Trend on increasing Mediterranean species arrival into the Black Sea

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The flora and fauna of the present-day meromictic Black Sea, which was formed under conditions of relatively low salinity combined with the existence of an anoxic zone beneath the upper oxygen-containing layer, is distinguished by a low species richness and by a low species diversity in most of the taxonomic groups represented. Meanwhile, it features a rather high productivity, particularly in near-shore regions, a high abundance of mass species, and a richness of fish resources.

The Black Sea biota is composed for 80% by species of Atlantic-Mediterranean origin, and for 10.4% and 9.6% species of freshwater and Ponto-Caspian origin, respectively. One may add an arctic assemblage, which is extremely poor and mainly contains flora (Mordukhai-Boltovskoi, 1969). The dominant group from Atlantic-Mediterranean origin comprises species of Lusitanian province, and of the boreal Atlantic Ocean. Species with Lusitanian origin belong to warm water species and inhabit the upper layer of the Black Sea. Species of Atlantic boreal origin belong to moderately cold water species. They have clear features of cold-water relicts. Among them one finds mainly benthic, demersal and pelagic species, which live in the cold intermediate layer and below down to the boundary of anoxic layer. Only the most eurythermal of them may rise to the surface layers.
In addition to salinity, qualitative impoverishment of the Black Sea biota is due to the absence of deep-water species at depths greater than 125-200 m.
At present, the total number of species recorded in the Black Sea is relatively small and stands at 3,774 spp. Of these 1,619 are fungi, algae, and higher plants; 1,983 are invertebrates, 180 are fish, and four are sea mammals-dolphins (Zaitzev and Alexandrov, 1998).

In the 20th century, especially in its second half, under the influence of climatic and anthropogenic factors, significant changes have occurred in the diversity of the flora and fauna of the Black Sea. Among the most pronounced anthropogenic factors, we note:
- regulation of the runoff of major rivers;
- increase in the supply of dissolved mineral forms of phosphates and nitrates from large rivers accompanied by reduced silicate supply. This resulted in a decrease in the Si : P and Si : N ratios, which are important for the functioning of phytoplankton;
- increase in the supply of organic matter from the Danube River, which caused mass development of mixotrophic algae;
- changes in the composition of phytoplankton species and their proportions: domination of dinoflagellates instead of domination of diatoms, significant growth in the phytoplankton biomass and outburst in the development of harmful algae;
- subsequent eutrophication;

- corresponding increase in the primary production: twofold on the average over the entire sea and tenfold in its northwestern part;
- subsequent outbursts of native gelatinous species such as *Aurelia aurita* and *Noctiluca scintillans*;
- deterioration in the condition of spawning and feeding areas of fishes;
- high pressure of fishery resulted in decreasing stocks of large pelagic fishes - migrants from the Aegean and Marmara Seas and dolphins;
- invasion of non-native species, some of which negatively affected the communities in which they introduced or replaced native species.

The classical scheme of the functioning of a balanced ecosystem in an inland basin is based on a "top-down control" against predators that descends from large pelagic fishes and mammals to small pelagic fishes and below to zooplankton (when large edible zooplankton dominates) and algae (when diatoms dominate).

As a result of the man-induced changes that affected the Black Sea ecosystem by the end of the 1980s, it evolved into a mesotrophic or eutrophic (in its northwestern and the western parts) basin with disturbed functioning, which was favorable for the development of gelatinous plankton.

The occasional and sometimes intentional introduction of non-native species of animals and plants is a global phenomenon that concerned the Black Sea as well, which received non-native species (both marine and brackish) of different origins.

Alltogether 156 (or 171?) species were established, which belong to different taxonomical groups (Figure 1).

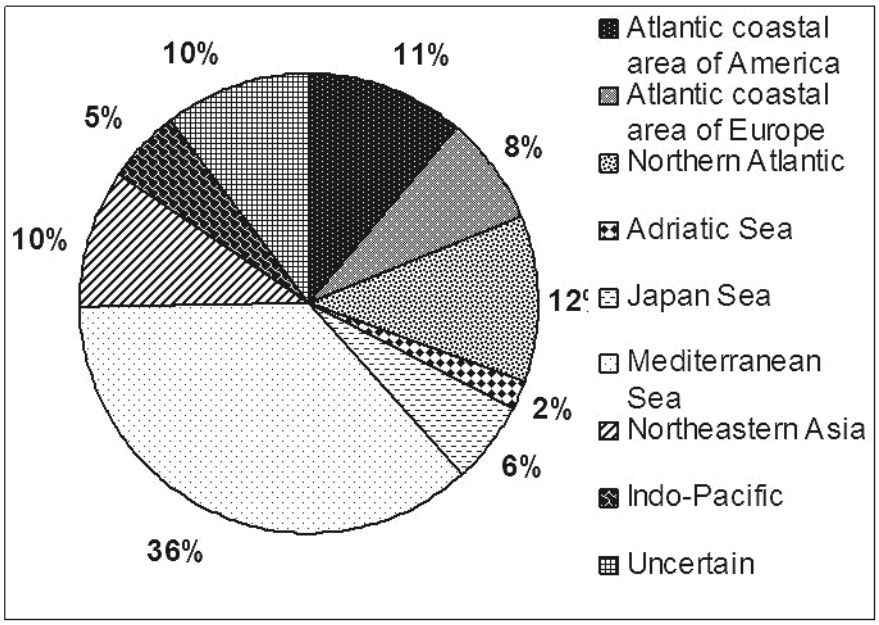

Figure 1. Donor areas of the non-native species and their share (%) in the Black Sea.

The disturbance of the Black Sea has favored the establishment of new gelatinous representatives of macroplankton such as the predatory warm-water ctenophore *M. leidyi*. Within the heated zone of the surface layer of the Black Sea it found conditions optimal with respect to the temperature, salinity, and productivity. Under these conditions, it became capable of developing a high activity (intensity of the metabolism and, hence, the feeding and growth rates) and reached extremely high abundances. After the *M. leidyi* invasion, cascading effects occurred at the higher trophic levels, from a decreasing zooplankton stock to collapsing planktivorous fish and dolphins (bottom-up). Similar effects occurred at lower trophic levels: from a decrease in zooplankton stock to an increase in phytoplankton, relaxed from zooplankton grazing pressure (top-down) and from increasing bacterioplankton to increasing zooflagellata and ciliates (Shiganova *et al.*, 2004).

Ten years later another warm-water ctenophore *Beroe ovata* – a natural predator on *M. leidyi* – was introduced with ballast waters from the same source area (coastal area of north America) and established. This resulted in population decrease of *M. leidyi* and the ecosystem began to recover trophic web at all levels (Shiganova *et al.*, 2000; 2003).

In addition during last decades, Black Sea temperature increased both in the surface, mixed and cold intermediate layers (Figure 2), which facilitated the population increase of thermophilic species and their northward expansion from the Mediterranean. Until recently new Mediterranean species have been recorded temporally or permanently mainly in the near-Bosporus region. Therefore, they are usually not regarded as established non-native species. But if we take into account only established species, their share in the total numbers of non-native species consists of 36%. Since 1960s (and certainly earlier) the Bosporus Strait delivered many Mediterranean species from different taxonomic groups. But selected Mediterranean taxa (phyto-, zooplankton, benthic and fish species) are more and more often recorded also off northwestern and northeastern coastal areas. At present, this process is facilitated by rising temperature. Species that penetrated beyond the Bosporus reached the centre, southwest, southeast and northeast, moving with the currents or lenses of Mediterranean water. Others, released with ballast water, increased especially around harbor areas.

