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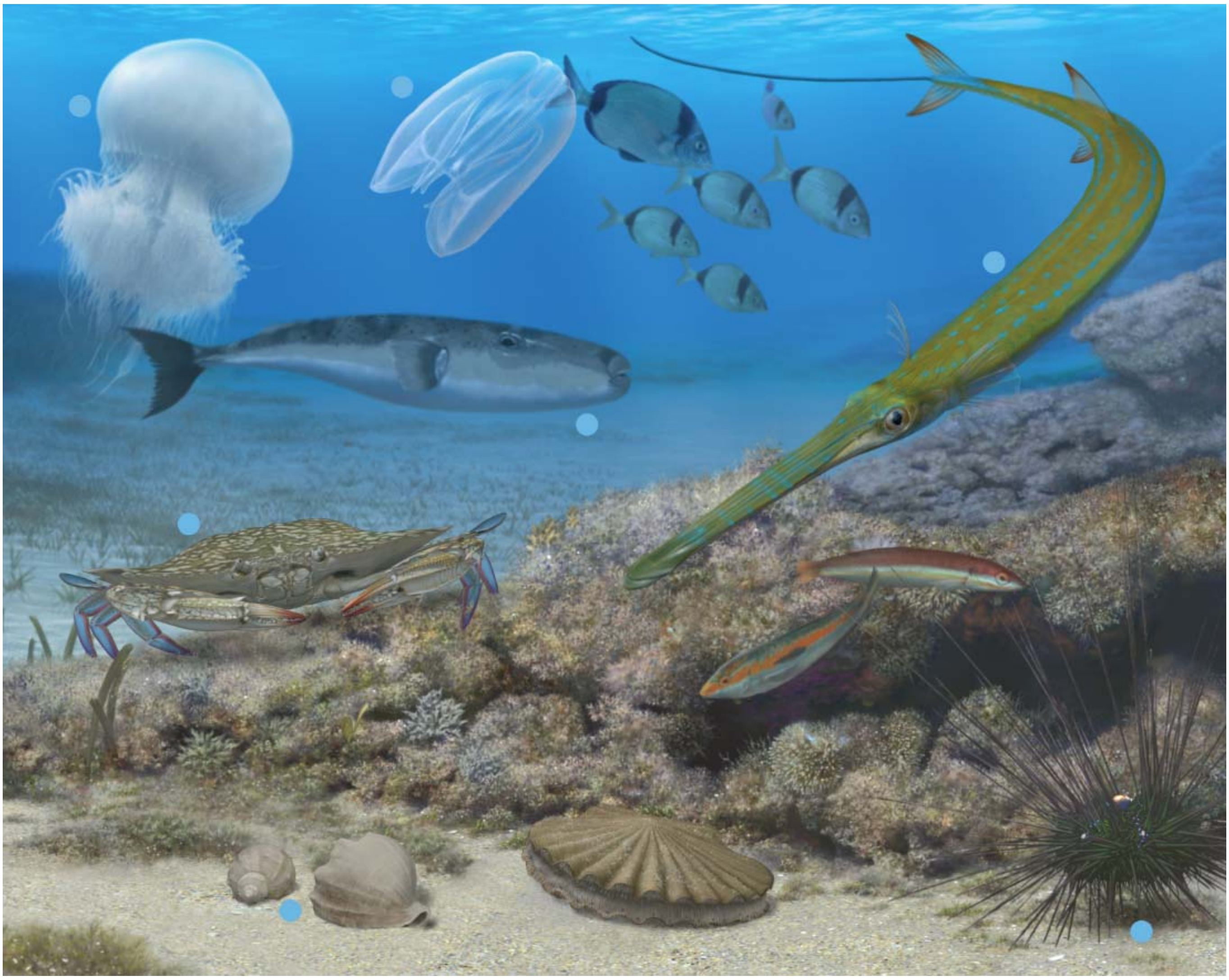
STATUS OF ALIEN SPECIES IN THE MEDITERRANEAN AND THE BLACK SEA



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PREPARATION OF THIS DOCUMENT

This document was prepared by Mr Bayram Öztürk, Ph.D., from the Faculty of Fisheries, Istanbul University, and Turkish Marine Research Foundation, Istanbul, Turkey. This analysis stems from the outcomes of the meeting of the eleventh session of the Sub-Committee on Marine Environment and Ecosystems (SCMEE) (Malta, November–December 2010) and of the Workshop on alien species and their interaction with fisheries, held back-to-back with the SCMEE meeting. On this occasion, the SCMEE encouraged GFCM members to carry out and disseminate educational and informative material in the Mediterranean and Black Sea countries to raise awareness about harmful alien species.

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ABSTRACT

This study, undertaken upon request by the General Fisheries Commission for the Mediteranean (GFCM), summarizes the available information about the status of alien species in the Mediterranean Sea and the Black Sea.

The biota of the Black and Mediterranean Seas has started to change with the introduction of alien species in the last few decades due to increasing shipping activities, lessepsian migration, Atlantic influx, intentional or unintentional introduction as well as climate change.

The Black Sea suffered from the alien combjelly *Mnemiopsis leidyi* for long years since the late 1980's in terms of biodiversity and decrease in fish catch, mostly of small pelagic fish such as anchovy. Mediterranization is also a growing trend and many Mediterranean origin species have penetrated to the Black Sea, most probably due to climate change in recent years. On the other hand, a sea snail, *Rapana venosa*, is the most commercial alien species harvested by the Black Sea countries.

The Sea of Marmara has crucial importance between the Black and Aegean Sea due to the exchange of water mass and marine biota. The Sea of Marmara was also negatively impacted by the combjelly *Mnemiopsis leidyi* with the recovery taking place in terms of small pelagic fish only in recent years. Lessepsian fish and invertebrates are increasing in the Sea of Marmara but overall impacts are not yet known. *Rapana venosa* has been commercially exploited also in the Sea of Marmara.

The Eastern Mediterranean Sea has been invaded by numerous lessepsian species entering through the Suez Canal. Some, not all, lessepisan species are found in the Central and Western Mediterranean Sea. Marine Protected Areas and protecting native species can be effective for mitigating negative impacts of the invasion of alien species. Furthermore, as a consequence of the increase in populations of lessepsian species, consumption of some of such species has been started and they are influencing the local market mostly in the eastern Mediterranean region. This new market of alien species shows an increasing trend. Some alien species have negative impacts on human health, tourism and fisheries, such as puffer fishes and jellyfish, and need to be particularly monitored. Important impacts on the biodiversity are already reported especially in the eastern Mediterranean Sea as habitat displacement and competition with native species.

In total, over 900 species are alien species in the Black and Mediterranean Seas. Various fishing techniques such as trawling, purse seining, setnets, gillnets and pots are used for alien species fishery. Due to lack of overall statistics, total catch in the entire basin is not known and not predictable. Some of alien fishes which do not have commercial value, such as pufferfish and cornetfish, are discards. Some Atlantic orginated fish and invertabrate have also extended to the eastern part of the Mediterranean Sea. Besides, ship ballast water and intentional and unintentional introduction are growing threats for marine biodiversity in both basins.

Information dissemination and raising public awareness mostly for harmful species is important on a regional level. Regional cooperation for monitoring and protecting marine bioidversity is essential to minimize and reduce the impacts of alien species both in the Black and Mediterranean Seas. Besides, the enforcement of the legal measures is also necessary to reduce the introduction of alien species.

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GLOSSARY

Alien species: According to the World Conservation Union (IUCN) (2002), an alien species (exotic, non-native, non-indigenous) is a species, a sub-species or a lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans). It includes any part, gametes or propagule of such species that might survive and subsequently reproduce.

Alien invasive species: An alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity. However, there is no uniform terminology for the alien species and some organizations use different definition such as the United Nations Environmental Programme (UNEP), the Internationl Council for the Expolaration of the Sea (ICES) or the United States Environmental Protection Agency (EPA).

Lessepsian migrant: term used for the first time by Por (1969, 1971) to define the Red Sea origin species which had passed through the Suez Canal and settled in the Eastern Mediterranean.

Lessepsian migration: Unidirectional migration of the Red Sea species to the Mediterranean via the Suez Canal.

Anti-lessepsian: Contrary migration to the lessepsian migration, i.e. from the Mediterranean Sea to the Red Sea.

CBD: Convention on Biological Diversity

CPUE: Catch per unit of effort, i.e. the amount of catch taken per unit of fishing effort (e.g. number of fish per longline hook-months)

CIESM: International Commission for the Scientific Exploration of the Mediterranean Sea

EEA: European Environment Agency

FAO: Food and Agriculture Organization of the United Nations

FIPS: Statistics and Information Service, Fisheries and Aquaculture Policy and Economics Divison, FAO Fisheries and Aquaculture Department

GFCM: General Fisheries Commission for the Mediterranean, regional fisheries body for the Mediterranean and the Black Seas

GFCM Area: Thirty-seven major fishing areas of the Mediterranean and the Black Seas according to the FAO major fishing area map (FAO, 2006)

ICCAT: International Commission for the Conservation of Atlantic Tunas

IMO: International Maritime Organization

IOC: Intergovernmental Oceanographic Commission

IUCN: World Conservation Union

MEPC: Marine Environment Protection Committee

RAC/SPA: Regional Activity Center/Special Protected Areas

UNEP/MAP: United Nations Environment Programme/Mediterranean Action Plan

EXECUTIVE SUMMARY

Biota of the Black and Mediterranean Seas have started to change with the introduction of alien species in the last few decades due to lessepsian migration, Atlantic influx, intentionally or unintentionally introduction and climate change. The dispersion of alien species is a dynamic process that shows an increasing trend and is likely to continue in the future. This phenomenon causes severe ecological, socio-economical and human health problems in the entire basin.

Shipping and intentional introduction are the main vectors of alien species introduction to the Black Sea. In the Black Sea, several alien species dispersed and caused threats to the native biota due to the low biodiversity and a character as an enclosed sea. A comb jelly, *Mnemiopsis leidyi,* which was transported to the Black Sea with ship ballast water and caused ecological impacts and economical damages to the riparian countries' fisheries due to feeding of mostly the larvae and eggs of small pelagic fishes, mainly anchovy, horse mackerel and spratt. A gastropod, *Rapana venosa,* is the first alien commercial species in the Black Sea and after 1980s it became an export product for all the Black Sea countries. Meanwhile, its impact on the native fauna, especially on mussel and oyster beds, was detrimental.

Mediterranization is also a growing trend and many Mediterranean origin species have penetrated to the Black Sea, even a stinging compass jelly fish, *Chrysaora hysoscella*. Recently, lessepsian fish migrants such as blunt barracuda *Sphyraena pinguis* and a coral-dwelling fish, *Heniochus acuminatus,* had been reported for the first time. On the contrary, an intentionally introduced species, *Liza haematocheila*, penetrated to the Aegean and Mediterranean Sea through Turkish Straits. It shows that these two basins are closely interacting with each other.

The Marmara Sea is a link between the Black and Mediterranean Seas and serves as a biological corridor, an acclimization area and a barrier for alien species. *M. leidyi* had also a detrimental effect on anchovy fisheries in the Marmara Sea and the recovery of the stocks has started in the recent years. Poisonous lessepsian fish migrant, *Legocephalus scelaratus,* and an alien stomatopod shrimp, *Erugosquilla massavensis,* have also been reported in the Marmara Sea recently. Shiping is the main vector for alien species in the Marmara Sea.

As for the Mediterranean Sea, alien species enter from the Atlantic Ocean through the Gibraltar Strait, the Red Sea through the Suez Canal, from the Black Sea through the Canakkale Strait (Dardanelles) and by intentional or unintentional introduction. Some lessepsian sprinter fish species pass the Sicily Strait which is known as a biogeographical boundary between the eastern and western Mediterranean Sea. On the other hand, some species of Atlantic-origin penetrated into the Mediterranean Sea farther east reaching the coast of Sicily from the originally established areas near the Gibraltar Strait.

The main vectors of the Mediterranean alien species are the Suez Canal, shipping and aquaculture. A general trend shows that the number of alien species has increased in recent years but the number itself is debatable. Nevertheless, alien species are increasing regional marine biodiversity in the Black and Mediterranean Seas.

Alien species have had several consequences on fisheries, biodiversity, human health and economy in the Mediterranean Sea. Some of the alien fish species have become economically important after the establishment of sustainable populations, such as lizard fish, goatfishes, Spanish mackerel and round herring mostly in the eastern Mediterranean region. Similarly some of the crustacean species are also commercially important, such as kuruma prawn, green tiger prawn, mantis shrimp, swimming crabs, and blue crabs. Some introduced mollusc species, such as the Japanese oyster and Pacific carpet clam, already have a market value. Besides, some species have negative impacts on human health, mostly puffer fishes, *Legocephalus* spp., an alien jellyfish, *Rhopilema nomadica*, and a hydroid, white stinger, *Macrorhynchia philippina,* in the eastern Mediterranean countries. The eradication of *Caulerpa taxifolia* and *Caulerpa racemosa* negatively impact the fisheries and ecosystem in the Mediterranean Sea. Some species badly affect fishing gears by causing mesh clogging, fouling and damaging. Some

alien species impacted also on marine biodiversity, mainly by habitat competition and species displacement.

Regional cooperation is essential to minimize and reduce the impacts of alien species both in the Black and Mediterranean Seas. In this context, regional and international organizations should establish a common alien species database easily accessible to all stakeholders or should harmonize already existing databases on alien species. An early warning system needs to be developed for unpredictable alien species blooms or impacts. Countries should collect also catch statistics of most commercial alien species for better fisheries management. Specific studies mostly on the impacts on fisheries by alien species are highly required to develop fisheries reporting and monitoring system. Besides, for some countries, it is highly recommended to implement capacity building programmes in terms of species identification and data collection. Finally, key species and key habitats, for example, *Posidonia* meadows, should be protected to combat alien species invasion.

INTRODUCTION

The invasion of alien or exotic species in the Black and Mediterranean Seas has been recorded for many years. It has speeded up in recent years, with many examples of negative impacts on marine ecosystems, on the local marine fauna and flora and on socio-economic activities, such as fisheries.

The Black and Mediterranean Seas are interconnected by the Turkish Straits System. These narrow straits act as a biological corridor, a barrier or an acclimatization zone for marine species. Ship-transported species, such as *Rapana venosa*, or introduced species to the Black Sea, such as *Liza haematocheila*, dispersed to the Mediterranean Sea. Since the Suez Canal opening, the Mediterranean Sea has been connected also to the Red Sea, thus the Indian Ocean, and allowed a massive invasion of tropical fauna to the mostly eastern Mediterranean Sea. Several Indo-Pacific species (lessepsian migrants) have entered and started to colonize in the western Mediterranean Sea besides the Aegean, Marmara and Black Seas. The Black and Mediterranean Seas, due to strong temperature gradients spatially from Gibraltar to Kerch Strait, temporally tropical in summer and temperate in winter, represents a suitable area for the introduction of species from different origin and region.

In recent years, the fish composition and fish catch amount have changed due to the alien species. Moreover, some poisonous fish and invertabrate species also established themselves mostly in the eastern Mediterranen Sea and start causing problems for human health and biodiversity. As it happened in the Black Sea, some intentionally- or unintentionally-introduced species are found in the Mediterranean Sea. It is foreseen that alien species might affect more seriously the fisheries of the Black and Mediterranean basin in the coming years.

In this review, the Black and Mediterranean Seas are examined separately to be more concise, although they are interconnected each other both physically and ecologically.

1. STATUS OF ALIEN SPECIES IN THE BLACK SEA

1.1 Main characteristics of the Black Sea

The Black Sea is one of the world's most isolated seas from the major ocean and the largest anoxic body of water on planet (87 percent of its volume is anoxic). The total surface area of the Black Sea is 423 000 km^2 and its catchment area is over 2 million m^2. It is surrounded by Turkey, Bulgaria, Romania, Ukraine, the Russian Federation and Georgia (see Figure 1). On the north-eastern corner, the Black Sea is connected to the Sea of Azov through the Kerch Strait, and on the south-western corner, to the Sea of Marmara through the Istanbul Strait (Bosphorus). The maximum depth is 2 212 m. The most striking characteristic of the Black Sea is probably the high level of hydrogen sulphide (H_2S). The level of H_2S is 150–200 m deep and has been relatively stable, although seasonal and annual fluctuations have been observed.

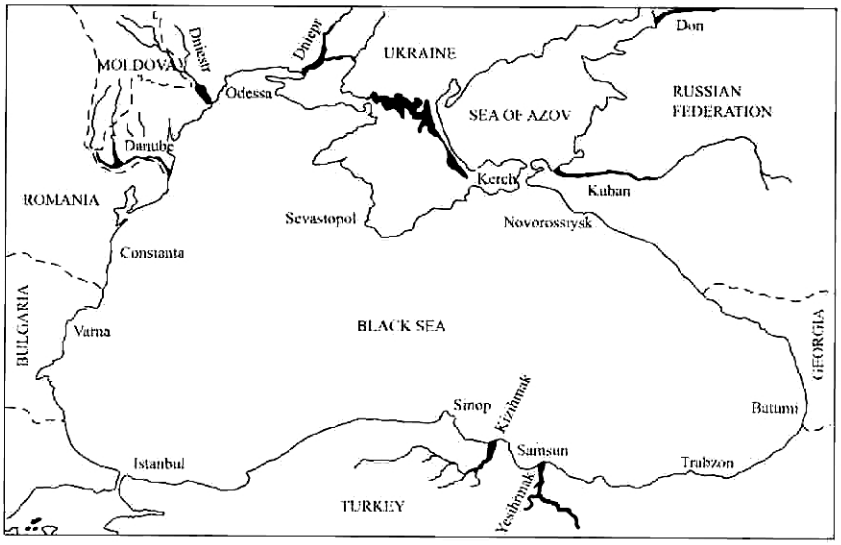

Figure 1 – The Black Sea

The presence of a permanent halocline between 150 and 200 m is another major distinguishing characteristic (Figure 2). The stratification is affected by the fresh water input and the Mediterranean inflow of highly saline water. The average surface salinity is about 18–18.5 per mille during winter, and increases by 1.0–1.5 per mille in summer. The temperature shows more variation than the salinity, seasonally as well as regionally. The mean annual surface temperature varies from 16°C in the south to 13°C in the northeast and 11°C in the northwest. While the upper 50–70 m water layer has seasonal fluctuations in temperature and there is considerable vertical variation, the temperature of the deeper water remains constant throughout the year. Typically, the temperature at a depth of 1 000 m is about 9°C and shows only a slight increase of 0.1°C per 1 000 m towards deeper sections (Balkas *et al.*, 1990).

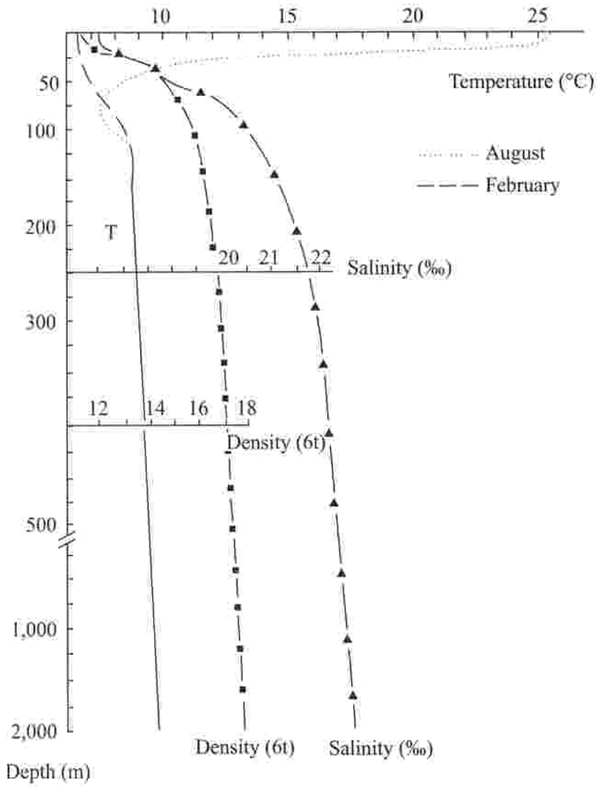

Figure 2 – Vertical profile of salinity, temperature and density of the Black Sea

The changes in the Black Sea ecosystem that have occurred since the 1960s due to the concurrent impacts of eutrophication, overfishing, climatic fluctuation and alien species invasions have been studied extensively. A synthesis provided recently in *State of the Environment Report* (BSC, 2008) examines the changes in pelagic and benthic ecosystems.

The Black Sea's biodiversity clearly reflects its geological history. Brackish water fauna known as "Caspian relics" originated from the Neoeuxinian Lake, and the components of this fauna are found only in waters with low salinity. Some bivalves, such as *Dressenia,* and fishes, such as gobies and sturgeons, are good examples. Another group of species is called "cold water relics" and includes ctenophores (*Pleurobrachia*), copepods (*Calanus*), and fishes such as spiny dog fish, sprat, flounder and whiting (Zaitsev and Mamaev, 1997), (Öztürk and Öztürk, 2005). This group is the second oldest inhabitants of the Black Sea, entering the sea between the Neoeuxine Lake Period and the early stage of the formation of the Istanbul Strait (Bosphorus). After the Istanbul Strait (Bosphorus) established a connection with the Mediterranean Sea about 7 000–10 000 years ago, the salinity of the Black Sea rose gradually and soon the Mediterranean species were established in the Black Sea. Today, 80 percent of total fauna in the Black Sea is of Mediterranean origin. According to Slastenenko (1959), the Black Sea received more than one third and about one fifth of its fauna from the Aegean Sea and the Mediterranean Sea, respectively. The last group of species is called "alien species", which includes those introduced either intentionally or unintentionally by human activities from the various seas and oceans of the world.

1.2 Vectors for the alien species in the Black Sea

In recent years, the Black Sea has become home for a large number of alien plants and animals. There are three main vectors for alien species to reach the Black Sea. These are: a) shipping activities, which is the most common way; b) intentional or unintentional introduction by humans; c) Mediterranization, which means that Mediterranean originated species pass all ecological barriers in the Turkish Straits and penetrate to the Black Sea.

1.2.1 Shipping activities

The most common way of invasion of alien species is via ocean-going ships. Marine organisms usually travel either as a part of the fouling attached to ship hulls either in tank sediment or in ballast water. (Zaitsev and Mamaev, 1997; Zaitsev and Öztürk, 2001; Öztürk 2002a;b; Gomiou *et al*., 2002; Streftaris *et al*., 2005). Shipping activities are intense in the Black Sea mainly due to the Caspian petrol transportation from Novorossisk, the Russian Federation, to the Mediterranean countries via Turkish Straits (Figure 3). It is also known that the largest unintentional pathway for the transport of marine organisms is the ballast water of commercial vessels and a typical commercial bulk vessel may carry over 30 000 metric tonnes of ballast water to provide stability and trim adjustment during a voyage (cited in Wonham *et al*., 2000).

Hundreds of algal and animal species, both microorganisms and even smaller organisms, are known to travel by attaching themselves to the hulls of the ship. Most of them are attached to the living substrate such as algae, clams and barnacles. However active non-sessile forms can also be found, such as amphipods, shrimps, crabs and fishes. When the ship is in motion they hide in barnacles and other similar shelters, so as not to be swept away by the current.

Ballast water pumped to tanks to stabilize a ship when it is not carrying any cargo. When ships fill their ballast tanks in ports or sometimes in certain areas, suspended matter and various planktonic organisms are also pumped into the tanks with the water. Many organisms survive the trip in the ballast water or sediment, sometimes as spores and eggs. Upon arrival at the ship's destination, the ballast water is discharged into the sea and the organisms find themselves in a new environment. If the conditions are favorable to their particular needs, the organisms may survive and even become naturalized. The huge number of ocean-going ships means that many new species are introduced into new environment constantly.

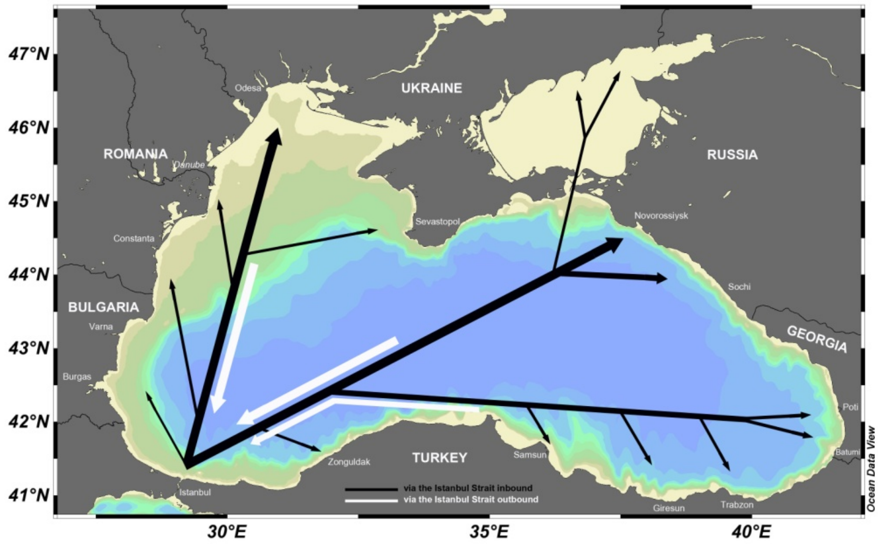

Figure 3 – Main shipping routes in the Black Sea

1.2.2 Intentional or unintentional introduction by humans

Several alien species have been introduced to the Black Sea for aquaculture or other reasons. The mosquito fish *Gambusia affinis* is a good example of this type of introduction. This fish is well known for its ability to feed on neuston larvae and mosquito eggs, including those species which transmit malaria. It was, thus, introduced to the wetlands to combat malaria in the entire Black Sea basin. After the fish was adapted and reproduced, *Gambusia* turned to euryhaline species. Today *Gambusia* is widespread in the Black Sea basin. There are several examples of intentional introduction to the Black Sea.

1.2.3 Mediterranization effects

This is a relatively new phenomenon and the reason for the invasion of the Mediterranean originated species to the Black Sea seems to be related to water temperature rise as a consequence of climate change (Oğuz, 2005). Even though the Turkish Straits (Istanbul and Çanakkale Straits) serve as an ecological barrier for these species due to totally different oceanographic peculiarities of the Black Sea from the Mediterranean Sea, some phyto and zoo plankton species penetrate to the Black Sea (Georgieva, 1993; Kovalev, 2006; Selifinova *et al*., 2008). Because of the temperature rise due to the climate change, some Mediterranean fish species have also penetrated into the Black Sea, such as sardine, bouge and wrasse, in recent years.

1.3 Alien species in the Black Sea

Twenty-six alien species from the Black Sea have been described by Zaitsev and Mamaev (1997). According to Zaitsev and Öztürk (2001), there are 59 species of alien marine organisms in the Black Sea and only a few species have been well studied, in terms of the impacts on fisheries, such as whelk *Rapana* and a ctenophore *Mnemiopsis leidy*. Çinar *et al*. (2005) reported 20 alien species from the Turkish part of the Black Sea. Alexandrov *et al*. (2007) reported 240 alien species from the Ukrainian fresh, brackish and marine waters. Shiganova and Öztürk (2009) reported 156 alien species from the Black Sea and most of these came from the Mediterranen Sea (see Figure 4).

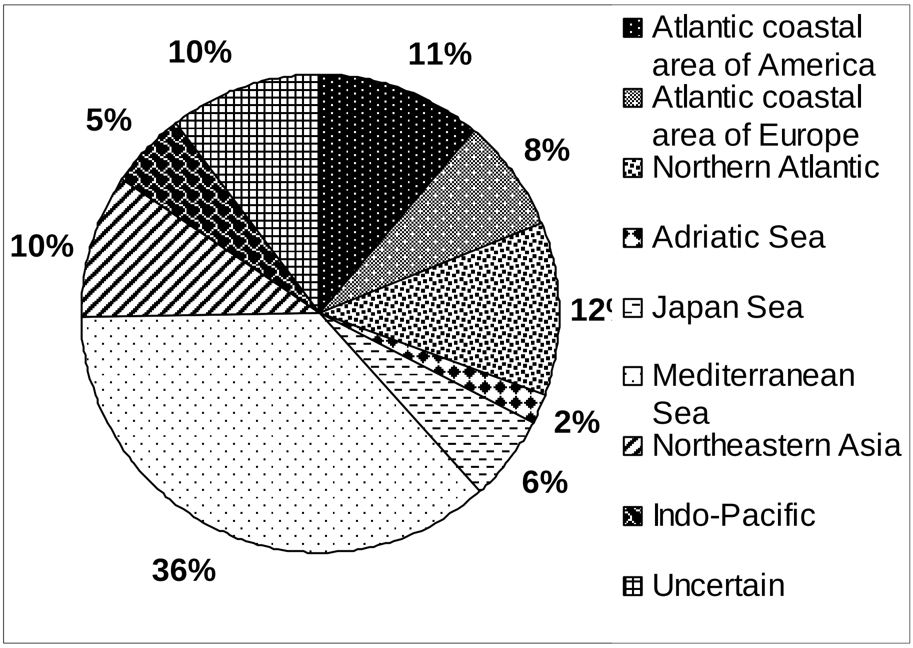

Figure 4 – Donor areas of alien species and their proportions in the Black Sea (Shiganova and Öztürk, 2009)

1.3.1 Alien invertebrates in the Black Sea and their impacts on biodiversity

During the last several decades, several alien invasive species, among which a mollusc species, *Rapana venosa*, a bivalve species, *Mya arenaria,* and *Anadara inaequivalvis,* a gelatinous carnivore *Mnemiopsis leidyi* and *Boreo ovata* have developed mass populations and have given rise to considerable impacts on the pelagic and/or benthic food webs of the Black Sea of severe ecosystem transformations.

Mnemiopsis leidyi

Mnemiopsis leidyi is a carnivorous ctenophore. It is characterized by two big lobes referred to as lateral or oral lobes. The oral lobes are derivated of the ctenophore body (Spherosome). Four smaller lobes are situated under the two principal oral lobes. The size of the animal varies from 40 to 180 mm in length in the Black Sea. The adult animal is about 100 mm in length, specimens larger than this are rare. There are four relatively short, simple auricles arising from the sides of the body immediately above the mouth and close to the sides of the oral lobes. The introduction of the ctenophore *M. leidyi* with ballast water by ships from the northern American Atlantic areas at the beginning of the 1980s (Shiganova, 1998; Zaitsev and Öztürk, 2001).

