INVASIVE AQUATIC SPECIES OF EUROPE. DISTRIBUTION, IMPACTS AND MANAGEMENT

Edited by

Erkki Leppäkoski

Department of Biology,
Åbo Akademi University,
Turku, Finland

Stephan Gollasch

GoConsult,
Hamburg, Germany

and

Sergej Olenin

Coastal Research and Planning Institute,
Klaipeda University,
Klaipeda, Lithuania

KLUWER ACADEMIC PUBLISHERS

DORDRECHT / BOSTON / LONDON

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN 1-4020-0837-6

Published by Kluwer Academic Publishers,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

Sold and distributed in North, Central and South America
by Kluwer Academic Publishers,
101 Philip Drive, Norwell, MA 02061, U.S.A.

In all other countries, sold and distributed
by Kluwer Academic Publishers,
P.O. Box 322, 3300 AH Dordrecht, The Netherlands.

Printed on acid-free paper

Photo:Stephan Gollasch, 1998
Juvenile Chinese Mitten Crabs migrating upstream in the river Elbe near Hamburg. The crab was first recorded in German waters in 1912. Mass developments occurred in 1930s, 1960s and 1990s.

Printed in the Netherlands.

THE BLACK SEA - A RECIPIENT, DONOR AND TRANSIT AREA FOR ALIEN SPECIES

MARIAN-TRAIAN GOMOIU[1], BORIS ALEXANDROV[2], NICKOLAI SHADRIN[3] & YUVENALY ZAITSEV[2]
[1]*GeoEcoMar, Constanta, Románia*
[2]*Institute of Biology of the Southern Seas, Odessa Branch, Ukraine*
[3]*Institute of Biology of the Southern Seas, Sevastopol, Ukraine*

Abstract
There is evidence of large-scale biological contamination of the Black Sea ecosystem by nonindigenous species: benthic communities are mostly altered in the western and northwestern parts of the Sea, while the pelagic part are affected in the whole basin. Recent invasion status of the Black Sea is briefly reviewed with special focus on most successful recent invaders.

1 Introduction

The Black Sea ecosystems underwent a number of major changes provoked by invasive aliens. More than 43 new species have become common in the Black and Azov seas (Table 1) and more than 10 occasional species have been recorded (Gomoiu & Skolka 1996; Alexandrov & Zaitsev 2000; Shadrin 2000; Zaitsev & Öztürk 2001). Several reasons may explain their immigration success: (i) the high probability of transfer due to increased ship traffic - from 24,100 vessels (average tonnage 105,500) passing the Bosphorus in 1985 to 49,950 (156,060) in 1996 (Safety precautions against disasters 1996); (ii) the existence of artificial waterways connecting the Black Sea and other seas, (iii) the development of mariculture; (iv) the relatively low ecosystem immunity due to low species diversity and, as a result, reduced ecosystem immunity against bioinvasions (Stachowicz et al. 1999); (v) growing anthropogenic load that leads to environmental degradation and reduction of the immunity to aliens (170 million humans live within the catchment area), and (vi) reduced river inflow due to increased water use in the agriculture and industry.

2 History and recent invasion status of the Black Sea

The shipworm *Teredo navalis* was carried from the Mediterranean by ancient ships in 750-500 BC. (Gomoiu & Skolka 1996). Ancient civilizations were well aware of the shipworm and its ravages. The Phoenicians coated the hulls of their ships with pitch and, later, copper sheathing. An oil mixture of arsenic and sulphur was used by the 5th century BC, and the Greeks used lead sheathing as early as in the 3rd century BC.

The scientifically documented settlers were the barnacles *Balanus improvisus*, introduced around 1844 (Gomoiu & Skolka 1996) and *B. eburneus*, first recorded in 1892 (Ostroumov 1892). The Indo-Pacific polychaete *Ficopomatus* (*Mercierella*) *enigmaticus* was first found in the 1920s, the North American decapod *Rhithropanopeus harrisi* in 1938, and the bivalves *Mya arenaria* in 1966 and *Anadara* (*Scapharca*) *inaequivalvis* in 1982 (Zaitsev & Öztürk 2001).