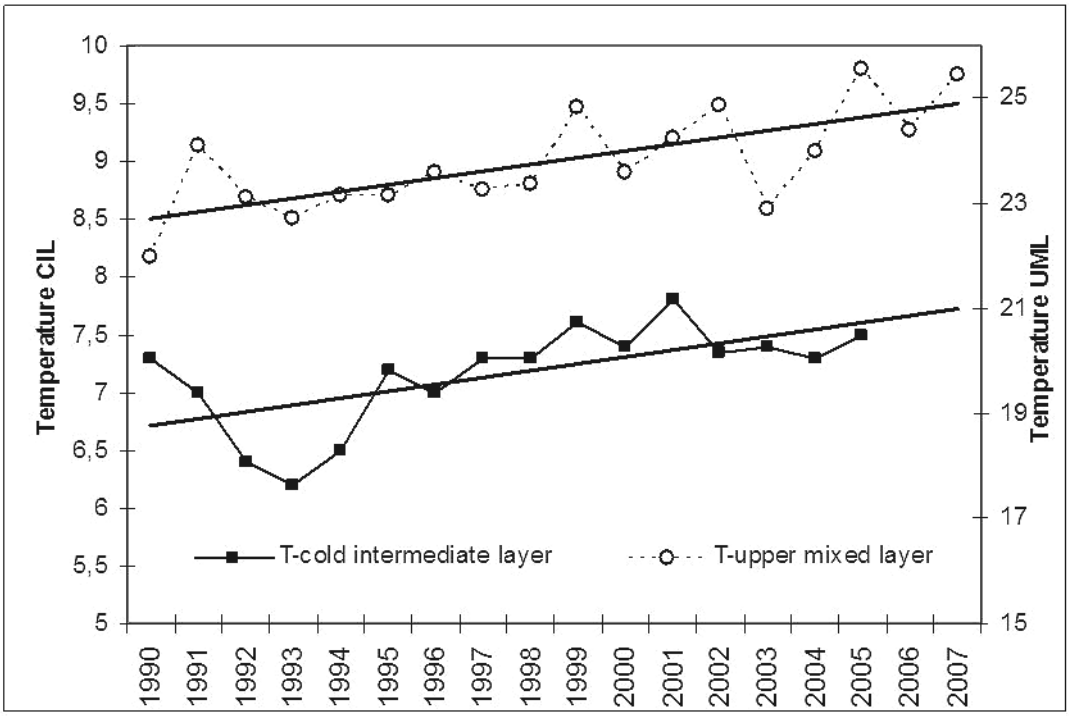

Figure 2. Rising water temperature from1990 till 2007 (data of Lab. Hydrophysics of Southern branch of SIO RAS).

As a rule, invaders remain rare or are abundant only in definite years, which suggests a high stability of the communities of the Black Sea with respect to establishment of non-native species and/or that conditions of the Black Sea (with low salinity and low winter temperature) are not favorable.

MICROPLANKTON

Microplankton elements are Mediterranean tintinnids, first found in the northwestern Black Sea in 2002 (Polikarpov *et al.*, 2003).

PHYTOPLANKTON

Mediterranean phytoplankton species new for the Black Sea are recorded year after year, and their numbers keep increasing. A significant number of species native to the Mediterranean colonize the Bosporus region (Table 1). Some of them might survive only in this area where salinity is higher than in other regions of the Black Sea. Examples include the diatoms *Fragillaria striatula* and *Thalassiothrix frauenfeldii*, the coccolithophorid *Calyptrosphaera incriase* and the peridinean *Ceratium macroceros*, recorded since the beginning of the 1960s at a salinity of 34‰ and a temperature of 14°C. These conditions significantly differ from the Black Sea (Georgieva, 1993). However, some other newcomers of the 1960s and early 1970s were found not only near the Bosporus but also near Crimea (Table 2) (Kuzmenko, 1966; Senichkina, 1973; Kovalev *et al.*, 1998).

Table 1. Mediterranean phytoplankton species found near the Bosporus in the Black Sea (Georgieva, 1993).

	T °C	**S‰**
Amphidinium conradi (Conrad) Schill.	7.44	18.38
A. mannanini Herd.	10.79	18.18
A. vigrense Wolosz	10.79	18.18
Biddulphia alternans (Bail.)V. H.	7.70	19.34
Ceratium furca var. eugrammum (Eht.) Jorg.	18.67-24.97	16.44-18.39
C. fusus var. seta (Eht.) Jorg.	7.80	18.39
C. hexacantum f. aestuarium (Schrod.) Schill.	7.81	18.39
C. hexacanthum f. contortum (Lemm.) Jorg.	7.80	18.39
C. massiliense (Gourret) Jorg	7.81	18.39
C. teres Kof.	-	-
C. trichoceros (Eht.) Kof.	10.79	18.18
C. tripos var. atlanticum Ostf.	7.81	18.39
Coccolithus pelagicus (Walich.) Schill.	7.55	18.20
Cochlodinium citron Kof. et Sw.	7.39	18.50
Eucampia cornuta (Cl) Grun	8.40	19.78
Gymnodinium paradoxum Schill.	-	-
G. pygmaeum Leb.	10.79	18.18
Oxytoxum parvum Schill.	7.41	18.33
O. variabile Schill	23.98	15.73
O. viride Schill.	8.88	20.32
Peridinium sinaicum Matz	18.82	18.36
Pronoctiluca acuta (Lohm.) Schill.	9.14-9.85	18.57-18.96
P. pelagica Pavill	7.64	-
Pyrocystis hamulus Cl.	13.20	17.20
P. fusiformis (W.Th.) Mur.	9.51	21.42
P. pseudonoctiluca (W.Th.) Schill.	6.52	18.40
Rhabdosphaera stylifera Lohm.	8.74	20.14
Rhizosolenia styliformis Brightw	17.13	17.59
Syracosphaera coronata Lohm.	7.44	17.98
S. cornifera Schill. (Helladosphaera)	16.10	17.98
S. quadricornu (Anthosphaera) Schill.	8.74	29.14
S. spinosa Lohm.	7.31	18.52
Thalassiothrix mediterranus Pavill	7.89	19.13
Total 33 species		

Table 2. Mediterranean algal species recorded in the Black Sea: A- Phytoplankton; B- Macrophytes.

