On the biology of the Turkish straits system

by

Bayram ÖZTÜRK[1] and Ayaka Amaha ÖZTÜRK[2]

[1]*Faculty of Fisheries,* [2]*Science and Technology Institute, Istanbul University, Laleli, Istanbul, Turkey*

ABSTRACT

The Turkish straits system – the Dardanelles, Bosphorus and Marmara Sea – represents a transitional zone between the Mediterranean and Black Sea basins. As such it constitutes either a barrier, a corridor or an acclimatization zone for living organisms. The peculiar hydrological characters of the Turkish straits limit the distribution of some species. Once major biological corridors for pelagic fish migrating between the Mediterranean and the Black Sea, they have ceased to be so due to the destabilization of the pelagic and benthic ecosystems. On the other hand the straits allow the acclimatization of certain species of mediterranean origin, such as decapod crustaceans, anthozoans and sponges, penetrating to the Marmara Sea and Black Sea. Alien species, such as *Rapana thomasiana, Mnemiopsis leidyi* and *Cunearca cornea*, have also become resident. Major sources of pollution, overfishing, ship accidents and heavy marine traffic, constitute major threats for the biological diversity of the Turkish straits system and hence for the ecological balance of adjacent seas, as exemplified by the disappearance of resident populations of *Phocoena phocoena*, *Tursiops truncatus*, *Delphinus delphis* and *Monachus monachus* from the straits.

RÉSUMÉ

Le système des détroits turcs – Dardanelles, Bosphore et mer de Marmara – représente une zone de transition entre les bassins de la mer Méditerranée et de la mer Noire. Il constitue soit une barrière, soit un couloir ou encore une zone d'acclimatation pour les organismes vivants. Les particularités hydrologiques des détroits turcs limitent la distribution de cer-

taines espèces. Autrefois importants couloirs de migration entre la Méditerranée et la mer Noire pour les espèces pélagiques, ils ne jouent plus ce rôle en raison de la déstabilisation des écosystèmes pélagiques et benthiques. Par ailleurs, les détroits permettent l'acclimatation de certaines espèces méditerranéennes pénétrant en mer de Marmara et mer Noire telles que les crustacés décapodes, les anthozoaires et les éponges. Des espèces exotiques, comme *Rapana thomasiana, Mnemiopsis leidyi* et *Cunearca cornea*, sont devenues résidentes. De nombreux polluants, la "sur-pêche", les accidents de navires et un trafic maritime intense constituent des menaces majeures pesant sur la biodiversité des détroits turcs et, par là, sur la balance écologique des mers adjacentes. En témoigne la disparition des populations autrefois résidentes de *Phocoena phocoena*, *Tursiops truncatus*, *Delphinus delphis* et *Monachus monachus*.

INTRODUCTION

The Turkish straits system includes the straits of Istanbul (Bosphorus), Canakkale (Dardanelles) and the Marmara Sea (Fig. 1). Biological, physiographical, meteorological and hydrological characteristics combine there to form a peculiar ecosystem between the Mediterranean and Black seas. While the hydrological aspects of the straits are well documented (see for instance OZSOY, 1996, this volume), biological data remain very limited.

