthic and pelagic. These species have been introduced on different times and in different locations. Particularly six of them easily adapted new environment and acted as invaders, had significant impacts not only ecosystem but also regional fisheries. Introduction, distribution and impacts of two molluscs species, Rapa whelk and blood-cockle, are evaluated in this study. Rapa whelk had a major impact on benthic habitats through heavy predation on limited bivalve stocks, while blood-cockle competes with other bivalve species for space and food. Since, adult Rapa whelks have no predator in the Black Sea, over-population controlled through fishing and
source limitations, particularly scaring food sources. There are indications of food limitation for Rapa whelk and decline in mean size. Therefore, particularly Rapa whelk should be closely monitored and developed ecosystem based management plans.

REFERENCES