Species name	Origin	First record in Black Sea	Location of first record	Establish-ment	Abundance	Geographic distribution	Tolerance limits	Vector	Reference
A- Phytoplankton									
Dinophyceae *Alexandrium pseudogonyaulax* (Biecheler) Horiguchi ex Yuki et Fukuyo	Mediterranean	2001-2002	Odessa Bay	established	abundant, potentially toxic	Mediterranean, eastern Atlantic	euryhaline, euryterm	shipping	Terenko, 2003
Gessnerium mochimaensis Halim 1967	Mediterranean	1991	Varna Bay	established?	not abundant	Mediterranean, tropical and subtropical Atlantic	marine, Tropical, subtropical	shipping	Moncheva et al., 1995
Cochlodinium polykrykoides Margalef	Mediterranean	2001,2002	Varna Bay, north-eastern Black Sea	established	abundant	Mediterranean, eastern Atlantic	subtropical	shipping	Terenko, 2003; Vershinin et al., 2004
Gyrodinium cf.aureolum Hulburt	Mediterranean	2002	Varna Bay	established?		Mediterranean, eastern Atlantic	subtropical	shipping	Terenko, 2003
Gymnodiniaceae *Gymnodinium sanguineum* Hirasaka=*Gymnodinium splendens* Lebour	Mediterranean	2000	Off Crimea, Bulgarian coast, Odessa Bay	established	abundant	Mediterranean	subtropical	shipping	Senecheva, 2002
G. blax Harris	Mediterranean?	1998	Odessa Bay	established?		Mediterranean?		shipping	Terenko, Terenko, 2000
G. lacustre Stein	Mediterranean?	1999	Odessa Bay	established?		Mediterranean?		shipping	Terenko, Terenko, 2000
Amphidinium acutissimum Schill	Mediterranean?	1999	Odessa Bay	established?		Mediterranean?		shipping	Terenko, Terenko, 2000
A. lanceolatum Schrod	Mediterranean?	1996	Odessa Bay	established?		Mediterranean?		shipping	Terenko, Terenko, 2000
A. larvale Lindem	Mediterranean?	1999	Odessa Bay	established?		Mediterranean?		shipping	Terenko, Terenko, 2000
A. vigrense Wolosz	Mediterranean?	1995	Odessa Bay	established?		Mediterranean		shipping	Terenko, Terenko, 2000
Ceratium furca var.eugrammum (Her) Jorg.	Mediterranean?	1999	Odessa Bay	established?		Mediterranean?		shipping	Terenko, Terenko, 2000
C. longirostrum Gourr.	Mediterranean?	1999	Odessa Bay	established?		Mediterranean?		shipping	Terenko, Terenko, 2000
Cochlodinium geminatum (Schutt)	Mediterranean?	1998	Odessa Bay	established?		Mediterranean?		shipping	Terenko, Terenko, 2000
Spatulodinium pseudonoctilca (Pouchet) Cachon et Cachon	Mediterranean	2002	Odessa harbour	established?	a few ind.	Mediterranean, North Atlantic	temperate	shipping	Terenko, 2003
Dinophysis odiosa (Pavillard) Tai & Scogsberg (=*Protodinophysis odiosa* Pavillard Loeblich III= *Phalacroma odiosa* Pavillard	Mediterranean	2001;	Northern Black Sea	established		Mediterranean	subtropical	shipping	Senecheva, 2002
Talassionemataceae *Lioloma pacificum* (Cupp) Hasle (=*Thalassiotrix mediterranea* var. Pacifica Cupp)	Mediterranean	2001; 2002-2003	coastal waters of Sevastopol, Odessa Bay	established	abundant off Sevastopol, Odessa	Mediterranean, North Atlantic	subtropical	shipping	Senecheva, 2002; Alexandrov, 2004
Cем. Bacillariaceae *Pseudo-nitzschia inflatula* Hasle (=Nitzschia infantula Hasle)	Mediterranean	1999-2001	coastal waters of Sevastopol, Odessa	established		Mediterranean	subtropical	shipping	Senecheva, 2002
Sceletonema subsalsum (Cleve)?	Mediterranean?	1993	coastal waters of Romania	?		Mediterranean? North Atlantic	temperate	shipping	Alexandrov, 2004
Bacillariophyceae Protoraphidiaceae *Asterionellepsis glacialis* Cleve et Molle (= *Asterionella japonica (Castracane)* F.E.Rount 1990)=Asterionella glacialis Castracane	Mediterranean	1968	coastal area of Sevastopol	established		Mediterranean	eurythermal	shipping	Senicheva, 1971
B- Macrophytes									
Ulvaceae Lamour.ex Dumort *Enteromorpha kylinii* Bliding	Mediterranean	1990	coastal area of Turkey	established		Mediterranean, Northwest Atlantic	temperate	penetration? shipping?	Bavaru et al.,1991; algaebase

Ulva curvata Kutz. De Toni	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean, northern Atlantic	subtropical	penetration? shipping?	Aysel, 1995; algaebase
U. fasciata Delile	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean, global	subtropical,tropical	penetration? shipping?	Aysel, 1995; Taskin et al., 2008
Cladophorales Haeckel Cladophoraceae Wille *Cladophora flexuosa* (O.F.Muller) Kulz	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean, northern and southern Atlantic, Pacific	temperate	penetration? shipping?	Aysel, 1995; Taskin et al., 2008
C. lehmanniana (Lindenb)	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean, South Africa	subtropical	penetration? shipping?	Aysel, 1995, Guery, 2001
C. pellucida (Huds.) Kutz	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean, South Africa	subtropical	penetration? shipping?	Aysel, 1995; Guery, 2001
C. prolifera (Roth.) Kutz.	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean, Western Indian Ocean	subtropical	penetration? shipping?	Aysel, 1995; Guery, 2001
Cystoseira compressa (Esper) Gerloff et Nizamuddin f.compressa	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean	subtropical	penetration? shipping?	Aysel, 1995; Guery, 2001
C. corniculata (Wulf.) Zanard	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean	subtropical	penetration? shipping?	Aysel, 1995; Taskin et al., 2008
C. schiffneri Hamel =C.discors (L.)	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean, Adriatic	subtropical	penetration? shipping?	Aysel, 1995; Ribera et al.,1992
Sargassaceae Kutz. *Sargassum acinarium* (L) C.Ag.=S.Ag.f.linifolium (Turn.)C.Ag.	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean, Atlantic	subtropical	penetration? shipping?	Aysel, 1995; algaebase
S. hornschuchii C.Ag.	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean	subtropical	penetration? shipping?	Aysel, 1995; algaebase
Rhodophycea Ceramiales Oltm *Antithamnion heterocladum* Funk	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean	subtropical	penetration? shipping?	Aysel, 1995
Ceratium flaccidum (Kutz.) Ardiss	Mediterranean?	early 1990s	coastal area of Turkey	established		Mediterranean	subtropical	penetration? shipping?	Aysel, 1995
C. tenerrimum (G.Martens) Okamura var Tenerrimum	Mediterranean?	early 1990s	coastal area of Turkey	established		Mediterranean	subtropical	penetration? shipping?	Aysel, 1995
Compsothamnion thuyoides (Sm.) Nageli	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean,north Europe	temperate	penetration? shipping?	Aysel, 1995
Dasyaceae Kutz. *Dasya ocellata* (Gratel.) Harv	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean	subtropical	penetration? shipping?	Aysel, 1995
Neosiphonia elongella (Harv.)M.S.Kim et I.K.Lee=*Polysiphonia elongella* Harv.)	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean	subtropical	penetration	Aysel, 1995; Garreta et al., 2001
*Polysiphonia deusta (*Roth) Spreng	Mediterranean	early 1990s 2001	coastal area of Turkey	established		Mediterranean	subtropical	penetration	Aysel, 1995
P. paniculata Mont.	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean, Atlantic	subtropical	penetration? shipping?	Aysel, 1995; Garreta et al., 2001; Taskin et al., 2008
P. stricta (Dillw.) Grev.=P.urceolata (Lightf. Ex Dillw.) Grev.)	Mediterranean?	early 1990s	coastal area of Turkey	established?		Mediterranean? Northwest Atlantic		penetration? shipping?	Aysel, 1995
P. subulata (Ducl.)P.Crouan et H.Crouan = *P.violacea* (Roth) Grev.	Mediterranean	early 1980s	coastal area of Turkey	established		Mediterranean	temperate	penetration	Dimitrova-Konaklieva, 1981 Aysel, 1995; Garreta et al., 2001
P. tenerrima Kutz	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean	subtropical	penetration	Aysel, 1995
P. tripinnata J. Ag	Mediterranean	early 1990s	coastal area of Turkey	established		Mediterranean	subtropical	penetration	Aysel, 1995; Karacuha et al., 2007

Kuzmenko (1966) recorded *Dynophysis schuttii* Murr. et Whitt. and *Podolampas spinifer* Okatumura, previously unknown in the Black Sea but typical of the Mediterranean, off the southern coast of the Crimea at a salinity of 18-18.5‰. In the early 1990s, *Katodinium rotundatum* (Lohm) Fott, *Achradina sulcata* Lohm., and *Pronoctiluca* sp., appeared in shallow water off Yalta. *Distephanus octonarius* var. *Polyactis* (Jorg) Gleser and *D. speculum* var. *Septenarius* Jorg, previously unknown in the Black Sea were also discovered off Crimea area (Senichkina, 1993). In all, 37 representatives of Mediterranean phytoplankton were registered in subsurface waters of the Bosporus region (Table 1) (Georgieva, 1993). Many of these species, such as *Syracosphaera*

cornifera, Ceratium furca var. *eugrammum, Pyrocystis hamulus*, *Pronoctiluca acuta* etc., were recorded not only in the waters originated from the Sea of Marmara and Mediterranean but also in typical pelagic Black Sea waters.

Not all species found recently can be considered as newcomers as some of them were discovered after more detailed examinations of ancient Black Sea samples. Thus in coastal northwestern Crimea, long-term observations (1968-2002) brought to light new species for the Black Sea, such as the diatoms *Asterionellapsis glacilis*, *Chaetoceros tortissimus*, *Thallassiosira nordenskioeldii*, *Lioloma pacificus*, *Pseudonitzschi inflatula*, two subspecies of *Chaetoceros*, and the dinophyte *Dinophysis odiosa*, as author assumed they arrived from the Mediterranean (Senicheva, 2002).