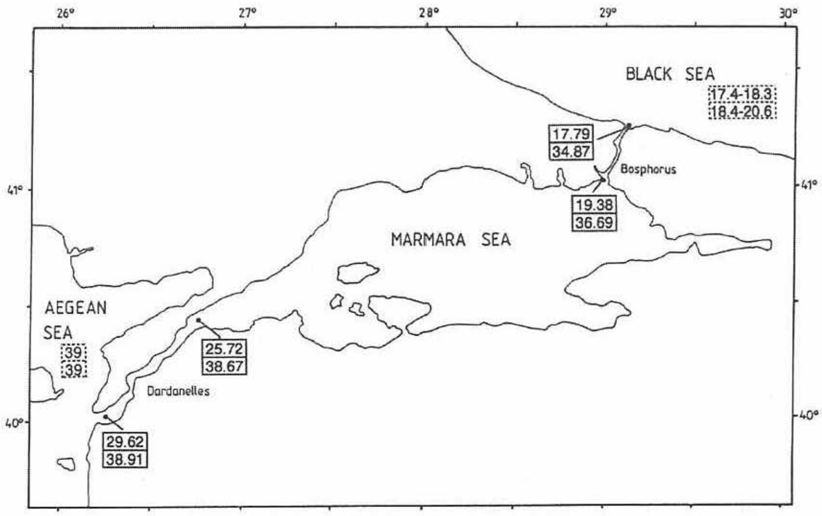

Figure 1 – Map of the Turkish straits and salinity (‰). Salinity of surface water is in the upper square and that of deeper (50-100 m) in the lower quare. Data in solid lines were extracted from OZSOY *et al.* (1988). Data in broken lines are the average salinity of Aegean and Black seas (respectively KOCATAS and BILECIK, 1992 and RASS et SIGANOVA, 1994)

MAIN BIOLOGICAL CHARACTERISTICS

The Turkish straits play significant roles in the biology of the Mediterranean and Black Sea basins.

Biological barrier

The Turkish straits serve as a barrier between the Aegean and Marmara seas and between the Marmara and Black seas. For example, the northern distribution of the mediterranean endemic seagrass, *Posidonia oceanica*, is limited by the Dardanelles Strait (AUGIER, 1985). Another example is the cetacean *Phocoena phocoena* which lives mostly in the Black Sea and partially in the Marmara Sea. Its southernmost distribution is limited by the Dardanelles Strait (OZTURK, 1995a).

Biological corridor

Through this biological corridor, mediterranean species of phytoplankton and zooplankton penetrate into the Black Sea with the Bosphorus underflow (KOVALEV *et al.*, 1976). Thus NALBANTOGLU (1957) found typical mediterranean zooplankters in the stomach contents of *Scomber scombrus* in the Black Sea, Bosphorus and Marmara Sea: among them, *Muggiaea kochi, Solmundella mediterranea, Eucalanus crassus, Calanus tenuicornis, Microsetella rosea, Clytemnestra rostrata, Microstella norvegica, Mormonilla phasma* and *Clausocalanus arcuicornis*. According to SOROKIN (1983) about 20 species of mediterranean zooplankters ride the deeper Bosphorus current from the Sea of Marmara into the Black Sea where they are found in the upper waters far from the Bosphorus, up to the coast of Crimea. Other zooplankters of mediterranean origin, such as *Centropages furcifer, C. typicus, Pontella lobiancoi* and *P. mediterranea* are found in the Marmara Sea (KOCATAS *et al.*, 1993). Vice versa, zooplankters of Black Sea origin, such as *Paracalanus parvus* and *Acartia clausi,* are also found in the Aegean Sea (MORAITOU-APOSTOLOPOULOU, 1976). The straits system plays an important role as well as a corridor for the penetration of Atlantic-Mediterranean fishes. In general, this migration originates from the Aegean Sea in the spring and returns to the Marmara and Aegean Sea in the autumn (Table I).

Among the mediterranean invertebrates penetrating the Marmara Sea, one may cite *Spongia officinalis* (Porifera, Demospongia) reported by VACALET (1989), *Gerardia savaglia* (Cnidaria, Anthozoa) by OZTURK and BOURGUET (1990), *Parapenaeus longirostris* and *Penaeus kerathurus* (Crustacea, Decapoda) by DEMIR (1959), *Calocaris maecandrae, Nephrops norvegicus, Sergia robusta* and *Polycheles typhlops* (Crustacea, Decapoda) by OZTURK *et al.* (1994). A total of 11 cephalopod species has been recorded in the Sea of Marmara (KATAGAN *et al.*, 1993). No cephalopod is known from the Black Sea (MANGOLD and BOLETZKY, 1987). Salinity was likely a limiting factor for the stenoterm species (CASPERS, 1968). Of the 177 decapod species recorded in all Turkish waters, only 17 species (7 Natantia species, 2 Anomura species and 8 Brachiura species) live in the Turkish waters of the Black Sea. No Reptantia species has been recorded (KOCATAS, 1981). The Black Sea is poorer in zoobenthos species than the Mediterranean and Marmara Sea because of its lower salinity and the presence of an intensive anoxic water mass which restricts life to a narrow habitable upper layer (VODYANDSKYI, 1937, cited in ZENKEVICH, 1963). The straits system clearly represents a major barrier for these invertebrates.