E. Leppäkoski et al. (eds.), Invasive Aquatic Species of Europe, 341–350.

Table 1. Non-native species in the Black Sea and the Sea of Azov. For references, see Cvetkov & Marinov (1986), Gomoiu & Skolka (1996), Shadrin (2000), and Zaitsev & Öztürk (2001)

Species	Donor region	Year of introduction or finding
Bacteria		
Vibrio cholerae	SE Asia	1970
Phytoplankton		
Mantoniella squamata	?	1980
Alexandrium monilatum	N America	1991
Gymnodinium uberrimum	fresh waters of Europe	1994
Phaeocystis pouchetii	Arctic or N Atlantic	1989
Asterionella japonica	Pacific or Atlantic Ocean	1968
Rhizosolenia calcar-avis	Pacific or Atlantic Ocean	1926
Thalassiosira nordenskioldi	Arctic or N Atlantic	1986
Phaeophyta		
Desmarestia viridis	N Atlantic	1992
Ectocarpus caspicus	Caspian Sea	1980
Higher plant		
Azolla caroliniana	South-Eastern Asia	1989
Azolla filiculoides	South-Eastern Asia	1989
Hydrozoa		
Blackfordia virginica	N America	1925
Perigonimus (Bougainvillia) megas	N America	1933
*Tiaropsis multicirata*****	N Europe	1990
Eudendrium annulatum	N Atlantic	1990
Eudendrium capillare	N Atlantic	1990
Ctenophora		
Mnemiopsis leidyi	N America	1982
Beroe ovata	N America	1997
Monogenoidea		
Ligophorus kaohsinghsieni	Sea of Japan	1994
Gyrodactylus mugili	Sea of Japan	1995
G. zhukovi	Sea of Japan	1995
Polychaeta		
Ficopomatus enigmatica	Indian Ocean	1929
Hesionides arenarius	Pacific or Atlantic Ocean	1950s
Ancistrosyllis tentaculata	N Atlantic	1950-60
Streblospio shrubsolii	N Atlantic	1950s
Glycera capitata	Pacific Oc. or N Atlantic	1960-70
Nephtys ciliata	N Atlantic or Pacific Oc.	?
Streptosyllis varians	N Atlantic or Pacific Oc.	1960s
Capitellathus dispar	Indian Ocean	?
Magelona mirabilis	English Channel, Mediterranean Sea	1990s
Mollusca		
Mya arenaria	N Atlantic	1966
Anadara inaequivalvis	Indian Ocean	1982
Doridella obscura	N America	1986
Rapana thomasiana	Sea of Japan	1946
Potamopyrgus jenkinsi (antipodarum)	Pacific Ocean	1952
Crassostrea gigas	Sea of Japan	1980***
Teredo navalis	Atlantic, Pacific	750-500 B.C.
Entoprocta (Kamptozoa)		
Urnatella gracilis	N America	1954
Crustacea		
Balanus improvisus	N America	1844
B.eburneus	N America	1890s
Acartia tonsa	N America or Indo-Pacific	1976
Schizopera neglecta	Caspian Sea	1967
Rhithropaneus harrisi	N America	1932
Callinectes sapidus	N America	1967
Eriocheir sinensis	Pacific Ocean	1997
Sirpus zariquieyi	Mediterranean Sea	1980
Euchaeta marina	Mediterranean Sea	1999