During the last years a large number of Mediterranean species, new to the Black Sea, were found around the ports (Table 2) (Alexandrov, 2004; Moncheva, 1995; Terenko and Terenko, 2000; Terenko, 2003; Senicheva, 2001).

In early August 2001 the Mediterranean *Chaetocerus tortissimus*, *Cochlodinium polykrikoides*, and *Alexandrum* sp. were recorded in the coastal area of northeastern Black Sea (coastal Bolshoi Utrish). *Cochlodinium polykrikoides* reached a biomass of ca 500 $\mu g.l^{-1}$ (Vershinin *et al.*, 2004). It was observed also in Odessa Bay in 2002 (Terenko, 2003).

Altogether 11 Mediterranean species of phytoplankton were found recently in areas far from Bosporus; 10 more species found in the Black Sea are considered as species probably Mediterranean origin (Table 2).

ZOOPLANKTON

High numbers of holozooplankton species are dispersed with Low-Bosporus current into the Black Sea and are found off the Bosporus. Among them, 54 species are Copepoda. All of them were recorded along the southern Black Sea but none of them became abundant (Table 3).

Table 3. List of Mediterranean Copepoda found in the Black Sea prior to 1998 (with additions after Kovalev *et al.,* 1998).

Reference*	**1**	**2**	**3**	**4**	**5**	**6**
Species						
Calanus gracilis Dana		+				
Calanus minor Claus				+		
Calanus tenuicornis Dana					+	
Calocalanus pavo Dana	+	+	+	+	+	
Calocalanus pavoninus Farr.	+		+			
Calocalanus plumatus Shmel.		+		+		
Calocalanus plumulosus Claus					+	
Calocalanus (tenuis?) Farr.			+			
Candacia athiopica Dana		+				
Centropages typicus Kroyri				+		+
Clausocalanus (Brady)		+		+		+
Clausocalanus arcuicornis (Dana)	+	+	+			
Clausocalanus mastigophorus (Claus)				+		
Clausocalanus parapergens Frost, Flem		+				
Clausocalanus paululus Farr.		+	+	+		
Clausocalanus pergens Farr.		+		+		+
Corycaeus clausi F. Dahl	+		+			
Corycaeus flaccus Giesbr.	+		+			
Corycaeus furcifer Claus	+	+	+		+	
Corycaeus latus Dana		+		+		
Corycaeus limbatus Brady				+		
Corycaeus sp.	+		+	+		
Corycaeus typicus Kroger	+		+	+		

Corycella gracilis Dana		+				
Corycella rostrata Claus				+		
Corycella sp.	+		+			
Ctenocalanus vanus Giesbr					+	+
Eucalanus sp.					+	
Euterpina acutifrons Claus	+	+	+	+		
Lucicutia flavicornis Claus			+			
Lucicutia gemina Farr				+		
Macrocetelia gracilis Dana		+				
Mecynocera clausi Thompson				+	+	
Micsetelia gracilis Dana	+	+	+	+		+
Oithona sp.		+	+			+
Oncaea subtilis Giesbr.					+	
Oncaea conifera Giesbr.	+		+	+	+	
Oncaea curva Sars		+				
Oncaea dentipes Giesbr.	+	+	+	+		+
Oncaea media Giesbr.		+				
Oncaea mediterranea Claus	+		+	+	+	
Oncaea minuta Gieshr.	+	+	+	+		+
Oncaea similis Sars		+	+	+		
Oncaea subtilis Giesbr.		+				
Oncaea venusta Philippi					+	
Paracalanus aculiatus Giebr.					+	
Paracalanus nanus Sars				+	+	
Paroithona parvula Farr.					+	
Phaenna spinifera Claus					+	
Pleuromamma abdominalis Lubb				+		
Pleuromamma gracilis Claus				+		+
Pleuromamma sp.		+				
Scolecithrix danae Lubb		+				
Temora stylifera Dana				+		
Total 54 species						

***References:** 1- Pavlova, 1964; 1965; Pavlova and Baldina, 1969; 2- Kovalev *et al.*, 1976; 3- Kovalev, 1971 4- Kovalev *et al.*, 1987; 5- Porumb, 1980; 6- Kovalev *et al.*, 1998.

In the last decade, some 50 additional species of Mediterranean and Marmara Sea Copepoda were found in the southern Black Sea (Zagorognya *et al.*, 1999; Tarkan *et al.*, 2005): they may be considered as regular migrants arrived with Mediterranean water masses.
Recently the compass jellyfish *Chrysaora hysoscella* was recorded in pre-Bosporus area (Öztürk and Topaloglu, 2009), following its 2000 record in the Sea of Marmara (Inanmaz *et al.*, 2003) and now this stinging species is also found into the Black Sea. This species has not been a threat yet, but is beginning to increase its area of distribution. This species is planktophagous, consuming a range of planktonic animals (<http://www.nhm.ac.uk/nbn>).

In the northeastern Black Sea off Gelendzhik three species of Mediterranean Copepoda were recorded: *Euchaeta marina, Rhyncalanus nasutus, Pleuromamma gracilis* and one species of Ostracoda: *Philomedos globosa* (Musaeva, pers. comm.). *E. marina* and *P. gracilis* have already been found off Bosporus (Kovalev *et al.*,1998), two others were recorded for the first time. Most probably they were brought with ballast waters but did not get established as they were not found in following years.

In the coastal waters off Crimea, the numbers of non-native planktonic species observed all of Mediterranean origin keep increasing. To date, it is not clear whether all will be capable of establishment. Among them, one finds the harpacticoids *Amphiascus tenuiremis*, *A. parvus*, *Leptomesochra tenuicornis*, *Idyella palliduta*, *Ameiropsis reducta*, and *Proameira simplex*, the

planktonic copepods *Oithona brevicornis, O. plumifera*, *O. setigera*, *Clausocalanus arcuicornis*, and *Scolecetrix* sp.. Species of the family Clausidiidae, *Rhincalanus* sp. and *Oncaea minuta* – were found off Crimea in the area of Smeinyi Island. Some species were represented by few specimens or single individuals (Zagorodnya and Kolesnikova, 2003). But we cannot yet consider them as established species, although some of them were rather abundant.
In 2005-2006 the species of Copepoda *Oithona brevicornis* reached a very high abundance (in autumn 42,667 ind.m^{-3} in the central part of Sevastopol Bay. Since the middle of September until the end of 2006 *O. brevicornis* comprised from 70% to 96-97% of total mesozooplankton. Most probably this species is establishing now in the Black Sea (Altukhov and Gubanova, 2006; Gubanova and Altukhov, 2007). *O. brevicornis* was recorded also off Novorossiisk, Tuapse (Seliphonova, 2009).

In May-June 2001 during the R/V Knorr cruise 33 Mediterranean species of Copepoda were recorded in the western Black Sea. All of them were found in good conditions in water with low salinity (Seliphonova *et al.*, 2008).

Overall more and more Mediterranean subtropical species of mesozooplankton are recorded in the Black Sea outside the Bosporus area, most probably they were brought with ballast waters, but now we may consider only *Oithona brevicornis* as established species (Table 4).

Table 4. Mediterranean invertebrate species recorded in the Black Sea.