Mature specimens of *Mnemiopsis* spawn at night in summer temperatures of 20 to 23°C in upper layer of the sea. Embryonic development takes about 20–24 hours. Size of the larvae is 0.3–0.5mm (Zaika and Sergeeva, 1990). The *Mnemiopsis* average egg production in the coastal zones of the Black Sea is very high and exceeds 1 000 eggs per individual in one day. Total number of eggs in one laying is 2 000–4 000. Equations for determination of wet weight (W, mg) on the base of the total length (L, mm) of the body are:

$W = 3.1 \cdot L^{2.22}$ for L<45 mm or $W = 3.8 \cdot L^{2.22}$ for L>45 mm (Vinogradov *et al*., 2000).

This species comes originally from the Atlantic coasts of North America. *Mnemiopsis* is found in coastal waters of North America from Cape Cod southwards to Carolina. It is abundant in ports and harbors of the above areas and can be pumped (presumably as larvae or small juveniles) or gravitated (as adults as well) with ballast water into cargo ships. While sufficient zooplankton may be available to sustain this comb jelly in ballast water on a voyage lasting 20 or more days from the Americas to the Black Sea, food resources are not necessary, since *Mnemiopsis* can live for three or more weeks without food, reducing body size at the same time (Reeve *et al*., 1989). Like other ctenophores, *Mnemiopsis* is a simultaneous hermaphrodite. This means, in theory, that a single animal could successfully invade a new area.

The first record of *Mnemiopsis* appearance in the coastal water of the Black Sea goes back to 1982 (Pereladov, 1988). The first registration of this species in open water was made in winter 1986–1987 (Zaitsev *et al.,* 1988). The massive growth of the Black Sea population started in 1988 and at first covered only bays, gulfs and coastal waters. Its abundance reached 10–12 $kg \cdot m^{-2}$ in several coastal areas (e.g., Anapa, the southwestern Bulgarian coast) although it did not exceed 1.5–3 $kg \cdot m^{-2}$ in the open sea (Shushkina and Vinogradov, 1991). Maximal development of this species was registered in 1989 and 1990 (about 1 200 $g \cdot m^{-3}$), but then its abundance started to decrease (Vinogradov *et al*., 2000). For example, the average biomass of *Mnemiopsis* during 1991–1994 in the Romanian littoral zone was 2.2–3.5 $g \cdot m^{-3}$ and decreased to 0.2 $g \cdot m^{-3}$ in 1995 (Radu *et al*., 1996–1997). The same quantitative distribution was investigated in the Dnieper River influence zone of the Black Sea. Average biomass of *Mnemiopsis* between 1993–1997 was 3.2–5.1 $g \cdot m^{-3}$. Its population density during these years stabilized at 300 to 800 $g \cdot m^{-2}$ in the Black Sea and at 500 to 600 $g \cdot m^{-2}$ in the Sea of Azov (GESAMP, 1997).

Meanwhile, another ctenophore species, *Beroe ovata*, which is a predator of *Mnemiopsis*, was introduced to the Black Sea presumably by ballast water and observed in 1997. As explained in the below section for *Beroe*, this introduction helped mitigate the *Mnemiopsis* outburst.

The distribution maps of *Mnemiopsis* in the Black Sea have been prepared for different years and seasons. To make a generalized map, the model description of this comb jelly was used. This description was based on peculiarity of its biology (reproduction, growth, mortality) and water mass transportation in the Black Sea (Lebedeva, 1998). The map showing the generalized distribution of *M. leidyi* was made for the water layer of 0–30 m (typical inhabited layer for this species) for September 1998 (Figure 5).

Mnemiopsis is usually found close to shore, in bays and estuaries, although they have been collected occasionally several hundred kilometers offshore. They are able to tolerate a wide range of salinity and temperature, and can live and reproduce in temperatures ranging between 1.3^{o}C and 32^{o}C and in salinities ranging between 3.4 and 75 ‰. They survive well in oxygen-poor environments. They are most abundant in brackish waters with high levels of suepended materials and appear to be little affected by contaminants. The only factors which appear to restrict their rapid population growth are the temperature, the availability of food and the presence of predators (GESAMP, 1997).

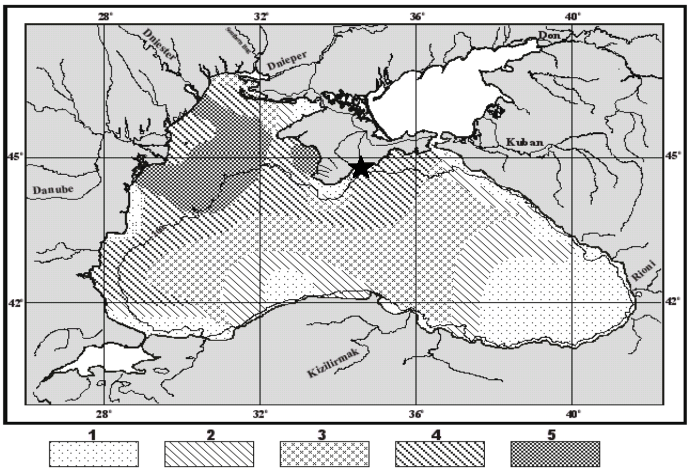

Figure 5 – Distribution of *Mnemiopsis leidyi* in the Black Sea during the maximum development in September 1998.
Range of biomass ($g \cdot m^{-2}$): 1- <200; 2- 200-600; 3- 600-1000; 4- 1000-1400; 5- >1400.★: Place of the first registration (Zaitsev and Öztürk, 2001)

M. leidyi is the most striking example of the negative impacts of alien species on the Black Sea ecosystem. After its invasion, the structure of the planktonic communities in the coastal waters and the open part of the sea significantly changed. The general abundance of subsurface mesozooplankton declined 2–2.5 times or more on average, compared to the previous period. The biomass of some species (small copepods *Oithona*, *Paracalanus*, *Acartia*, *Pseudocalanus*) decreased 3–10 times or more. A pronounced decrease (approximately 2–10 times) of meroplankton in summer was also observed, showing the grazing impact of *Mnemiopsis* upon the larvae of benthic animals. The subsequent decrease of the zoobenthos biomass was estimated at about 30 percent (Volovik *et al.*, 1993; Shiganova, 1998).

In summary, three main impacts of *Mnemiopsis* on the fisheries were identified as:

1) predation on fish eggs and larvae. For example, in shelf waters, *Mnemiopsis* was estimated to graze up to 70 percent of total ichthyoplankton stock (Tsikhon-Lukanina *et al*., 1993);
2) feeding on larvae and adult fish food, such as zooplankton, thus causing starvation;
3) further accelerating of ongoing ecological change, presently being experienced due to eutrophication. For example, direct environmental impacts on the pelagic and benthic systems (anoxia) due to a massive precipitation of mucus and dead ctenophores to the bottom on the shallow shelf.

All of these events related to the new predator resulted in a drastic decrease of fish production – 4–5 times for Black Sea shad and over 10 times for anchovy. Mass occurrence of *M. leidyi* appears to be one of the most important reasons for the sharp decrease of anchovy and other pelagic fish stocks in the Black Sea. There was a decline in the biomass of both populations and catch in about the same proportions, which caused large-scale damage to the fishery.

The annual loss of the fish catch attributed to the Mnemiopsis plague was calculated at approximately 200 million USD in the Black Sea and 30–40 million USD in the Sea of Azov (GESAMP, 1997).

Beroe ovata

Another alien ctenophore species, *Beroe ovata,* needs to be examined as it is the competitor of *M.leidyi*. This species is miter-shaped and the lateral compression is very marked, the broad lateral diameter being fully twice the width of the narrow one. The size of eggs of Black Sea *Beroe* is 300–350 μm with gelatinous capsule of 0.9–1.0 mm in diameter. The abundance of eggs in one laying depends on the size of the comb jelly. The ctenophore with a length of 5–6 cm has 2 000–3 000 eggs, individuals with a length of 8–10 cm have 5 000–7 000 eggs (Shiganova *et al.*, 2000; Volovik, 2004).

This species is circumpolar in distribution. It extends along the coast of New Engand, Greenland and is common in the Labrador current. It is abundant in the North Sea and off the coast of Scotland, Pacific coast of North America. This species inhabits the eastern coast of Japan and also the Antarctic, Pacific and Indian Oceans (Mayer, 1912).

The possible mechanism of penetration of this comb jelly into the Black Sea is probably the same as for *Mnemiopsis*. In the ballast waters, *Beroe* has been most likely transferred from the estuaries along the North Atlantic Ocean where this species is tolerant to lower salinity and is a native predator of *M. leidyi.* Another hypothesis is that *Beroe,* which lives in the Mediterranean and Marmara Sea, penetrated and had a chance to acclimatize itself in the Black Sea, due to abnormal warm winters in 1997–1998 and 1998–1999 and, in particular, in summer 1999 in the north-eastern part of the Black Sea. Interestingly, comb jelly *B. ovata* was also recommended to the GEASMP commission to combat the outburst of *M. leidyi*.

The appearance of *B. ovata* during 1998 in the Black Sea, a predator of the ctenophore *M. leidyi*, led to a partial recovery of the planktonic food web structure by compensating the negative impacts of *M. leidyi*.
B. ovata predominantly inhabits 30 mile-width of the coastal zone of the Black Sea. Most probably the reproduction of this species takes place in open waters.

Most experts considered that *Beroe* feeds exclusively on other comb jellies during all of its development stages (Nelson, 1925,Kamshilov,1955). It is known that during one month one individual of *Beroe* with length 35 mm may consume 44 individuals of *Bolinopsis* with length 10–35 mm and grows up to 44 mm (Zaitsev and, Öztürk, 2001). Besides, *Beroe* is a food web dead-end due to the lack of natural enemies in the Black Sea. Thus either direct or indirect impact through the entire food web could be expected, e.g. copying *Mnemiopsis*' history and further adding to the problem of gelatinous species in the Black Sea.

Sea snail *(Rapana venosa)*

Rapana venosa is known as a sea snail or a whelk. *Rapana thomasiana* is its synomym. It is assumed that this sea snail was brought to the Black Sea with ballast water from its home sea of the Indian-Pacific Oceans (Gomoiu, 1972; Sorokin, 1982). Near the Ukrainian coast, this sea snail becomes mature at the age of 2–3 old; it lives till 8–9 years and reproduces during warm periods (July-September). Pelagic larvae of sea snail feed on nanoplankton algae and their adults feed mainly on bivalves of families Cardiidae, Mytilidae, Veneridae, and Archidae. They travel over large distances for feeding. In some periods of the year, it buries itself into the soft sediment. Introduction of this predatory mollusc into the Black Sea ecosystem turned out to be a catastrophe for oyster and mussel biocenoses. Distribution of sea snail is associated with reduction in area and density of mussel settlements, in particular near the coasts of Anatolia and Caucasus. In the Ukrainian waters this sea snail destroyed the oyster banks in the area of the Kerch Strait and in Karkinitsky Bay, the biocenoses of other molluscs associated with depth down to 30 m suffered as well.

Turkey has been conducting large-scale harvesting of sea snail since the mid-1985s (Bilecik, 1990). The other Black Sea countries joined to its fisheries (see Figure 6). The Turkish catch remained, however, much higher than other countries, followed by Bulgaria. It also became a commercially-important resource in Bulgaria after 1994. Prior to the beginnig of its regular harvesting, the biomass on the coastal grounds between Kaliakra and Pomorie was estimated at about 2 000 tonnes (Prodanov and Konsulova, 1995). Bottom trawling and dredging are officiallly forbidden, although these fishing gears are used for the sea snail fishery. Romania has lately joined Rapana fisheries.

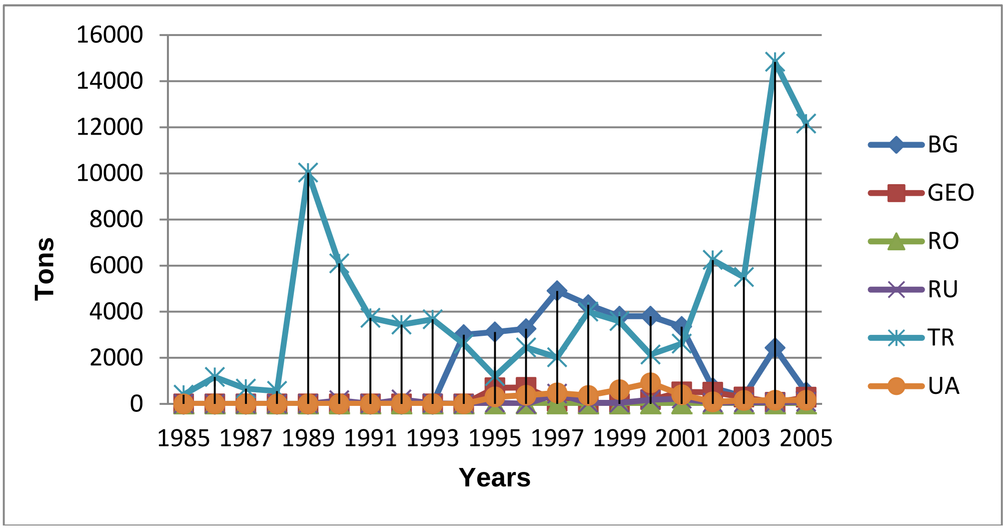

Figure 6 – Catch of *Rapana venosa* by the Black Sea countries (in 1985–2005) (Modified from BSC, 2008)

In Turkey, the catch of sea snail has been greatly increasing in the recent years. Analysis of fisheries along the eastern coast of Turkey (Samsun Province) showed that the number of vessels using dredges for sea snail harvesting in 2000–2005 increased by large rates, especially in the vessel group 33–149 HP. These are typical boats that combine sea snail dredging, bottom trawling and net fishing (Knudsen and Zengin, 2006). Although the resource of this mollusc is still withstanding, such high intensity of fisheries, a large-scale implementation of dredges has a destructive effect on the bottom biocenoses and the ecosystems as a whole (Düzgüneş *et al*., 1997). In recent years, some studies have been initiated for new catching methods, such as pots and surface supplied diving system in the Black Sea (Kideys, 2002; Kideys *et al*., 2007; Saglam *et al*., 2007). Some diving accidents have been reported from the Turkish coast. However fishers do not like the operational costs of the new environmentally friendly system. Culha *et al*. (2009) reported that the highest number of *Rapana* was found at 15 m depth in the sandy-muddy biotopes in the Sinop Peninsula on the Turkish coast. According to the data collected by the fisheries cooperatives, a total of 65 boats actively catch *Rapana* in the Turkish part of the Black and Marmara Seas See (Table 1.1).

Table.1.1 – Number of *Rapana* boats in the Turkish Black Sea and Marmara Sea coasts in 2009

Region	Port	Number of boats	Boat size
Marmara Sea	Rumelifeneri	6	> 9 m
	Poyraz	3	> 9 m
	Anadolu Kavağı	3	> 9 m
	Kumkapı	6	> 9 m
Black Sea	İğneada	4	> 10 m
	Kıyıköy	3	> 9 m
	Şile	6	> 9 m
	Zonguldak	3	> 8 m
	Kastamonu	7	> 9 m
	Sinop	3	> 10 m
	Samsun	6	> 8 m
	Giresun	3	> 9 m
	Trabzon	9	> 9 m
	Rize	3	> 8 m

Until the early 1990s along the Ukrainian coast, the sea snail was harvested in an amateurish way to be used as fine shells souvenirs. The distribution and the stock assessment of sea snail in the Ukrainian territorial waters in the araea from Takil Cape to Chauda Cape were undertaken in 1990, 1994 and 1999. The stocks of this mollusc were assessed at 2 800 tonnes, 1 500 tonnes and 1 300 tonnes, respectively. The former two assessments belonged to the initial commercial exploitation of this ground, the latter to the period of the intensive fisheries. Reduction in the sea snail stocks from 1 500–2 800 tonnes (virgin population) to 1 300 tonnes (exploited population) is the evidence of the impact made by dredge fisheries. The use of knife-edge dredges adversely affected the bottom biocenoses (Shlyakhov and Daskalov, 2008).

In 1994, the sea snail stocks were assessed along the southern and western coasts of Crimea from Cape Ilya to Cape Evpatoriisky at 14 000 tonnes. The limit for its harvesting in the waters of Ukraine was established at 3 000 tonnes (Shlyakov and Daskalov, 2008). Prodanova and Konsulova (1995); Prodanov *et al*. (1995) presented the stock assessment and growth rate of *Rapana* in the Bulgarian part of the Black Sea. They found out that in ten fishing regions the biomass of the commercial stock (individuals with flesh weight above 60 g) and the total allowable catch of *Rapana* along the Bulgarian coast during 1993 were 7 482.6 and 3 217.6 tonnes, respectively.

1.3.2 Alien invertebrate species and impacts on biodiversity

According to non-indigenous plankton species from the Black Sea, the prymnesiophyte *Phaeocystis pouchetii,* was extremly abundant and clogging the gills of fish in the Bulgarian coast of the Black Sea. There is also a list of the non-indigenous species proposed by Moncheva and Kamburska (2002), although Gomez and Boicenco (2004) did not fully agree to the list.

The bivalve *Mya arenaria,* a native of the Northern Atlantic, was first detected in 1966 and became very abundant in a short period of time in the northwestern and western part of the Black Sea, reaching its peak abundance in 1972. Even though it was affected later adversely by regular hypoxia-anoxia crisis that destroyed the entire benthos in the 1980s, it still retains considerable abundance in the western coastal waters. This species is a competitor for habitats with small local bivalve, *Lentidium mediterraneum*, which avoids sandy bottoms siltated by *M. arenaria*. Large amounts of washed molluscs on the beach attract their consumers, such as gulls and crows.

Another bivalve of Indo-Pacific fauna, *Anadara inaequivalvis,* was found in the Black Sea in 1968, and has spread to the whole basin. This species has a potential for commercial harvesting in Turkey (Sahin *et al*., 2006).

In 2001, two new non-native bivalvia species were found in the Odessa Bay: edible *Mytilus edulis* and *Mytilus trossulus* (Alexandrov, 2004). *M. edulis* was brought probably with ballast waters from the Mediterranean, where it is cultured off the Spanish and Italian shores. A Pacific species *M. trossulus* was brought probably with ships from Far East Russian coasts, where it is a main cultivated species (Suprunovich and Makarov, 1990). Shipworm, *Teredo navalis,* one of the oldest alien bivalve species found in the Black Sea, is in small numbers and its impacts are not significant at present because wood is replaced by concrete or metallic underwater construction and also because ship worms become rare.

Other alien species such as ivory barnacle, *Balanus eburneus,* and acorn barnacle, *Balanus improvises,* are typical organisms of fouling communities, which may have an adverse effects on the net cages of sea bass aquaculture in Trabzon on the Turkish Black Sea coast.

A Mediterranean jellyfish has become a threat for humans in the Marmara and Black Sea. Compass jellyfish *Chrysaora hysoscella* (Linnaeus, 1767), a temperate planktophagous species, was firstly reported from the Sea of Marmara by Inanmaz *et al*. (2002). This species made a large bloom in the Marmara Sea, Istanbul Strait and Turkish part of the Black Sea in July 2009 (Öztürk and Topaloglu, 2009). Most of beach bathers used fishing nets to protect themselves from this stinging jellyfish. While this species is venoumous, this needs to be monitored in the Black Sea in terms of the impact on human health and interrelation with the entire Black Sea biota. It seems that *C. hysoscella* could establish its population in the Black Sea shortly.

Moreover, in November 2009, a few individuals of a jellyfish from the Red Sea, *Cassiopea andromeda,* were found on the shore of Kilyos, just off the Istanbul Strait.

1.3.3 Impacts of alien species on pelagic fisheries in the Black Sea

Alien species in the Black Sea have been examined in several studies. There is, however, no accurate data to explain their impacts on the fisheries of some commercial pelagic fishes, such as bluefish, mackerel, and bonito, and commercial demersel fishes, such as whiting, turbot, red mullet, and striped mullet. On the other hand, the impacts of *M. leidyi* and *B.ovata* on small pelagic fish, such as anchovy and sprat, have been studied intensively as described below.

Sprat

Sprat, *Sprattus sprattus,* is one of the most abundant and commercially important pelagic fish species in the Black Sea, and it serves also as an important food source for larger fish as well (Ivanov and Beverton, 1985). Sprat reaches maturity at one year and reproduces during the whole year, but its peak spawning takes place between November and March.

Its spawning during winter and spring in deeper layers was relatively unaffected by *M. leidyi* because of its low biomass in those deep layers. Thus, there is little competition for prey and predation on sprat eggs and larvae (Shylakov and Daskalov, 2008).

In summer, the juvenile and adult sprats leave the upper warmed layer, avoiding severe competition for food with other plankton-consumers including *M. leidyi*. During this period, their preferred food consists mainly of the cold-water *Calanus* and *Pseudocalanus* copepod species living below the cold intermediate layer of the water column. It should be noted that these preys are also available to *M. leidyi* as they migrate to the thermocline at night for their daily feeding where they can be consumed by the ctenophore. This can partly explain the reduction of the sprat stock during the *Mnemiopsis* population outburst in the early 1990s. Like the other commercial stocks, heavy overfishing took also place before and during the *M. leidyi* outbreak, aggravating the stock depletion (Prodanov *et al*., 1997).

Black Sea anchovy

The Black Sea anchovy, *Engraulis encrasicolus,* is the most important commercial pelagic fish species distributed over the whole Black Sea. In October-November, it migrates to the wintering grounds along the Anatolian and Caucasian coasts and forms dense wintering concentrations until March, becoming subject to intensive commercial fishery.

Anchovy competes for food with *M. leidyi* (Grishin *et al*., 1994) and this competition probably further affected the anchovy population growth (Oğuz *et al*., 2008). The initial outbreak of *M. leidyi* was reported in 1988–89 in the Black and Azov Seas. It appears that the catastrophic reduction of the Black Sea anchovy stocks in the late 1980s was due to the combined effect of two factors: the excessive fishing and *M. leidyi* outburst (Grishin *et al*., 2007). It is noteworthy that the sharp decline in anchovy catch happened after the outburst of *M.leidyi* at the end of 1980s and the early 1990s (Niermann, 2004) (Figure 7). In addition, Kideys (2002) mentioned that as *Mnemiopsis* feeds on the eggs and larvae of the anchovy, it was responsible for the collapse of the anchovy fisheries.

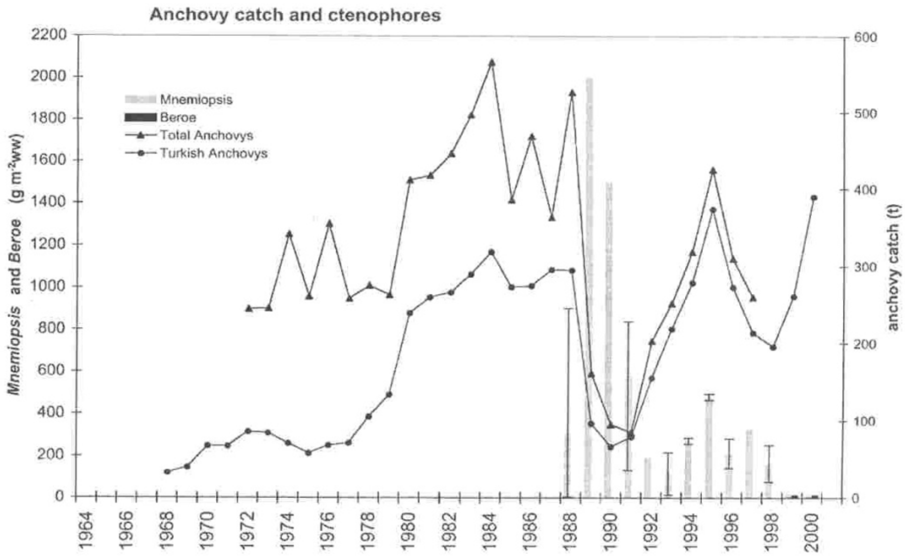

Figure 7 – Anchovy catch and ctenophore biomass in the Black Sea (Niermann, 2004)

The catch increased after the outburst of a competitor species *Beroe ovata* at the end of the 1990s. In a way, *B. ovata* helped the ecosystem to recover by feeding almost exclusively on *Mnemiopsis*. Catch of anchovy by Turkish fishers was stabilized after the 1990s to 2000s in the Black Sea (see Figure 8).

The total loss of the anchovy catch over the years between 1989 and 1992, due to the *M. leidyi* outbreak, can only be roughly estimated. According to Campbell (1993), the total annual loss of fish processing factories was estimated at USD 11 million and the total annual loss in fishing itself was very roughly estimated at approximately USD 330 million in 1992. The economic damage caused to the Turkish fishery is conservatively estimated at several hundred million dollars.

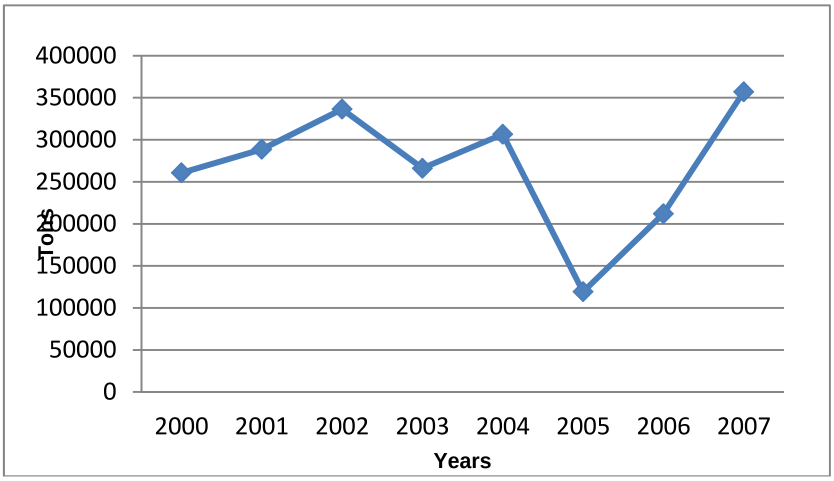

Figure 8 – Catch of anchovy by Turkey (2000–2007)

The damage of *M. leidyi* to the anchovy population was most likely done through food competition, as the unusual low level of zooplankton biomass was observed in the top 50 m layer in summer of the early 1990s (Oğuz *et al*., 2008). Anchovy larvae could also be affected by *M. leidyi* predation. The abundance of anchovy larvae peaks in July and August when *M. leidyi* biomass has also a seasonal peak (Grishin *et al*., 2007). *M. leidyi* can consume a daily ration several times greater than its own weight (Lipskaya and Luchinskaya, 1990). Its food spectrum is quite wide and includes anchovy eggs as well as larvae. There was an overlap in the distributions of anchovy larvae and *M. leidyi*, even though anchovy larvae were predominantly found in the narrow coastal zone while the ctenophore was distributed further offshore. Oğuz *et al*. (2008) reported that the switch of a large marine ecosystem to a totally gelatinous invader-dominated state requires an extremely strong environmental perturbation. More often, environmental disturbance creates a suitable niche for an alien gelatinous invader to become a member of the food web structure, and to share food resources with the native small pelagic fish community.

Horse mackerel

Dietary studies of juvenile and adult horse mackerel *Trachurus* spp. have shown that both habitats and diet of juvenile horse mackerel and *M. leidyi* overlapped each other; therefore the strong feeding pressure by *M. leidyi* on zooplankton affects directly larval and juvenile horse mackerels.

As the first outburst of *M. leidyi* occured in autumn 1988, the zooplankton maximum production in summer did not suffer much from the devastating effect of *M. leidyi*. The copepods *Oithona nana* and *Oithona similis* which constituted the main food of larval horse mackerels (Revina, 1964) were especially abundant. However, the favorable trophic conditions for larvae in summer 1988 failed to ensure the formation of a strong year-class because juveniles were faced with strong feeding competition with *M.leidyi* further in the year. Sharp decline in *Oithona* under the predation pressure of *M. leidyi* in the subsequent years affected the survival of horse mackerel (Vinogradov *et al*., 1993). Meanwhile recent data shows that the stocks of the horsemackerel have been stabilized in Turkish coasts (see Figure 9).

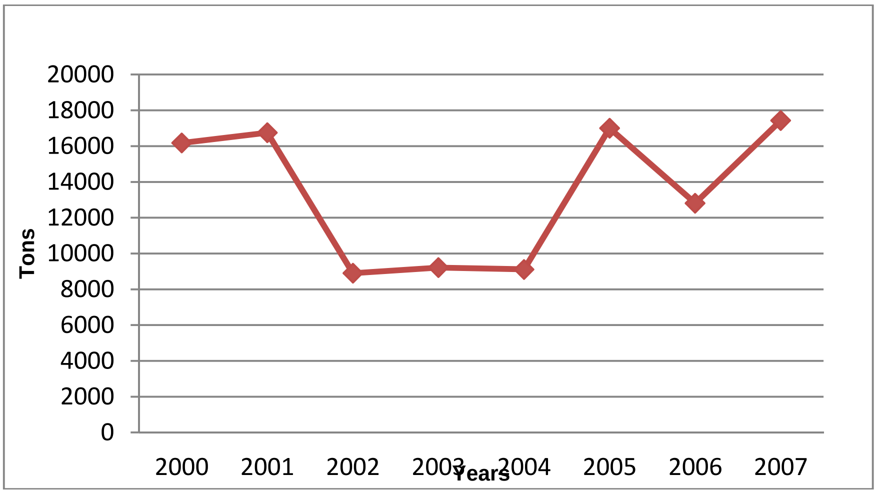

Figure 9 – Catch of the horse mackerel from the Turkish part of the Black Sea

1.3.4 Alien fish species and their impacts

According to Slastenenko (1955–1956), a total of 189 fish species can be found in the Black Sea; 34 of them live in the estuary and lagoon areas in the Black Sea. However, in recent years, some fish species which are ecologically tolerant to temperature and salinity have settled in the Black Sea. These fishes migrated from the Mediterranean Sea and are extending their northern distribution up to the Crimian Peninsula. Besides, Indo-Pacific species, such as blunt barracuda *Sphyraena pinguis* and a coral-dwelling fish, *Heniochus acuminatus,* have recently extended their distribution ranges to the Black Sea (Boltachev and Astakhov, 2004; Bolthachev, 2009). These fish species are lessepsian migrants and, after the Aegean Sea, ultimately reached to the Black Sea. Even though temperature is a primary factor for the dispersion of lessepsian fish and lower temperature is an impeding factor for tropical fish, these fishes actually penetrated to the Black Sea. Nevertheless, only a few species of these lessepsian migrants need to be monitored in the Black Sea in terms of distribution and abundance.