Species	Donor region	Year of introduction or finding
Rhinocalanus nasutus	Mediterranean Sea	1999
Pleuromamma gracilis	Mediterranean Sea	1999
Scolecithrix danae	Mediterranean Sea	1999
Philomedes globosa	Mediterranean Sea	1999
Pisces		
Pseudorasbora parva	Sea of Japan	1980
Gambusia affinis	N America (intentional)	1925
Lepomis gibbosus	N America (intentional)	1930s
Mugil soiuy	Sea of Japan (intentional)	1972-82
Oryzias latipes	SE Asia (intentional)	?
Hypophthalmichthys molitrix	E Asia	1950s
Micromesistius poutassou	N Atlantic	1999
Aves		
Vanellochettasia lencura*	Caspian Sea *	1997
*Rubifrenta ruficolis***	Caspian Sea**	1970
Mammalia		
Ondatra zibethicus	North America	1930s
Nyctereutes procyonoides	Easten Asia	1930s
Delphinopterus leucas	Sea of Okhotsk	1992
Callorhinus ursinus	Bering Sea	1990s
Eumetopias jubatus	North Pacific Ocean	1990s

* nesting, ** wintering, *** accidentally introduced by ships on the beginning of the 20[th] century, and intentionally for cultivation, in 1980 from the Posjet Bay of the Sea of Japan, **** reidentified as *Opercularella nana* (N.Grishicheva, pers.comm.)

The invasion rate estimated for Romania is: one new species every 3-4 years for marine waters and 4-5 years for fresh waters, since the beginning in the second half of the 19[th] century. In total, 67 alien species, of them 60% of marine and 40% of limnic origin, have penetrated coastal and inland waters of that Black Sea country. Most of these species (up to 93% in marine environment) were introduced accidentally, being Atlantic-Mediterranean immigrants or originating from the North-American and Indo-Pacific regions (M-T Gomoiu unpubl. data).

Several of the most successful invaders were unintentionally introduced in the Black Sea by ships, either in ballast tanks (the soft-shell clam *Mya arenaria,* the rapa whelk *Rapana thomasiana,* the comb jellies *Mnemiopsis leidyi* and *Beroe ovata,* etc.) or attached to ship hulls (the polychaete *Ficopomatus enigmaticus,* barnacles *Balanus* spp., the nudibranch gastropod *Doridella obscura,* etc.).

There are few examples of non-target species associated with intentionally imported species for aquaculture, ornamental trade and even scientific experiments (bacteria and various parasites, e.g. Trematoda, which pose a threat for the native biota, and the fishes *Pseudorasbora parva* and *Lepomis gibbosus*).

For several species, passive or active migration facilitated by natural or man-made waterways has been a key vector. For instance, marine planktonic forms of Copepoda, could enter into the Black Sea either in a natural way, carried by the bottom current from the Marmara and Mediterranean Seas through the Bosphorus Strait, or brought by ships' ballast water. It is not clear, if these species recently immigrated into the Black Sea or if they expanded their natural ranges into a new sea area? The species may have occurred for a long time, however, they were previously overlooked by the scientists before investigation and sampling techniques were improved. Consequently, one cannot quote these as new immigrants but as cryptogenic species (*sensu* Carlton 1996). It is well known that the biodiversity inventory of many areas is far from being complete and the adequate development of research may reveal many new species.

3 The Black Sea as a donor and transit area

Table 2 provides a list of indigenous Black Sea species that have penetrated other seas. Exotic species for which the Black Sea was a transit water body in their further expansion are presented in Table 3. The majority (32 species) of the accidental immigrants in the Caspian Sea originate from the Black Sea; about 60% of the alien free-living animal species found there are not native to the Black and Azov seas. For these species the Black Sea was a bridge on their way to other seas, where step-by-step acclimation to new environmental conditions took place.

Table 2. Indigenous Black Sea species introduced in other water bodies.