Species name	Origin	First record in Black Sea	Location of first record	Establishment	Abundance	Habitat	Geographic distribution	Tolerance limits	Vector	Reference
Scyphozoa Pelagiidae *Chrysaora hysoscella* (Linne, 1766)	Mediterranean	July 2009	off Bosphorus	a few ind.	a few ind.	marine and brackish	Mediterranean, Northeast and southern Atlantic, Marmara	subtropical, temperate	expansion	Inanmaz et al., 2003 Öztürk and Topaloglu, 2009 in press
Echinodermata *Arbacia lixura*	Mediterranean	2007	Canakkale Strait, later Marmara Sea	locally	not abundant	rocky, muddy area of Turkish coast	Mediterranean	subtropical	not known	Öztürk, 2006
Echinodermata *Asterias rubens*	Mediterranean	1996, 2003	off Bosphorus	locally	not abundant	marine benthic	Mediterranean	subtropical	expansion, shipping?	Albayrak, 1996; Karhan et al., 2007
Echinodermata *Amphiura filiformis*	Mediterranean	recently	off Bosphorus	locally		marine benthic	Mediterranean	subtropical	expansion, shipping?	Sergin, Kideys, 2009
Echinodermata *Asterina gibbosa*	Mediterranean	recently	off Bosphorus	locally		marine benthic	Mediterranean	subtropical	expansion, shipping?	Sergin, Kideys, 2009
Bivalvia *Mytilus edulis* Linne, 1758	Mediterranean	2001	Odessa Bay	single individuals	single ind.	marine benthic	Mediterranean North Atlantic	subtropical	expansion	Alexandrov, 2004
Bivalvia *Mytilus trossulus* ? Gould, 1850	Pacific Ocean		Odessa Bay	single individuals	single ind.	marine benthic	West Pacific	subtropical, temperate	ballast waters	Alexandrov, 2004
Anadaridae *Anadara demiri* (Piani, 1981)	Mediterranean	1968	Black Sea near Bosphorus and north-western Black Sea	established	abundant	marine benthic	Mediterranean, Aegean	subtropical	natural expansion	Öztürk,1998 Turkey Country report
Anadara cornea (Reeve, 1844)	Mediterranean, introduced from Indo-Pacific		Southern and off Bosphorus	established		marine benthic	Aegean (non-native), Southern Atlantic, Indo-Pacific	subtropical, tropical	expansion	Öztürk,1998
Cirripedia Balanidae *Balanus amphitrite?*	Mediterranean	2001	Odessa Bay		a few ind.	marine benthic	Mediterranean, Northern Atlantic		shipping	Alexandrov, 2004
Polychaeta Capitellidae *Capitellethus dispar* (Ehlers, 1907)	Northeast Atlantic, Indo-pacific, Mediterranean?	1972	off Bosphorus		a few ind.	marine demersal	Mediterranean Northeast Atlantic and Indo-West Pacific	temperate	shipping	Alexandrov, 2004
Crustacea Decapoda *Paleamon longirostris* H. Milne-Edwards	Eastern Mediterranean, Marmara Sea	2005	off Bosphorus	few ind.	few ind.	marine	Mediterranean, Marmara Sea, Eastern Atlantic, the Baltic Sea	temperate-subtropical	expansion	Sezgin et al., 2007
Crustacea Decapoda *Sirpus zariquieyi* Gordon, 1953	Mediterranean	2000	off Bosphorus	few ind.		marine	Mediterranean, Aegean, Marmara Sea	subtropical	shipping?	Zaitsev and Ozturk, 2001
Copepoda Oithonida *Oithona brevicornis* Giesbrecht, 1891	Adriatic Sea? Mediterranean?	2002	Sevastopol Bay	established	abundant	marine euryhaline	Adriatic Sea Mediterranean, North Atlantic	subtropical, temperate	ballast waters	Gubanova, Altukhov, 2006

BENTHOS

Via Bosporus penetrate many larvae of benthic animals. Some of them may find a proper substratum and settle. If density of individuals is high, they may create self-reproducing population.

Among benthic species which penetrated from the Mediterranean and now live in the near Bosporus area there are representatives Gastropoda. According to their origin they may be subdivided: five Mediterranean (*Scissurella laevigata, Proneritula westerlundi, Alvania cimex, Doto paulinae, Calmella cavolinii*), eleven - Mediterranean-boreal (*Diodora graeca, Calliostoma granulatum, Aporrhais parpelicani, Turritella communis, Lunatia fusca, Trophonopsis muricata, Tritonalia erinacea, Tritia incrassata, Cylichnina cilindracea, Philine quadripartita, Leiostraca glabra*), two - Mediterranean - Lusitanian (*Payraudeutia intricata, Mitrella scripta*) (Chukhchin, 1984).

Area of distribution: twenty two species of Mediterranean Bivalvia are limited off Bosporus. Among Anisopoda also two species *Leptochelia mergellinae* Smith and *Pontotanais borceai* Bacescu occur off Bosporus (Makkaveeva, 1979).

Thirty Mediterranean species of Polychaeta were recorded off the Bosporus area. Among them already in the 1960s two Polychaeta species *Sternaspis scutata* and *Ophiothrix tragilis* were found. In addition among Mediterranean species which occur near the Bosporus area of the Black Sea: three Ophiuroidea species, one Echinoidea species, one Asteroidea species, one Scaphopoda species, eleven Ostracoda species, eight Echinodermata species (Kiseleva, 1979).

The numbers of Mediterranean species off Bosporus area keep increasing.

During the last decades some species which occurred earlier only off Bosporus area began to penetrate in other areas of the Black Sea. Three species of Amphipoda (*Synchelidium maculatum, Megamphopus cornutus, Monoculodes gibbisus)* were found in the near Bosporus area, off the western shores of Crimea and of Caucuses. Cirripedia *Verruca spengleri* that occurred previously only off Bosporus was found in high abundance in the coastal area of Crimea even in 1950s (Aykubova, 1948).
Among similar species recorded far from the southern part of the Black Sea we may mention Amphipoda *Colomastix pusilla* recently found in the northwestern area of Crimea and near Kerch Strait (Revkov *et al.*, 2003). Representative of Isopoda *Gnathia bacescoi* also occurred only near Bosporus but since 1969 was recorded in the coastal area of Crimea (Zaitsev and Alexandrov, 1998). Representative Pantopoda *Anoplodactylus petiolatus*, recorded earlier off Bosporus in 1986, was found in the coastal area of Crimea near Yalta at the depths 10-20 m in community *Chamelea gallina* (Sergeeva, 1992). Three Bivalvia species, found earlier only off Bosporus were recorded in a few numbers in the coastal areas of Crimea. Among them *Clausinella fasciata*, *Hiatella rugosa* (Revkov *et al.*, 2003) and *Acanthocardia tuberculata* were found near Kerch straight (Terent'ev,1998).

In 2001 live individuals of juveniles of one more gastropod *Neptunea arthritica* (Bernardi, 1857) (Gastropoda, Buccinidae) were recorded in Kamyshevaya Bay (Sevastopol, Crimea). They were probably brought in an ova laying. *Neptunea arthritica* is a Far East species, predator which can live in brackish waters. Establishment of this species may create deteriorations in the benthic communities of the Black Sea (Shadrin *et al.*, 2002).

In 2001 two new non-native Bivalvia species were found in the Odessa Bay: *Mytilus edulis* and *Mytilus trossulus* (Alexandrov, 2004). *M. edulis* probably was brought with ballast waters from the Mediterranean, where it is used for aquaculture in Spain and Italy shores mainly. Probably the Pacific species *Mytilus trossulus* was brought with ships from Far East Russian areas, where it is a main cultivated species (Table 4) (Suprunov and Makarov, 1990).

Thus numbers of Mediterranean benthic species in the near Bosporus area are increasing more than other groups and some of these species appear also in the north-western Black Sea. Such systemic groups as Echinodermata are represented now with more and more species (Table 4).

Mention should be made to species, that arrived from the Adriatic Sea, because conditions of the north Adriatic are closer to the Black Sea. There are only few of them: *Anadara inaequivalvis* and *Crassostrea gigas*. None of them is native to the Adriatic Sea. *A. inaequivalvis* was brought to the Adriatic Sea from the coastal waters of the Philippine Islands. After arrival into the Black Sea *A. inaequivalvis* became a natural widespread component of the coastal communities. *C. gigas* entered the Black Sea from the Adriatic, where it had been brought from the Sea of Japan (Skarlato and Starobogatov, 1972). It occurs in few numbers. Attempts have been made to cultivate it in oyster farms in the northeastern Black Sea, using special methodology (Zolotarev, 1996).

MACROPHYTES

The list of macrophytes of the Black Sea was published in 1975. It now counts 38 additions. The most significant change is the almost twofold increase in the number of *Cladophora*, *Ulva*, *Ceramium*, *Polysiphonia*, *Cystoseira* and *Sargassum*; many of them play a key role in the bottom communities of the Mediterranean (26 species) (Table 2). Most are thermophilic and indicators of the transition zone between the boreal and tropical domains (Milchakova, 2002).