Acclimatization zone

The Bosphorus Strait acts also as an acclimatization zone for the mediterranean species (PUSANOV, 1957, cited in CASPERS, 1968). BACESCU *et al.*

TABLE I

Migration and spawning of fishes in the Turkish straits system

Fish species	**Migration period** Dardanelles	Bosphorus	**Spawning**	**Source**
	⇒ from Aegean to Marmara ⇐ from Marmara to Aegean	⇒ from Marmara to Black Sea ⇐ from Black Sea to Marmara	Period Ground	
Pomatomus saltator	⇒ March-May ⇐ October	⇒ March-May ⇐ August-October	June-September Black Sea	OZARSLAN, 1974
Sarda sarda	⇒ May-July ⇐ August-November	⇒ May-July ⇐ August-November	Mid May-mid July Black Sea and Marmara	ACARA, 1957
Sardina pilchardus	⇒ Spring ⇐ Autumn	- -	November-June Aegean and Black Sea	OZARSLAN, 1974
Scomber japonicus	⇒ June ⇐ October-November	⇒ August ⇐ October-November	June-mid August Marmara Sea	KOCATAS *et al.*, 1993
Scomber scombrus	- -	⇒ Spring ⇐ Autumn	Mid March-late May Marmara Sea	OZARSLAN, 1974
Thunnus thynnus	⇒ ? ⇐ ?	⇒ April ⇐ September	Summer Black Sea	DEVEDJIAN, 1926 AKSIRAY, 1987
Trachurus mediterraneus	- -	⇒ Summer ⇐ Autumn	March-July Black Sea	KOCATAS *et al.*, 1993
Xiphias gladius	⇒ June-July ⇐ Summer	⇒ June-July ⇐ Summer	June-September Mediterranean Sea Mid April-early July Marmara Sea	OZARSLAN, 1974

(1971) mentioned that of the 1785 zoobenthic species in the Black Sea 150 species of mediterranean origin are exclusively found in the limited area near the mouth of the Bosphorus Strait. This implies that these 150 species expanded their distribution to the Black Sea through the straits where they were acclimatized gradually to the environmental conditions of the Black Sea. Table II shows the penetration of the invertebrate species from the Marmara Sea into the Bosphorus. Except for the Polychaeta group, the number of invertebrate species decreases as the distribution reaches into the Bosphorus.

TABLE II

Invertebrate fauna of the Sea of Marmara and Bosphorus Strait (after KOCATAS et al., *1993)*

Group	**Number of species**	
	Marmara Sea	Bosphorus
Amphipoda	41	16
Polychaeta	83	118
Echinodermata	44	12
Ascidia	12	2
Bryozoa	47	2
Hydrozoa	38	22
Porifera	8	-
Anthozoa	15	3
Plathelminthes	10	7
Nemertinea	5	6
Cirripedia	4	3
Isopoda	17	15
Decapoda	49	22
Mollusca	98	41
Total	472	41

MARINE MAMMALS

There are three cetacean species living in the Turkish straits system and the Black Sea: *Delphinus delphis, Tursiops truncatus* and *Phocoena phocoena*. Migration of the cetaceans in the Aegean, Marmara and Black seas is a key factor for the conservation of these animals, although there are few studies on this matter. The occurrence of *Delphinus delphis* and *Phocoena phocoena* (recorded as *Delphinus phocaena*) was first mentioned in the Marmara Sea by DEVEDJIAN (1926). BERKES (1977) reported that the mediterranean dolphin *Delphinus delphis* migrates through the Marmara and Bosphorus to the Black Sea in the spring and back to the Mediterranean Sea in the autumn. Schools of *Tursiops truncatus* and *Delphinus delphis* migrate in May-April from the Aegean Sea to the Marmara Sea in search of pelagic fish. These three species of cetaceans occur in all seasons in the straits and Marmara Sea (BEAUBRUN, 1995), but, due to the heavy marine traffic and other ecological stresses in the Bosphorus, their migration does not occur regularly anymore.