Species	Recipient	Year
Nitzchia seriata	Caspian Sea	1990
Acrochaete parasita	Caspian Sea	1955-60
Ectochaete leptochaete	Caspian Sea	1955-60
Enteromorpha tabulosa	Caspian Sea	1955-60
E. salina	Caspian Sea	1955-60
Ectocarpus confervoides	Caspian Sea	1955-60
Entoneum oligosporum	Caspian Sea	1955-60
Acrochaetium daviesii	Caspian Sea	1955-60
Ceramium diaphanum	Caspian Sea	1955-60
Polysiphonia variegatum	Caspian Sea	1955-60
Lecudina sp.	Caspian Sea	1955-60
Chephalodophora communis	Caspian Sea	1955-60
Moeristia maeotica	Caspian Sea	1955-60
Bacciger bacciger	Caspian Sea	1955-60
Cercaria discursa	Caspian Sea	1955-60
Membranipora crustulenta	Caspian Sea	1955-60
Barentsia benedeni	Caspian Sea	1955-60
Mytilaster lineatus	Caspian Sea	1920-28
Dreissena bugensis	Caspian Sea, Great Lakes	1990-1994
*Mytilus galloprovincialis**	Hong-Kong	1979-1983
	Sea of Japan	1988-89
Palaemon adspersus	Caspian Sea	1930-40
Neogobius melanostomus	Great Lakes	1989-1993
Proterorhinus marmoratus	Great Lakes	1989-1993
Nereis diversicolor	Caspian Sea	1939
	Aral Sea	1960-69
Abra ovata (Syndosmya segmentum)	Caspian Sea	1947-1955
	Aral Sea	1960-1969
Calanipeda aquae-dulcis	Aral Sea	1965-70
Liza aurata	Caspian Sea	1930-40
Liza saliens	Caspian Sea	1930-40

*donor sea was the Black or Mediterranean Sea

The Volga-Don Canal, opened in 1952, formed an invasion corridor for Black Sea species to penetrate the Caspian Sea. It would be reasonable to expect a mutually enriching species exchange between the two seas; however this scenario has not come true. Only two Caspian newcomers (*Ectocarpus caspicus* and *Shizopera neglecta*) have reached the Black Sea but they never became mass species there. The influx from the Black Sea into the Caspian Sea has been disproportionately larger; those immigrants rapidly increased their abundance and now they are often dominant in plankton and benthos of the coastal zone of the Caspian Sea (Ardabieva et al. 2000; Orlova 2000; Shadrin 2000; Tinenkova et al. 2000, and others).

Why is an invasion corridor often a one-way street? Two assumptions may serve a working hypothesis: (i) the flux of non-native species will be from water bodies with high ecosystem immunity, i.e. with high biodiversity into water bodies with lower immunity (low biodiversity); (ii) it is more probable that water bodies with higher inertia potential would supply alien species into water bodies with lower inertia potential. The inertia potential is expressed by a morphometric index: m = L/Hmean, where L is the length of the shoreline and Hmean is mean depth of the water body. The relationship between biological characteristics and morphometric index of a water body has been discussed by Shadrin (1985). This scenario may be valid for both the Caspian and Baltic Seas in respect to the Black Sea. It is reasonable to expect that the exotic species, which have established themselves in the Black Sea, may achieve even greater success in the Caspian and then in the Baltic Sea.

4 Spread and impact of some recent invaders

Plants - exceptions among Black Sea invaders. Even if the number of animal invaders is relatively high in the Black Sea, there are only a few nonindigenous plant species recorded in these seas. In phytoplankton, the North American species *Alexandrium monilatum* (Pyrrophyta), the flagellate *Mantoniella squamata* (origin unknown), and two Atlantic species, *Phaeocystis pouchetii* (Prymnesiophyceae) and *Rhizosolenia calcar-avis* (Centrophyceae) are known to cause blooms in the western Black Sea (Zaitsev & Öztürk 2001). Astonishingly, the North American soft sour weed *Desmarestia viridis* is the only alien macrophyte species recorded so far.