The greatest number of species probably penetrated with currents, and became established in near-shore waters of the Anatolian coast. Their proportion reaches 26% of the total number of macrophytes. Among them, green Chlorophyceae, brown Fucophyceae, and red Rhodophyceae are represented by ten, five, and twelve species, respectively (Aysel and Erdugan, 1995).

Off the coasts of Rumania and Bulgaria, six new Cladophora among other green algae were brought with ballast water but their origin is uncertain (Bavaru *et al.*, 1991; Milchakova, 2002).

In 1990, in Odessa Bay, the near-shore euryhaline brown *Desmarestia viridis* was found for the first time in the Black Sea. By winter 1994/1995, *D. viridis* had already become a major presence in the near-shore zone of the bay. In recent years, *D. viridis* has spread over to the northwestern Black Sea (Minicheva, 2007a). This species was most probably brought with shipping from the north Atlantic, and it is also species which was introduced into the Mediterranean in the coastal zone of France (Minicheva and Eremenko, 1993).

FISHES

Some Mediterranean fishes perform regular feeding and/or spawning migrations to the Black Sea. This refers, first of all, to valuable large predator species: the Mediterranean-Atlantic horse mackerel *Trachurus trachurus trachurus* (Linnaeus), the Atlantic bonito *Sarda sarda* (Bloch), the bluefish *Pomatomus saltatrix* (Linnaeus), the Atlantic mackerel *Scomber scombrus* (Linnaeus), and the Mediterranean mackerel *S. japonicus colias* Gmelin.

The swordfish *Xiphias gladius* Linnaeus, the blue-finned tuna *Thunnus thynnus thynnus* (Linnaeus), the Mediterranean picarel *Spicara moena*, and the European pilchard *Sardina pilchardus* used to visit and even spawn in the western and northwestern parts of the sea (Svetovidov, 1964; Gordina and Bagnyukova, 1992). In the 1970s-1980s, the abundance of migrating species significantly decreased and most of the species virtually stopped entering the Black Sea. In recent years, the conditions for fattening have improved, owing to increase in the stock of small pelagic fishes after the *Beroe ovata* invasion that controlled *M. leidyi* abundance. As a result, some Mediterranean species reappeared both in the western part of the sea (the mackerels, the bonito, and the bluefish) (Abaza *et al.*, 2006) and in its northwestern part (the horse mackerel, the bonito, the bluefish, the Mediterranean picarel *Spicara moena* (L), the European pilchard *Sardina pilchardus* (Walbaum), the green wrasse *Labrus viridis* (Linnaeus), and triplefin *Tripterygion tripteronotus* (Risso) (Boltachev, 2006). In addition, starting from 1999, their feeding area expanded and new Mediterranean fish species appeared; for example, in the near-shore waters off Crimea, the dorado *Sparus aurata* Linnaeus, the salema *Sarpa salpa* (Linnaeus), and the thick-lipped gray mullet *Chelon (=Mugil) labrosus* (Risso) appeared and intensely reproduced (Table 6) (Boltachev, 2006).

Table 5. Mediterranean and Indo-Pacific invertebrates recorded in the Sea of Marmara.

Species name	Origin	First record in Black Sea	Location of first record	Establishment	Abundance	Habitat	Geographic distribution	Tolerance limits	Vector	Reference
Cnidaria, Scyphozoa Rhisostomea *Cassiopea andromeda*	Mediterranean	—	Marmara	established	abundant	Aegean Sea	entered into Mediterranean via Suez Canal		Lessepsian Mediterranean, expansion	Ozgur, Ozturk, 2008
Scyphozoa Pelagiidae *Chrysaora hysoscella* (Linne, 1766)	Mediterranean	August 26, September 18, 2000	Bay of Erdek (southern Mediterranean	established locally	not abundant	central part of Marmara and near Istanbul off Bosphorus in July 2009 fist record of the Black Sea				Inanmaz et al., 2003 Öztürk and Topaloglu, 2009 in press
Trachimedusa *Liriope tetraphylla*	Mediterranean	2005	Coastal area off Dardanelles	established	abundant	Marmara Sea	Mediterranean	marine, subtropical	expansion	Yilmaz, Yuksek, 2009
Echinodermata *Arbacia lixura*	Mediterranean		Caanakkale Strait, Marmara Sea	locally	not abundant	Turkish coast of Marmara Sea	Mediterranean	subtropical	Aegean Sea	Öztürk, 2006
Echinodermata *Asterias rubens*	Mediterranean	1996	off Bosphorus	locally	not abundant	marine species		subtropical	shipping?	Albayrak, 1996; Karhan et al., 2007
Asterias rubens	Mediterranean	2007	Black Sea	established	not abundant	marine species	Mediterranean, Marmara	subtropical	expansion	Karhan et al., 2007
Erugosquilla massavensis Kossmann, 1880	Indian Ocean	2002	Sea of Marmara	a few	not abundant	marine	Indian Ocean	tropical	Suez Canal	Katagan et al., 2004

Table 6. Mediterranean fishes species recorded in the Black Sea.

Species name	Origin	First record in Black Sea	Location first recorded	Establish-ment	Abundance	Habitat	Geographic distribution	Tolerance limits	Vector	Reference
Clupeidae *Sardinella aurita* Valenciennes	Mediterranean, Marmara	1997	along the shores of Crimea, Turkish coast, Sile	migration increased	increase abundance	marine, brackish water species; pelagic	Eastern Atlantic, Mediterranean	subtropical	migration	Boltachev, 2006; Fishbase, FAO; Ozturk, 2006
Gadiformes Gadidae *Micromesistius poutassou* (Ricco)	Western Mediterranean,Atlantic?	1999	coastal area of Crimea; off Turkey	a few ind. present in Turkish waters for many years	a few ind. off Cape Aiya, common for Turkish area	marine, bathy-pelagic	western Mediterranean, North Atlantic: Barents Sea, along the African coast to Cape Bojador	boreal	migration	Boltachev, 2006; Fishbase, FAO; Ozturk, 2006
Mugilidae *Chenon labrosus* (Risso)	Mediterranean	1999	Crimean coast; southern Back Sea	increase in abundance, established	migration	demersal; catadromous	Mediterranean, Eastern Atlantic	subtropical	migration	Boltachev, 2006; Fishbase, FAO
Liza ramada (Risso)	Mediterranean	1950, 2007	Crimea, north-western Black Sea	increase in abundance	migration	marine, pelagic	Mediterranean, eastern Atlantic	subtropical	migration	Boltachev, 2009; Fishbase, FAO
Labridae *Thalassoma pavo* (L)	Mediterranean, Marmara	2006	Igneada	migration	migration	marine, reef-associated; marine; depth range 1-150 m	Mediterranean, eastern Atlantic, Marmara	subtropical	migration	Fishbase, FAO; Ozturk, 2006
Sparidae *Sarpa sarpa* (L)	Mediterranean, Marmara	2001	extension	migration	increase in abundance	marine, pelagic	Mediterranean, Eastern Atlantic	subtropical	migration	Fishbase, FAO, Ozturk, 2006
Sparidae *Sparus aurata* (L)	Mediterranean		Crimean coast	migrant, increase presence in the Black Sea	increase in abundance	marine and brackish	Mediterranean, Marmara	euryhaline eurythermal	migration	Fishbase, FAO, Boltachev, 2006