Black Sea dolphins, and *Delphinus delphis* particularly, feed on migratory fish such as *Trachurus trachurus* and *Pomatomus saltator* (SLASTENENKO, 1955). It is known among fishermen that the dolphins wait for the migration of their prey at the mouth of the Bosphorus in the spring. Decreasing fish stocks in both the Marmara Sea and Bosphorus have created a food shortage for the dolphins. The more coastal species *Phocoena phocoena* and *Tursiops truncatus* feed mostly on benthic fishes (KLEINENBERG, 1956) which are affected by the destabilization of the coastal ecosystem in the straits and Black Sea. Therefore, these two coastal species may also suffer food shortage. *Phocoena phocoena* is not observed in the Aegean Sea (OZTURK, 1995a) where it is perhaps limited by the higher temperature.

In 1958, TEZEL reported the presence of a resident population of dolphins in the Bosphorus Strait; it is no longer present today. Stranded dolphins of all three species (Table III) have been collected in the Bosphorus, including those killed by the oil spill caused by the tanker *Nassia* collision in 1994.

TABLE III

Stranding of cetaceans in the Bosphorus Strait

Year	Number of stranded animals			Source
	Phocoena phocoena	*Delphinus delphis*	*Tursiops truncatus*	
1989-91	11	2	2	OZTURK, 1992
1992	-	1	-	OZTURK (unpubl. data)
1993	-	1	-	OZTURK (unpubl. data)
1994	9 (8)*	2	4 (2)*	OZTURK (unpubl. data)

* *Figures in the parentheses indicate the number of animals died due to the accident of the tanker* Nassia *(see text for details).*

These species, already protected by national laws and international conventions, remain clearly vulnerable to pollution and marine traffic, especially in the peak migration season. In this context the First International Symposium on the Marine Mammals of the Black Sea, held in Istanbul in 1994, called for monitoring and regulating heavy marine traffic during the major migration period of dolphins in the Bosphorus as well as in the Kerch Strait at the mouth of the Azov Sea.

Another marine mammal in the Turkish straits system is *Monachus monachus*. Among the rarest animals of the world, *Monachus monachus* is under great threat both in the Black Sea and the Marmara Sea. The monk seal was a resident in the Bosphorus during the 1940s (BERKES *et al.*, 1979). Today, there is no resident population in the Bosphorus anymore, probably due to the loss of adequate habitats (OZTURK, 1992a). In the period 1987-1992, only one old animal and one pup were reported in the Marmara Sea (OZTURK, 1994). They belonged to the northern Aegean population and were presumably visiting the Marmara Sea for feeding. Since no resident seal has been observed in the Bosphorus since 1987, a possible genetic bridge seems closed for the metapopulation still surviving in the Black Sea (OZTURK, 1993).

SEA BIRDS

There has not been any systematic study on the avifauna of the Turkish straits, except that of ERTAN *et al.* (1989) which identified 29 sea bird species. The most abundant species are *Gavia arctica, G. stellata, Podiceps cristatus, P. griseigena, P. nigricollis, Puffinus puffinus, Phalacrocorax aristotelis, P. carbo, Ardea cinerea, Anas crecca, A. querquedula, Mergus serrator, Fulica atra, Haematopus ostralegus, Charadrius dubius, C. alexandrinus, Larus ridibundus, L. minutus, L. melanocephalus, L. argentatus, L. fuscus, L. canus, Sterna sandvicensis, S. hirundo, S. albifrons, Chlidonias leucopterus, C. hybrida, Gelochelidon nilotica* and *Hydroprogne tschegrava*.

The migration pattern of 16 species of seabirds between the Aegean Sea and Black Sea over the straits system is shown in Table IV. These species feed on pelagic fish, such as *Atherina boyeri, Trachurus trachurus* and *Sprattus sprattus*. Due to the decline of these fish populations, their migration has become irregular (ERTAN and ERTAN, 1994).