The bivalve *Mya arenaria* - a successful molluscan invader. The introduction of the soft clam *M. arenaria* into the Black Sea in 1960s was one of the most drastic and successful bioinvasions into the region before the establishment of the "famous" ctenophore *Mnemiopsis leidyi* in 1980s. First reported in 1966, in the Odessa Gulf and off the estuaries of the Dnieper and the Bug Rivers, the soft clam rapidly spread in other regions: in 1970s, *Mya* became the dominant benthic species along the Romanian coast in zones from mobile sediments of the upper underwater slope to a depth of 30-40 m. After 4-5 years from its colonisation its biomass exceeded that of other molluscs, reaching up to 16,000 g wwt m^{-2} with abundance over 8,000 ind m^{-2} (Gomoiu & Porumb 1969). The huge beach deposits of decaying *Mya* formed after storms attracted and maintained abundant populations of sea gulls, the local people also used them to feed poultry.

The introduction of the soft clam has had multiple consequences on the structure and functioning of the invaded ecosystem. It outcompeted some indigenous species, e.g., by competition for habitat with the small native bivalve *Lentidium mediterraneum*, which avoids sandy bottoms silted by *Mya*. For example, in the Odessa Gulf, the area dominated by *L. mediterraneum* in the 1980s reduced fivefold as a result of the expansion of *M. arenaria* (Zaitsev & Öztürk 2001). Young specimens of *Mya* offer an additional food source for adult bottom-eating fish (gobies, flounder, turbot and sturgeons), gulls and other marine birds. *Rapana*, another exotic mollusc, eats adult specimens of *Mya*. Moreover, *Mya* became an additional biofilter in the coastal zone, which is an important function in eutrophicated coastal waters.

Table 3. Exotic species for which the Black Sea was a transit water body in their voyage to other seas.

Species	Recipient	Year
Blackfordia virginica	Caspian Sea	1955-58
Bougainvillia megas	Caspian Sea	1955-58
Mnemiopsis leidyi	Marmara Sea, Mediterranean Sea Caspian Sea	1989-93 1999
Ficopomatus enigmaticus	Caspian Sea	1956-57
Rapana thomasiana	Marmara Sea, Mediterranean Sea Cheasapeake Bay* Atlantic France	1970-1990 1996-97 1999-2000
*Acartia tonsa***	Caspian Sea	1980-81
Balanus improvisus	Caspian Sea	1955-58
B. eburneus	Caspian Sea	1955-58
Rhithropaneus harrisi	Caspian Sea Aral Sea	1955-65 1970
Mugil so-iuy	Marmara Sea, Mediterranean Sea	1990-1997

* introduced from the Sea of Japan or the Black Sea
** at first identified as *A. clausi*

The effects of eutrophication and pollution caused great changes in the *Mya* populations. Heavy blooms in mid 1970s decimated the soft clam population on the Romanian shelf: in 1982 it vanished from the large areas, especially in shallow water zones, where still in 1974 it occupied all sedimentary bottoms, forming biomasses more than 1 kg m^{-2}. Together with other macrobenthic species, *Mya* was adversely affected by hypoxia in the late 1980s, and its amount decreased from more than 6,000 ind m^{-2} (biomass 3, 000 g wwt m^{-2}) in 1970-1975, to 400 ind m^{-2} (260 g wwt m^{-2}) in 1991 (Leppäkoski & Mihnea 1996). Over the period 1973-1982, the total mortality loss of *Mya* was estimated at 4.1 million tons on sedimentary bottoms down to 30 m depth between the Danube delta and Constanta (Gomoiu & Skolka 1996).