Sparidae *Boops boops* (L)	Mediterranean, Marmara	1989	Turkish coast, Sile; population increased and distribution extended	migration	migration	demersal marine	Atlantic-Mediterranean	subtropical	migration	Fishbase, FAO Ozturk, 2006
Umbrina cirrosa (Linnaeus, 1758)	Mediterranean	1962, 1999	Northestern Black Sea	a few, rare occurred in the Black and Azov Seas	reappeared	demersal; brackish; marine	Eastern Atlantic: Bay of Biscay and Gibraltar to southern Morocco, including the Mediterranean	subtropical	migration	Pashkov, 2005; Fishbase
Centracanthidae *Centracanthus cirrus* Raffinesque	Mediterranean	1988	off Odessa, littoral zone of Romania, Turkey area	a few individuals, eggs in 1988 2 adults off Romania in 2004, common in Turkish area	increase in abundance	marine, bentho-pelagic	Mediterranean, Marmara, Eastern Atlantic	subtropical	migration	Tsokur, 1988; Radu, 2006 (pers. com.)
Centracanthidae *Spicara maena* (L)	Mediterranean		off Bulgaria, Crimea, Caucasus	migrant, increased presence in the Black Sea	increase in abundance	marine, neretic	Eastern Atlantic, Mediterranean	marine, subtropical	migration	Svetovidov, 1964; Salekhova, 1979; Salekhova et al., 1989
Gobiidae *Gobius auratus* Risso	Eastern Mediterranean		common for Crimea, Turkish area		established	saltwater, marine, demersal	Eastern Mediterranean, Adriatic Sea, Atlantic	subtropical	shipping? migration?	Gordina, 1967; Fishbase
Gobiidae *G. cruentatus*	Mediterranean		off Crimea, Turkish area		established?	marine, demersal; In the Medi-terranean found in eel-grass beds	Mediterranean, Atlantic, Marmara	subtropical	shipping? migration?	Boltachev, 2006; Fishbase
Gobiidae G. xanthocephalus	Mediterranean		off Crimea, Turkish area		established	marine	Mediterranean, Atlantic, Marmara	marine, subtropical	shipping? migration?	Boltachev, 2006; Ozturk, 2006
Gobiidae *Tridentiger irigonocephalus* (Gill, 1859)	Pacific		Sevastopol Bay			demersal; brackish; marine	Pacific Ocean	temperate	shipping, ballast waters?	Boltachev, 2009;
Blenniidae *Parablennius incognitus* Bath, 1968	Mediterranean		common for Crimea, common for Turkish area		established	demersal; marine, between algae in shallow, rocky, littoral areas	Mediterranean, Marmara, Eastern Atlantic	marine, subtropical	migration?	Boltachev, 2006; Fishbase
Syngnathidae *Syngnathus acus L.*	North Atlantic		Crimean coast			lives amongst seaweed or sea-grass at depths down to 20 m	around the coasts of Britain and Ireland	temperate	migration? shipping?	Boltachev, 2006

Previously, in contrast to the gilthead bream, the thick-lipped gray mullet had never been recorded in the northwestern part of the Black Sea. For the first time, a juvenile of *Chelon labrosus* was caught in October 1981 in Donzulav Bay. In October 1983, shoals of the thick-lipped gray mullet consisting of 10-15 fishes were observed in the waters off Sevastopol (Salekhova, 1987). Starting from 1999, the thick-lipped gray mullet has been repeatedly found in the areas off Sevastopol. A specimen of the salema off the Crimea was first noted in 1999 (Boltachev, 2006). At present, its abundance in this region is rapidly increasing.

The dorado is often recorded as single specimens or minor shoals in Balaklava Bay and adjacent near-shore waters. Probably, the dorado and the salema may stay for overwintering now in the coastal waters off Crimea (Boltachev, 2006).

The Mediterranean umbrine *Umbrina cirrosa* was once found in the Black Sea Biosphere reserve in 1962 (Tkachenko, 1994). In summer 1999, one female with eggs was caught again in Pshada Bay (Pashkov, 2005).

All the above-mentioned species are seasonal Mediterranean migrants rather than invaders into the Black Sea. Among the non-native species, three species of fishes previously not encountered in the Black Sea were found in the coastal waters of Crimea. They include two specimens of the barracuda *Sphyraena pinguis* that were caught with a bottom trawl in Balaklava Bay in August 1999. This is an Indian-Pacific species, which penetrated as a Lessepsian migrant via the Suez Canal to the eastern Mediterranean including the Aegean Sea in 1931 and ultimately reached the Black Sea. This species is increasing area of distribution in the Mediterranean and became commercial species (Boltachev, 2009). Two individuals caught were identified as *Sphyraena obtusata* as well, but after very detailed analyses they were determined as *S. pinguis* (Boltachev, 2009). Another record concerns the Indian-Pacific species *Sphyraena obtusata*, a Lessepsian migrant that penetrated into the Mediterranean recently only in 1992 (Table 7). This species is not abundant, occuring rarely in the Mediterranean. A few individuals were found off the Bosporus area (Öztürk, 2006).

Table 7. Indo-Pacific fish species recorded in the Black Sea.

Species name	Origin	First record in Black Sea	Location of first recorded	Establishment	Abundance	Habitat	Geographic distribution	Tolerance limits	Vector	Reference
Sphyraenidae *Sphyraena obtusata* Cuvier	Indo-Pacific, Red Sea, Mediterranean	1999	Turkish area Şile	a few ind.	migrant, a few ind.	pelagic, marine	Indo-Pacific, Red Sea and East Africa to Samoa, migrate to eastern Mediterranean	marine, brackish; tropical	Lessepsian migrant	Fishbase, FAO, Öztürk, 2006
Sphyraenidae *Sphyraena pinguis* Gunter,1874	Indo-Pacific, Mediterranean	2004	coastal area of Crimea	a few ind.	a few ind. a few ind.	pelagic, marine	Indo-pacific pelagic, migrant	marine, tropical	Lessepsian migrant	Boltachev, 2009
Gobiidae Tridentiger irigonocephalus (Gill, 1859)	Pacific Ocean		Sevastopol Bay			demersal, brackish; marine	Pacific Ocean	temperate	shipping, ballast waters?	Boltachev, 2009
Tetraodontidae *Lagocephalus spadiceus* (Richardson, 1845)	Mediterranean, Pacific Ocean	2008	Çanakkale, the Sea of Marmara	a single ind.	a single ind.	demersal; marine, also brackish waters	Indo-West Pacific: Australia. Introduced (Lessepsian) in eastern Mediterranean	subtropical	Lessepsian migrant	Tuncer et al., 2008

A specimen of the northern blue whiting *Micromecisthis poutassou* 15.7 cm long was caught in January 1999 at a depth of 60 m off Balaklava (Crimea). It is a typical Atlantic-boreal species widely spread in the Mediterranean basin, including the Aegean Sea and the Sea of Marmara; most probably, it penetrated from the Mediterranean Sea. Blue whiting performs long-lasting migrations; it is known as a stenohaline eurythermal species dwelling at salinities no less than 33‰, but was first encountered at a salinity of 18‰. There are two ways of explanation of the appearance of the above two species in the Black Sea: fishes might migrate from the Sea of Marmara or the Mediterranean Sea or, which seems more probable, might be brought with ballast waters.

The third species is the coral-dwelling butterfly fish *Heniochus acuminatus*. A specimen 76 mm long was caught by a net in Balaklava Bay in October 2003. It is a typical tropical Indian-Pacific species and the conditions of Balaklava Bay are hardly favorable for it. This fish was most probably delivered with ballast waters (Boltachev, 2006).

In recent years, in the waters off Rumania, *Centracanthus cirrus,* which probably also penetrated from the Mediterranean Sea, was observed. To date, it has significantly increased its abundance and now represents a commercial fish in the littoral zone of Rumania (Abaza *et al.*, 2006) and off the Turkish coast (Öztürk, 2006). In the central part of the sea, its developing eggs were first found in June 1982 (Tzokur, 1988).

The golden goby *Gobius auratus* Risso, first found in the communities of near-shore macrophytes off Crimea and recently in the northeastern part of the sea may also be referred to as a Mediterranean invader (Nadolinsky, 2004). Two more Mediterranean species of Gobiidae *G. cruentatus* and *G. xanthocephalus* were recorded recently off Crimea and Turkish area (Boltachev, 2006; Öztürk, 2006).

Another indo-Pacific Gobiidae *Tridentiger irigonocephalus* was recorded off Crimea and Turkish areas (Boltachev, 2009). Representatives of Gobiidae are small species; it is probable that they were brought with ballast waters, particularly in the case of *Tridentiger irigonocephalus*.

One more indo-Pacific species recorded in the Turkish area of the Black Sea is the half-smooth golden pufferfish *Lagocephalus spadiceus* in 2008 (Tuncer *et al.*, 2008).