An intentionally introduced fish, haarder, Mugil soiuy, the synonim of *Liza haematocheila,* has become an important commercial species and distributed in the coastal waters of the Black Sea, Azov Sea, Sea of Marmara and Mediterranean Sea, even in the Algerian coasts. Its annual catch in the Black Sea exceeds 10 000 tonnes (Zaitsev and Öztürk, 2001). Okumus and Basçınar (1997) reported that this fish appears to have established a population in the Black Sea, the growth rates seem to be much better and the age at first sexual maturity is earlier than that of the native mullet species. Age at first maturity was estimated at 3–4 years for males and 4–5 years for females and the spawning period extends from the end of May to the beginning of July. Its pelagic eggs are 0.8–0.9 mm in diameter and have large oil droplets, which constitute up to 23 percent of the egg volume. This is the reason of high floatability of haarder's eggs, which can develop in low saline water in some coastal wetlands. The fries of the haarder are feeding on zooplankton and therefore can compete with local plankton-eating fish. This species feeds on small bottom living organisms mostly of meiobenthos, thus, compete with plaice and turbot juveniles in the coastal areas (Kazanskji, 1989; Ünsal, 1992). Some specific parasites (*Trematoda, Monogenea*) associated with the haarder were introduced in the Black Sea and were found in the body of local grey mullets as well. This consequence needs to be further investigated for human health and biota of the Black Sea. It is expected that this species will be more commercialized in next years in the Black and Mediterranean Seas.

Table 1.2 – Alien species intentionally or unintentionally introduced to the Black Sea (sources: Zaitsev and Öztürk, 2001; Gomoiu *et al*., 2002; Alexandrov *et al*., 2007)

Species	Purpose of introduction	Years	Origin of the species	Inoculation places
Gambusia affinis (Mosquito fish)	To combat malaria	1925s	Mediterranean Sea, North America	Russia, Turkey
Lepomis gibbosus (Freshwater sun fish)	Aquarium	1920s	North America, Europe	Odessa Gulf
Pandulus kesleri (Far eastern shrimp)	Aquaculture	1960s	Far east	Odessa, Kizilcay Region
Roccus saxatilis (Striped bass)	Aquaculture	1965-1972	Atlantic Ocean	Dnestrovsky
Plecoglossus altivellis (Salmon)	Aquaculture (Failed)	1963	Sea of Japan	Odessa
Salmo gaidneri (Steelhead trout)	Aquaculture (Failed)	1960s	Atlantic Ocean	Dnesterovsky
Oryzias latipes (Japanese medeka)	Aquaculture	1970s	Sea of Japan	Black and Azov Seas
Panaeus japonicas (Japanaese shrimp)	Aquaculture	1970s	Japan	Romania
Oncorhyncus keta (Far Eastern keta)	Aquaculture	1970s	Europe	USSR
Lateolabrax japonicas (Sea perch)	Aquaculture	1978	Japan	USSR
Dicentrarchus labrax (Seabass)	Aquaculture	1979	Mediterranean Sea	USSR
Crassostrea gigas (Giant oyster)	Aquaculture	1980	Sea of Japan	USSR
Mugil soiuy:Lisa haematocheila (Haarder)	Acclimatization	1972–1980	Sea of Japan	USSR
Salmo salar (Salmon)	Aquaculture	1990	Norway	Turkey, Ukraine
Onchorhynchus mykiss (Rainbow trout)	Aquaculture	1970	Denmark	Turkey, Ukraine
Carassius auratus	Aquaculture	1900s	Southeast Asia	Ukraine
Micropterus salmonides	Aquaculture	Late 19th century	North America	Ukraine
Ictalurus nebulosus	Aquaculture	1935	North America	Ukraine
Ictalurus puncatus	Aquaculture	1935	North America	Ukraine
Perccottus glehni	Aquarium trade	1948	South Asia	Ukraine
Channa argus argus	Aquaculture	1950s	South Asia	Ukraine
Coregonus albula	Aquaculture	1950s	Holarctic	Ukraine
Tribolodon brandtii	Unintentional	1950s	Pacific	Ukraine
Aristichytys nobilis	Aquaculture	1953	Southeast Asia	Ukraine
Hypophthalmichthys molitrix	Aquaculture	1953	Southeast Asia	Ukraine
Coregonus nasus	Aquaculture	1954	Holarctic	Ukraine
Coregunus peled	Aquaculture	1954	Holarctic	Ukraine
Ctenopharyngodon idella	Aquaculture	1954	Southeast Asia	Ukraine
Coregonus autumnalis	Aquacultrue	1957	Holarctic	Ukraine
Coregonus lavaretus	Aquaculture	1960s	Holarctic	Ukraine
Salmo ischchan	Aquaculture	1960	Sevan Lake	Ukraine
Mylopharyngodon piceus	Aquaculture	1961	Southeast Asia	Ukraine
Orchynchus gorbuscha	Aquaculture	1961	Pacific, Asia	Ukraine
Pseudobrasbora parva	Unintentional introduction	1990	Asia	Ukraine
Oreochromis mossambicus	Aquaculture	1996	Africa	Ukraine
Coregonus laveratus	Aquaculture	1965	Holarctic	Ukraine
Morone saxatilis	Aquaculture	1965	North America	Ukraine
Oreochromis niloticus	Aquaculture	1970s	Africa	Ukraine
Tilapia zilli	Aquaculture	1970s	Africa	Ukraine
Ictiobus bubalus	Aquaculture	1975	North America	Ukraine
Ictiobus cyprinellus	Aquaculture	1975	North America	Ukraine
Ictiobus niger	Aquaculture	1975	North America	Ukraine

A total of 42 marine species were intentionally or unintentionally introduced to the Black Sea by the Russian Federation, Romania, Ukraine and Turkey (Table 1.2). Distribution is very little known for these organisms. They need to be investigated in many aspects such as parasites, genetic differentiation, etc. Most of other introduced species failed to survive in the Black Sea for various ecological reasons.

Among intentionally introduced species, the rainbow trout, *Onchorhynchus mykiss,* and salmon, *Salmo salar,* are also commercially produced mostly in the Turkish part of the Black Sea. The sea trout production is estimated at approximately 2 000 tonnes per year and the salmon production reaches 1 500 tonnes yearly (Okumuş and Deniz, 2007). The problem of the intentionally introduced species is the risk of the hybridizing with native species when they escape from cages at sea.

1.3.5 Alien marine mammal species in the Black Sea

The white whale or beluga, *Delphinopterus leucas,* was captured in the Sea of Okhosk and it was accidentally released from Sevastopol Aquarium to the Black Sea in 1991. The northern fur seal *Callorhinus ursinus,* was captured from the Bering Sea and accidentally released to the Black Sea. The Steller sea lion, *Eumetopias jubatus,* was originally from the Sea of Okhotsk and accidentally released to the Black Sea. It should be noted that except for native dolphins, the Black Sea is not hospitable for large fish-eating marine mammals (Zaitsev and Öztürk, 2001).

1.4 Conclusion and recommendations for the Black Sea

The introduction process of alien species is still ongoing in the Black Sea and it needs to be monitored at the national, regional and international level. A special monitoring programme is requested for key areas, such as Istanbul, Canakkale and Kerch Straits, in order to understand better the dispersion patterns of alien species.

The impact of the alien species is complex and most of the time unpredictable due to lack of monitoring and the lack of scientific knowledge about those species. Experts on alien species, such as taxonomists, should be trained and encouraged. Capacity building for riparian countries is essential for the monitoring of alien species. Initiatives for the database management on *Mnemiopsis* and other jellyfish should be continued by an international organization like the Black Sea Commission.

The International Convention for the Control and Management of Ship's Ballast Water and Sediment (BWM Convention) within the International Maritime Organization (IMO) system was adopted in 2004. This convention has not come into force yet but in some countries like, the Russian Federation, Turkey and Ukraine the port authorities request the reporting of ballast water and follow ships to their ports. In a Russian port, Novorossisk, ballast water is monitored for chemical contamination. Ukrainian authorities sample ballast water to assess possible chemical contamination (Matej and Gollash, 2008). Turkish authorities conduct a project for the impacts of the ship ballast waters on the Turkish Seas. This kind of implementation should be encouraged to prevent alien species to enter local seas. To control alien species via incoming ships, a defined concerted area for discharging ballast water should be established in the Black Sea.

Fishery statistics should be harmonized among the Black Sea countries for a better understanding of the impacts on the local fishery and native species by intentionally or unintentionally introduced alien species. Separate alien species catch and fleet statistics should be established with the guidance of GFCM and its relevant subcommittee. For that purpose, an informative booklet in native languages should be prepared for the national fisheries authorities.

It should be reminded that alien species may carry several parasites or fungi which may threaten native fauna and flora and thus may cause harm to local fisheries. Therefore they should be monitored by the riparian governments with national capacity as well as relevant international agencies.

As a consequence of recent climate change and water temperature rise, some Mediterranean species, such as sardine, bouge and wrasse, have also penetrated into the Black Sea and it is likely that the fishing catch amount will change in the future. Mediterranean originated species need to be monitored in the Black Sea. General trends show that a miniature Mediterranean Sea is going to be established within the Black Sea since several species penetrate to the Blak Sea with various vectors. Besides, alien species penetration into the Black Sea puts pressure on the autochthonous Black Sea endemic species. They retreat to the brackish water areas and take refuge in estuaries and deltas. Impacts of the alien species on the native species may be the loss of ecological niches mostly in the mouths of rivers, such as the Danube, Dnieper, Dniester, Kizilirmak, Yesilirmak and Sakarya. Because of low salinity brackish water of the Black Sea, euryhaline and eurytherm species are more suitable to settle.

Due to overfishing, the reduction of total fish biomass in the Black Sea at the end of 1980s to less than one third of its maximum value in the 1970s has caused a partial emptiness of the occupied ecological niche. According to the general rule *"Natura abhoret vacuum"* they were occupied by invader planktophagous *M.leidyi*. Overfishing, therefore, should be avoided for all fish species to minimize the risk of alien species invasion. *M.leidyi* has already penetrated to the Mediterranean Sea and the lesson learned in the Black Sea should be applied to the Mediterranean Sea case in terms of impacts on the fisheries and whole biota.

Public awareness and sensibilization programmes for local people, fishers, boat crew, harbor masters and coast guards are needed to explain alien species and their impacts on nature, human health and fisheries. Special education programmes should be given to the fisheries cooperatives to inform local fishers of the impacts of alien species.

Legal measures for intentional introduction to the Black Sea should be taken by national authorities and international conventions, such as Bucharest and Bern Conventions. The international cooperation is essential to combat alien invasive species in the entire ecosystem. The significant impacts of climate change and Mediterranization should also be taken into account for the Black Sea.

2. STATUS OF ALIEN SPECIES IN THE MARMARA SEA

2.1 Main characteristics of the Marmara Sea

The Marmara Sea, including the Istanbul Strait (Bosphorus), Marmara Sea and Canakkale Strait (Dardanelles), which constitute the Turkish Straits System, is located between 40°00' and 41°10' N and 26°15' and 29°55' E. The surface area of the sea is 11 500 km² and its volume is 3 378 km³. The length of the coastline is 927 km. This sea is surrounded by the Anatolia and Trace regions in Turkey (Figure 10).

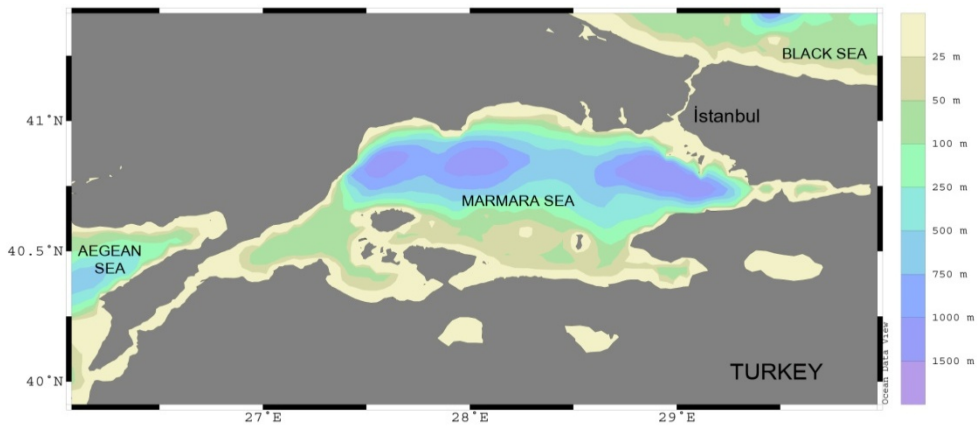

Figure 10 – The Marmara Sea

It is one of the busiest water ways in the world because of the shipping activities between the Mediterranean and the Black Sea basins; in fact approximately 55 000 ships pass there every year (Öztürk *et al*., 2006).

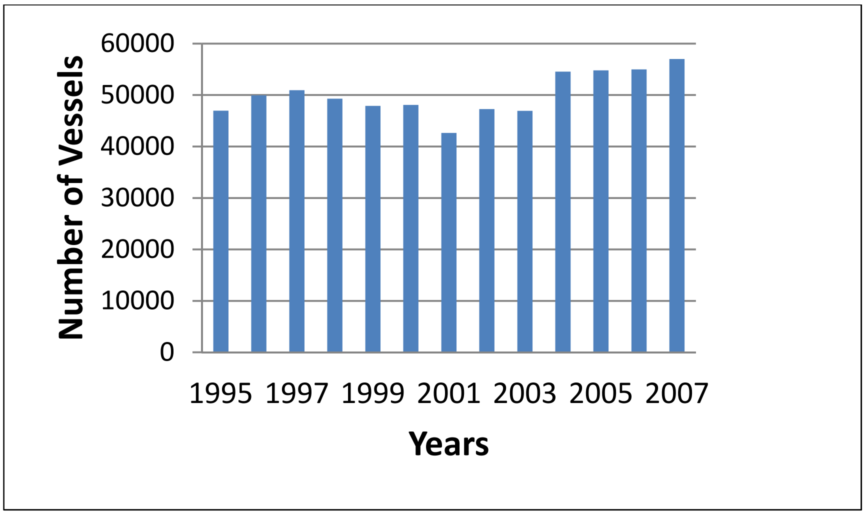

Figure 12 – Shipping traffic in the Straits of Istanbul (1995–2007)

As seen in Figure 12, the shipping traffic trend is growing in the Istanbul Strait and thus poses new risks for the Black Sea, while shipping is the main vector for alien species in this region.

Due to the geographical and hydrographical characteristics of the Marmara Sea, it represents a peculiar ecosystem as it is a transitional zone between the Mediterranean and the Black Sea. As such, it constitutes a barrier, a corridor or an acclimatization zone for living organisms (Öztürk and Öztürk, 1996). The Marmara Sea serves as a barrier because it limits the distribution of both warm water marine species of Mediterranean origin and cold water, low saline species from the Black Sea. On the other hand, the Marmara Sea is the most important biological corridor for many species of migratory fish, birds and marine mammals between the Mediterranean and Black Seas. In this acclimatization zone, some Mediterranen species adjust slowly to the new environment of the Black Sea, or the Black Sea species to the Aegean Sea.

The Marmara Sea is made up of two layers of Black Sea and Mediterranean origin water, separated by a transitional layer of 8–10 m. Therefore, the hydrography of the Marmara Sea is dominated by the conditions of the adjacent basins. The Black Sea water enters the Marmara Sea through the Istanbul Strait as an upper current of 15–20 m depth and exits through the Canakkale Strait. On the contary, the Aegean water enters through the Canakkale Strait in a deeper layer flow and enters the Black Sea with the Istanbul Strait underflow. The upper layer has a volume of 230 km^3 and an average renewal time of 4–5 months. The deeper layer has a volume of 3 378 km^3 and an average renewal time of 6–7 years (Besiktepe *et al*., 2000). Life in the upper layer is nourished primarily by brackish water of the Black Sea (Tugrul and Salihoglu, 2000). The temperature of the surface water of the Marmara Sea, which is under the influence of the Black Sea, ranges from 4 to 24°C. The salinity varies between 10 and 18 per mille. Deeper water shows pronounced changes in salitiny and temperature. The salitiny at 20 m depth rises to 30 per mille and at 40-50 m depth to 37 per mille. The temperature of the surface water of the Canakkale Strait is 6 to 26°C and the salinity 24 to 36 per mille. In deeper water, at 70 m depth, the temparature ranges from 14 to 17°C. The salinity at a depth of 30 m rises to 37.5 per mille and below it to 39 per mille (Kocatas *et al*., 1993).

2.2 Alien species of the Marmara Sea

Zaitsev and Öztürk (2001) reported 14 alien species and Çınar *et al*. (2005) reported 48 alien species in the Marmara Sea. A compiled alien species list is given in Table 2.1. However, it should be noted that these numbers do not include Mediterranean species even though there are several species found recently in the Marmara Sea which are originally from the Mediterranean Sea. This factor is mostly related to climate change and the cause of Mediterranization is not discussed in this study.

Alien fauna and flora of the Marmara Sea have been introduced with various vectors: mainly by ships in ballast water, sediment tanks, e.g. *Mnemiopsis leidyi*, or on ship's hull, or through man-made introduction, e.g. *Gambusia affinis*. Lessepsian species, which enter the Mediterranean Sea from the Red Sea through the Suez Canal, are only a few in the Marmara Sea as it serves as a barrier for many thermophilic fish species. However, the Marmara Sea is likely to act as a major transitional acclimatization and colonization zone prior to the settlement in the Black Sea. For example, Katagan *et al*. (2004) and Tuncer *et al*. (2008) reported the settlement of a Lessepsian migrant stomatopod shrimp *Erugosquilla massavensis* and fish *Lagocephalus spadiceus*, for the first time in the Sea of Marmara, whereas they have not been reported yet in the Black Sea. Even *Callinectes sapidus* is known from the Marmara Sea. *Solea senegaelensis* is the only example of the Atlantic alien species in the Marmara Sea. Manila clam, *Ruditapes philippinarum* have also been reported form the Sea of Marmara (Tuncer *et al*, 2004). Besides these, only three intentionally-introduced species are found in the Marmara Sea, namely *Gambusia affinis, Liza haematocheila* and *Marsupenaeus japonicus*.

Table 2.1 – List of alien species in the Marmara Sea. Modified from Zaitsev and Öztürk (2001); Öztürk (2002a); Çınar *et al.* (2005)

Phytoplankton
*Rhizosolenia calcar-avis (*M. Schultze, 1858)
Alexandrium monilatum (Howell) (F.J.R. Taylor, 1979)
Phaeocystis pouchetii (Hariot) (Lagerherim, 1893)
Acanthophora nayadiformis (Delile) (Papenfuss, 1968)
Acrochaetium codicolum (Børgesen, 1927)
Asparagopsis armata (Harvey, 1855)
*Bonnemaisonia hamifera (*Hariot, 1891)
Codium fragile (Suringar, 1867)
*Chondria collinsiana (*Howe, 1920)
Chondrophycus papillosus (C. Agardh) (Garbary and Harper 1998)
Ganonema farinosum (Lamouroux) (Fan and Wang, 1974)
Gracilaria arcuata (Zanardini, 1858)
Griffthsia corallinoides (Linnaeus) (Trevisan, 1845)
Hypnea variabilis (Okamura, 1909)
Radicilingua thysanorhizans (Holmes) (Papenfuss, 1956)
*Rhodophysema georgii (*Batters, 1900)
Chorda filum (Linnaeus) (Stackhouse, 1797)
Ectocarpus siliculosus (Dillwyn) (Lyngbye, 1819)
Halothrix lumbricalis (Kützing) (Reinke, 1888)
Pilayella littoralis (Linnaeus) (Kjellman, 1872)
*Protectocarpus speciosus (*Boergesen, 1902)
Sargassum latifolium (Turner) (C. Agardh, 1820)
Sphaerotrichia divaricata (Agardh) (Kylin, 1940)
Bryopsis pennata (Lamouroux, 1809)
Ulva fasciata (Delile, 1813)
Copepoda
Centropages furcatus (Dana, 1846)
Parvocalanus latus (Andronov, 1972)
Parvocalanus elegans (Andronov, 1972)
Acartia tonsa (Dana, 1848)
Ctenophora
Mnemiopsis leidyi (Agassiz, 1865)
Beroe ovata (Mayer, 1912)
Polychaeta
Lepidonotus carinulatus (Grube, 1870)
Harmothoe boholensis (Grube, 1878)
Harmothoe minuta (Potts, 1910)
*Ancistrosyllis rigida (*Fauvel, 1919)
Sigambra constricta (Southern, 1921)
Nereis zonata persica (Fauvel, 1911)
*Glycera alba adspersa (*Fauvel, 1939)
Lumbrineris debilis (Grube, 1878)
*Dasybranchus carneus (*Grube, 1870)
Timarete dasylophius (Marenzeller, 1879)
Timarete anchylochaeta (Schmarda, 1861)

Ficopomatus enigmaticus (Fauvel, 1923)
Crustacea
Decapoda
Callinectes sapidus (Rathbun, 1896)
Marsupenaeus japonicus (Bate, 1888)
Stomatopoda
Erugosquilla massavensis (Kossmann, 1880)
Mollusca
Gastropoda
Rapana venosa (Valenciennes, 1846)
Bivalvia
Teredo navalis (Linnaeus, 1758)
Anadara inaequivalvis (Bruguière, 1789)
Crassostrea gigas (Thunberg, 1793)
Mya arenaria (Linnaeus, 1758)
Ruditapes philippinarum (Adams & Reeve, 1850)
Echinodermata
Asterias rubens (Linnaeus,1758)
Pisces
Osteichthyes
Liza haematocheila (Temminck&Schlegel, 1845)
Solea senegalensis (Kaup, 1858)
Gambusia affinis (Girard, 1859)
Lagocephalus spadiceus (Spadiceus,1845)

2.2.1 Ctenophore, Mnemiopsis leidyi, and its impacts on fisheries and fish stocks in the Marmara Sea

The detailed description of *Mnemiopsis leidyi* is in the above section for the Black Sea. *M leidyi* had severe negative impacts on the fisheries and this needs to be evaluated in terms of fisheries and fishery stocks in the Marmara Sea. This species was first introduced to the Black Sea, then via the surface current to the Marmara, Aegean and Mediterranean Seas. It was first recorded in the Marmara Sea by Artuz (1991). In October 1992, an extremely vigorous outbreak was recorded in the Marmara Sea (GESAMP 1997). The abundance of *M. leidyi* was as high as 4.3 kg m^{-2} near the Istanbul Strait and 9.7 kg m^{-2} near the Canakkale Strait, mostly in 10–30 m deep water (Shiganova *et al*., 1995). This species was also reported from the Turkish coasts of the Aegean and Mediterranean Seas (Kideys and Nierman, 1994; Isinibilir and Tarkan, 2002). *M. leidyi* is a euryhaline organism tolerating a wide range of salinity of 4–75 per mille (Burrel and Van Engel, 1976). Since *M. leidyi* is a voracious predator, it has caused a decline of zooplankton. Masses of carcasses of this ctenophore caused anoxia in bottom-near waters. They have also been entangled to the fishing nets causing substantial damage.

The pelagic fish stocks in the Marmara Sea declined since the pelagic fish feed mainly on copepods and cladocerans, which are also foraged by *M. leidyi*. Furthermore, *M. leidyi* feeds on fish eggs and larvae, seriously affecting some economically-important fishes, such as *Scomber scombrus, Sardina pilchardus, Sprattus sprattus*, *Engraulis encrasicholus*, *Trachurus trachurus* and *Pomatomus saltator,* which use the Marmara Sea as spawning grounds. Isinibilir (2007) reported that the abundance of the *M. leidyi* become limited in summer, when *Beroe ovata* is present in Izmit Bay. It means that like in the Black Sea, *B.ovata* managed to control the *M. leidyi* stocks. As clearly seen in Figure 13, the catch of the main pelagic commercial fish species declined in 1989. After the outbrust of *Mnemiopsis* in 1989 in the Black Sea (which could be assumed for the Marmara Sea as well), the fish catch was increasing steadily until 1999 (up to almost 55 000 tonnes). While the Sea of Marmara represents about 15 percent of the total catch amount of Turkey, any harmful alien species can make substantially severe impacts on the fisheries stocks and fishing community.

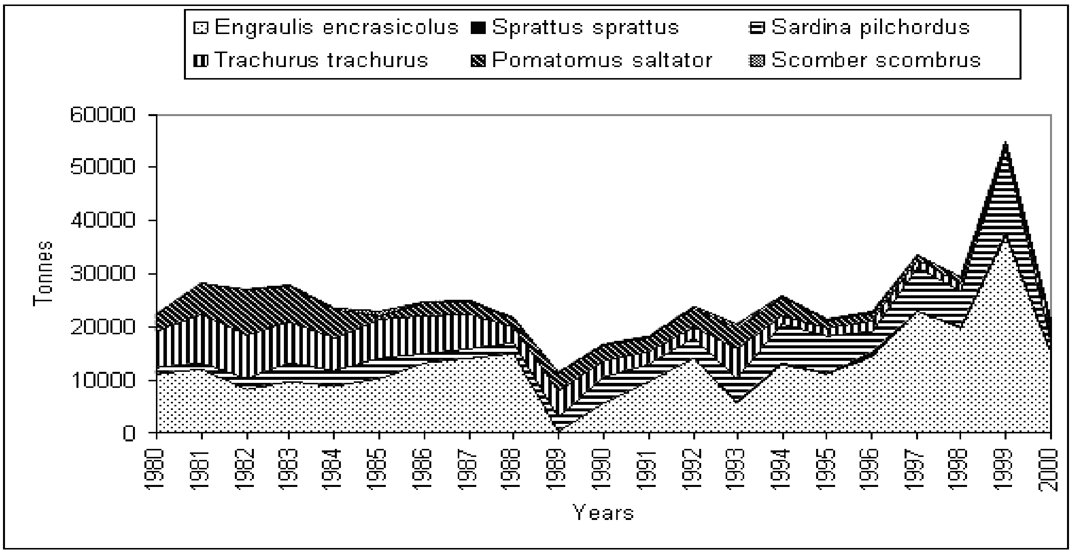

Figure 13 – Catches of some pelagic fish species in the Marmara Sea (1980–2000) (Isinibilir *et al.*, 2004)

Yuksek *et al*. (2007) reported that biomass and abundance of *M. leidyi* decreased sharply between 1995 and 2006. Some authors also mentioned that between 1997 and 1998, according the size frequency data, small individuals were abundant through the year, while highest increase was observed in July-September, when water temperature was at highest. Figure 14 shows that between 2000 and 2007 main pelagic fish stocks were recovering themselves, including anchovy which is severely impacted by the *Mnemiopsis* outbreak, the catch amount was increased even greater than the previous amount. It can be concluded that anchovy population has recovered after the *Mneniopsis* invasion since 1991 in the Marmara Sea.

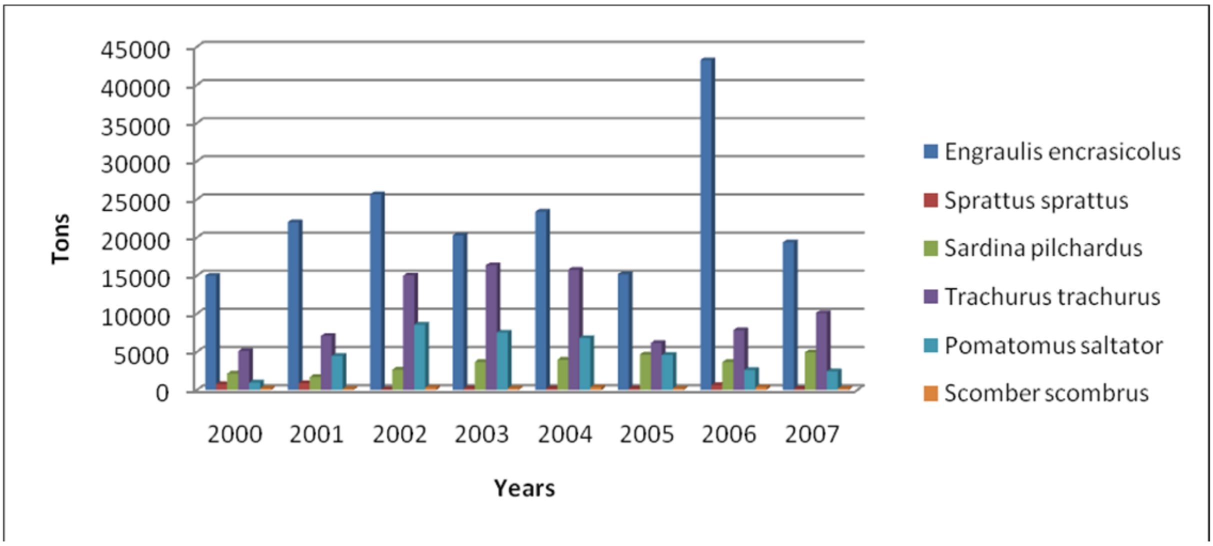

Figure 14 – Catches of some pelagic fish species in the Marmara Sea (2000–2007)

Nevertheless, from 1991 to 2000, the decline of fish stocks and economic loss of fisheries was estimated at 400 000 USD for Turkey (Öztürk and Öztürk, 2000).

Another economic impact of *M. leidyi* was also important. In fact, the fresh water reservoir of the Istanbul City was invaded by this species and it caused a serious economic loss due to the damage of the pipeline (Öztürk *et al*., 2001).

2.2.2 Sea snail, *Rapana venosa*, and its impacts on fisheries in the Marmara Sea

Rapana venosa is a whelk shell and native of the Sea of Japan. Its possible way of introduction into the Black Sea, is by ballast water and eggs attached to ship hulls. *R. venosa* penetrated the Marmara Sea in the 1960s and settle in the Aegean Sea at a later stage (Figure 15).