Ups and downs of *Rapana thomasiana*. Native to the Sea of Japan, this gastropod was first observed in the Black Sea (Novorossiysk Bay) in 1946, but it was considered to have settled in the Pontic basin already in the in 1930s-1940s. *Rapana* was found at Yalta and Sevastopol in 1954 and along the Romanian shores in 1963 (Gomoiu & Skolka 1996; Zaitsev & Öztürk 2001). Being very fertile, without serious competitors and endowed with high adaptive capacity to tolerate low salinity, water pollution and hypoxic conditions, the newcomer succeeded in forming rich populations. This largest mollusc in the Black Sea (maximum shell height > 140 mm) became very common and numerous, not only on rocky bottoms down to 30 m depth, where they feed upon oysters, mussels (mainly *Mytilus galloprovincialis*) and other bivalves, but also on sandy bottoms. Mussel beds became largely destroyed by *Rapana*. Having destroyed its preferred food - the large-sized species (*Ostrea edule taurica*, *M. galloprovincialis* and *Modiolus adriaticus*), *Rapana* was forced to attack smaller-sized species such as *Chione* *gallina*, *Pitar rudis*, *Paphia rugata*, and *Spisula subtruncata*. The total biomass of *Rapana* on the Caucasian shelf was estimated at 2,800 tons and on the northeastern shelf in front of the Kerch Strait at 6,000 tons (Grishin & Zolotarev 1988).

As reflected by present composition of beach deposits, *Rapana* populations are in decline at the Romanian coast: trophy shells, caught in important quantities in the beginning of the1990s, have become very rare. Along the Anatolian coast there are no more *Rapana* reserves that can be exported to Japan as in the 1970s (> 800 tons snail meat exported per year). In the northwestern part of the sea the *Rapana* populations are poor and their influence on the marine ecosystems seems to be fairly weak. It is likely that the overfishing of *Rapana* has lead to the population decline (Zaitsev & Öztürk 2001).

***Anadara inaequivalvis* - an Indo-Pacific invasive bivalve.** *Anadara* was accidentally introduced into the Mediterranean in the 1960s. It was recorded for the first time in the early 1980s in the Black Sea. Presently it is quite widespread along all coasts and in the southern part of the Sea of Azov (since 1989-1990), inhabiting sandy and muddy bottoms to 40 m depth and reaching densities of 100 ind m^{-2} and biomass > 1 kg m^{-2} (Zaitsev & Öztürk 2001). In areas along the Bulgarian coast, *A. inaequivalvis* became very numerous: within less than five years, this newcomer reached maximum biomass values of up to 4,300 g m^{-2} (Cvetkov & Marinov 1986). This species tolerates both waters with variable salinity and periodical hypoxia and anoxia.

***Acartia tonsa* substitutes native planktonic copepods.** This species, previously known as native to the coastal zone of the West Atlantic and Indo-Pacific, was first recorded in the North Sea in 1914, in the Baltic Sea in 1925 and in the Black Sea in 1990, in the area off the Crimea peninsula (Belmonte et al. 1994). *A. tonsa* consumes detritus, phytoplankton, ciliates and small copepods. It rapidly adapts to changing food conditions and propagates even at very low ingestion rates (Kiørboe et al. 1985), being able to survive starvation for 6-10 days (Dagg 1977). Temperature is the factor that controls the geographical distribution of *A. tonsa*: the reproduction rate is low under 10 °C (Jeffries 1962). This species dominates in summer and autumn in warm waters in the upper layers at 0-20 m. For example, in the Baltic Sea mass development of *A. tonsa* occur in June-September at the temperature 16-17 °C and salinity 4-5 PSU (Silina 1989).

There is no information available on any significant impact of *A. tonsa* on the pelagic community, most probably due to its low density in the Black Sea. However the reproduction potential of this species is high: in other regions it is known to develop in mass abundance, e.g., up to 10,000 ind m^{-3} in the Baltic Sea (Silina 1989). Benthic invertebrates can utilize dormant eggs of *Acartia* of high food value; ca. 55% of the egg biomass is protein (Kiørboe et al. 1985).

Presently, the summer mesozooplankton in the Sevastopol Bay (Crimea peninsula) is dominated by two alien species, *A. tonsa* and larvae of the barnacle *Balanus improvisus* (Pavlova & Kemp 1999). *A. tonsa* occupies mainly the ecological niche that was previously occupied by the native species *Acartia latisetosa*. These two copepod species are very similar in size and ecological requirements. A. *latisetosa* had vanished in the bay before the introduction of *M. leidyi* (1986) but several years after the introduction of *A.*

tonsa (1976). The main reason for vanishing was likely increased sedimentation and pollution destroying benthic resting egg stage of *A. latisetosa* (Shadrin et al. 1999).