In the last years the Mediterranean species *Parablennius incognitus* became common in Turkish area and appeared off Crimea (Öztürk, 2006; Boltachev, 2009 and this volume). Among other species *Syngnathus acus* L. was recently found off Crimea (Boltachev, 2009 and this volume). Its origin is not clear. Probably it was brought from the northern Atlantic Ocean with ballast waters.

DISCUSSION

During the second part of the 20th century the Black Sea became the main recipient area for non-native temperate and warm water marine and brackish water species which arrived from different donor areas. Euryhaline and eurythermal species of Atlantic origin became abundant, often forming large populations. In turn most of these established species affected other seas of the Mediterranean basin and the Caspian Sea (Shiganova and Dumont, unpubl. data).

Since the end of 1980, with the beginning of warm period, more and more warm-water species of different origin have established in the Black Sea.

During the last decades a new trend has appeared. The Mediterranean species which have always penetrated into the Black Sea with Low Bosporus current and could live only off Bosporus area began to disperse with the currents or survive ballast waters release in other areas of the Black Sea. Earlier they could not settle due to low temperature, particularly in winter, but now with increasing temperature the share of these non-native species of Mediterranean origin is gradually increasing.

Organisms driven with currents and ballast waters represent phyto- and zooplankton, macrophytes, benthic or demersal organisms, and fishes. These species as a rule have subtropical and in some cases even tropical origin (Tables 1-7). None of them became very abundant; their greater number still occur only in the near-Bosporus and southern parts of the Black Sea where salinity is higher. Selected species migrated to the near-shore regions off Bulgaria, Rumania, and the Crimea also with currents or via ship ballast waters (Tables 8, 9).

Table 8. Mediterranean species found in the southern Black Sea (mainly off Bosphorus).

	<1960s	1960-1970	1971-1980	1981-1990	1991-2000	2001-2009
Phytoplankton		37				
Copepoda		15	19	12	7	51
Gelatinous plankton						1
Macrophytes					26	
Benthos	1	45	30	56		5
Fish					9	5
Total	**1**	**97**	**49**	**68**	**42**	**62**

Table 9. Mediterranean species found in the northwestern and western Black Sea.

	prior to 1991	1991-2000	2001-2009
Phytoplankton	—	23	11 (+10)
Copepoda	—		47
Gelatinous plankton	—		
Benthos	—		12
Fish	—	9	
Total		**32**	**70 (+10)**

The appearance of species of Indo-Pacific origin is a new event for the Black Sea.

Shift from fish to gelatinous plankton

The most significant events were the arrival of two warm water ctenophores: *Mnemiopsis leidyi* and *Beroe ovata*. The first affected all trophic web of ecosystem and became the main driver of the Black Sea ecosystem functioning. The stocks of most of commercial fish greatly dropped (Shiganova *et al.*, 2003; 2004). Arrival of the second species induced the recovery of the Black Sea ecosystem. But then *Mnemiopsis leidyi* spread from the Black Sea to the Sea of Marmara, the Aegean Sea and recently in further areas of the Mediterranean with ballast waters (Shiganova *et al.*, 2001; Shiganova and Maley, 2009; Galil *et al.*, 2009).

Recent years marked a new trend: the arrival of gelatinous species from the Mediterranean. Several Mediterranean jellyfishes have penetrated the Sea of Marmara, notably *Chrysaora hysoscella*, *Cassiopea andromeda*, Trachimedusa *Liriope tetraphylla*. In 2009 *C. hysoscella* was recorded for the first time in the Istanbul Strait and the Turkish part of the Black Sea (Öztürk and Topaloglu, 2009). This is a temperate planktivorous species and it cannot be excluded that it will establish in the Black Sea if salinity conditions allow.

Northward extension, increase abundance and change phenology

Significant range northward extensions have been recorded for Mediterranean fishes, with seasonal migrations in the Black Sea. Some of them have changed phenology: they used to spend a short period of warm seasons in the Black Sea for spawning/ and feeding but now some of them stay longer in the Black Sea, intensively reproduce and even most likely stay for overwintering. This was not observed earlier (the dorado *Sparus aurata*, the salema *Sarpa salpa*).

Arrival and establishment of Mediterranean species

We may consider that nine Mediterranean species of fish were most likely established in recent years in the Black Sea (Table 6). But we still cannot consider most of phytoplankton and zooplankton species, which were recorded both in the southern and northwestern areas of the Black Sea, as established. The main reasons are low salinity and cold winters. Among Copepoda only temperate *Oithona brevicornis* has established. Among phytoplankton 11 species have established: there are mainly representatives of Dinophyceae, which develop in spring and summer and are capable to produce cysts in unfavorable conditions. *Gymnodinium sanguineum* is among them: it lives in upwelling and is therefore tolerant to low temperatures (Table 2).
Most benthic species and macrophytes may be considered as established species in the southern Black Sea and in other parts as well.

Thus there is a progressing trend of arrival of Mediterranean species into the Black Sea both with the currents as natural expansion and with ballast waters. Most of these species arrived in previous years, but relatively low temperature and low salinity prevented their establishment. Now with rising temperature some species can establish. First of all benthic species that inhabit at depths where salinity is higher, especially in the southern part of the Black Sea. Due to intensification of shipping (Table 10), particularly between Mediterranean and Black Sea countries (62% of vessels in Novorossiysk harbor arrived from the Mediterranean countries – Matishev *et al.*, 2005) the numbers of species released with ballast waters also increased. Some of these species began to establish in the vicinity of harbors.

Table 10. Numbers of vessels crossing the Bosphorus Strait and mean volume of released ballast waters (Matishev *et al.,* 2005; Ozturk, 2006).

Year	Number of vessels	Mean volume of ballast waters
1938	4500	7500
1985	24 100	105,500
1996	49952	156,057
2001	56000	110,000,000
2002	47283	103,897,121
2003	46936	102,943,762
2004	54564	116,342,089
2005	54794	115,298,453
2006	53721	78,987,432

The total numbers of Mediterranean species found only in the southern Black Sea comprise 240 species. At present time it is difficult to determine exactly how many of them might be included in the list of established species. We consider as established among them 23 species of macrophytes. Zoobenthic species, which are most probably, would be established as well in future, we have not included in the list of established species. Species found in the northwestern and western Black Sea comprised 84 species. Among them we consider 33 species as established: 10 species of zoobenthos, 11 species of phytoplankton, 3 species of microplankton (fam. Tintinnidae) and 9 fish (Table 9). This process is ongoing and these numbers probably omitted certain species which were recorded recently and locally.

In the Black Sea the total established non-native species (without all near Bosporus Mediterranean species) from all areas account for about 4% of the native biota (Figure 1).

By comparison, in the Mediterranean Sea, the fraction of established non-native species (see CIESM Atlas on line) is between 6 and 7% of the native biota (about 12,000 species). Black Sea biodiversity is about 3,5 times less than in the Mediterranean. The numbers of established non-native species decrease in the same proportion for these seas. So, the basin appears capable to accept the numbers of non-native species in proportion equal natural biodiversity (Shiganova and Dumont, in press).

The most euryhaline and eurytermal non-native species from other areas did spread or were brought with ballast waters from the Black Sea into the Sea of Azov and the Caspian Sea where they could establish. None of the Mediterranean species spread from the Black Sea farther to these seas. The only exception concerns three species of Tintinnidae, which were found in the Sea of Azov. The reason is a low salinity of these seas (low than 15‰, the boundary of mesohaline water, which is important for biota).
Not all non-native Mediterranean species are harmful for the Black Sea ecosystem with the exception of gelatinous species. The rising of the numbers of species, abundances and areas of distribution of gelatinous plankton – both native and invaders – are the most dramatic events for Mediterranean, Sea of Marmara and the Black Sea. Expansion of gelatinous species from the Mediterranean to the Sea of Marmara and after that farther to the Black Sea is a particular threat for their ecosystems. Continuation of expansion of the aggressive Black Sea invader *Mnemiopsis leidyi* in different areas of the Mediterranean Sea is also cause for much concern.