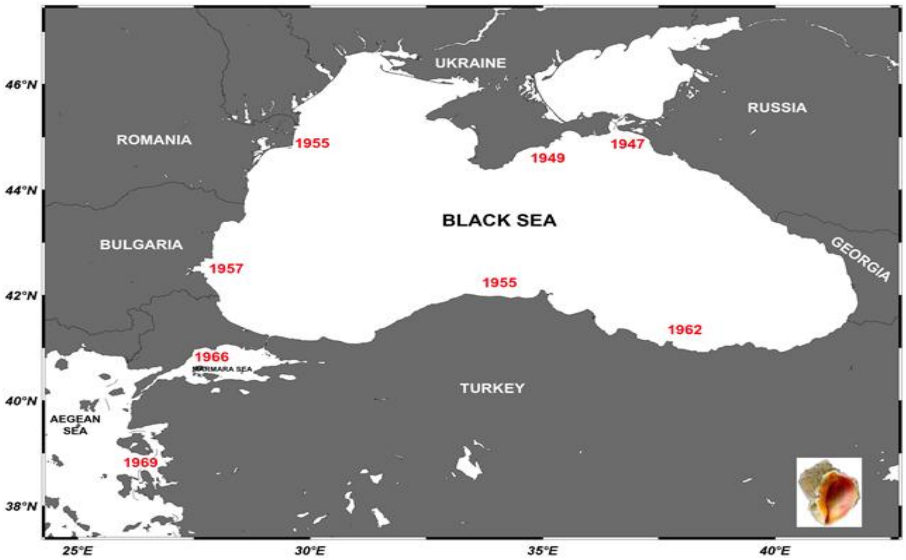

Figure 15 – Years of the first records of *Rapana venosa* at various locations in the Black, Marmara and Northern Aegean Seas

R. venosa feeds mainly on mussels and oysters on rocky bottoms. In the Marmara Sea, it is quite abundant at 5–25 m depth (maximum density is 15–20 ind. m^{-2}). The total distribution area of *R. venosa* had increased to 170 km² (Öztürk, 1999). Due to the high population density of *R.venosa* along the Marmara coasts, oysters and mussels have been exterminated from these areas where the bivalve harvesting used to be commercially important. For the first time in 1982, this speices gained an economic importance and was exported as *Rapana* meat to Japan. Then it became beneficial to the Turkish fisheries economy; the profit derivating from the export was estimated at approximately 2 million USD and about 600 persons were directly involved in this business (Öztürk, 2002b). Eighteen boats operate for Rapana in the Marmara Sea in 2009 (See Figure 1). Between 1999 and 2007, a total of 1 444 tonnes of *Rapana* were caught in the Marmara Sea (see Figure 16). This gastropod is harvested by diving and by dredging. The dredging method is harmful to benthic ecosystem, as it is a non-selective method, unlike diving.

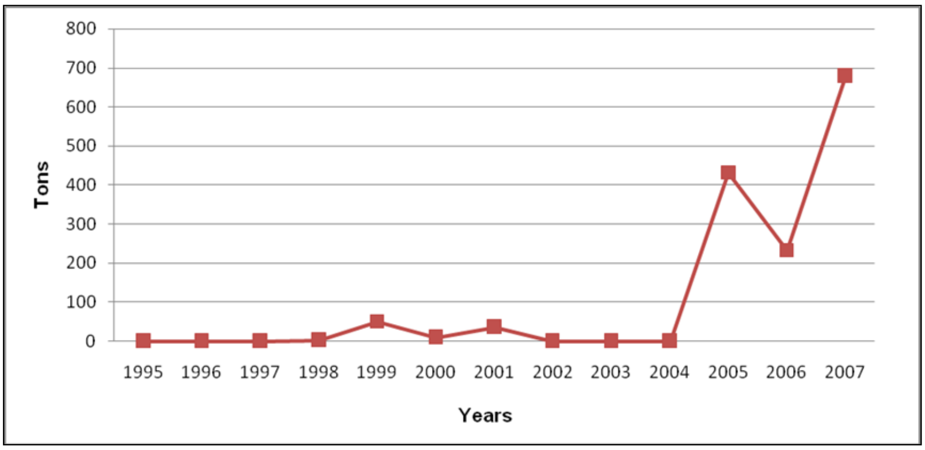

Figure 16 – Catch of *Rapana venosa* in the Marmara Sea from 1995 to 2007

2.2.3 Other alien species and impacts on fisheries in the Marmara Sea

The Indo-Pacific prawn *Marsupenaeus japonicus* was intentionally introduced to the Marmara Sea in the late 1960s from Iskenderun Bay on the Turkish coast of the Mediterranean Sea (M. Demir, pers. comm.). However, its population did not increase as much as expected.

Another Indo-Pacific crustacean, *Erugosquilla massavensis* (Kossmann, 1880), a mantis shrimp, was found in the central Marmara Sea in 2004 (Katagan *et al*., 2004). This is the second Indo-Pacific crustacean species reported from the Marmara Sea. Mantis shrimps do have a commercial value in the Turkish part of the Mediterranean Sea, but no fishing has been made yet in the Marmara Sea due to its small stock size.

An intentionally inroduced fish, haarder, *Liza haematocheila*, native to the Amu Darya River basin, reached the Turkish Black Sea coast from the Sea of Azov and migrated to the west, reaching the Marmara Sea and later the coasts of the Aegean Sea. This species has potential commercial importance (Figure 17). Annual catch of *Mugil* spp. in the Marmara Sea is between 900 and 5 000 tonnes for the period 1995–2007. Unfortunaley there is no separate statistic for *M. haematocheila* only.

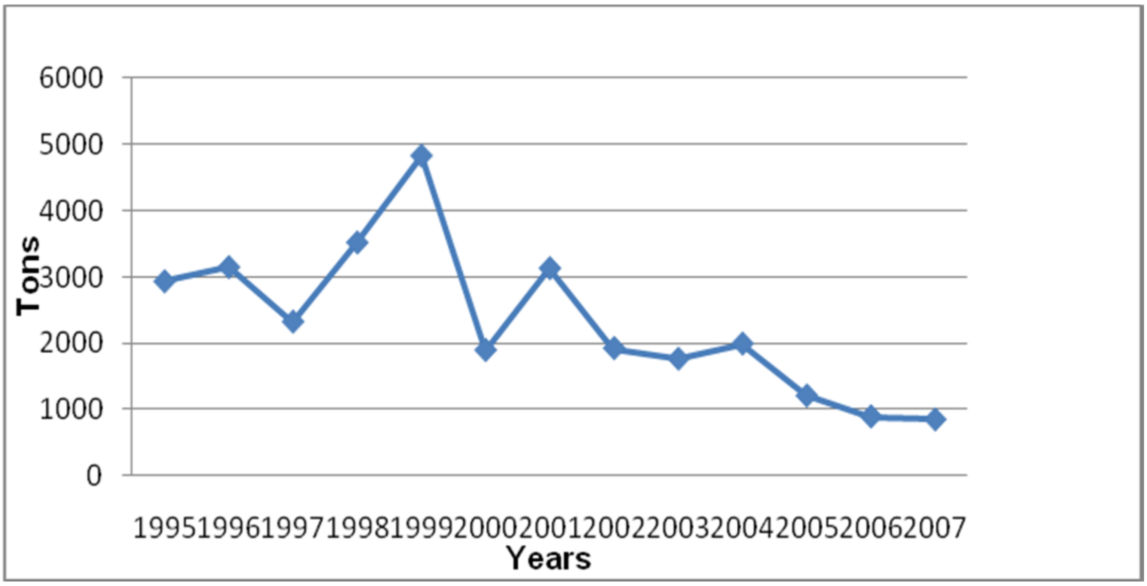

Figure 17 – Catch of *Mugil* spp. in the Marmara Sea (1995–2007)

The Indo-Pacific originated *Lagocephalus spadiceus* (Richardson, 1845) is one of the most abundant non-indigenous pufferfishes of the eastern Mediterranean Sea, distributing along the entire Levantine coasts from Port Said to the southern Aegean Sea (Golani *et al*., 2002). It is known to be poisonous to eat. Colonization of this species needs to be monitored in terms of fisheries and human health as well as its impacts on native fish fauna in the Marmara Sea.

Bivalves, *Anadara inaequivalvis* and *Mya arenaria,* are also remarkable alien mollusc species in the Marmara Sea. These bivalves are found between 3–15 m depth dominantly. *M. arenaria* is preyed on by *Rapana venosa* and demersal fishes, such as turbot, goby and mullet, in the Marmara Sea. Around the Prince Islands, its average biomass was 1 kg.m^{-2} in 1999. The alien starfish species *Asterias rubens* was observed in the Marmara Sea – Istanbul Strait in 1996 (Albayrak, 1996). But the interaction with mussel community seems to be slow in the Marmara Sea.

A Mediterranean originated compass jellyfish, *Chrysaora hysoscella* (Linnaeus, 1767), was reported in the Marmara Sea (Inanmaz *et al*., 2002). Blooms of this species were observed in the Marmara Sea, Istanbul Strait and the Black Sea in July 2009 (Öztürk and Topaloglu, 2009: Figure 18).

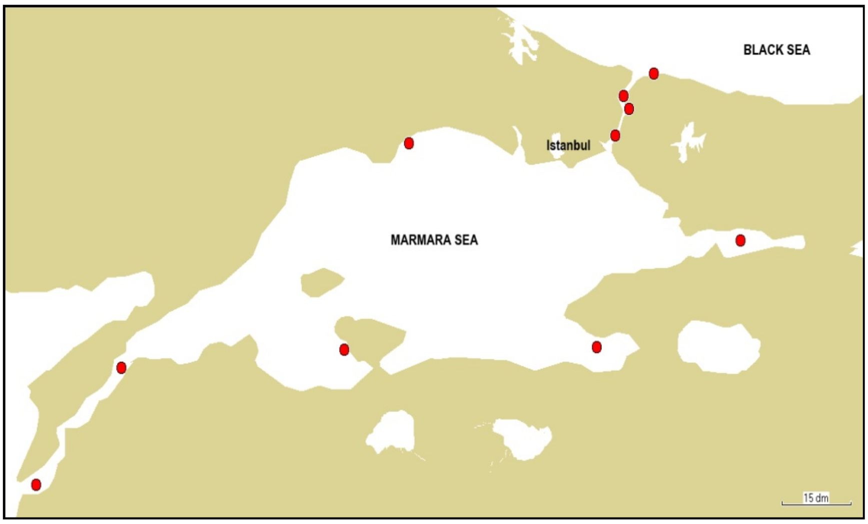

Figure 18 – Sightings of *Chrysaora hysoscella* in the Marmara and Black Seas in 2009 (shown by red dots)

Due to this jellyfish bloom, beach bathers used fishing nets to protect themselves from these animals in 2009. As this species is venomous, it needs to be monitored in the Marmara Sea in terms of impacts on human health and interrelation with fishing. Sesonal blooms of *C. hysoscella* damage fishing nets, mostly purse-seines and gillnets thus affect fishing yields and cause socio-economical problems for mostly artisanal fishers.

2.3 Conclusion and recommendations for the Marmara Sea

The Marmara Sea is a link between the Mediterranean and Black Seas, which is the reason why alien species, originally introduced to either of the two seas, are found there. However, for certain species, the Marmara Sea serves as a barrier which limits their distribution, while for others, it serves as a corridor for enlarging their distribution ranges. The Istanbul Strait (Bosphorus) plays a crucial role for dispersion of marine organisms. A permanent plankton runoff from the Black Sea to the Sea of Marmara takes place in the Istanbul Strait due to surface water current, and the Black Sea origin organisms are common in the northern part of the Sea of Marmara, some of them reaching the Aegean Sea. On the other hand, the bottom saline water in the Istanbul Strait transport Mediterranean organisms to the Black Sea. Few of them can survive in low salinity water. Hence, the Black and

Marmara Sea interactions should always be considered. The Marmara Sea is also a small acclimatization area for alien species. Consequently, more detailed investigations and monitoring studies are needed for the alien species and their impacts on biota and fisheries. Ballast water needs to be particularly monitored due to heavy ship traffic.

Interestingly, some alien species have turned out to be highly valuable resources, such as *Rapana venosa* and *Liza haematocheila.* On the contrary, some species, such as *Mnemiopsis leidyi*, have turned out to be extremely harmful to the native fauna and flora, creating a considerable economic loss. The other species given in Table 2.1 are less important in terms of fisheries.

It is predicted that more alien species will be observed in the near future due to heavy shipping activities between the Mediterranean and Black Sea. The total number of alien species in the Marmara Sea reaches 48. Although the vectors for most species are ships, some species were intentionally introduced in the Black Sea and subsequently settled in the Marmara Sea: *Gambusia affinis* and *Marsupenaeus japonicus. Liza haematocheila* needs to be monitored due to the possibility of displacement with other native mullet species. A pufferfish, *Lagocephalus spadicus,* and a jellyfish, *C. Hysoscella,* are poisonous and need special attention for public health, biota and impact on fisheries.

Special monitoring programs are needed for the toxic phytoplankton species jellyfish, such as *B. ovata,* and *M. leidyi,* due to their important impacts on the fisheries not only in the Marmara Sea but also in the Mediterranean and Black Seas. The Marmara Sea is a kind of “test laboratory” for alien species and monitoring of these alien species in this sea may help prediction on the Black and Aegean Seas.

3. STATUS OF ALIEN SPECIES IN THE MEDITERRANEAN SEA

3.1 Main characteristics of the Mediterranean Sea

The Mediterranean Sea is the largest semi-enclosed Sea (Figure 18), characterized by a narrow shelf, a narrow littoral zone and a small drainage area especially in the northern part. The Sicilian Channel (150 km wide, 400 m depth) separates two distinct basins, the western and eastern and functions as a geographical and hydrographical border between them. This and other channels play a significant role in determining the oceanographic characteristics of each regional sea, such as the Adriatic, Aegean and Levantine Sea. The size of the Mediterranean Sea from west to east, from Gibraltar to Syrian Arab Republic, is about 4 000 km. At its greatest breadth, from the coast of France to that of Algeria, the distance is 900 km. The area of the Mediterranean, including all of its adjacent seas except the Black Sea, is 2 523 000 km^2 and its volume is 3 708 000 km^3, giving a mean depth of 1 470 m (Miller, 1983).

Oxygen level is almost saturated in the surface layer (6 ml/l in winter and 4.8 ml/l in summer). In deep water the oxygen concentration is about 4.5 ml/l in the western and 4.2 ml/l in the eastern basin. The Mediterranean Sea has seasonal variation in the surface temperature. During summer, warm water (warmer than 20ºC) at the surface creates important stratification of water. During winter, cold water (12–15ºC), which distributes homogeneously between the surface and depth, causes important vertical convections (upwelling), recycling nutrients abundant in the depths (these convections are induced in particular by wind, thus largely dependent on wind speed) (Fontenau, 1996).

The circulation of the water masses in the Gibraltar Strait has a vital importance for the biota of the Mediterranean. A permanent surface current towards the east, the entry of superficial Atlantic water into the Mediterranean Sea and a deep current of the Mediterranean water flowing westwards, is remarkable for the water circulation. However, this circulation pattern may change with climate change in near future.

Figure 18 – Mediterranean Sea

The Mediterranean Sea is an oligotrophic sea and has low phytoplankton biomass and low primary production due to weak fluvial supplies and poor surface water input from the Atlantic. The Mediterranean fauna and flora have evolved over millions of years and by the mixture of temperate and subtropical elements include a large proportion (28 percent) of endemic species (Fredj and Meinardi, 1992). However, in the last 50 years, many alien species have been observed in the

Mediterranean Sea (Figure 19). Ship transportation is the main vector for the alien species with ballast tanks and hull fouling. Meanwhile, after the opening of the Suez Canal, some species pass to the Eastern Mediterranean Sea from the Red Sea. It is called lessepsian migration (Por, 1978). Some commercial species have been intentionally introduced, like the Japanese oyster *Crassostera gigas* or the venerid *Ruditapes philippinarum*, which have also been established in the Mediterranean Sea. Accidentally introduced *Caulerpa taxifolia* has also spread around the Mediterranean. All these alien species dispersed over the Mediterranean have changed marine biodiversity and fisheries in this unique sea.

The present Mediterranean fauna and flora are a mixture of the Mediterranean and Red Sea biota components due to the Suez Canal. It is possible to call the eastern Mediterranean Sea a lessepsian province after this biotic change. Nevertheless, a total of 10 000 to 12 000 marine species have been recorded in the Mediterranean Sea and this rich biodiversity represents 8–9 percent of the total number species in the world's seas (EEA, 2006). It should be noted that the deep sea part of the Mediterranean Sea is still poorly studied and more potential species may be discovered in the next years if the research intensity is increased in the region, particularly in the deep basins.

3.2 Main vectors for alien species in the Mediterranean Sea

The main vectors for alien species in the Mediterranean Sea can be described as follows:

a) shipping, ship's ballast waters, tank sediments, hull fouling, and marine debris;
b) straits: the Kerch and the Turkish Straits System for the Black Sea species and the Gibraltar Strait for the Atlantic species. These straits also play an important role for the introduction of the Black Sea originated alien species, such as *Liza haematocheila*, *Mnemiopsis leidyi* and *Rapana venosa*, and the Atlantic originated alien species, respectively.
c) the Suez Canal: one of the major vectors for the Indo-Pacific originated species or lessepsian species,
d) intentional or unintentional introduction by humans: this introduction is generally for aquaculture or aquarium; and
e) besides these main vectors, aquarium, fish baits and other minor vectors should also be considered.

According to Streftaris *et al*. (2005), shipping, although it contributed more than aquaculture as a vector, appears to have had a less significant role (20 percent) in the Mediterranean than the Suez Canal (52 percent). Galil (2008a) reported 558 and Galil (2009) 573 species from the Mediterranean Sea. However, this number was estimated as thousands by Por (2009).

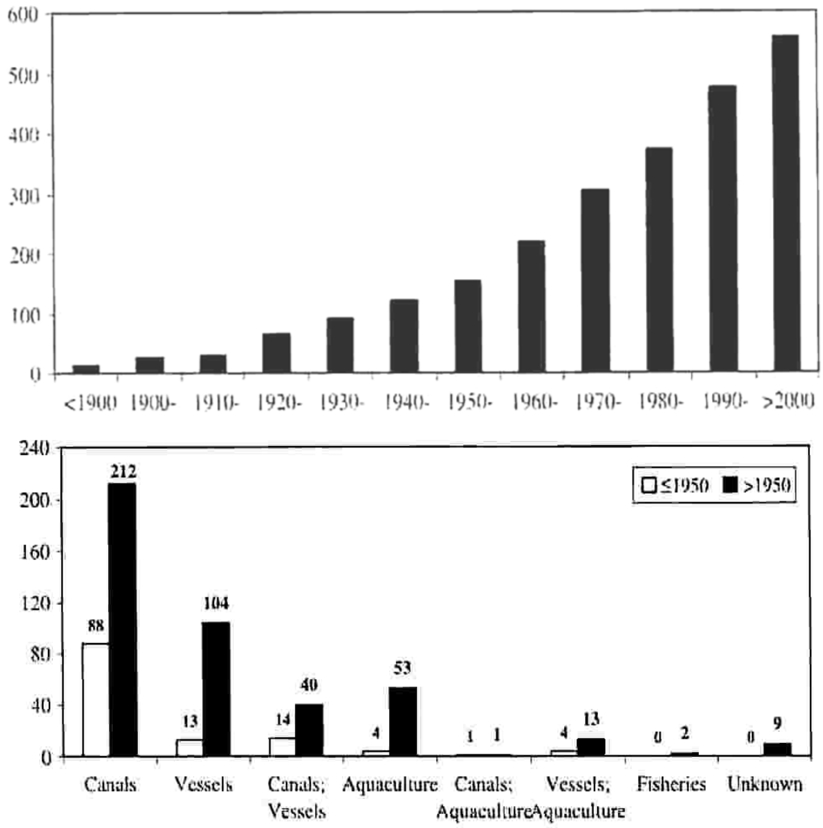

Figure 19 – Cumulative number of alien species recorded in the Mediterranean Sea from 1900 to 2007 (top) and number of alien species in the Mediterranean Sea, presented by means of introduction, before and after 1950 (bottom) (Galil, 2008a)

3.2.1 Shipping

Ship-transported species spread over many parts of the world ocean. The routes of the access of alien species by ship transportation may be categorized such as transportation with ballast water or sediment, sessile (fouling) and vagile (clinging) form on ship hulls, or even drilling platforms. In the Mediterranean Sea shipping is the biggest factor for the introduction of alien species. It is estimated that the Mediterranean Sea carries 30 percent of the international cargo volume, and 20 percent of petroleum (Dobler, 2002) (Figure 20). With some 2 000 merchant ships sailing in the Mediterranean at all times, the transfer of biota stemming from the regular operation of these ships is significant. Intermediterranean and North/South (Black Sea – Mediterranean Sea via Turkish Straits, Mediterranean Sea - Indian Ocean via Suez Canal) marine traffic is increasing due to the expansion of global trades. Galil (2000) underlines the important role of shipping on the transportation of alien species.

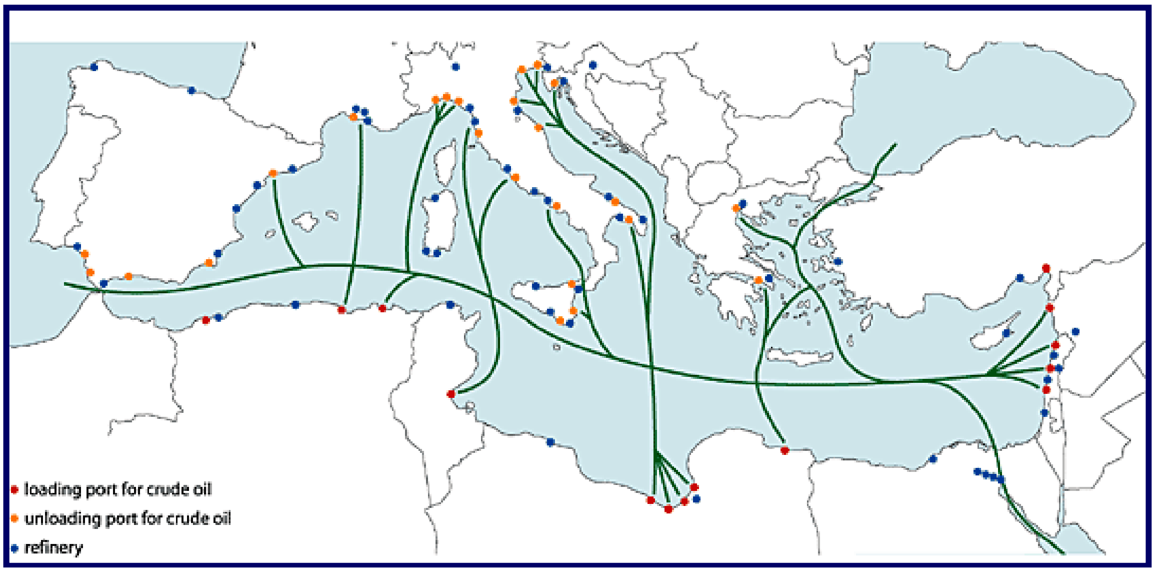

Figure 20 – Main routes of shipping in the Mediterranean Sea (www.unep.org/geo/geo3/english/fig195.htm)

Verlaque *et al*. (2007) reported a total of 110 alien marine macrophyte species in the International Commission for the Scientific Exploration of the Mediterranean Sea (CIESM) Atlas for alien species. They pointed out several vectors of the alien species such as hulls of ships, fouling, deballasting of water and solid matter transported by ships, opening of the Suez Canal, intentional and unintentional introduction.

Ballast water plays a minor role as a vector for introduction of macrophytes to the Mediterranean (Boudouresque and Verlaque, 2002). Fouling seems to be more important as a vector for their introduction than ballast water. Oyster transfer which is probably responsible for the introduction of 44 macrophyte species is most important in Thau Lagoon in France (Ribera, 2002; Verlaque, 2001).

Maritime transport is an essential factor for the worldwide dispersal of alien species. In the Mediterranean, 13 percent of alien plant species were carried on ship's hulls and 3 percent from deballasting process (Siguan, 2002). Wyatt and Carlton (2002) reported 7 phytoplankton species introduced to the European and Mediterranean coastal waters with ballast water, oysters or multiple as possible vectors. Por (1978), Kovalev (2006) reported several alien zooplankton species which entered via the Suez Canal and Gibraltar to the Mediterranean Sea. Çiçek and Bilecenoğlu (2009) recently reported an Indo-Pacific alien fish species likely via ballast water: *Champsodon nudivittis.* Toxic algae can be introduced or has been transferred to new environement with ship's ballast water.

3.2.2 Straits

International straits used for navigation in the Mediterranean and Black Sea are biological corridors at the same time from the biogeographical point of view (See Figure 21). For example, one of the intentionally introduced fish species, *Liza haematocheila,* was first introduced to the Azov Sea and after the successful colonization it entered to the Black Sea via the Kerch Strait. Later it entered the Turkish Straits (Istanbul and Çanakkale) and is currently found in the Aegean Sea (Kaya *et al*., 1998) and the Mediterranean Sea. There are some other examples such as *Rapana venosa* and *Mnemiopsis leidyi*. They were first recorded in the Black Sea and after its successful migration through the Turkish Straits, they penetrated to the Aegean and Mediterranean Seas.

On the other end of the Mediterranean, the Gibraltar Strait is also a long biological corridor for alien species from the Atlantic Ocean. The Atlantic-Mediterranean faunistic connection had an impact on the Mediterranean biogeography, even it is not similar to the Mediterranean-Red Sea connection. From Pliocene to date, Atlantic fauna has been established in the Mediterranean Sea via the Gibraltar Strait. Quignard and Tomasini (2000) reported 26 fish species to be recent neocolonizers of Atlantic origin. These Atlantic origin fish migrated from west to east, such as *Sphoeroides pachygaster* and *Sphyraena viridensis,* later found in Lebanon, Israel and Turkey. Some of the Atlantic species are also well established up to the Iberian coast. Bradai *et al*. (2004a) reported that eight Atlantic origin alien fish species were found in the Tunisian water, representing 2.36 percent of the Tunisian ichtyofauna. In recent years, Atlantic originated alien species have extended their distribution range to the eastern Mediterranean Sea. Similarly, Lasram-Rais and Mouillot (2009) reported that 62 Atlantic species entered through the Strait of Gibraltar. The first report of such fish was made in 1810 by Risso, when *Entelurus aequoraeus* and *Pristis pectinata* were recorded.

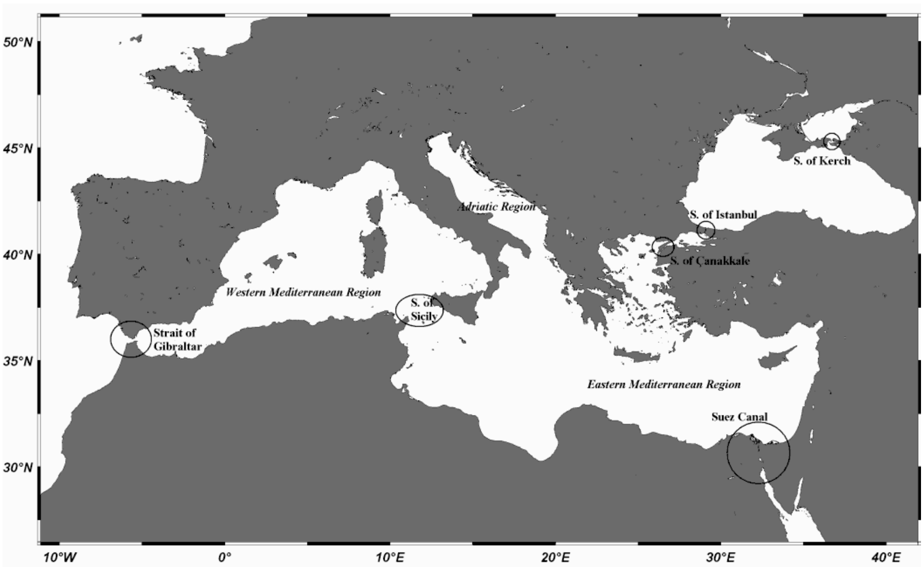

Figure 21 – Straits in the Mediterranean and Black Seas

3.2.3 The Suez Canal

The Suez Canal was opened in 1869 to shorten the trade route between the Mediterranean and Indian Ocean. Ferdinand de Lesseps (1805–1894), a French engineer in charge of the construction of the Suez Canal which joined the Mediterranean and Red Seas for the first time in 1869 and substantially reduced sailing distances and time between the West and the East. The opening of the Suez Canal in 1869 created the first salt-water passage between the Mediterranean and Red Seas (see Figure 22). The Red Sea is higher than the Eastern Mediterranean, so the canal serves as a tidal strait that pours the Red Sea water into the Mediterranean. The Bitter Lakes, which are hypersaline natural lakes forming a part of the canal, blocked the migration of Red Sea species into the Mediterranean for many decades, but as the salinity of the lakes gradually equalized with that of the Red Sea, the barrier to migration was removed, and plants and animals from the Red Sea have begun to colonize the eastern Mediterranean. The Red Sea is generally saltier and more nutrient-poor than the Atlantic, so the Red Sea species have advantages over the Atlantic species in the less salty and nutrient-rich Levant Basin.

Figure 22 – The Suez Canal (Por, 1978)

The construction of the Aswan High Dam across the Nile River in the 1960s reduced the inflow of freshwater and nutrient-rich silt from the Nile into the eastern Mediterranean, making conditions there even more similar to the Red Sea, thus increasing the impact of invasions and facilitating the occurrence of new ones. The Red and Mediterranean Seas removed a geographic barrier between them, then the migration began from the Red Sea to the Mediterranean and many Red Sea species (lessepsian) penetrated to the Mediterranean. As a result, various changes have occurred in the biota of the Mediterranean. Accordingly, most invasions are of Red Sea species into the Mediterranean, and only a few in the opposite way (Ben-tuvia, 1966; Avşar, 1999).

Enlargement of the Suez Canal is also a facilitating factor for Lessepisan migrants to settle or pass to the Mediterranean Sea. The Suez Canal was deepened and widened several times, and now has a navigational depth of 14.5 m and width of 365 m (see Table 3.1).