The mass occurrence of the comb jelly Mnemiopsis leidyi – an unwanted success story. Recent mass occurrence of the newcomer ctenophore *Mnemiopsis leidyi*, first found in the northeastern part of the Black Sea (Southern Crimea coastal waters) in 1982, is one of the most spectacular events in the history of species introductions into marine systems (e.g., Leppäkoski & Mihnea 1996). This species, from the Atlantic coasts of the USA, spread rapidly all over the Black Sea. Introduced further into the Sea of Azov via ships and/or with currents from the Black Sea, it was recorded first in August 1988 after a mass development in the Black Sea.

In 1988 *Mnemiopsis* developed biomasses up to > 1 kg m^{-2} in the open sea, and 5 kg m^{-2} in coastal waters. It remained numerous until 1991-92, when its biomass reached 10-12 kg wwt m^{-2} in some coastal areas. However, it did not exceed 1.5-3 kg m^{-2} in the open Black Sea in 1988-90. Since then, its abundance decreased 4-6 fold (Vinogradov et al. 1993) but increased soon again. In August 1995 there were approximately 12-16 million tons of fresh comb jelly mass in the waters covering the Romanian continental shelf only (Gomoiu & Skolka 1996).

The introduction of *Mnemiopsis* caused severe disturbances in the ecosystems which had already been disturbed by eutrophication and pollution. From the ecosystem point of view *Mnemiopsis* is a dead-end organism in the food chains of the Black Sea. It is a consumer of large amounts of zooplankton and ichthyoplankton and a food competitor of pelagic planktophagous fish, most importantly of anchovy. The zooplankton communities of the Black Sea and the Sea of Azov were severely affected by this invasive predator, which mass development began in 1987. This resulted in drastic decrease of fish production, e.g. for kilka 4-5 times and anchovy > 10 times (Volovik et al. 1993). According to Caddy & Griffits (1990), the damage caused by *Mnemiopsis leidyi* in the late 1980s for Black Sea fisheries reached up to US$ 200,000,000 per year. Much more, according to the same authors, is the damage caused through the inactivity of fishing vessels, fishing ports and factories. In the Sea of Azov, the annual economic losses caused by *Mnemiopsis* (when only the reduction of catches of anchovy *Engraulis encrasicholus maeoticus* and tyulka *Clupeonella cultriventris* were considered) reached up to US$ 40,000,000 (Volovik 2000).

The comb jelly *Beroe ovata* – a cryptogenic invader. *Beroe* (first found in Odessa Bay in 1997) was first identified as *Beroe cucumis* (Zaitsev 1998) in the Black Sea, later on as *B. ovata* (Vinogradov et al. 2000). The possible mechanism of penetration of this circumpolar species into the Black Sea is probably the same as for *Mnemiopsis leidyi*, most likely transferred from the North Atlantic Ocean. Another hypothesis is that *Beroe*, which lives in the Mediterranean and Marmara Seas, was carried by currents and had a chance to acclimatize in the Black Sea during abnormally warm winters 1997/1998 and 1998/1999, which promoted its adaptation.

In May-August 1998, mass development (up to 35-1,500 ind m^{-3}) of *Beroe* was recorded in the northwestern part of the Black Sea along the coastal zone of Romania (M-T. Gomoiu, unpubl.) and Ukraine from the Danube river mouth to Odessa Bay (Nastenko & Polishchuk 1999). In 1999, *Beroe* increased along Crimean coast, in the Sea of Azov and in the coastal water of the northeastern Black Sea (Vinogradov et al. 2000).