TABLE IV

Migration of sea birds in the Turkish straits (modified from ERTAN and ERTAN, 1994)

Bird species	Migration period	
	Dardanelles	Bosphorus
	⇒ from Aegean to Marmara	⇒ from Marmara to Black Sea
	⇐ from Marmara to Aegean	⇐ from Black Sea to Marmara
Gavia arctica	-	⇒ March
G. stellata	-	⇐ January - February
Laurus canus	-	⇒ March-April
L. fuscus	-	⇐ October-November
L. melanocephalus		
Phalacrocorax aristotelis	⇒ March-April	⇒ March-April
P. carbo	⇐ November	⇐ October
Chlidonias hybrida		
C. leucopterus		
Gelochelidon nilotica		
Hydroprogne tschegrava	⇒ April	⇒ May
Podiceps cristatus	⇐ October-November	⇐ September
P. griseigena		
P. nigricollis		
Sterna sandvicensis		
S. hirundo		

EXOTIC SPECIES

The best known example of species introduction is that of *Rapana thomasiana* which was first recorded in the Turkish side of the Black Sea by FISHER (1960). This species is to have been brought with ship ballast water from the Sea of Japan. In the absence of a natural predator in the Black Sea, the population grew rapidly, feeding on mussels, oysters and clams and expanding around the Bosphorus and Marmara Sea at the depth of 25 m. *Diplodus vulgaris* which also feeds on mussels much decreased as a result (BILECIK, 1990). To date, the southernmost distribution point of the species is the Dardanelles Strait.

The ctenophore *Mnemiopsis leidyi* is another species transferred by ballast water of ships, this time from the Atlantic coast of North America to the Black Sea (VINOGRADOV *et al.*, 1989). The first occurrence of this species in the Bosphorus, Marmara Sea and Dardanelles was reported by ARTUZ (1991). The abundance of *Mnemiopsis leidyi* was later recorded at 4.3 kg/m^2 near the Bosphorus and 9.7 kg/m^2 near the Dardanelles, mostly in 10-30 m deep water (SHIGANOVA *et al.*, 1995). Pelagic fish stocks in the Marmara Sea have declined as a result since their main food consist of copepods and clodocerans which are also foraged by *Mnemiopsis leidyi*. Furthermore, *Mnemiopsis leidyi* feeds on fish eggs and larvae, seriously affecting fish such as *Scomber scombrus* which use the Marmara Sea as a spawning ground.

Cunearca cornea is an exotic bivalve found in the muddy water of the Marmara Sea and Bosphorus. This species is well adapted to the eutrophic waters of the straits system (OZTURK, 1992b) and, like the other species mentioned above, is also found in the Black Sea (ZAITSEV, 1993).

POLLUTION SOURCES

Pollution load of the Turkish straits system is very closely related to the adjacent seas. Industrial and domestic pollutions come mainly from the Black Sea, which receives pollutants from eastern and central Europe through major rivers such as the Danube, Dnieper and Dniester.

The Marmara Sea and Bosphorus are eutrophic in character. SOROKIN *et al.* (1995) evaluated the average microbial decomposition amount in the surface water of the Marmara Sea as 0.15 mg O_2l/day, which is a typical value of eutrophic waters. Eutrophication is due first to the high pollution load of the Black Sea compounded by the domestic and industrial discharges of Istanbul. In the Istanbul region, nearly 766 million m^3/year of waste water is discharged into the Sea of Marmara (KOCATAS *et al.*, 1993). The fauna is significantly affected by pollution. To take polychaetous annelids as an example, the number of species has decreased while the number of individuals per species has increased (UYSAL, 1988). Furthermore, three pollution indicator species, *Capitella capitata, Scololepis fuliginosa* and *Polydora ciliata* were found dominant in the Golden Horn, a small inlet attached to the Bosphorus near the Marmara Sea. Table V shows the substantial decrease of macrobenthic organisms in the Bosphorus Strait in recent years, compared to the 1950s.