Table 3.1 – Dimension of the Suez Canal over the years (Halim, 1990)

Years	1869	1956	1981
Width at sea surface (m)	52	160	365
Width of navigable channel (m)	44	110	190
Total depth (m)	7.8	12	14.5
Cross-sectional area (m^2)	304	1 200	3 600

This enlargement of the canal increased its water circulation, then the salinity gradually decreased in Bitter Lakes. This has resulted in the disappearance of the salinity barrier. The increased salinity in the Eastern Mediterranean (as a consequence of the reduced water flow from the Nile) in itself supports the lessepsian migration (Por, 1978). High water temperature and turbidity in the Canal were other barriers of the Suez Canal. These factors were significantly reduced with the enlargement of the Canal.

The term “lessepsian“ was first used by Por (1964) to characterize the new phase into which the Eastern Mediterranean had entered with the opening of the Suez Canal. Por (1969, 1971) coined the term “lessepsian migrant” for the Red Sea species which had passed through the Suez Canal and settled in the Eastern Mediterranean (Por, 1978). Lessepsian migration (also called Erythrean migration) is the ongoing unidirectional migration of marine species through the Suez Canal, from the Red Sea to the Mediterranean Sea.

Through the Suez Canal, several marine species migrate to the Mediterranean Sea such as marine fishes, phanerograms, macrophytes, coelenterates, molluscs, crustaceans as well as echinoderms. The rate of this migration is growing and the eastern Mediterranean may be called a “lessepsian province” in terms of biodiversity or due to the various Red Sea originated species: a new geographic region has appeared.

Direction of the migration is also another important matter. Even a large number of marine species have migrated to the Mediterranean Sea since the opening of the Suez Canal, only a few species migrated to the Red Sea side, which is called anti-Lessepisan migration. A possible reason for this could be that the Indo-Pacific origin species might be more adaptable to different ecological conditions than the Atlanto-Mediterranean ones and the dominant current and wind system may facilitate carrying eggs and larvae from the Red Sea to the Mediterranean and later to the Levantine Sea with the local gyre of the region. Mavruk and Avşar (2008) reported that the establishment of the lessepsian fish populations in the Levantine Basin(eastern Mediterranean Sea) is facilitated by similar conditions such as Iskenderun and Mersin Bay and Red Sea in terms of salinity and temperature. All these conditions have formed an ecosystem which is similar to that of a tropical ecosystem. With higher salinity, temperature and as an oligotrophic sea, the Levantine Basin has poor species diversity compared to other parts of the Mediterranean Sea. Bernardi *et al.* (2010) reported that the passage used by larvae and/or adults to enter the Mediterranean (the Suez Canal) had the potential to sustain great numbers of migrants and high gene flow, at least for most of these colonists.

In the last decade, this migration phenomenon is monitored by several scientific institutions, regional and international organizations, such as CIESM, the Regional Activity Center/Special Protected Areas (RAC/SPA), World Conservation Union, GFCM, the European Union (EU), European Environment Agency (EEA) and others. Most of the researches have been carried out on fish species because fish has a much more economic value than other species. Other species need to be more deeply investigated.

3.3 Lessepsian migration and species

The colonization of the Mediterranean Sea by Red Sea marine species has been reviewed by several authors, i.e., Koswigg and Ben-Tuvia (1953). Ben-Tuvia (1978) listed 36 Red Sea immigrants. Interestingly in that time, Red Sea immigrants constitute 12 percent of the population in the Levant Basin and 7 percent for the Mediterranean as a whole but only 1 percent of the population in the central part of the sea. None of the Red Sea immigrants had reached the western basin. Por (1978, 1990) reported that, as far as the fauna was concerned, lessepsian alien species represented about 4 percent of the Mediterranean specific diversity and 10 percent of the Levantine Basin. These percentages, however, have changed in the last ten years. Galil (2008a) reported that of the 124 alien species known in 1950, 82 percent entered the Mediterranean through the Suez Canal, 10 percent were vessel-transported and 4 percent were from mariculture introduction (see Fig 3.2). Galil (2009) underlines that the majority of aliens in the Mediterranean entered through the Suez Canal (54 percent). Another important issue is that some lessepsian species migrate not only to the Levantine Basin, but also beyond the Sicily Strait to the western Mediterranean Sea or even up to the Black Sea.

Golani (1996) reported that 59 lessepsian fish species comprise 14 percent of the ichthyofauna of the eastern Mediterranean: the east of the line connecting from Antalya to Port Said. These species represent 42 families, 15 of which were not present in the Mediterranean prior to the lessepsian migration. Golani (2002) also pointed out that 38 lessepsian fish species established sustainable populations in the eastern Mediterranean, with a significant impact on the local ecosystem. Four years later, Golani *et al*. (2006) and Golani (2006) reported that about 60 and 65 species, respectively, were lessepsian migrants. Bilecenoğlu *et al*. (2002a) reported range extension of three lessepsian migrant fishes (*Fistularia commersoni, Sphyraena flavicaudata* and *Lagocephalus suezensis*) in the Mediterranean Sea. Besides, Bilecenoğlu *et al*. (2002b) reported several lessepsian fish species on a checklist.

Similarly, Dulcic *et al*. (2002) reported 407 fish species from the Adriatic Sea and 6 species were identified as lessepsian. In 2009, the CIESM Website had 116 alien fish species recorded although this number does not include lessepsian migrants only, but also those from the Atlantic and other areas. It is known that temperature is the most important abiotic factor in determining the dispersal of lessepisan fish(Ben-Tuvia and Golani, 1995). Similarly, Dulcic and Gerbec (2000) found that the change of the ichtyofauna in the Adriatic was associated with climatic and oceanographic changes. According to Lasram–Rais *et al*. (2008), thirty percent of the lessepisan species succeeded in dispersing over the Mediterranean Sea and lessepsian fish represent only 5.72% of the Red Sea fish fauna. It is already known that only over 1000 fish species have been found in the Red Sea.

Besides fish, the number of lessepsian mollusc species also has been increasing. Zenetos *et al*. (2003) reported 137 exotic mollusc species in the “CIESM Atlas of Exotic Species in the Mediterranean”. This number has been increasing in recent years in parallel with the research intensity in the region. A list of alien mollusc species is given in Appendix 1, it was taken from various sources such as scientific papers, articles and Website: www.ciesm.org. Çevik *et al*. (2001) reported *Crasostre gigas* and *Saccostrea commercialis* from Iskenderun Bay, both of which are alien commercial species. Another commercial mollusc species, *Strombus persicus* is also reported from Turkish waters. Özgür and Öztürk (2007) stated that in rocky reefs in Ölüdeniz/Fethiye this species was found in dense colonies. Çevik *et al*. (2005) reported first record of *Electroma vexillum* from the Easterm Mediterranean. Çınar *et al*. (2006) reported 16 opisthobranchs from the Turkish coasts. Similarly, Daskos and Zenetos (2007) reported two alien opisthobranch species are recorded from Greece in 2003–2004, C*hromodoris annulata* may have been introduced by shipping, whereas *B. leachii* has long been considered to have immigrated via the Suez Canal.

Çevik *et al*. (2007) reported that in Iskenderun Bay, 67 of the 181 mollusc species were exotic, which consists of 37 percent of total mollusc fauna, a percentage by far higher than those reported elsewhere. Doğan and Nerlovic (2008) reported *Pinctada radita* from Croatia, which is a Red Sea-origin bivalve species. It clearly shows that Lessepisan molluscs dispersed as fas as to the Adriatic Sea. Sraieb *et al*. (2009) reported two alien molluscs *Bursatella leachii* and *P. radiata* from the Ghar El Melh Lagoon in Tunisia.

Alien crustacean species in the Mediterranean Sea have been also reported by several experts, such as Galil (1992) who reported that 20 percent of the decapod fauna in the Levant Basin migrated through the Suez Canal. Galil *et al*. (2002) reported 59 decapod species and one stomatopod, i.e. a total of 60 exotic species from the Mediterranean Sea, of which 37 species have established their populations. Kocatas and Katagan (1994) reported 20 lessepsian alien species recorded from the Turkish coasts. Çınar *et al*. (2005) reported 45 alien crustacean species. Yokes *et al*. (2007) reported that thirty of 33 alien decapod crustacean species have been reported on the Turkish Mediterranean coast. Later Özcan *et al*. (2010) reported 36 decapod and 2 stomotopod alien species. Yokes and Galil (2006a), Pancucci-

Papadopoulou and Naletaki (2007) also reported alien crustacean species from the eastern Mediterranean Sea.

A compiled table has been prepared according to various sources, including CIESM Atlas of Exotic Crustacean Species (2009). A total of 75 alien crustaceans are listed for the Mediterranean Sea with information on countries and vectors (Appendix 2).

Besides fish, molluscs and crustaceans, some other alien taxa, such as jellyfish, ctenophores, polychaetes, ascidians and echinoderms are also found mostly in the eastern Mediterranean Sea.

3.3.1 Lessepsian fish species

Alien fish species entered the Mediterranean Sea via four pathways:

a) via the Strait of Gibraltar;
b) via the Suez Canal;
c) via the Çanakkale Strait (Dardanelles); and
d) via human activities such as ship, meditated transportation, mariculture and others.

Several studies have been made mostly for lessepsian fish migrant species such as Koswigg (1953), Ben-Tuvia (1953, 1966, 1978), Demetropoulos and Neocleous (1969). The first lessepsian fish species recorded was *Atherinomorus lacunosus,* 33 years after the opening of the Suez Canal (Ben-tuvia, 1985). Golani *et al*. (2002) reported 90 exotic fish species including Atlantic origin fish, representing 56 families, among a total of 650 fish species in the Mediterranean Sea. Nowadays, Eastern Mediterranean ichthyo-fauna includes approximately 15 percent lessepsian species (Golani, 1996; Mavruk and Avşar, 2008). Before the opening of the Suez Canal, not enough data on the Mediterranean Sea was available and this impeded any comparison to be made. One of the lessepsian fish species, *Siganus luridus,* has extended its distribution up to France beyond the Sicily Channel in the Mediterranean Sea (Daniel *et al*., 2009). Some studies were also conducted in the Tyrrhenian Sea (Psomadakis *et al*., 2009), Tunisia (Ktari and Ktari, 1974; Ben Soussi *et al*., 2004), Ligurian Sea (Garibaldi and Relini, 2008), Adriatic Sea (Dulcic *et al.*, 2004; 2008), Montenegro coast in the Adriatic Sea (Joksimovic *et al*., 2009) and in the Algerian coast (Kara and Oudjane, 2009).

In Tunisia, Bradai *et al*. (2004a) reported 15 alien species, among which eight species were lessepsian and seven were of Atlantic origin, and Bradai *et al.* (2004b) pointed out that the Tunisian coasts are invaded by alien species originating from the tropical Atlantic and Indo-Pacific areas. Ben Soussi *et al*. (2004) reported *Fistulaira commersonii* from Tunisia. This species is a fast sprinter and found in Italian waters and most probably in Spanish and French coast as well (Garibaldi and Relini, 2008). Rim Ktari *et al*. (2007) found that the spawning of *S. chrysotaenia* from the Gulf of Gabes took place between May and November. Similarly, Rim Ktari (2008) found that among a total of 22 alien species from Tunisia 14 of them were Lessepisan and 8 were Atlantic species. Bradai *et al*. (1993) reported *Spheroides cutaneus* from the Gulf of Gabes.

It is clear that lessepsian fish migrants can be found beyond the Sicily Channel. Golani (1998) reported only four Lessepisan species between Tunisia and Italy, actually this number increased to 14 in Tunisia only (Lasram-Rais *et al*., 2008). The Sicily Channel is a classical biogeographic border between the eastern and western Mediterraean Sea but it seems that this boundary is changing due to the increasing number of the Atlantic-origin alien species and lessepsian species, especially fish species.

In the eastern Mediterranean Sea, several new alien fish species has been reported. Başusta *et al*. (2002) and Bariche *et al*. (2003) reported spawning and reproduction cycles of some Lessepisan fishes. Gökoglu *et al*. (2003) reported *Henichus intermedius* from the Mediterranean Sea. Golani *et al*. (2007) reported 108 fish species representing 61 families, 37 of which were new for the

Mediterranean ichthyofauna and the increase of 20 percent within four years only. Zenetos *et al*. (2007) updated the number of alien species in Greek waters as increased from 102 to 110. Out of the eight new records, five are zoobenthic species, two zooplanktonic and one is a teleost fish. Ergüden *et al*. (2009) studied the weight-length relationship for 20 lessepsian fish species in the Eastern Mediterranean. Yokes *et al*. (2009) pointed out that *Vanderhorstia mertensi* (Klausewitz, 1974), is a recently acknowledged alien fish in Fethiye Bay and that its population has increased rapidly.

Dispersion of the lessepsian fish in the Mediterranean Sea depends on several factors such as cyclonic Mediterranean shore currents to the Levantine Sea, and similar temperature conditions. Most of the successful species are euryterm and euryhaline species and they can adapt to other ecological conditions such as feeding and habitat type (Mavruk and Avşar, 2008). Gücü and Gücü (2002) reported that low native species diversity was affecting the rate and the success of immigrant colonization. Furthermore, the absence of *Posidonia oceanica* meadows was found to be another important factor, affecting the success of lessepsian invasion. *P. oceanica,* the endemic seagrass that is the key species of the Mediterranean coastal ecosystem, was found responsible for defending the Levant Sea's ecological integrity and its native characteristics against invasion. Its absence has resulted in a successful invasion of lessepsian species.

In Appendix 3, alien fish species are listed according to various sources including Websites such as www.ciesm.org, www.fishbase.org, Oral (2010), Lasram-Rais and Mouillot (2009).

Marttin *et al*. (2006) widely examined the fisheries sector in the eastern Mediterranean under the MEDFISIS Project and they found that the abundance of some native species has declined while that there has been an increased abundance of lessepsian species. Competition within the same ecological niche and the direct interference could be possible explanations for the successful colonization (Golen and Galil, 2005). It has been reported that the increasing exploitation of non-native species caused a shift of the trawl fishing ground towards shallower waters where their biomass density is highest (i.e. at bottom depth up to 50 m), and a consequent increase of the ratio of non-native to native species in Levantine trawl landings (Pisanti and Grofit, 1991). Marttin *et al*. (2006) listed the species successfully established and commercially important in Levantine fisheries according to the CIESM exotic species book and seven fish and three crustacean species were reported as commercially exploitable alien species from the Eastern Mediterranean Sea.

The vertical distribution of lessepsian fish species has also been examined by several authors. Bilecenoğlu and Taşkavak (2002) reported that a few specimens of *Upeneus moluccensis* were found at a depth of 180–190 m in the Turkish coasts and that this species seemed to be very adaptive to the low temperatures prevailing in such depths throughout the eastern Levantine Basin. Similarly, Golani (1996) found some species at a depth of 200 m off the coast of Ashdod in Israel. As a matter of fact, lessepsian fish has higher mobility as opposed to most invertebrates and the majority of the fish species found at 20–40 m depth as stated by Por (1978). But bathymetric distribution changes below 70 m, which has a threshold effect as a limiting factor due to low temperature occupation of the circumlittoral zone.

Lessepsian fish migrants are also utilized for several purposes like aquaculture, aquarium, game fish and as bait in the fishing industry (see Table 3.2).

Table 3.2 – Lessepsian fish species used for various purposes (Compiled from www.fishbase.org and various sources)

Species name	Fisheries*	Aquaculture	Aquarium	Game fish	Bait fish
Abudefduf vaigensis (Quoy and Gaimard, 1825)	x		x	x	
Crenidens crenidens (Forsskal, 1775)	xxx				x
Decapterus russelli (Rüppell, 1830)	xxxx				x
Dussumieria elopsoides Bleeker, 1849	xx				
Epinephelus coioides (Hamilton, 1822)	xxx	x			
Epinephelus malabaricus (Bloch and Schneider, 1801)	xxxx	x		x	
Etrumeus teres (Dekay, 1842)	xxxx				
Fistularia commersonii (Rüppell, 1835)	xx		x		
Hemiramphus far (Forsskal, 1775)	xxx			x	x
Herklotsichthys punctatus (Rüppell, 1837)	xx				
*Heniochus intermedius (*Steindachner, 1893)			x		
Himantura uarnak (Forsskal, 1775)	xxx			x	
Hippocampus fuscus (Rüppell, 1838)	xx				
Iniistius pavo (Valenciennes, 1840)	xxx		x	x	
Lagocephalus sceleratus (Gmelin, 1789)			x		
Liza carinata (Valenciennes, 1836)	xxx				
Lutjanus argentimaculatus (Forsskal,1775)	xxx	x		x	
Muraenesox cinereus (Forsskal, 1775)	xxxx	x		x	x
Nemipterus japonicus (Bloch, 1791)	xxx				
Nemipterus randalli (Russell, 1986)	xx				
Oxyurichthys petersi (Klunzinger, 1871)			x		
Platax teira (Forsskål, 1775)			x	x	
Papilloculipes longiceps (Ehrenberg in Valenciennes, 1829)	x				
Parexocoetus mento (Valenciennes, 1846)	xx				
Pelates quadrilineatus (Bloch, 1790)	xx				
Platycephalus indicus (Linnaeus, 1758)	xxx	x		x	
Plotosus lineatus (Thunberg, 1787)	xxx		x		
Pomadasys stridens (Forsskal, 1775)	xxx				
*Pteragogus pelycus (*Randall, 1981)			x		
Pterois miles (Bennet, 1803)			x		
Rastrelliger kanagurta (Cuvier, 1816)	xxxx			x	x
Rhabdosargus haffara (Forsskal, 1775)	xxx				
Sargocentron praslin (Lacepède, 1802)	xx				
Sargocentron rubrum (Forsskal, 1775)	xx		x		
Saurida undosquamis (Richardson, 1848)	xx				
Scarus ghobban (Forsskål, 1775)	xxx		x		
Scomberomorus commerson (Lacapede, 1800)	xxxx			x	
Siganus luridus (Rüppell, 1828)	xx				
*Siganus rivulatus*Forsskal, 1775	xx	x			
Sillago sihama (Forsskal, 1775)	xxx	x			
Silhouetta aegyptia (Chabanaud, 1933)			x		
*Sphyraena chrysotaenia (*Klunzinger, 1884)	xx				
*Sphyraena flavicauda (*Rüppell, 1838)	xxx				

Species name	Fisheries*	Aquaculture	Aquarium	Game fish	Bait fish
Sphyraena obtusata (Cuvier, 1829)	xxx			x	
*Sphyraena pinguis (*Günther, 1874)	xxxx				
Spratelloides delicatulus (Bennett, 1831)	xx				x
*Stephanolepis diaspros (*Frase- Brunner, 1940)	xx				
Terapon puta (Cuvier, 1892)	xx				
Tetrosomus gibbosus (Linnaeus, 1758)	xx		x		
Tylosurus choram (Rüppell, 1837)	xxx				
Upeneus moluccensis (Bleeker, 1855)	xxx				
*Upeneus pori (*Ben-Tuvia and Golani, 1989)	xxx				

Fisheries*: x subsistence, xx minor commercial, xxx commercial, xxxx highly commercial

3.3.2 Evaluation of lessepsian fish migrants catch

Many alien fish species are fished for economical purpose in the Eastern Mediterranean Sea (Table 3.2). Trawling and purse seining techiques are the most common technıque used for catching lessepisan fish in the basin. However, there is no available accurate data for most of the species from riparian countries. It should be noted that lessepsian fish are not only demersal fish anymore, but also include pelagic fishes as well in the eastern Mediterranean Sea (see Turkey below). A brief summary of commercial alien species for each country in the eastern Mediterranean Sea is presented below.

Algeria

The Spanish mackerel is commercially important and 499 tonnes have been declared as its catch.

Cyprus

No commercial lessepsian fish has been reported from Cyprus in a substantial manner. Only sporadically a few specimens were observed in the Nicosia fish market. Golani(2000) reported that the lessepsian migrant The Red-eye round herring , *Etrumeus teres* is caught in commercial fisheries.Tzomos *et al*. (2010) reported 25 lessepsian fish species from Cyprus.

Egypt

El-Sayed (1992) reported 32 lessepsian migrants from the Mediterranean coast of Egypt. Not much data on lessepsian fish species is provided by the Egyptian fisheries. Rabbitfishes acquired an economic importance in the Egyptian coasts (Hamza *et al*., 2000). Red-eye round herring (*Etrumeus teres*) and Narrow barred Spanish mackerel (*Scomberomorus commerson*) are also exploited in Egypt.Its one of the important species around Gulf of Suez.

Greece

Papaconstantinou (1990) reported that at least 11 species have reached the Aegean islands and that *Sargocentrom rubrum, Siganus rivulatus, Siganus luridus, Lagocephalus spadiceus, Stephanolepis diaspros, Upeneus mollucensis, Leiognathus klunzingeri, Saurida undosquamis, Pemperis vanicolensis, Hemiramphus far* and *Parexocoetus mento* were fished in Greece. Corsini-Foka and Kalogirou (2008) reported that *Scomberomorus commerson* was found for the first time around the Rhodes Island. This fish pontentially has commercial value .Besides ,Pancucci-Papadoupoulou and Corsini Foka(2010) reported that from economical point of view , a few introduced species are locally exploited and recent colonizers such as *S.lessoniana* and *U.pori* show a rapid increase.

Israel

The most comprehensive catch records have been made for the Israeli fishery. The catch of the Erythrean (lessepsian) species has been estimated at approximately a third of the total landing since 1954 (Galil, 1993). Nearly half of the trawl catches along the Israeli coast consists of lessepsian fish (Golani and Ben Tuvia, 1995). The lizard fish, *Saurida undosquamis,* was caught in Israel for the first time in 1952; only three years later 266 tonnes were landed by local trawlers, constituting almost 20 percent of the total trawler catch (Ben-Yami and Glaser, 1974). The dominant fish in the inshore fisheries (trammel-netting and hook-and-lining) are the rabbit fish *Siganus rivulatus* and *S. luridus,* blunt barracuda *Sphyraena chrysotaenia*, and Erythrean jack, *Alepes djedaba*. The above species, together with *Sillago sihama* and *Scomeromorus commerson*, are common in purse-seine landings.

The annual catch of the lizardfish which reached 400 tonnes in 1960 soon after its arrival declined to 100 tonnes in the mid-1960s, but has increased since then and catch fluctuations are correlated with the catch per unit of effort (CPUE). Catch statistics for mullids do not distinguish between the natives, *Mullus barbatus* and *M. surmuletus* and the alien fish *Upeneus moluccensis* and *U. pori*, but a study of the frequency of the latter in trawl catches conducted in the mid-1980s showed that they formed 87 percent of the mullid catch off the coast of Israel at depth of 20 m, and 50 percent at 55 m, whereas the native mullids are more abundant in deeper waters (Golani and Ben Tuvia, 1995). The percentage of the Erythrean mullids in the total mullid catch has increased steadily; from 30 percent in 1980, 42 percent in 1984, to 47 percent in 1989 (Golani and Ben Tuvia, 1995).
Similarly, the catch statistics of sphyraenids do not separate the Red Sea blunt barracuda from native Mediterranean species *S. sphyraena* and *S viridensis*. However, the examination of the landed catch showed that the lessepsian barracuda had outnumbered the native sphyraenids in inshore trawl and purse-seine catches (Grofit, 1987).

Golani (2006) reported the Indian shad, *Decapterus russelii,* from the Israeli coast. If this fish successfully colonizes, it may become one of the commercial fish species in the region.

Lebanon

In southern Lebanon, lessepsian fish species constituted 37 percent in the weight of the total landings of the artisanal fishery (Carpentieri *et al*., 2008). In Lebanon, Spanish mackerel *S. commerson* has become abundant in recent years and this species is exploited by large mesh size gillnet. Several alien fishes have now become common in the local markets, characterizing the fish community of the southern Lebanese coast as a mixed Mediterranean-Red Sea composition and even exported to the Gulf countries.

Libyan Arab Jamahiriya

Shakman and Kinzelbach (2007) mentioned six lessepsian fish species from the Libyan Arab Jamahiriya and more than 37 percent of all lessepsian species have become commercially valuable, especially rabbit fish (*Siganus* spp.) on the Libyan coasts. These species are now found regularly in the Libyan catch. Ten species (62.5 percent), however, are characterized as having no commercial value.

Malta

Sciberras and Schembri (2007) reported 13 fish species. Until recently, no alien species that has established itself in the wild in Maltese waters has been commercially exploited in Malta. However, recently, a small number of *Siganus luridus* appeared in oneof the local fish markets. This species is not targetted but if caught it is offered for sale by individual fishers (pers.com.P.Schembri).

Syrian Arab Republic

Saad (2005) recorded 37 lessepsian fish species from the Syrian Arab Republic which represents 16.5 percent of the total number of bony fish species recorded in the Syrian Arab Republic marine water. However, no commercial catch data from Syrian Arab Republic has been reported for the alien fish species. In Lattikia Harbour, some alien fish species, such as *U. mullucensis* and *U. pori,* were sold in 2007 and 2008 (unpublished data, B. Öztürk).

Tunisia

Rim-Ktari (2008) reported a total of 22 alien fish species from the Tunisian waters and ten of them have commercial importance. Among alien fish known in Tunisia, a few species are observed occasionally in the markets such as *Stephanolepis diaspros*, *Siganus luridus*, *Scomberomorus Commerson* (in large quantities in summer 2009). *Solea senegalensis* is observed in the northern markets. Therefore, it represents 25 percent of Soleidae caught in Bizerte (Lake Ichkeul) (Chaouachi and Ben Hassine, 1998). However, there is no statistical data available.

Turkey

Gücü and Bingel (1994a) summarized that there is no specific catch statistics to evaluate the contribution of the Red Sea species in total landing. However, their importance in the total demersal fish biomass is 62 percent in the Gulf of Iskenderun, 34 percent in Mersin Bay and 27 percent in the coastal strip between Incekum and Anamur. Torcu and Mater (2000) reported that *Upeneus moluccensis* and *Saurida undosquamis* have economical values in the eastern Mediterranean trawl fisheries. Can and Demirci (2003) reported that the lizard fish *Saurida* spp. had provided approximately 50 percent of the total economic catch in Iskenderun Bay. Çiçek and Avşar (2003) reported that 17 species were lessepsian among 90 fish species collected by trawl samplings during 2002–2003 in the northeastern Mediterranean Sea. They found that the CPUE for lessepsian fish ranged from 3.39 kg/h in November to 11.73 kg/h in September 2002, and its mean value was calculated as 5.28 ± 3.32 kg/h, most of the lessepsian biomass was obtained the near shore, which is located in 0–20 m depth ranges, the number of lessepsian fish species constituted 18.9 percent of total number of fish species, while 26.66 percent of total biomass was shared by lessepsian fishes. Among them the most abundant lessepsian fish was *S.undosquamis* with a value of 47.16 percent, followed by *Upeneus pori* (29.92 percent), and *Leiognathus kluzengeri* (13.25 percent). Başusta and Erdem (2000) found 22 Indo-Pacific origin fish in the Iskenderun Bay, which is one of the important fishing grounds for Turkey in the eastern Mediterranean Sea. Ismen (2002) stated that in the eastern Mediterranean 98 percent of the total biomass of *U. pori* was trawled in less than 50 m deep water and its market increased in the recent years.

Lessepsian fishes are not only demersal fish anymore, but they include pelagic fishes in the eastern Mediterranean Sea as well. Yilmaz and Hossucu (2003) reported that 360 tonnes of the round herring, *Etrumeus teres,* has been caught in Antalya Bay, according to the unofficial fish market record in Turkey. Yesilcimen and Kusat (2007) reported that the lessepsian fish *S. undosquamis* is one of the commercial fish species in Antalya Bay in Turkey. Yilmaz and Hossucu (2007) compared length-weight relationship and relative condition factor of lessepsian *S. undosquamis* and native *S. saurus* and found that environmental condtions are suitable for both species in Antalya Bay.

Özgür-Özbek *et al*. (2010) reported that the abundance and biomass of the 18 exotic fish species caught during the bottom trawl survey carried out in the Gulf of Antalya in the summer period of 2009. Among 76 teleost species identified, alien species constituted 11.6 percent of the average abundance and 12.08 percent of the average biomass of the teleosteans.*Siganus luridus, S. rivulatus,H.far,E.teres,S.undosquamis,S.commerson,U.moluccensis,U.pori,S.chrysotaenia* and *N. randalli* mostly have commercial value mainly in İskenderun. Besides, because *Lagocephalus* spp. are venomous and do not have commercial value, they are discarded.

Beside the above mentioned countries, in Italy, Croatia, Montenegro, some lessepsian fish species are found but caught only as by-catch and have no market value so far.

A success story of a lessepsian fish: the narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacepede, 1800)

Among the alien fish species, the narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacepede, 1800) is an epipelagic, neritic species, known to undertake lengthy coastal migrations (Collette and Nauen, 1983). This species entered the Mediterranean where it was recorded in Palestine in 1935 (Hornell, 1935). In the following years the species was found in Lebanon (George and Athanassiou, 1965), Turkey (since 1981, in Gücü *et al*., 1994), and Aegean Sea (Buhan *et al*., 1997; Golani *et al*., 2002). At present, fishery statistics show commercial quantities in Israel, Lebanon, Egypt and Algeria. Commercial quantities are reported also for the Libyan Arab Jamahiriya (Shakman and Kinzelbach, 2007) and a few specimens have been also recorded in Sicily. The maximum length in the Mediterranean, 113 cm FL, was recorded in Turkish waters.

The only information existing in the Mediterranean was reported by Ogretmen *et al*. (2005) in the Turkish waters. According to this information, the minimum, maximum and mean values of TL and TW were 520 mm, 870 mm, 618 mm, and 1 050 g, 3 300 g, 1 553 g, respectively in Gulluk Bay and Gokova Bay (South Aegean Sea) in November and December 1994. One large specimen, with a FL of 113 cm, was collected in Gulluk Bay.

Among all Mediterranean countries, only three countries declared the catch of this species (Algeria, Egypt, and Israel; Figure 23). The largest catch has been declared by Algeria (499 tonnes) followed by Egypt (309 tonnes). Israel has not declared any catch since 1992. The biggest catch in recent years was reported by Egypt. New unpublished information from Lebanon gives a rough estimate on the catch of this species, as about 30 tonnes in 2007 (Di Natale *et al*., 2009).