Beroe feeds mainly upon other comb jellies during all development stages. In the Black Sea, one individual of *Beroe* consumes 0.3 averaged sized individual of *M. Leidyi* per hour, or ca. 2.5 g of wet weight, equal to 2.5 mg C_{org} (Vinogradov et al. 2000). This might lead to a reduction of the native comb jelly *Pleurobrachia rhodopis* quantity and to an inhibition of *Mnemiopsis*. Obviously these two ctenophores are interacted in a feedback system (an increase of *Beroe* population will result in a decrease of *Mnemiopsis*, followed by a successive increase of zooplankton and pelagic fish). In addition, *Beroe* is a food-web dead-end organism due to the lack of native predators in the Black Sea. Thus, either direct or indirect impact through the entire food web could well be expected and further add to the problem of gelatinous species in the Black Sea.

Non-native fish species. The occurrence of introduced fish species in the Black Sea is restricted mainly to the brackish estuaries and wetlands, among them two North American species, the mosquitofish *Gambusia affinis* (brought from Italy in 1925) and the sunfish *Lepomis gibbosus* (introduced to Europe by aquarists in the 1920 and found in Danube delta since 1930s).

The haarder *Mugil soiuy* is an important commercial species in the Black and Azov Seas; its annual catch in the Black Sea exceeds 10,000 tons. It was transferred from the Amur River estuary in 1972-1982 and released in some coastal brackish lakes (limans). The haarder is highly euryhaline, living from fresh water to 35 PSU in some limans. First breeding of naturalized fish in the Black Sea was noted in 1982. The impact of the haarder on native species is insufficiently known. Its fry feed upon zooplankton and can compete with local plankton-eating fish. Some specific parasites (Trematoda, Monogenea), associated with the haarder, were introduced in the Black Sea and have been found in native grey mullets (Zaitsev & Öztürk 2001).

Mammals in coastal wetlands. The muskrat *Ondatra zibethicus*, native to North America, was introduced in the URSS in the 1930s as a fur animal. It lives in coastal wetlands and is a mass inhabitant of the Danube, Dniestr and Dnieper river deltas. The East Asian raccoon-dog *Nyctereutes procyonoides* was introduced in the Black Sea wetlands in the 1930s as a fur animal. It is omnivorous and feeds mainly upon fish, crayfish and molluscs. In the Danube delta it also eats the soft-shelled clam *Mya arenaria*, which is washed ashore in large numbers on windward sandy beaches (Zaitsev & Öztürk 2001).

5 Conclusions

The consequences of invasions into the Black Sea have been discussed in a number of publications (e.g. Zaitsev 1993; Zolotarev 1996; GESAMP 1997; Zaitsev & Mamaev 1997; Shadrin 1999; Alexandrov & Zaitsev 2000; Leppäkoski & Olenin 2000; Zaitsev & Öztürk 2001).

Invasion is never neutral. Even if an incomer does not replace a native species but occupies the niche, which is or has became vacant owing to some other factors, it excludes the possibility for the native species to recolonise this niche. A species having been accidentally brought into a water body undergoes phenotypic and genetic changes, triggered by the unusual environmental vectors. As a result, the variability and the invasive capacity of the colonizer can increase over time.

In conclusion, the lessons we have learned from the invasion history of Black Sea as a receiving area for exotic species can be summarized: (i) the process of introduction is still going on - we have to pay more attention to the toxic and harmful species; (ii) the impact of alien species is complex and unpredictable; (iii) the problem of invasive non-native species has long gone beyond the bounds of pure science and has gained a socio-economic dimension, (iv) species diversity monitoring is necessary, a special attention must be directed to the proper monitoring of microflora and microfauna; (v) legal measures and regulations to limit the penetration of immigrants are necessary; (vi) training biologists in taxonomy and systematics must be given high priority; the old generation of marine'botanists and zoologists is getting reduced and to understand correctly the Black Sea ecosystem and what must be done for its protection, we have to gain deeper knowledge of its biota through young educated marine biologists.