TABLE V

Changes in the density (expressed as number of specimens/m^2) of macrobenthos in the Bosphorus Strait region between 1958 and 1989 (after ZAIKA, 1994).

Date	**July 1958**	**August 1989**
Number of stations	10	10
Depth	70-100	70-100
	Density	Density
Marmara Sea species	580	10
Black Sea species	1686	299
Polychaeta	752	146
Crustacea	865	37
Mollusca	51	42
Echinodermata	426	67

The benthic community of the Marmara Sea has been particularly studied by OZTURK (1992 b) who reported that most of the *Phyllophora nervosa* beds were slowly dying due to high suspended solid materials around the Prince Islands. *Mytilus galloprovincialis* is also sensitive to the suspended materials: in the northern part of the Marmara Sea, mussel beds show mass mortality as a result of hypoxia and silting. *Ostrea edulis*, also very sensitive to silting, has almost disappeared in Gemlik Bay. The major biofiltering and oxygen producing community in the Marmara Sea, the *Phyllophora-Mytilus* complex, is degraded by pollution. Around the Marmara Island, some beds of black coral *Gerardia savaglia* are destroyed. Dissolved oxygen deficiency of the Marmara Sea is one of the main problems for the biota.

Industrial pollution also is quite significant. In the bottom sediments of the Marmara Sea, one finds concentrations of the main part of oil products, bituminous matter, within the range of 0.01-0.15 g/kg (0.032 on the average) and those of the radionuclid, cesium-137, within the range of 0.13-1.67 Bq/g (on the average 0.72) (SHIMKUS *et al.*, 1993).

A diversity of pollution sources is identified in the Bosphorus. For example, the pollutants entering Beykoz Inlet, located in halfway between the Black Sea and the Marmara on the Asian side of the Bosphorus Strait, are as follows (TOPALOGLU and KIHARA 1993). The petroleum depot uses about 3 000 l/day of fresh water and discharges this water directly into the sea. The alcohol factory discharges 700 m^3/day of cooling water and 235 m^3/day of alcohol-contaminated waste water to the inlet. The glass factory is a significant polluter, using sand, borax, dolomite, potassium carbonate, lead oxide, sodium nitrate, quartz, sodium sulfate and water (1 585 m^3/day) and it discharges 606 m^3/day of cooling waters and 390 m^3/day of domestic waste water directly to the sea. The leather factory, which processes 5 000 t of leather per day, uses many chemicals such as $Ca(OH)_2$, $NaHS0_3$, and discharges cooling water (95 m^3/day) and domestic waste water (788 m^3/day) which is treated incompletely prior to release into the inlet.

Survey of heavy metal pollution in five algal species and in the phanerogam *Zostera marina* in the Bosphorus showed higher metal levels in the latter species than in the algae. The metal contents were always higher in the sediment than in the marine flora. The sites with the highest metal content in the sediments were Sarayburnu, Beykoz and Pasabahce. The station in Pasabahce, which is affected by shoes and glass factories, had the highest contamination level in the whole Bosphorus (GUVEN *et al.*, 1993).

In the rocky substrata, the Chlorophyta *Enteromorpha linza* and *Ulva rigida* and the Phaeophyta *Cystoseira barbata* are common in the algal flora, while the crustaceans *Balanus* spp and *Gammarus* spp and the molluscs *Mytilus galloprovincialis* and *Ostrea edulis* dominate the fauna (ARTUZ, 1962). Sand substrata are dominated by *Chamelea gallina, Cardium edule* and *Ruditapes decussatus* until 15 m depth. Muddy substrata host mostly polychaetes, such as *Phylodoce tuberculata, Capitella capitata* and *Nereis zonata*, isopods and sea grass, such as *Zostera marina and Zostera noltii,* until 15 m depth.