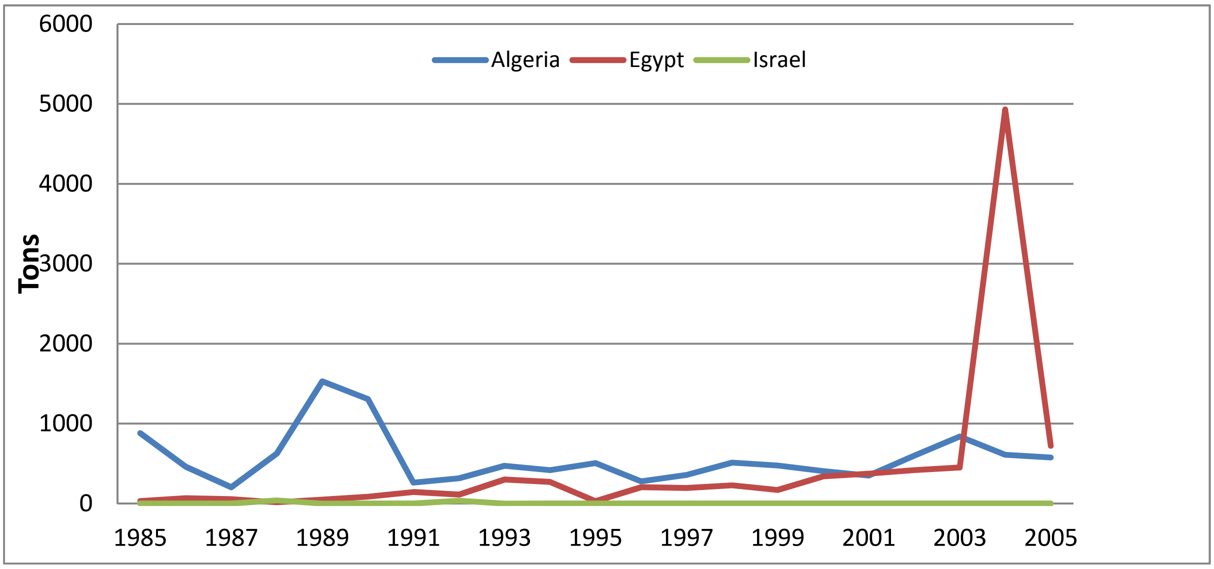

Figure 23 – Catch of the narrow-barred Spanish mackerel from 1985 to 2005 for Algeria, Egypt and Israel

3.3.3 Evaluation of lessepsian crustaceans catch

Doğan *et al*. (2007a) reported that the following crustaceans have a commercial importance in the Turkish Aegean and Mediteranean Seas: *Fenneropenaeus merguiensis, Marsupenaeus japonicus, Melicertus hathor, Metapenaeus monoceros, Metapenaeus stebbingi, Penaeus semisulcatus, Callinectes sapidus* and *Portunus pelagicus*. Geldiay and Kocatas (1972) reported that in the

Iskenderun Bay, *Penaeus kerathurus,* was substantially caught by fishers but it had been replaced by *M japonicus.* Similarly the blue crab is common in Turkey, Greece, Syrian Arab Republic, Lebanon, Israel and Egypt. Off the southeastern coast of Turkey, the alien shrimps, *M. japonicus* and *P. semisulcatus,* are the most important species in the landings (Duruer *et al*., 2008). Lessepsian penaeid shrimps make up most of the shrimp catches along the southeastern Levantine coasts. The lessepsian shrimps, in particular *M. japonicus*, *M. monoceros* and *P. semisulcatus*, are highly prized (Galil, 2007b). Among crustaceans *M. japonicus* is commercially exploited also in Lebanon (Carpentieri *et al*., 2008). The manthis shrimp, *Erugosquilla massavensis*, has commercial importance in Turkey. Blue crab, *Callinectes sapidus,* has an important market value in Turkey; 22 tonnes were caught in 2007 and 17 tonnes in 2008 between Antalya and Iskenderun Gulf. Hassan *et al*. (2008) reported 15 lessepsian decapod crustacean species and their commercial importance in Syria.

Chaouachi *et al*. (1998) found out that *M. monoceros* had a rapid expansion and may be a threat for *Metapenaeus kerathurus* fisheries in the Gulf of Gabes in Tunisia. Abdellah *et al*. (2003) reported that Lessepisan crustacean, *M. monocerus,* is well adapted to the Gulf of Gabes. *M. monoceros* could adapt to climatic and environmental conditions in the Gulf of Gabes where it reproduces since 1993. It has been caught in the Gulf of Gabes since 1994 with the autochthonous shrimp *Penaeus kerathurus* but with some significant fluctuation from one year to another (Ben Abdallah *et al*., 2003). In 1994–1998, after its appearance in the Gulf, the annual production of this shrimp was lower, not reaching 300 tonnes. In 2000, it reached the maximum of 2 484 tonnes, then in 2001–2002, dropped again. In 2003, it again increased to1 829 tonnes.

The crab, *Portunus pelagicus,* and shrimps *Penaeus japonicus, P. monoceros* have been caught commercially for many years in Egypt. Facia *et al*. (2009) reported that a single individual of red king crab, *Paralithodes camtschaticus,* a boreal species, was found in the Ionian Sea and the most likely way of introduction was ballast water. This species also has a commercial potential in the future.

Most commercialized alien crustacean species are listed in Table 3.3. A total 9 species are sold in the markets. Market for alien crustaceans is new but there is a growing trend like some alien fish species, mostly in the eastern Mediterranean Sea.

Table 3.3 – Commercialized alien crustacean species in the Mediterranean Sea

Species name	Country
Callinectes sapidus	Turkey, Greece, Lebanon, Syrian Arab Republic, Egypt
Portunus pelagicus	Egypt, Lebanon,Turkey, Syrian Arab Republic
Marsupenaeus japonicus	Egypt, Israel, Turkey, Lebanon, Syrian Arab Republic
Trachysalambria palaestinensis	Turkey, Lebanon, Tunisia, Syrian Arab Republic
Metapenaeus monoceros	Egypt, Israel, Turkey, Tunisia, Syrian Arab Republic
Erugosquilla massavensis	Turkey
Metapenaeus stebbingi	Israel, Turkey
Penaeus semiculcatus	Turkey, Israel, Syrian Arab Republic
Melicertus hathor	Turkey

3.3.4 Evaluation of lessepsian molluscs catch

Not much data on commercial mollusc species is available. However, Salman, (2002) and Lefkaditou *et al*. (2009) reported that the big fin reef squid, *Sepioteuthis lessoniana,* has a commercial value in

Turkey and Greece. Tzomos *et al*. (2010) reported 38 mollusc species from Cyprus and *Sepioteuthis lessoniana,* a lessepsian cephalopod species, is well established and found in Cypriot fish markets.

Besides the conch, *Strombus persicus*, however, is served in seafood restaurants in Israel and Greece. *Pinctata radiata, Strombus persicus* and *Crasostrea gigas* have minor commercial value in Greece (Katsanevakis *et al*., 2008). In Tunisia, *P. radiata* occurs occasionally with bottom trawls and dredges. It is comsumed in Tunisia, mainly in Kerkennah and Djerba. The market is growing as well.

3.3.5 Lessepsian marine mammal species

Only one marine mammal species can be considered in the Eastern Mediterranean as a lessepsian migrant, which is a cetacean species, the rough toothed dolphin, *Steno bredanensis*. This species is known to distribute widely in the tropical and temperate waters around the world, generally inhabiting deep oceanic waters (IUCN, 2009). Although it is known to occur only as visitors in the Mediterranean Sea, either through the Strait of Gibraltar from the Atlantic or through the Suez Canal from the Red Sea, multiple sightings have been reported from the Mediterranean coast of Israel (Reeves and Notarbartolo Di Sciara, 2006), which implies that these dolphins are migrating from the Red Sea. Since mammals are slow reporducers compared to other organisms, their population may not increase much compared to other lessepsian migrants. However, some recent observations (Tim Lewis, Pers.comm.) confirm the presense of a calf, which implies that they are in the process of establishing a self-sustainable population in the Mediterranean Sea.

4. HARMFUL ALIEN SPECIES AND IMPACTS

4.1 Poisonous alien fish species

The issue concerning the venomous fish species is a significant one and it needs to be deeply investigated in many aspects such as public health and damage to fishers. Poisonous alien fish species are known from the eastern Mediterranean countries (Table 4.1), such as Greece (Kasapidis *et al*., 2007), Israel (Golani, 1996), Syrian Arab Republic (Saad, 2005), and Turkey (Akyol *et al*, 2005; Bilecenoğlu, 2003; Bilecenoğlu *et al*., 2006). Tetraodontid species (pufferfish), namely *Lagocephalus sceleratus*, *Lagocephalus spadiceus, Lagocephalus suezensis*, *Torquigener flavimaculosus*, and *Plotosus lineatus* invaded the Mediterranean Sea and caused severe problems for local people by poisoning the internal organs and flesh. Galil (2007b) reported that silverstripe blaasop (*L. scelaratus*) and the striped catfish (*P. lineatus*) pose severe health hazards in Israel. Zaki (2004) also reported eight fatalities in Suez City from the tetrodoxin poisoning by eating the striped catfish. The population explosion of a pufferfish, *L. scleratus*, in the last few years in Cyprus waters is remarkable. *L. spadiceus* is found only in small numbers.

For venomous fish species, public awareness campaigns through posters or leaflets have been started in some countries, such as Turkey, Greece and Israel.

Table 4.1 – Distribution of poisonous fish species in the Eastern Mediterranean countries

Species	Cyprus	Egypt	Greece	Lebanon	Libyan Arab Jamahiriya	Israel	Syrian Arab Republic	Turkey
Lagocephalus suezensis	+	+	+	+	–	+	+	+
Lagocephalus spadiceus	+	–	+	+	–	+	+	+
Lagocephalus sceleratus	+	+	+	+	+	+	+	+
Torquigener flavimaglosus	–	–	+	–	–	+	–	+
Plotosus lineatus	–	+	–	–	–	+	–	–

4.2 Harmful alien jellyfish and its impacts

In recent years, more alien jellyfish species have been observed in several coasts of the Mediterranean Sea. Jellyfish expansion caused severe anxiety among fishers and tourists in many countries. Even some of the jellyfish species are not harmul and native to the Mediterranean Sea, their distribution has been enlarged. For example, *C.hysoscella* has never made big blooms in the northern Aegean, but in recent years the situation has changed.

Jellyfish of Indo-Pacific origin like *Rhopilema nomadica* and *Cassiopea andromeda* established themselves in the eastern Mediterranean Sea and cause damage to local economies to some extent when entangled infishing nets or stranded on beaches, frightening visitors.

Upside-down jellyfish, *Cassiopea andromeda,* is frequently encountered in the eastern Mediterranean Sea (Bilecenoğlu, 2002). Özgür and Öztürk (2008) reported that the distribution of this stinging species extended its distribution from south to further north, up to Fethiye on the Turkish

Mediterranean coast. Schembri *et al.* (2010) reported that *C. andromeda* was observed off the Maltese islands in the Central Mediterranean Sea.

4.3 Impacts on fisheries

Mostly in the eastern Mediterranean Sea, several alien species cause damages to fisheries. *Caulerpa taxifolia* cause considerable fouling on fishing nets. *Calinectes sapidus* also damages nets with entangling and cutting. In Turkey and Cyprus, fishers complain about *L. scelaratus* because they cut hooks of longlines and bite off the captured fish in the nets or on the lines, which has a negative economical impact on fishers of Israel and blocked gill-netting for several weeks (Spanier and Galil, 1991). Kideys and Gücü (1995) and Avşar (1999) reported that the proliferation of *R. nomadica* off the eastern Mediterranean coast of Turkey has a potential risk to human health, tourism and fisheries. In August 1995, many swimmers were stung and sought medical treatment. Local fishers claimed that the catch from the gill net fisheries decreased and that the jellyfish entangled in their nets were a major nuisance. In Iskenderun, due to mass jellyfish blooms, the fish farmers could not lift their nets to the surface when they wanted to take the fish from the cages. *R. nomadica* do not move actively, thus penetrates the Levant Sea like other lessepsian species' spread pattern, following the Levantine current system. Avşar (1999) also reported that firstly they reached Lebanon and Syrian Arab Republic, then the Turkish eastern Mediterranean coasts, clinging to fishing nets and causing economic damages.

Impacts of the alien species should be considered also for the fisheries management, because the traditional mesh size of the fishing nets may need to be changed due to new commercial species mostly in the eastern Mediterranean countries. This involves extra costs for fishers or fishing communities, which were difficult for traditional fishers who have limited financial source. Another issue is that fish inspectors can easily confuse native and alien fishes when they examine control the size limitation of the fish on the deck of fishing boats, e.g. native mullet *Mullus barbatus*, *Mullus surmelatus* vs *U. moluccensis.* Some of the Turkish fishers complain about discards of alien fish species such as *Lagocephalus spp* and *F. commersonii* which have no commercial value in the Mediterranean part of Turkey.

Some toxic algae give damage to fisheries due to contaminating filter-feeding shellfish species. In some areas they cause fisheries to be closed or partially closed. Consumption of the contaminated shellfish can be dangerous for human health.

4.4 Impacts on tourism, human health and other socio-economic activities

Alien jellyfish species are also a threat for tourism. In fact some people had to be hospitalized after having been in contact with these species in the eastern Mediterranean Sea countries. Jellyfish can be dangerous in case of allergy. The most important factor is the amount of poison put into blood. Death rarely occurs, but minor effects can be observed. These can be itching, severe poisoning, muscle cramps, abdominal rigidity, decrease in touch sensation, nausea, vomiting, serious back pain, speech difficulties, involuntary muscle contractions and breathing difficulty (Mariottini *et al*., 2008). Certainly venomous jellyfish have a negative impact on tourism (Spanier and Galil, 1991). Table 4.3 summarizes the impacts of alien species on tourism and human health either by stinging or by being eaten. In 2009, several blooms of *Rhopilema nomadica* were reported and some people were hospitalized in Antalya, Mersin, Iskenderun and Adana Provinces in the Turkish part of the Mediterranean Sea (Öztürk and İşinibilir, 2010). *R. nomadica* is also reported from Greece (Frangou-Siokou *et al*., 2006).

Table 4.3 – Harmful alien species and impacts on tourism and human health in the Mediterranean Sea

Alien species	Target groups	Results
R. nomadica, C.andromeda Phyllorhiza punctata	Tourists, fishers, divers, sailors, yatchman	Injury, hospitalized
Macrorhynchia phillipina	Tourists, divers, fishers	Injury, hospitalized
Diadoma setosum	Tourists, divers, fishers	Injury
Lagocephalus spp.	General public	Hospitalized
Torquigener flavimaculosus	General public	Hospitalized
Plotosus lineatus	General public	Hospitalized

White stinger, Hydrozoa, Cnidaria, *Macrorhynchia philippina*, is a common circumtropical species (Watson, 2002). This lessepsian migrant is found along the coast of Lebanon in 0–40 depths (Bitar and Bitar-Kouli, 1995; Zibrowius and Bitar, 2003) and is abundant near Mersin and Iskenderun Çınar *et al.*, (2006). Colonies of 10–15 cm height were frequently found at 1–2 m depth, on rocks. They are distributed in Turkey, Cyprus, Syrian Arab Republic, Lebanon and Israel. Dense populations of this species in shallow water may be a risk for tourism as it causes a painful and itching sting. White stinger is harmful for bathers, skin divers and sponge divers.

Alien echinoderm species, reported by Yokeş and Galil (2006b), the needle-spined urchin, *Diadema setosum,* is a threat for bathers due to its spines. This species is found in shallow water. Kocak *et al.* (1999) and Ergen *et al*. (2002) reported that fouling serpulid worms which are known as nuisance in ports and harbours in the Mediterranean Sea, as they cause economic losses.

Finally, there are economical damages caused by alien species, i.e. clogging the waters pipes in Turkey. Galil (2008b) mentioned that jellyfish-blocked water intake pipes poses a threat to the cooling systems of port-bound vessels and coastal power plants. In summer 2001, Israel Electric removed tonnes of jellyfish from its seawater intake pipes at its two largest power plants, at the estimated costs of USD 50 000. Toxic algae have severe impacts on tourism and recreation.

4.5 Impacts on biodiversity

Alien species increased regional marine biodiversity in both the Black and Mediterranean Seas. Alien species, however, may alter the evolutionary pathway of native species by competitive exclusion, niche displacement, predation and other ecological and genetic mechanisms (Mooney and Cleland, 2001). Furthermore, most ecological changes take place in the first 50 m depth in the eastern Mediterranean Sea. Bitar *et al*. (2007) point out that due to Red Sea alien species and tropicalization in the Mediterranean, particularly infralittoral (30–50 m) zone and to a lesser degree in circalittoral, some important changes occur in the Levantine basin in term of species distribution.

Alien organisms may reproduce with native species, altering the gene pool (Occhipinti-Ambrogi, 2001). In case of the Levantine Basin, rapid reduction in abundance of the herbivorous sparid *Salpa salpa*, a very common species in the rest of the Mediterranean, has been started by the settlement of a competitor, *Siganus rivulatus,* a lessepsian migrant has been recorded in the Levantine Basin since the early 1990s (Bariche *et al*., 2004). Niche displacement is also reported when Red Sea competitors of red mullet, *Mullus barbatus,* and hake, *Merluccius merluccius,* were displaced in deeper waters by their competitors (Por, 1978).

Harmelin-Vivien *et al*. (2005) reported that lessepsian migrants represent 13percent of the species richness and 19 percent of the total abundance of individuals along rocky coasts in Lebanon. Furthermore, they reported that lessepsian fish species occupy either similar ecological niches in the

Red Sea and in the Levantine Basin (such as seen in the cases of *P.vanicolensis, S. rubrum*) or enlarge their depth distribution towards deeper water in their new environment (such as seen in the cases of *S. luridus* and *S. rivulatus). S.luridus* and *S.rivulatus* extend their geographic range and both established large shoals with great numbers mostly along the Levantine coast. Bitar *et al*. (2007) reported that some Red Sea alien species and thermophilic species have successfully colonized the coast of the Levantine Basin and formed a particular fasies in the infralittoral biocenosis.

Trophic relationship among alien and native species is also an important issue if the ecosystem itself probably finds its balance at a new stage in the Mediterranean Sea. There are already some examples. Bariche (2006) found that *Siganus luridus* occasionally ingests the toxic exotic macrophyte *Caulerpa racemosa.* Some parasite species are also found in the Mediterranean Sea. Fishes like *S. rivulatus, S.luridus*, *Aphanius dispar* and *Pranesus pinguis* continue to host in the Mediterranean Sea their monogenean ectoparasites of erythrean origin (Paperna, 1972). Shakmar *et al*. (2009) recorded two native ectoparasitic isopods, cymothid species from the *S. lurides* and *S. rivulatus* from the Libyan water. This parasite species should be monitored for human health and biodiversity.

Bardamaskos *et al*. (2009) reported that among lessepsian fish migrants, *Siganus luridus* has established a permanent population in the south – east Ionian Sea, Greece. Crocetta *et al*. (2009) reported that two of lessepsian mollusc species, *Cerithium scabridum* and *Fulvia fragilis*, are well established along the Italian coasts, where new large and stable populations have been formed.

Besides the harmful effects of alien species on human activities mentioned above, the most important impact is that made on the local or native biodiversity. In recent year *Rhizostoma pulma* has been replaced with *Rhopilema nomadica* in the eastern Mediterranean Sea (Boudouresque, 1999). Swarm of *Rhopilema* may have also contributed to the population increase of the commercially important carangid fish *Alepes djeddaba*, whose juveniles shelter among the jellyfish tentacles (Galil *et al*., 1990).

Galil *et al*. (2009a) mentioned that *Phyllorhiza punctata* reappeared along the Israel coast. *M. leidyi* is reported in several parts of the Mediterranean Sea from Turkey to Italy (Uysal and Mutlu 1993; Kideys and Niermann, 1994; Shiganova *et al*., 2001; Boero *et al*., 2008; Galil *et al*., 2009b; Shiganova and Malej, 2009). This species is also known as one of the'100 world's worst' invaders by Lowe *et al*. (2000). While this species was the cause of the hypoxia and the collapse of the fisheries in the Black Sea fisheries, some of the major questions are how *Mnemiopsis leidyi* will impact on the Mediterranean fisheries, will the same thing happen in the Mediterranean as in the Black Sea or to what extent will it have an impact on or threat fisheries in the Mediterranean Sea.

Since both *Mnemiopsis* and anchovies inhabit mainly the upper mixed layer and the peak of spawning of the anchovy and ctenophore coincide in time and space, both are correlated with high water temperatures and both consume mainly the same prey organisms. This phenomenon is also important for the Mediterranean Sea. Some of the alien combjelly like *M. leidyi* also spread to the northern Aegean Sea (Isinibilir and Tarkan, 2002), further to the Adriatic Sea and up to the Sicily Island (Faris, 2009).

While *M. leidyi* and *B. ovata* invaded up to the Central Mediterranean Sea, it should be reminded that since 1992 this species has been found in the eastern Mediterranean Sea (Uysal and Mutlu, 1993) and has not have any major impact on pelagic fisheries, such as anchovy, horse mackerel and sardine fisheries, at least in the Turkish part of the Aegean and Mediterranean coasts so far. In addition, the Mediterranean ecosystem is totally different from the Black Sea in terms of the number of species, biodiversity, competition, current systems, etc. Moreover, there are combjelly such as *Beroe forskalii*, *B. cucumis* and *Balinopsis vitrea* which are native to the Mediterranean Sea and predators of *M. leidyi.* Besides, *Beroe ovata* is also a competitor for *M. leidyi* in the Mediterranean Sea and is found in several Mediterranean countries. Nevertheless, the main reason of the jellyfish invasion is more substantial and it seems that a shifting process, from a fish to a jellyfish in the Mediterranean Sea, is evolving. Most of the fish suffer overfishing in the Mediterranean and the alien species can easily find empty niches to establish themselves in the new environment. Certainly more researches are needed to better understand impacts of *M. leidyi* on fisheries, local communities and Mediterranean biota. Besides, *M. leidyi* and *B. ovata* are also reported from the eastern Mediterranean Sea and the Aegean Sea (Shiganova *et al*., 2007).

Galil (2007b) reported that grouper feeds mainly on siganids in the Israeli waters. Popper and Gunderman (1975) reported that *Fistularia commersonii* feeds on fry of siganids. An alien coral, not lessepsian, *Oculina patagonica*, was reported in Spain and later in the eastern Mediterranean Sea. Por (2009) reported that the tropical enrichment of the Mediterranean Sea is significant and *O. patagonica* is probably of Atlantic origin and has taken advantage of the warming sea. Meric *et al*. (2002) reported that proliferation of the foraminifer *Amphistegina* spp, lessepsian foraminifer, change habitat type since the density becomes high around Antalya in the Turkish coast.
Rilov *et al*. (2004) mentioned that a massive buildup of Red Sea mussel, *Brachidontes pharaonis*, along the Israeli coast to a recent shift in habitat conditions due to the receding biogenic rim of vermitid platforms that allowed more effective washing, reduced sediment accumulation and perennial algae cover, making those platforms more suitable for mussels. This species has also spread to Sicily and established dense populations (Sara *et al*., 2006). Çınar (2006) reported 16 serpulid species, nine of which are considered to be alien species. Serpulids also clog seawater intake pipes of industrial cooling system.

Demir (1977) reported dense population of the *Anadara demiri* in Izmir Bay. Doğan *et al*. (2007b) reported that the Red Sea mussel does not form dense populations in the Aegean Sea because the water of the Aegean Sea is less saline and colder. Occhipinti-Ambrogi (2002) observed that *Anadara inaequivalvis* replaced native *Cerastoderma glaucum* in the northern Adriatic Sea. Streftaris and Zenetos (2006) described alien species according to their impacts on socio-economic conditions (fisheries/aquaculture, health and sanitation, infrastructure and building). They documented 43 species. Çınar *et al*. (2006) reported that an alien tunicate, *Phallusia nigra*, was found in Alanya harbour may cause fouling and economic loss if they foul ship hulls or pipes for water intake. Some ship-transported species gain economic importance like the swimming (blue) crab, *Callinectes sapidus*. Besides, some species like the serpulid worms cause nuisance in ports and marinas. *Halophila stipulacea* is the only succesful colonizer from the Red Sea among sea grasses in the eastern Mediterranean Sea and its impacts is not known clearly.

Özcan *et al*. (2008) reported that native mantis shrimp, *Squilla manthis*, has been displaced by an alien mantis species, *Erugosquilla massavensis,* along the Levantine coast of Turkey. *Rachysalambria palaestinensis* is an alien prawn species in Tunisia and displaced *P. kerathurus* in the Gulf of Gabes (Jarboui and Ghorbel, 1995). *Synaptula reciprocans* was reported in several regions, such as in the Turkish coast of the Mediterreanean and up to Ayvalik in northern Aegean Sea. The same species was also reported from Greek coasts (Antoniadou and Vafidis, 2009), Israel (Galil, 2007a).

Ruis *et al*. (2008) indicated that the ascidian *Microcosmus squamiger* is considered to be native to Australia, having been spread worldwide via transoceanic vessels. It has successfully invaded artificial and natural habitats where it has become a pest and there is a need to control this species, as it outcompetes the local biota and is an economic threat. Similarly, Shenkar and Loya (2009) reported seven non-indigenous ascidian species along the Mediterranean coast of Israel and indicated that the negative impact of non-indigenous ascidians on local species and habitats raises the necessity for long-term studies and monitoring of this group.

Sea water temperature rise due to climate change is likely to have a significant influence on the lessepsian alien species distribution. It is known that the Mediterranean Sea is in a tropicalization process and that an extension of the warm water species to the western part has already occurred. Some Atlantic originated species also migrated to the Mediterranean Sea with the Atlantic influx. There has been no extinction or disappearance of local species in the Black and Mediterranean Seas due to alien invasive species so far, but displacement of native species is expected more in the near future. In addition, Galil and Zenetos (2002) reported that if global warming was to affect the

Mediterranean sea – level temperature, then tropical invasive species would gain a distinct advantage over the native fauna.

The majority of the marine flora and fauna of the Mediterranean Sea belong to the Atlanto-Mediterranean Province. In recent period, however, numerous Indo-Pacific originated species attribute to this sea certain tropical and subtropical characteristics. This peculiarity is clearly seen particularly in the Levantine Basin. Some of the alien species may thrive in their new environment by displacing the native species. The number of alien species entering the Mediterranean will probably increase in the future and the gene pool of the recipient regions will also change. However, extinction of native marine species due to the influence of exotic invaders has not been identified yet in both basins.

4.6 Intentionally and unintentionally introduced alien species in the mediterranean sea and their impacts

Aquaculture is one of the important reasons for intentional introduction of alien species. In the Mediterranean Sea, aquaculture is one of the growing sectors because of the high demand of seafood and it is expected that this demand will increase in future. However, in bad weather conditions, some of the seabass and seabream cages broke and a lot of fish escaped from the cages in winter in Greece, Israel and Cyprus (UNEP/MAP/MEDPOL, 2004). Also in Turkey, mostly in the Aegean Sea, several fish cages broke and several tonnes of fish escaped from the cages. Genetic impacts of these escaped or released fish is a concern mostly for the genetic hybridization.

In the Mediterranean Sea, only two commercial invertebrate species, namely *Crasostrea gigas* and *Ruditapes philippinarum,* have been introduced for aquaculture purpose between the 1960s and 1970s. Catching of *R. philippinarum* in the Venice Lagoon has become a problem due to its disturbance to the benthic community. Some problems of disease occur with Japanese oyster, *C. gigas,* which was introduced to France. Intentional introduction may cause some problems and become a risk for human health and marine biodiversity. Some species like pearl oyster, *Pinctada radiata,* were introduced intentionally to Greece for aquaculture purposes (Serbetis, 1963). Japanese Oyster*, C. gigas*, is native of the Northwest Pacific. It is introduced gradually in the Medterranean through aquaculture. It was introduced in Tunisia in Lake Ichkeul for aquaculture purposes (Madhioub Zaouali, 1988). Alpbaz *et al*. (1991) reported successful *Crassostrea gigas* aquaculture in İzmir, Turkey. Munoz –Izquierdo (2009) reported that ten alien tunicates have become established and colonized some sectors of the Mediterranean since 1958. They entered the Mediterranean Sea through the Strait of Gibraltar and Suez Canal or introduced by shellfish culture.

Some accidental introduction has been observed with some species like *Caulerpa taxifolia* which escaped from aquaria (Jousson *et al*., 1998). This species was introduced in 1984. It was observed for the first time in Monaco and dispersed later in Spain, France, Italy and Croatia, to be reported finally in Turkey, even different strain in the Gulf of Iskenderun (Çevik *et al*., 2007). Impacts of *C. taxifolia* are the impoverishment of the Mediterranean algal communities which may reach 25–55percent; most of autochthonous algae tend to disappear dramatically (Verlaque and Fritayre, 1994). The number of polychaeta and especially amphipod species decreased in *C. taxifolia* meadows and, on contrary, the species diversity of molluscs increased. The population of sea urchins, fish, amphipods and polychaetes are also affected (Boudouresque *et al*., 1995). Francour *et al*. (1995) reported that *C. taxifolia* meadows seem to be a favorable environment for the recruitment of some species of Labriadae (*Coris julis, Symphodus ocellatus*), Sparidae (*Diplodus annularis*) and Serranidae (*Serranus caprilla*) in fall. Meinesz and Boudouresque (1996) indicated that *C. taxifolia* is a major threat for the coastal ecosystem of the Mediterranean Sea. Later, Meinesz (1997) reported that *C. taxifolia* forming a dense cover of more then 1 ha in 5 years (1984–89) and since 1987, it has spread by vegetative reproduction due to anchors and fishing activities (nets, trawls). He reported also that thirteen years after its first observation in the Mediterranean Sea, 3 000 ha has been more or less affected.

Besides *C. taxifolia, C. racemosa* is also important in terms of dispersion. This species has been already colonized in several Mediterranean countries, such as France, Italy, Spain, Greece, Albania, Malta, Croatia, Montenegro, Turkey, Cyprus, Lebanon, Libyan Arab Jamahiriya, and Syrian Arab Republic (Cirik and Öztürk, 1991; Verlaque *et al*., 2003; Macic and Kscelan, 2007; Lakkis and Novel-Lakkis, 2001). Akcali and Cirik (2007) reported that *C. racemosa* and *Halophia stipulacea* affect the biota in the Turkish coasts.

Sargassum muticum found in several areas of Spain, in some lagoons of France like Thau, and in Venice, inhibits the recruitment and growth of other algae species. *Laminaria japonica Asparagopsis armada, Asparagopsis taxiformis* and *Bonnemaisonia hamifera* also show invasive characteristics in the Mediterranean Sea. *Womersleyella setacea* and *Acrothamnion pressii* are invasive on the Italian coasts and clog up the fishing nets and impact on fishing (Verlaque, 1989). Boudouresque and Ribera (1994) estimated in 2050, between 250 to 1 000 alien marine macroalgae species may be found in the Mediterranean Sea and if this estimation becomes real, indigenous species and alien species will be almost equally represented in the Mediterranean Sea. Verlaque *et al*. (2007) reported that in the 34 Mediterranean coastal lagoons there were 67 exotic macrophyte species and oyster transfer was the most efficient vector for macrophyte introduction into the Mediterranean Sea. At least 30 introduced species were recorded in the Venice Lagoon, many of which have established large populations and have subplanted native species (Occhipinti-Ambrogi, 2000). Impact on the coastal lagoon ecosystems by *Undaria pinnatifida, Desmarestia viridis* and *Anthithamnion nipponicum* were reported. Zibrowius (1979) pointed out that *Pinctata radiate* has been recorded from Toulon and accidental occurrence was observed. Özcan *et al*. (2006) reported that banana prawn escaped or was released from aquaculture facilities in Iskenderun, Turkey.

4.7 Conclusion and recommendations for the Mediterranean sea

Galil (2009) reported that a total of 573 alien marine metazoan species have been identified in the Mediterranean Sea and over the past two decades an average of 10 alien species, new to the Mediterranean, can be recorded annually. However, Por (2009) pointed out thousands of tropical species settled in the Mediterranean Sea during last decade and as a result of congruence between the present climate optimum and the opening the contact with the Indo-Pacific realm through the Suez Canal and a renewed entry through the Gibraltar. Later, he mentioned re-colonization of the Mediterranean by Tethyan descendants, rather than an invasion by harmful alien species as happens elsewhere. The number of alien species in the Mediterranean Sea, therefore, is debatable and there is no consensus yet. For example, Zenetos *et al*. (2005) review alien species and later Zenetos *et al*. (2008) reported 903 alien species from the Mediterranean Sea. Zenetos (2010) disagreed the number of alien species reported by Galil (2009). Zenetos *et al*. (2010) reported a total of 955 alien species known in the Mediterranean, the vast majority of which having being introduced in the Eastern part (718), less in the Western part (328) and Central part (267), and least in the Adriatic (171). Of these, 535 species (56%) are established in at least one area. Aliens have increased the total species richness of the Mediterranean Sea by 5.9%. Species that are classified as invasive or potentially invasive are 134 in the whole of the Mediterranean: 108 are present in the Eastern part, 75 in the Central part, 53 in the Adriatic and 64 in the Western part. The Western Mediterranean hosts most invasive macrophytes. Nevertheless, the number of alien species may be debatable among experts due to many unknown or criptic species for some taxonomic groups, such as bacteria or phyto and zooplankton.

It is expected that more alien species will enter the Mediterranean Sea not only from the Suez Canal but also from the Atlantic Ocean or the Black Sea. Lasram Rais and Mouillot (2009) already reported 62 Atlantic origin alien species in the Mediterranean Sea. As in the other water bodies of the world, the Mediterranean Sea is currently becoming warmer: in the last 30–40 years, the temperature of the western Mediterranean Sea has been rising both in depth (Betroux *et al*., 1990) and at the surface (Diaz Almela *et al*., 2007), which is reflected in the increased presence of thermophilic marine species. Nevertheless, in the Mediterranean Sea, the main inhabiting species is originally from the Atlantic Ocean (Tortonese, 1964) where tropical species are very rare. But the species composition of the Levant Sea has been drastically altered after the opening of the Suez Canal. Bianchi (2007) pointed out that major biogeographicboundary between the western and eastern Mediterranean, the Sicily Strait has been changed.

Molecular approaches, however, may provide additional and precise information about the origin of the alien species and relation of each species, even regional similarity or dissimilarity.The Straits, such as Gibraltar, Sicily, Canakkale (Dardanelles), Istanbul (Bosphorus), Kerch, as well as the Suez Canal and even the Red Sea are transition zones and need studies on speciation and population genetics. Besides, the impact on genetic structure of the lessepsian or introduced species on taxonomically related native species also needs to be investigated. These straits are also hot spots and dispersal points for the alien species as they serve as ecological corridors and need to be monitored.

In the eastern Mediterranean Sea, the dispersion of the alien species to the central Mediterranean Sea or further up north already shows that environmental adaptation is not difficult for these species. Lessepsian aliens are more successful at shallower part and Por (1978) considers that temperature is the most important and single factor for the colonization success of the lessepsian migrants and their success in the intermediate layers at about 20–40 m is attributed again to relatively higher and stable temperature at this isobath.

It seems impossible to stop lessepsian aliens species from the Suez Canal. However, the slowing down of the alien species passage to the Mediterranean Sea should be urgently and deeply studied in terms of biodiversity, human health and to protect natural heritage of the entire Mediterranean and Black Seas. Further modification of the physical structure of the Canal, such as deepening of the Canal, can be one of the serious threats for the Mediterranean and Black Seas biota.

According to the protocol concerning biological diversity in the Mediterranean Sea, contracting parties have to take all appropriate measures to regulate the intentional or accidental introduction of non-indigenous species (Article 13). Besides, the United Nations Environment Programme/Mediterranean Action Plan (UNEP/MAP) in 2003 called and recommended to the parties to give importance to shipping-mediated introductions of non-indigenous species into the Mediterranean.

Close cooperation with the Marine Environment Protection Committee (MEPC) of IMO for the ballast water convention is needed for all Mediterranean countries. Nevertheless, Convention on the Control and Management of Ships Ballast Water and Sediment is a progress to mitigate ballast-transported alien species. For hull-fouling, which is another important factor for the dispersion of the alien biota, there is another convention on the control of harmful anti-fouling systems on ships. According to this convention, the paints including organotin compounds are forbidden and more environmentally friendly coating materials are recommended, such as silicon and others. Non-toxic coating materials, however, are not impeding hull-fouling for some sessile species.

Coordinating of the institutional efforts such as CIESM, RAC/SPA, IUCN, IMO, the Convention on Biological Diversity (CBD), the Intergovernmental Oceanographic Commission (IOC), EU and other organizations in the Black and Mediterranean Seas is essential. Specifically, Exotic species in the Mediterranean (www.ciesm.org/atlas) has been very useful in many ways for identifying and examing the current status of the alien species. Besides, RAC/SPA (2007) published a booklet and a CD for invasive species in the Mediterranean Sea (www.rac-spa.org).

Regulations related to the alien species in the Black and Mediterranean Seas are also of concern by the Marine Strategy Framework Directive (MSFD) and one of the MSFD is non-indigenous species introduced by human activities among eleven descriptors for achieving Good Environmental Status. Abundance and environmental impacts of alien species has particular importance.

Statistics for top ten commercial alien fish species, such as landing and catch amount, must be collected, which can be a target for GFCM for the coming years according to GFCM geographical sub-areas (GSAs). Very limited official fisheries data actually exist for alien species and more information is required. A permenant working group should be established by GFCM to monitor impacts on the fisheries and biodiversity. Trawling, purse seining, dredging, pots, long line, diving, gill nets and beach nets are main fishing techniques for alien species. Moreover, discard issue needs to be studied.

A special early warning system and a database are needed mainly for poisonous fish and other species like jellyfish and hydroids. Even some global, regional or national database exist, such as IMO Globallast, the Global Invasive Species, the FAO Database on Introductions of Aquatic Species, the CIESM Atlas, United States National Marine and Estuarine Invasions Database, Delivering Alien Invasive Species in Europe (DAISIE), etc. these are very useful but not adequate for fishers and local people in general. A regional alarming system is needed for toxic phytoplankton species, in case that they are transferred with ship ballast water to the Mediterranean or Black Sea, to mitigate negative impacts on fish, mussel and oyster farming and human health. Using satellite images may help facilitate this system.Besides,need to cooperate with Intergovermental Oceanographic Commision (IOC) for Harmful Algal Blooms.

Public awareness campaigns and educational materials are important to recognize, identify or disseminate information for alien species' distribution or harm for all stakeholders like fishers, harbour authorities, divers, tour operators, and fisheries cooperatives. Updated information can also be deployed from GFCM website and elsewhere.

Eradication or completely removal of the alien species from the ecosystem is almost impossible but the control or containment may be possible for some species like *Caulerpa taxifolia* or C. *racemosa*.

However, there is no succces story for Caulerpa species even though several initiatives have been developed for eradication of the species to the entire Mediterranean Sea.

To collect new and accurate information on the occurrence of alien species, a reporting and monitoring system is required. In this system, fishers must report to fisheries cooperatives or relavent fisheries authorities whenever they find unusual organisms in their catch. Then, the relevant authorities report to the Ministry in charge of fisheries. GFCM or other international organizations collect these data regularly to update the database. As several initiatives already exist for alien species, GFCM can focus particularly on the fisheries aspects. The riparian countries can benefit from this database in case of incidents related to alien species.

Regarding the introduction and transfer of alien species, some Mediterranean countries already have legislation and guidelines, but the regional enforcement is weak and a regional updated code of practice of the transfer or introduction of alien species is needed.

Marine Protected Areas (MPAs) to impove the conservation of native marine biodiversity, creating more MPAs and their networks in the Mediterranean and Black Seas may be mitigating fast spreading of the alien species.A healthy pristine ecosystem may defend the native fauna and flora of the Mediterranean and Black Seas while stress on marine environment favors the spreading and facilitating of alien species. Therefore key species and key habitats, for example, *Posidonia* meadows, should be protected for maintaining such healthy ecosystems to combat alien species invasion in the Mediterranean Sea.

Alien species have already created considerable new market at least in the eastern Mediterreanean Sea beside the fish production by aquaculture and regular fishing operations and this is considered as beneficial. This demand is growing due to mass tourism mostly during summer months in the eastern Mediterranean Sea.

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APPENDICES

Appendix 1: Alien mollusc species of the Mediterranean Sea (species of Indo-Pacific and Atlantic origin that entered the Mediterranean via the Suez Canal and Gibraltar, respectively)

Species	Origin	Vector	Turkey	Israel	Egypt	Greece	Libya	Cyprus	Lebanon	Syria	Italy	SC	Tunisia	Spain	France	Malta	SL	Portugal	Ionian Sea	Adriatic Sea
Cellana rota (Gmelin, 1791)	Red Sea, Indian Ocean	Suez Canal System	–	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Haliotis pustulata cruenta (Reeve, 1846)	Red Sea	Suez Canal System	–	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Diodora ruppellii (Sowerby, 1834)	Indo-Pacific, Red Sea	Suez Canal System	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Smaragdia souverbiana (Montrouzier, 1863)	Indo-Pacific, Red Sea	?	+	–	–	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Nerita sanguinolenta (Menke, 1829)	Red Sea	Suez Canal System	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Trochus erithraeus (Brocchi, 1821)	Red Sea	Suez Canal System	+	+	–	+	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Pseudominolia nedyma (Melvill, 1897)	Red Sea, Indian Ocean	Suez Canal System	+	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Stomatella impertusa (Burrow, 1815)	Indo-Pacific, Red Sea	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cerithium nesioticum (Pilsbry and Vanatta, 1906)	Red Sea, Indo-Pacific	Suez Canal System	–	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Cerithium scabridum (Philippi, 1848)	Red Sea, Indian Ocean	Suez Canal System; Ship	+	+	+	–	–	+	+	+	+	+	+	–	–	–	–	–	–	–
Cerithium egenum (Gould, 1849)	Indo-Pacific, Red Sea	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Rhinoclavis kochi (Philippi, 1848)	Indo-Pacific, Red Sea	Suez Canal System	+	+	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Clypeomorus bifasciatus (Sowerby G.B. II, 1855)	Red Sea, Indo-Pacific	Suez Canal System	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Angiola punctostriata (Smith E.A., 1872)	Suez Canal, Indo-Pacific	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Planaxis griseus (Brocchi, 1821)	Red Sea	Suez Canal System		+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Species	Origin	Vector	Turkey	Israel	Egypt	Greece	Libya	Cyprus	Lebanon	Syria	Italy	SC	Tunisia	Spain	France	Malta	SL	Portugal	Ionian Sea	Adriatic Sea
Gibborissoa virgata (Philippi, 1849)	Indo-Pacific	Suez Canal System	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Finella pupoides (Adams A., 1860)	Indo-Pacific	Suez Canal System	+	+	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Clathrofenella ferruginea (Adams, 1860)	Indo-Pacific, Red Sea	Suez Canal System	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Diala varia (Adams A., 1860)	Indo-Pacific, Red Sea	Suez Canal System		+	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Cerithiopsis pulvis (Issel, 1869)	Red Sea	Suez Canal System	+	+	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Cerithiopsis tenthrenois (Melvill, 1896)	Indian Ocean	Suez Canal System	+	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Metaxia bacillum (Issel, 1869)	Red Sea	Suez Canal System	+	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Rissoina bertholleti (Issel, 1869)	Red Sea, Indian Ocean	Suez Canal System	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Rissoina spirata (Sowerby, 1825	Indo-Pacific	?		+	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–
Alvania dorbignyi (Audouin, 1826)	Red Sea	Suez Canal System		+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Voorwindia tiberiana (Issel, 1869)	Red Sea	Suez Canal System	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Strombus persicus (Swainson, 1821)	Persian Gulf, Arabian Sea	Ship	+	+	–	+	–	+	+	+	–	–	–	–	–	–	–	–	–	–
Strombus mutabilis (Swainson, 1821)	Indo-Pacific, Red Sea	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sabia conica (Schumacher, 1817)	Red Sea, Indo-Pacific	Suez Canal System	–	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
Crepidula aculeata (Gmelin, 1791)	American Atlantic	Ship	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–
Crepidula fornicata (Linnaeus, 1758)	American Atlantic	Aquaculture	–	–	–	+	–	–	–	–	+	+	–	–	+	+	–	–	–	–
Erosaria turdus (Lamarck, 1810)	Red Sea, Indian Ocean	Suez Canal System	–	+	+		–	–	–	–	–	–	–	–	–	–	–	–	–	–
Purpuradusta gracilis notata	Indian Ocean, Red	Suez Canal System	+	+	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–

Species	Origin	Vector	Turkey	Israel	Egypt	Greece	Libya	Cyprus	Lebanon	Syria	Italy	SC	Tunisia	Spain	France	Malta	SL	Portugal	Ionian Sea	Adriatic Sea
(Gill, 1858)	Sea																			
Palmadusta lentiginosa (Gray, 1825)	Indian Ocean, Persian Gulf	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Natica gualteriana (Récluz, 1844)	Red Sea, Indo-Pacific	Suez Canal System	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cycloscala hyalina (Sowerby, 1844)	Red Sea, Indo-Pacific	?	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Sticteulima cf. lentiginosa (Adams A., 1861)	Indo-Pacific	?	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Ergalatax obscura (Houart, 1996)	Red Sea, Arabian Sea	?	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Thais lacera (Born, 1778)	Indian Ocean, Persian Gulf	Suez Canal System; Ship	+	+	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Thais sacellum (Gmelin, 1791)	Indian Ocean, Red Sea	Ship	–	–	–	–	–	–	+			–	–	–	–	–	–	–	–	–
Rapana venosa (Valenciennes, 1846)	Pacific Ocean	Aquaculture Ballast	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Murex forskoehlii (Röding, 1789)	Red Sea, Persian Gulf	Suez Canal System	–	+	–	+	–	–	+		–	–	–	–	–	–	–	–	–	–
Nassarius arcularia plicatus (Röding, 1789)	Red Sea, Indian Ocean	Suez Canal System	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fusinus verrucosus (Gmelin, 1791)	Red Sea	Suez Canal System		+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Zafra savignyi (Moazzo,1939)	Red Sea	Suez Canal System	+	+	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Zafra selasphora (Melvill and Standen, 1901)	Indian Ocean, Red Sea	Suez Canal System	+	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Conus fumigatus (Hwass in Bruguiere, 1792)	Red Sea	Ship	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Murchisonella columna (Hedley, 1907)	Indo-Pacific	?	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chrysallida fischeri (Hormung and Mermod, 1925)	Red Sea	Suez Canal System	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Species	Origin	Vector	Turkey	Israel	Egypt	Greece	Libya	Cyprus	Lebanon	Syria	Italy	SC	Tunisia	Spain	France	Malta	SL	Portugal	Ionian Sea	Adriatic Sea
Chrysallida maiae (Hormung and Mermod, 1924)	Red Sea	Suez Canal System	+	+	+	–	–	+	+	+	–	–	–	–	–	–	–	–	–	–
Chrysallida pirintella (Melvill, 1910)	Red Sea	Suez Canal System	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Adelactaeon fulvus (Adams A., 1851)	Indo-Pacific	Suez Canal System	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Adelactaeon amoenus (Adams A., 1851)	Indo-Pacific	Suez Canal System	+	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Styloptygma beatrix (Melvill, 1911)	Persian Gulf	Suez Canal System	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cingulina isseli (Tryon, 1886)	Red Sea	Suez Canal System	+	+	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Turbonilla edgarii (Melvill, 1896)	Indo-Pacific	Suez Canal System	+	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
Syrnola fasciata (Jickeli, 1882)	Indo-Pacific	Suez Canal System	+	+	–	–	–	+	+		–	–	–	–	–	–	–	–	–	–
Syrnola cinctella (Adams A., 1860)	Indo-Pacific, Red Sea	?	+		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Odostomia lorioli (Hornung and Mermod, 1924)	Red Sea	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Oscilla jocosa (Melvill, 1904)	Red Sea, Persian Gulf	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Iolaea neofelixoides (Nomura, 1936)	Pacific Ocean	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hinemoa cylindrica (de Folin, 1879)	Indo-Pacific	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Leucotina cfr. eva (Thiele, 1925)	Indo-Pacific	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Acteocina mucronata (Philippi, 1849)	Red Sea	Suez Canal System	+	–		+	–	+	+	–	–	–	+	–	–	–	–	–	–	–
Cylichnina girardi (Audouin, 1826)	Indo-Pacific	Suez Canal System	+	–	+	+	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Pyrunculus fourierii (Audouin, 1826)	Indo-Pacific, Red Sea	Suez Canal System	+	+	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Bulla ampulla (Linnaeus, 1758)	Indo-Pacific	Suez Canal System	+	+	–	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–

Species	Origin	Vector	Turkey	Israel	Egypt	Greece	Libya	Cyprus	Lebanon	Syria	Italy	SC	Tunisia	Spain	France	Malta	SL	Portugal	Ionian Sea	Adriatic Sea
Haminoea callidegenita (Gibson and Chia, 1989)	Pacific Ocean, American Atlantic	Aquaculture	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–
Haminoea cyanomarginata (Heller and Thompson, 1983)	Red Sea	Suez Canal System	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chelidonura fulvipunctata (Baba, 1938)	Indo-Pacific	Suez Canal System	+	+	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–
Bursatella leachi (De Blainville, 1817)	Circumtro-pical	Suez Canal System; Ship	+	–	–	+	–	–	+	–	+	+	+	–	–	+	+	–	–	–
Pleurobranchus forskalii (Rüppell and Leuckart)	Red Sea	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Polycerella emertoni (Verrill, 1881)	Tropical Atlantic	Fouling	–	–	–	+	–	–	–	–	–	–	–	+	–	+	–	–	–	–
Polycera hedgpethi (Marcus, Er. 1964)	North Eastern Pacific Ocean	Ship	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Plocamopherus ocellatus (Rüppell and Leukart, 1830)	Red Sea	Suez Canal System	+	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Discodoris lilacina (Gould, 1852)	Indo-Pacific, Red Sea	Suez Canal System	–	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Hypselodoris infucata (Rüppell and Leuckart, 1830)	Indo-Pacific, Red Sea	Suez Canal System	+	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Chromodoris quadricolor (Rüppell and Leuckart, 1830)	Red Sea	Aquarium	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Dendrodoris fumata (Rüppell and Leuckart, 1830)	Red Sea, Indo-Pacific	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Melibe fimbriata (Alder and Hancock, 1864)	Indian Ocean, Pacific Ocean	Ship	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cuthona perca (Marcus, 1958)	Pacific Ocean		–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Flabellina rubrolineata (O'Donoghue, 1929)	Indo-Pacific, Red Sea	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Species	Origin	Vector	Turkey	Israel	Egypt	Greece	Libya	Cyprus	Lebanon	Syria	Italy	SC	Tunisia	Spain	France	Malta	SL	Portugal	Ionian Sea	Adriatic Sea
Caloria indica (Bergh, 1896)	Indo-Pacific	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aeolidiella indica (Bergh, 1888)	Circumtro-pical	Ship; Fouling	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Siphonaria crenata (Blainville, 1827)	Indo-Pacific, Red Sea	Suez Canal System	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Acar plicata (Dillwyn, 1817)	Indo-Pacific, Red Sea	Suez Canal System		+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Anadara demiri (Piani, 1981)	Indian Ocean	Ship	+	–	–	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Anadara inaequivalvis (Bruguire, 1789)	Indo-Pacific	Ship		–	–		–	–	–	–	+	–	–	–	–	–	–	–	–	–
Anadara natalensis (Krauss, 1848)	WIO, Red Sea	Suez Canal System	+		+		–	–	–	–	–	–	–	–	–	–	–	–	–	–
Glycymeris arabicus (Adams H., 1871)	WIO, Red Sea	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Limopsis multistriata (Forsskal, 1775)	Indo-Pacific, Red Sea	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Musculista perfragilis (Dunker, 1857)	Indo-Pacific, Red Sea	Suez Canal System	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Musculista senhousia (Benson in Cantor, 1842)	Western Pacific Ocean	Aquaculture	–	+	+	–	–	–	–	–	+	–	–	–	+	–	–	–	–	–
Modiolus auriculatus (Krauss, 1848)	WI, Red Sea	Suez Canal System	–	–	–	–	–	–	–	–		–	–	–		–	–	–	–	–
Xenostrobus securis (Lamark, 1819)	Tropical Pacific Ocean	Aquaculture	–	–	–	–	–	–	–	–	+	–	–	–	+	–	–	–	–	–
Brachidontes pharaonis (Fischer P., 1870)	Indian Ocean, Red Sea	Suez Canal System; Ship	+	+	+	+	–	+	+	+	+	+	–	–	–	–	–	–	–	–
Septifer forskali (Dunker, 1855)	Red Sea	Suez Canal System	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Crassostrea gigas (Thunberg, 1793)	NWP	Aquaculture	–	–	–	–	–	–	–	–	+	–	+	+	+	+	–	–	–	–
Saccostrea cucullata (Born, 1778)	Indian Ocean, Red Sea	Ship; Fouling	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Saccostrea commercialis	Pacific Ocean	Aquaculture	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–

Species	Origin	Vector	Turkey	Israel	Egypt	Greece	Libya	Cyprus	Lebanon	Syria	Italy	SC	Tunisia	Spain	France	Malta	SL	Portugal	Ionian Sea	Adriatic Sea
(Iredale and Roughley, 1933)																				
Dendrostrea frons (Linnaeus, 1758)	Indo-Pacific	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pinctada margaritifera (Linnaeus, 1758)	Indo-Pacific, Red Sea	Aquaculture	–	–	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Pinctada radiata (Leach, 1814)	Indo-Pacific, Red Sea	Suez Canal System?	+	+	+	+	+	+	+	–	+	+	+	–	+	+	–	–	–	–
Malvufundus regulus (Forsskal, 1775)	Indo-Pacific, Red Sea	Suez Canal System	+	+	+	+	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Chlamys lischkei (Dunker, 1850)	American Atlantic	Ship	–	–	–	–	–	–	–	–	–	+	–	+	–	–	–	–	–	–
Spondylus spinosus (Schreibers, 1793)	Indo-Pacific, Red Sea	Suez Canal System Ship	+		+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
Spondylus groschi (Lamprell and Kilburn, 1995)	WIO, Red Sea	Suez Canal System; Ship	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Spondylus cf. multisetosus (Reeve, 1856)	Indo-Pacific	Ship	+		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Divalinga arabica (Dekker and Goud,1994)	Red Sea, Arabian Sea	Suez Canal System	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Trapezium oblongum (Linnaeus, 1758)	Indo-Pacific, Red Sea	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Diplodonta cf. subrotunda (Issel, 1869)	Red Sea	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chama pacifica (Broderip, 1834)	Indo-Pacific, Red Sea	Suez Canal System	+	+	+	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–
Pseudochama corbieri (Jonas, 1846)	Red Sea	Suez Canal System	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fulvia australis (Sowerby G.B., 1834)	Indo-Pacific, Red Sea	Suez Canal System		+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fulvia fragilis (Forsskål *in* Niehbur, 1775)	WIO, Red Sea	Suez Canal System; Ship?	+	+	–	+	–	–	–	–	–	–	+	+	–	–	–	–	–	–
Afrocardium richardi (Audoin, 1826)	Red Sea	Suez Canal System	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Species	Origin	Vector	Turkey	Israel	Egypt	Greece	Libya	Cyprus	Lebanon	Syria	Italy	SC	Tunisia	Spain	France	Malta	SL	Portugal	Ionian Sea	Adriatic Sea
Tellina valtonis Hanley, 1844	Indian Ocean, Red Sea	Suez Canal System	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Psammotreta praerupta (Salisbury, 1934)	Indo-Pacific, Red Sea	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hiatula ruppelliana (Reeve, 1857)	Red Sea	Suez Canal System	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mactra olorina (Philippi, 1846)	Red Sea	Suez Canal System	–	+	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Mactra lilacea (Lamarck, 1818)	Indo-Pacific, Red Sea	Suez Canal System	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Atactodea glabrata (Gmelin, 1791)	Indo-Pacific, Red Sea	Suez Canal System	–	+		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Gafrarium pectinatum (Linnaeus, 1758)	Indo-Pacific, Red Sea	Suez Canal System	+	+	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Circenita callipyga (von Born, 1778)	Indian Ocean, Red Sea	Suez Canal System		+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Clementia papyracea (Gray, 1825)	Indo-Pacific, Red Sea	Suez Canal System	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Paphia textile (Gmelin, 1791)	Indo-Pacific, Red Sea	Suez Canal System	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–
Mercenaria mercenaria (Linnaeus, 1758)	American Atlantic	Mk	–	–	–	–	–	–	–	–	+	+	–	–	+	–	–	–	–	–
Ruditapes philippinarum (Adams and Reeve, 1850)	Western Pacific Ocean	Aquaculture	?	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
Antigona lamellaris (Schumacher, 1817)	Indo-Pacific, Red Sea	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dosinia erythraea (Römer, 1860)	Red Sea, Western Pacific Ocean	Suez Canal System	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Timoclea roemeriana (Issel, 1869)	Red Sea	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Petricola pholadiformis (Lamarck, 1818)	American Atlantic	Aquaculture	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sphenia rueppelli (Adams A.,	Red Sea	Ship; Fouling	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Species	**Origin**	**Vector**	**Turkey**	**Israel**	**Egypt**	**Greece**	**Libya**	**Cyprus**	**Lebanon**	**Syria**	**Italy**	**SC**	**Tunisia**	**Spain**	**France**	**Malta**	**SL**	**Portugal**	**Ionian Sea**	**Adriatic Sea**
1850)																				
Mya arenaria (Linnaeus, 1758)	American Atlantic	Ship	–	–	–	–	–	–	–	–	+	+	–	–	+	–	–	–	–	–
Gastrochaena cymbium (Spengler, 1783)	Indo-Pacific, Red Sea	Suez Canal System	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Laternula anatina (Linnaeus, 1758)	Indo-Pacific, Red Sea	Suez Canal System	+	+	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Chiton hululensis (Smith E.A. *in* Gardiner, 1903)	Red Sea, Indo-Pacific	Suez Canal System	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Choromodoris annulata (Eliot, 1904)	Indian Ocean, Red Sea	?	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Amathina tricarinata (Linnaeus, 1767)	Red Sea	?	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
Cardites akabana (Sturany, 1899)	Red Sea, Suez Canal	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Petricola hemprichi (Issel, 1869)	Red Sea	?	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scapharca inflate (Reeve, 1844)	Arabian Sea	?	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Electroma vexillum (Reeve, 1857)	Red Sea	?	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Main sources: CIESM Atlas of Exotic Species (www.ciesm.org/online/atlas/intro.htm, accessed in 2009), www.journals.tubitak.gov.tr; Çeviker and Albayrak, 2002; Çevik *et al.*, 2005; Çeviker and Albayrak, 2006; Daskos and Zenetos, 2007; Gökoğlu and Özgür, 2008.

Appendix 2 (a): List of lessepsian crustaceans of the Mediterranean Sea (species of Indo-Pacific origin that entered the Mediterranean via the Suez Canal)

Species	Turkey	Sea of Marmara	Israel	Lebanon	Egypt	Cyprus	Syrian Arab Republic	Greece	Italy	Sicily	Ionian Sea	Tunisia	France
Marsupenaeus japonicus (Bate,1888)	+	+	+	+	+	+	+	+	+	_	+	_	+
Melicertus hathor (Burkenroad, 1959)	+	_	+	_	_	_	_	+	_	_	_	_	_
Metapenaeopsis aegyptia (Galil and Golani, 1990)	+	–	+	–	–	–	–	+	–	–	–	–	–
Metapenaeopsis mogiensis consobrina (Nobili, 1904)	+	–	+	–	–	–	–	–	–	–	–	–	–
Metapenaeus monoceros (Fabricius, 1798)	+	_	+	+	+	+	+	_	_	_	_	+	_
Metapenaeus stebbingi (Nobili, 1904)	+	_	+	+	+	_	+	_	_	_	_	_	_
Penaeus semisulcatus (de Haan, 1844)	+	_	+	+	+	_	_	_	_	_	_	_	_
Trachysalambria palaestinensis (Steinitz, 1932)	+	–	–	–	+	–	–	+	–	–	–	+	–
Solenocera crassicornis (H. Milne Edwards, 1837)	–	–	–	–	+	–	–	–	–	–	–	–	–
Lucifer hanseni (Nobili 1905)	_	_	_	_	+	_	_	_	_	_	_	_	_
Leptochela aculeocaudata (Paulson, 1875)	_	_	_	_	+	_	_	_	_	_	_	_	_
Leptochela pugnax (De Man, 1916)	+	_	+	_	_	_	_	_	_	_	_	_	_
Palaemonella rotumana (Borradaile, 1898)	+	_	+	_	_	_	_	_	_	_	_	_	_
Periclimenes calmani (Tattersal, 1921)	_	_	_	_	+	_	_	_	_	_	_	_	_
Urocaridella pulchella (Yokes and Galil, 2006)	+	–	–	–	–	–	–	–	–	–	–	–	–
Alpheus audouini (Coutière, 1905)	_	_	+	_	+	_	_	_	_	_	_	_	_
Alpheus inopinatus (Holthuis & Gottlieb, 1958)	+	–	+	–	+	–	–	–	–	–	–	+	–
Alpheus migrans (Lewinsohn & Holthuis, 1978)	+	–	+	–	+	–	–	–	–	–	–	–	–
Alpheus rapacida (De Man, 1908)	+	_	+	_	_	_	_	+	_	_	_	_	_
Ogyrides mjoebergi (Balss, 1921)	+	_	+	_	_	_	_	_	_	_	_	_	_
Panulirus ornatus (Fabricius, 1798)	_	_	+	_	_	_	_	_	_	_	_	_	_
Notopus dorsipes (Linnaeus, 1758)	_	_	+	_	_	_	_	_	_	_	_	_	_
Dorippe quadridens (Fabricius, 1793)	_	_	+	_	_	_	_	_	_	_	_	_	_
Ixa monodi (Holthuis and Göttlieb, 1956)	+	_	+	_	_	_	_	+	_	_	_	_	_
Coleusia signata (Paulson, 1875)	_	_	+	+	+	_	+	+	_	_	_	_	_
Myra subgranulata (Kossmann, 1877)	+	_	_	+	+	_	+	+	_	_	_	_	_
Micippa thalia (Herbst, 1803)	+	_	_	+	_	_	+	_	_	_	_	_	_
Ashtoret lunaris (Forsskål, 1775)	_	_	+	_	_	_	_	_	_	_	_	_	_
Calappa hepatica (Linnaeus, 1758)	+	_	_	_	_	_	_	_	_	_	_	_	_
Hyastenus hilgendorfi (De Man, 1887)	_	_	+	_	+	_	_	_	_	_	_	_	_
Charybdis (Goniohellenus) longicollis (Leene, 1938)	+	–	+	+	–	–	+	+	–	–	–	–	–
Charybdis (Charybdis) hellerii (A. Milne Edwards, 1867)	+	–	–	+	+	+	+	–	–	–	–	–	–
Portunus pelagicus (Linnaeus, 1758)	+	_	_	+	+	+	+	+	+	+	_	_	_

Species	**Turkey**	**Sea of Marmara**	**Israel**	**Lebanon**	**Egypt**	**Cyprus**	**Syrian Arab Republic**	**Greece**	**Italy**	**Sicily**	**Ionian Sea**	**Tunisia**	**France**
Thalamita poissonii (Audouin, 1826)	+	–	+	+	–	+	–	+	–	–	–	–	–
*Thalamita indistincta (*Apel and Spiridonov, 1998)	–	–	–	+	–	–	+	–	–	–	–	–	–
*Carupa tenuipes (*Dana, 1851)	+	–	+	–	–	–	–	–	–	–	–	–	–
Halimede tyche (Herbst, 1801)	–	–	+	–	–	–	–	–	–	–	–	–	–
Glabropilumnus laevis (Dana, 1852)	–	–	–	–	+	–	–	–	+	–	–	–	–
Pilumnopeus vauquelini (Audouin, 1826)	+	–	+	–	+	–	–	–	–	–	–	+	–
Pilumnus minutes (De Haan, 1835)	–	–	–	–	+	–	–	–	–	–	–	–	–
Atergatis roseus (Rüppell, 1830)	+	–	+	+	–	–	+	–	–	–	–	–	–
Daira perlata (Herbst, 1790)	+	–	–	–	–	–	–	–	–	–	–	–	–
Sphaerozius nitidus (Stimpson, 1858)	–	–	–	–	+	–	–	–	–	–	–	–	–
Eucrate crenata (De Haan, 1835)	+	–	+	–	+	–	–	–	–	–	–	+	–
Plagusia squamosa (Herbst, 1790)	–	–	+	+	–	–	–	–	–	–	–	+	–
Macrophthalmus graeffei (A. Milne-Edwards, 1873)	+	–	+	–	–	–	–	–	–	–	–	–	–
Erugosquilla massavensis (Kossmann, 1880)	+	–	–	+	+	+	–	+	–	–	–	–	–
Clorida albolitura (Ahyong and Naiyanetr, 2000)	–	–	+	–	–	–	–	–	–	–	–	–	–

Appendix 2 (b): List of non-lessepsian exotic crustaceans of the Mediterranean

Species	Origin	Vector	Turkey	Sea of Marmara	Alboran Sea	Spain	Italy	Ionian Sea	Tunisia	Israel	Greece	France	Egypt	Lebanon	Malta	Cyprus	Arab Syrian Republic	Croatia	Lybia
Merhippolyte ancistrota (Crosnier and Forest, 1973)	Tropical Eastern Atlantic	Gibraltar	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Processa macrodactyla (Holthuis, 1952)	Tropical Eastern Atlantic	Gibraltar	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Scyllarus caparti (Holthuis, 1952)	Tropical Eastern Atlantic	Ship, Aquaculture	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
*Scyllarus posteli (*Forest, 1963)	Tropical Eastern Atlantic	?	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
*Dromia spinirostris (*Miers, 1881)	Tropical Eastern Atlantic	?	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Calappa pelii (Herklots, 1851)	Tropical Eastern Atlantic	?	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Cryptosoma cristatum (Brullé, 1837)	Tropical Eastern Atlantic	?	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Herbstia nitida (Manning and Holthuis, 1981)	Tropical Eastern Atlantic	?	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Sirpus monodi, (Gordon 1953)	Tropical Eastern Atlantic	Ship																	
*Libinia dubia (*H. Milne Edwards, 1834)	American Atlantic	Ballast	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Callinectes danae (Smith, 1869)	American Atlantic	Ship	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Callinectes sapidus (Rathbun, 1896)	American Atlantic	Ballast	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-
Dyspanopeus sayi (Smith, 1869)	American Atlantic	Ballast	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Rhithropanopeus harrisii (Gould, 1841)	American Atlantic	Ballast	-	-	-	-	+	-	+	-	-	+	-	-	-	-	-	-	-
Percnon gibbesi (H. Milne Edwards, 1853)	American Atlantic, Tropical Eastern Atlantic, Eastern Pacific	Ship	+	-	-	+	+	+	-	-	+	-	-	-	+	-	-	-	+
Eriocheir sinensis (H. Milne Edwards, 1854)	Boreal Atlantic, Western Pacific	Garonne Canal System	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-
Fenneropenaeus	Indo-	Aquaculture	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Species	Origin	Vector	Turkey	Sea of Marmara	Alboran Sea	Spain	Italy	Ionian Sea	Tunisia	Israel	Greece	France	Egypt	Lebanon	Malta	Cyprus	Arab Syrian Republic	Croatia	Lybia
merguiensis (De Man, 1888)	Pacific, Western Pacific																		
Menaethius monoceros (Latreille, 1825)	Indo-Pacific	Ship	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Charybdis feriata (Linnaeus, 1758)	Indo-Pacific	Ship	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Thalamita gloriensis (Crosnier, 1962)	Indo-Pacific	Ship	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Actumnus globules (Heller, 1861)	Indo-Pacific	Ship	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Hemigrapsus sanguineus (de Haan, 1835)	Indo-Pacific	Ballast	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-
*Grapsus granulosus (*H. Milne Edwards, 1853)	Indo-Pacific	Ship	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Paralithodes camtschodes (Tilesius, 1815)	Northern Pacific	?	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Eurycarcinus integrifrons (De Man, 1879)	Indo-Pacific	Ballast	+																
Metapenaeus affinis (H. Milne Edwards, 1837)	Indo-Pacific	Aquaculture	+																
Rimapenaeus similis (Smith, 1885)	WA	Ballast							+										

Main sources: www.ciesm.org/online/atlas/intro.htm,2009; Özcan *et al.* (2010) and other sources for the update of the geographic extent of species

Appendix 3: Species number and distribution of alien fishes from Indo-Pacific (IP), Atlantic (A), Boreal Atlantic (BA) and Pacific Ocean (PO) to Mediterranean Basin

Species	Origin	Aegean	Marmara	Black Sea	Levantine Basin	Libyan Arab Jamahiriyan Sea	Ionian Sea	Thyrrenian Sea	Algerian Sea	Alboran Sea	Adriatic Sea	Ligurian Sea	Gulf of Lion	Gulf of Gabes	CIESM[1]
Tridentiger trigonocephalus (Gill, 1859)	?			+	+										
Acanthurus monroviae (Steindachner, 1876)	A				+				+	+					Y
Aluterus monocerus (Linnaeus, 1758)	A									+					Y
Anarhichas lupus (Linnaeus, 1758)	A							+							
Arius parkii (Günther, 1864)	A				+										Y
Beryx splendens (Lowe, 1934)	A											+			Y
Carcharhinus altimus (Springer, 1950)	A				+				+						Y
Carcharhinus brachyurus (Günther, 1870)	A							+	+	+					
Carcharhinus falciformis (Müller and Henle, 1839)	A				+			+	+	+					Y
Cephalopholis taeniops (Valenciennes, 1828)	A									+					Y
Chaunax pictus (Lowe, 1846)	A							+							
Chaunax suttkusi (Caruso, 1989)	A							+						+	Y
Cyclopterus lumpus (Linnaeus, 1758)	A										+				Y
Diodon hystrix (Linneaus, 1758)	A							+							Y
Diplodus bellottii (Steindachner, 1882)	A						+			+					Y
Enchelycore anatina (Lowe, 1839)	A	+			+										Y
Fistularia petimba (Lacepède, 1803)	A									+					Y
Gaidropsarus granti (Regan, 1903)	A				+			+							
Galeocerdo cuvier (Peron and LeSueur, 1822)	A							+		+					Y
Gephyroberyx darwini (Johnson, 1866)	A				+				+						Y
Halosaurus ovenii (Johnson, 1863)	A				+			+	+						Y
Lesueurigobius sanzi (de Buen, 1918)	A									+					
Microchirus (Zevaia) hexophthalmus (Bennett, 1831)	A							+							Y
Microchirus azevia (de Brito Capello, 1867)	A									+					
Microchirus boscanion (Chabanaud, 1926)	A									+					Y
Pagellus bellottii (Steindachner, 1882)	A				+				+	+					Y
Pinguipes brasilianus (Cuvier and Valenciennes, 1829)	A							+				+			Y
Pisodonophis semicinctus (Richardson, 1848)	A						+	+						+	Y
Pomadasys incisus (Bodwich, 1825)	A	+											+		
Psenes pellucidus (Lütken, 1880)	A				+			+	+	+					Y
Pseudupeneus prayensis (Cuvier, 1829)	A									+					Y
Rhizoprionodon acutus (Rüppell, 1837)	A						+	+		+			+		Y
Scorpaena stephanica (Cadenat, 1943)	A									+					Y
Selene dorsalis (Gill, 1862)	A						+								Y

[1] Y: Yes. Include in CIESM Atlas 2009 (online)

Species	Origin	Aegean	Marmara	Black Sea	Levantine Basin	Libyan Arab Jamahiriyan Sea	Ionian Sea	Thyrrenian Sea	Algerian Sea	Alboran Sea	Adriatic Sea	Ligurian Sea	Gulf of Lion	Gulf of Gabes	CIESM[1]
Seriola carpenteri (Mather, 1971)	A							+						+	Y
Seriola fasciata (Bloch, 1793)	A	+			+		+	+						+	Y
Seriola rivoliana (Cuvier, 1833)	A							+						+	Y
Solea senegalensis (Kaup, 1858)	A	+	+		+		+		+	+			+	+	Y
Sphoeroides marmoratus (Lowe, 1839)	A							+		+					Y
Sphoeroides spengleri (Bloch, 1785)	A									+					
Sphoeroides pachygaster (Müller and Troschel, 1848)	A	+			+		+	+	+	+	+	+	+	+	Y
*Sphyraena viridensis (*Cuvier, 1829)	A				+		+		+					+	
Sphyrna mokarran (Rüppell, 1837)	A							+							Y
Synaptura lusitanica (Capello, 1868)	A						+			+					Y
Trachyscorpia cristulata echinata (Koehler, 1896)	A									+					Y
Cheilopogon furcatus (Mitchill, 1815)	A													+	Y
Mycteroperca rubra (Bloch, 1793)	A										+				
Centrolabrus exoletus (Linnaeus, 1758)	BA									+					Y
Gymnammodytes semisquamatus (Jourdain, 1879)	BA						+	+		+					Y
Syngnathus rostellatus (Nilsson, 1855)	BA				+					+					Y
Abudefduf vaigensis (Quoy ann Gaimard, 1825)	IP				+			+				+			Y
Alepes djedaba (Forsskal,1775)	IP	+			+	+									Y
*Apogon nigripinnis (*Cuvier, 1882)	IP	+			+										
*Apogon pharaonis (*Bellotti, 1874)	IP	+			+										Y
Apogon queketti (Gilchrist, 1903)	IP				+										Y
Apogon smithi (Kotthaus, 1970)	IP				+										Y
Atherinomorus lacunosus (Forster in Bloch and Schneider, 1861)	IP	+			+	+	+								Y
*Callionymus filamentosus (*Valenciennes, 1837)	IP	+			+										Y
Coryogalops ochetica (Norman, 1927)	IP				+										Y
Crenidens crenidens (Forsskal,1775)	IP				+	+	+								Y
Cyclichthys spilostylus (Leis and Randall, 1982)	IP				+										Y
Cynoglossus sinusarabici (Chabanaud, 1931)	IP				+										Y
Decapterus russelli (Rüppell,1830)	IP				+										Y
*Dussumieria elopsoides (*Bleeker, 1849)	IP				+										Y
Epinephelus coioides (Hamilton, 1822)	IP				+			+			+				Y
Epinephelus malabaricus (Bloch and Schneider, 1801)	IP				+										Y
Equulites klunzingeri (Steindachner, 1898)	IP	+			+		+				+			+	Y
Etrumeus teres (Dekay, 1842)	IP	+			+			+							Y
Fistularia commersonii (Rüppell, 1835)	IP	+			+	+	+	+	+		+			+	Y
Glaucostegus halavi (Forsskäl, 1775)	IP				+										Y
Hemiramphus far (Forsskal,1775)	IP	+			+	+					+				Y
*Heniochus intermedius (*Steindachner, 1893)	IP				+						+				Y

Species	Origin	Aegean	Marmara	Black Sea	Levantine Basin	Libyan Arab Jamahiriyan Sea	Ionian Sea	Thyrrenian Sea	Algerian Sea	Alboran Sea	Adriatic Sea	Ligurian Sea	Gulf of Lion	Gulf of Gabes	CIESM[1]
Herklotsichthys punctatus (Rüppell, 1837)	IP				+	+									Y
Himantura uarnak (Forsskal,1775)	IP				+										Y
Hippocampus fuscus (Rüppell, 1838)	IP				+										Y
Hyporhamphus affinis (Günther, 1866)	IP				+										Y
Iniistius pavo (Valenciennes, 1840)	IP	+			+										Y
Lagocephalus sceleratus (Gmelin, 1789)	IP	+													Y
Lagocephalus spadiceus (Linnaeus, 1758)	IP	+	+		+										Y
Lagocephalus suezensis (Clark and Gohar, 1953)	IP	+			+										Y
Liza carinata (Valenciennes, 1836)	IP				+	+					+				Y
Lutjanus argentimaculatus(Forsskal,1775)	IP				+										Y
Makaira indica (Cuvier, 1832)	IP							+				+			Y
Monotaxis grandoculis Forsskål, 1775	IP				+										
Muraenesox cinereus (Forsskal,1775)	IP				+										Y
Nemipterus japonicus (Bloch, 1791)	IP				+										
Nemipterus randalli (Russell, 1986)	IP				+										Y
Omobranchus punctatus (Valenciennes, 1836)	IP				+										Y
Oxyurichthys papuensis (Valenciennes, 1837)	IP	+			+										Y
Pampus argenteus (Euphrasen, 1788)	IP										+				
Papilloculipes longiceps (Ehrenberg in Valenciennes, 1829)	IP				+										Y
Parexocoetus mento (Valenciennes, 1846)	IP	+			+		+				+			+	Y
Parupeneus forsskali (Fourmanoir and Guézé, 1976)	IP				+										
Pelates quadrilineatus (Bloch, 1790)	IP				+										Y
Pempheris vanicolensis (Cuvier, 1831)	IP	+			+		+							+	Y
*Petroscirtes ancylodon (*Rüppell, 1838)	IP	+			+										Y
Platax teira (Forsskål, 1775)	IP	+													Y
Platycephalus indicus (Linnaeus, 1758)	IP				+			+							Y
Plotosus lineatus (Thunberg, 1787)	IP				+										Y
Pomadasys stridens (Forsskal,1775)	IP				+			+							Y
Priacanthus hamrur (Forsskål, 1775)	IP													+	
Pteragogus pelycus Randall, 1981	IP	+			+										Y
Pterois miles (Bennet, 1803)	IP				+										Y
Rachycentron canadum (Linnaeus, 1766)	IP				+										Y
Rastrelliger kanagurta (Cuvier, 1816)	IP				+										Y
Rhabdosargus haffara (Forsskal,1775)	IP				+										Y
Rhynchoconger trewavasae (BenTuvia, 1993)	IP				+										Y
Sargocentron rubrum (Forsskal,1775)	IP	+			+	+	+								Y
Saurida undosquamis (Richardson, 1848)	IP	+			+	+	+	+			+				Y
Scarus ghobban (Forsskål, 1775)	IP				+										Y
Scomberomorus commerson (Lacapede, 1800)	IP	+			+	+									Y

Species	Origin	Aegean	Marmara	Black Sea	Levantine Basin	Libyan Arab Jamahiriyan Sea	Ionian Sea	Thyrrenian Sea	Algerian Sea	Alboran Sea	Adriatic Sea	Ligurian Sea	Gulf of Lion	Gulf of Gabes	CIESM[1]
Siganus luridus (Rüppell, 1828)	IP	+			+	+	+	+			+		+	+	Y
*Siganus rivulatus*Forsskal,1775	IP	+			+	+	+	+			+			+	Y
Silhouetta aegyptia (Chabanaud, 1933)	IP				+										Y
Sillago sihama (Forsskal,1775)	IP	+			+										Y
Sorsogona prionota (Sauvage, 1873)	IP				+										Y
*Sphyraena chrysotaenia (*Klunzinger, 1884)	IP	+			+	+	+	+			+			+	Y
*Sphyraena flavicauda (*Rüppell, 1838)	IP	+			+										Y
Sphyraena obtusata (Cuvier, 1829)	IP				+	+									
Sphyraena pinguis (Günther, 1874)	IP	+			+	+									
Spratelloides delicatulus (Bennett, 1831)	IP				+										Y
Stephanolepis diaspros (Fraser Brunner,1940)	IP	+			+	+	+	+			+			+	Y
Synagrops japonicus (Doderlein, 1884)	IP							+				+			Y
Terapon puta (Cuvier, 1892)	IP				+										Y
Terapon theraps (Cuvier, 1829)	IP										+				Y
Tetrosomus gibbosus (Linnaeus, 1758)	IP				+										Y
*Torquigener flavimaculosus (*Hardyand Randall, 1983)	IP	+			+										Y
Tylerius spinosissimus (Regan, 1908)	IP	+			+										Y
Tylosurus choram (Rüppell, 1837)	IP				+										Y
Tylosurus crocodilus (Péron and Lesueur, 1821)	IP	+													
Upeneus moluccensis (Bleeker, 1855)	IP	+			+	+	+								Y
*Upeneus pori (*BenTuvia and Golani, 1989)	IP	+			+	+	+								Y
Zenopsis conchifer (Lowe, 1852)	IP						+								Y
Heniochus acuminatus (Linnaeus, 1758)	IP			+											
*Vanderhorstia mertensi (*Klausewitz, 1974)	IP				+										
Elates ransonnetti (Steindachner, 1877)	PO							+							Y
Liza haematocheila (Temminck&Schlegel, 1845)	PO	+	+	+											Y
Pagrus major (Temminck and Schlegel, 1843)	PO										+				Y

Species
Entelurus aequoraeus (Linnaeus, 1758)
Ephippion guttiferum (Bennett, 1831)
Galeoides decadactylus (Bloch, 1795)
Galeus atlanticus (Vaillant, 1888)
Gobius couchi (Miller and El-Tawil, 1974)
Hyperoglyphe perciformis (Mitchill, 1818)
Laemonema latifrons (Holt and Byrne, 1908)
Lampanyctus intricarius (Tåning, 1928)
Lepidion guentheri (Giglioli, 1880)
Lipophrys pholis (Linnaeus, 1758)

Champsodon nudivittis (Ogilby, 1895)
Nerophis lumbriciformis (Jenyns, 1835)
Parablennius pilicornis (Cuvier, 1829)
Parapristipoma octolineatum (Valenciennes, 1833)
Pontinus kuhli (Bowdich, 1825)
Pristis pectinata (Latham, 1794)
Serranus atricauda (Günther, 1874)
Serrivomer brevidentatus (Roule and Bertin, 1929)
Squalus megalops (Macleay, 1881)
Tetrapturus georgei (Lowe, 1841)
Torpedo fuscomaculata (Peters, 1855)
Umbrina canariensis (Valenciennes, 1843)

Main Sources: CIESM Exotic Fish Species Atlas www.ciesm.org (accessed in 2009), www.fishbase.org (accessed in 2009), Lasram-Rais and Mouillot (2009) Oral (2010).

Appendix 4: Pictures of some alien species from the Black and Mediterranean Seas which are important as commercially, impact on human health or biodiversity

Lagocephalus sceleratus

Lagocephalus spadiceus

Lagocephalus suezensis

Sphyraena chrysotaenia

Upeneus pori

Upeneus moluccensis

Saurida undosquamis

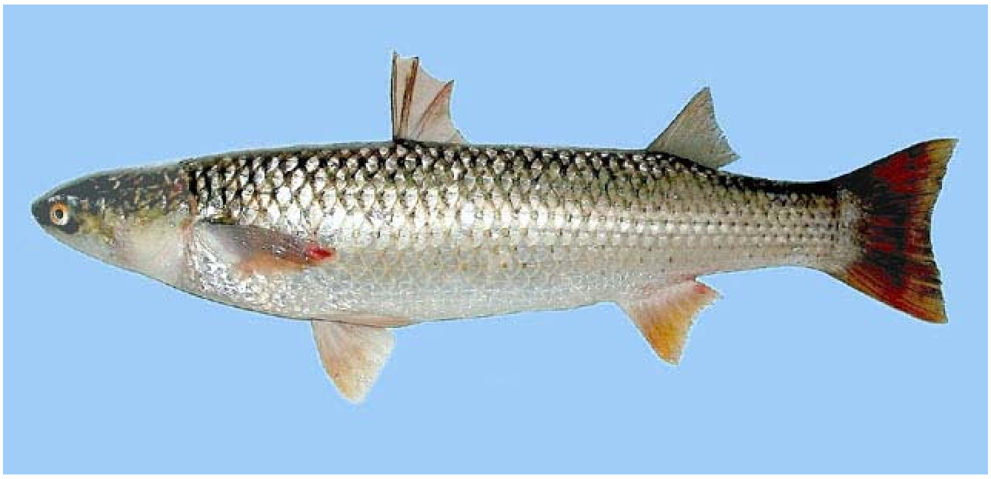
Scomberomorus commerson

Sargocentron rubrum

Etrumeus teres

Phemperis vanicolensis

Fistularia commersonii



Liza haematocheila (*Mugil soiuy*)

Hemirhampus far

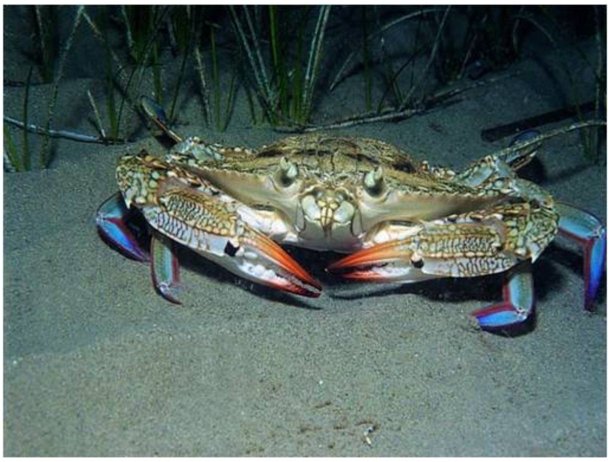
Nemipterus randalli

Sillago shiama

Siganus rivulatus

Siganus luridus

Portunus pelagicus

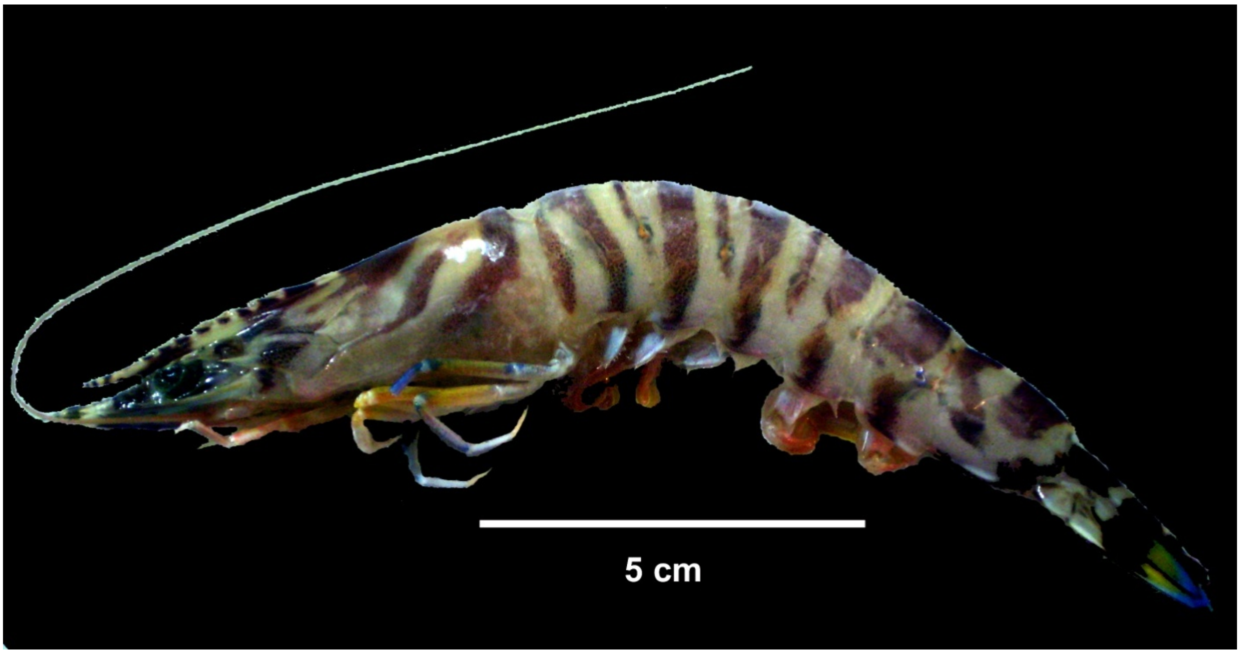


Calinectes sapidus

Erugosquilla massavensis

Synaptula reciprocans

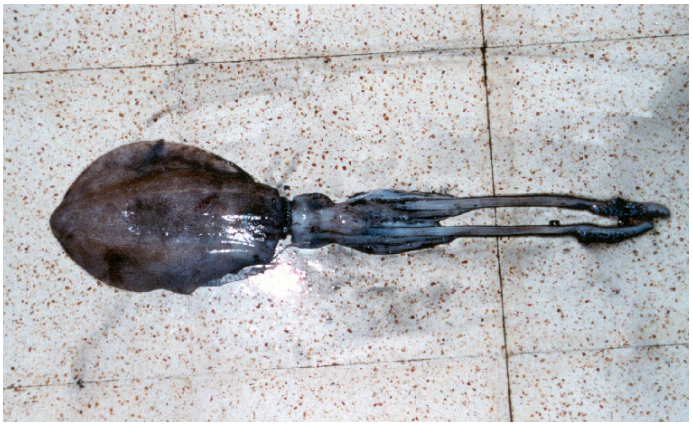
Rapana venosa



Marsupenaeus japonicus

Melicertus hathor

Penaeus semisulcatus


Sepioteuthis lessoniana


Diadoma setosum


Beroe ovate


Cassiopea andromeda


Macrorhynchia philippina


Mnemiopsis leidyi


Caulerpa taxifoli


Rhopilema nomadica


Caulerpa racemosa

This study, undertaken upon request by the General Fisheries Commission for the Mediteranean (GFCM), summarizes the available information about the status of alien species in the Mediterranean Sea and the Black Sea. The biota of the Black and Mediterranean Seas has started to change with the introduction of alien species in the last few decades due to increasing shipping activities, lessepsian migration, Atlantic influx, intentional or unintentional introduction as well as climate change.

In total, there are over 900 alien species in the Mediterranean and the Black Sea. Several fishing techniques such as trawling, purse seining, setnets, gillnets and pots are used for alien species fishery. Due to a lack of overall statistics, total catch in the entire basin is not known and not predictable. Some alien fishes which do not have any commercial value, such as pufferfish and cornetfish, are discards. Some Atlantic-originated fish and invertebrates have also extended to the eastern part of the Mediterranean Sea. Besides, ship ballast water and intentional and unintentional introduction are growing threats for marine biodiversity in both basins.

Information dissemination and raising public awareness, mostly for harmful species, are therefore particularly important at a regional level. Moreover, regional cooperation for monitoring and protecting marine biodiversity is essential to minimize and reduce the impacts of alien species both in the Mediterranean and Black Sea. Finally, the enforcement of the legal measures is necessary to reduce the introduction of alien species.

Examples of alien species:
1. *Rhopilema nomadica*; 2. *Mnemiopsis*; 3. *Fistularia commersonii*; 4. *Lagocephallus sceleratus*; 5. *Calinectes sapidus*; 6. *Rapana venosa*; 7. *Diadoma setosum*.