The phytobenthos is badly affected by the vessel-generated pollution. In 1994, *Ulva rigida* and *Codium tomentosum* were affected by the oil dispersion and stranded as a result of mass mortality after the tanker *Nassia* accident. There was once a high diversity of brown, red and green algae along the Bosphorus coast, but eutrophic-tolerant species with short seasonal life cycles, such as the green alga *Enteromorpha intestinalis,* now dominate. The brown alga *Cystoseira barbata*, once dominant on rocky shores, is now nearly extinct. The cover of the sea grass *Zostera* spp has decreased drastically in recent years due to the coastal bivalve fisheries and boat anchorage. Destruction of the *Ulva rigida* community caused a decline of *Crangon crangon* population (OZTURK, 1995b).

In the Istanbul Strait, *Mytilus galloprovincialis* populations registered mass mortality at 8-13 m depth due to local hypoxia in some of the inlets (*i.e.* Beykoz and Tarabya). Due to the synergetical effect of the various types of pollution, the populations of molluscs, such as *Ostrea edulis* and *Ruditapes decussatus*, the populations of crustaceans, such as *Crangon crangon, Palaemon adspersus, Palaemon elegans* and *Palinurus elephas,* have declined in the Bosphorus Strait. As a result the structure of the faunal community in some of the bays and inlets has been very much altered. In Poyraz Bay near the Black Sea mouth of the Istanbul Strait, the *Mytilus*-algae assemblage has decreased while *Capitella capitata* and *Nereis zonata* has become dominant. A hard-bottom fauna has been replaced by a soft-bottom fauna of polychaetes (OZTURK, 1995b).

Pollution derived from the marine traffic in the Turkish straits is no less serious. Beside sea accidents which are examined in detail in the following section, bilge piping, garbage unloading, dirty oil unloading and waste water discharging, which results from deck cleaning and leakage, all contribute their share. In particular transit vessels illegally pipe bilge at night and this bilge is washed to shores where it pollutes many recreational beaches in the straits system. Oil and other liquid wastes leaking from the vessels during the transit pass sink and precipitate in the biochemical cycle after dispersion on the sea surface (BAYKUT *et al.*, 1985). Garbages unloaded to the sea are complex in origin and they pollute the sea shore, depending on the type of the garbage, either by dispersing on the surface or by gradually stranding to the shores after sinking or suspending. Beaches around the mouth of the Black Sea, such as Riva, Poyraz and Altinkum, are under the influence of such pollutants originated in the Istanbul Strait.

SEA ACCIDENTS

Around 40 000 vessels pass the Istanbul Strait every year. The total cargo transported by vessel passing through the Marmara Sea and the Istanbul Strait is 42 million tons, of which more than 16 million tons is crude oil (OZKAN, 1995). Under the Montreux Treaty, commercial vessels and tankers, whatever flag they carry, have freedom of transit passage and navigation day and night regardless of their cargo through the straits and the Marmara Sea. This poses great risk in case of heavy traffic, poor sight, strong waves and vessel failures. Moreover, through the connection of the Danube with the rivers of central and northwestern Europe, additional traffic of small vessels much increased the traffic in the Turkish straits in recent years. In addition, 2 000 trips/day across the Bosphorus are made by domestic small boats for commuting (OGUZULGEN, 1995).

Sea accidents in the Turkish straits are examined mainly under four categories: collision, grounding, fire and stranding. Each has a distinct effect on the marine ecosystem. Between 1982 and 1994, 207 incidents occurred, demonstrating the vulnerability of the straits (OGUZULGEN, 1995).

Collision is the dominant type of accidents in the area (Fig. 2A). It is caused by poor visibility and strong currents, which result in navigation failure. One of the largest collisions occurred in 1979 between the Greek cargo ship *Evriyali* (weight 10 000 t DWT) and the Romanian tanker *Independenta* (weight 165 000 t DWT) which carried 94 000 tons of Libyan crude oil. The collision occurred at the entrance of the Marmara side of the Strait. This was by far the largest sea accident in Istanbul harbour and the straits, causing heavy air and sea pollution in the Istanbul area and the Sea of Marmara. The maximum accumulation of particles during the fire reached up to 1 000 mg/m^3 in the air which was at least four times greater than the permissible limit set for human health. Heavy oil contamination formed on the surface of the sea and on the shores of the Marmara and Bosphorus. It was estimated that 30 000 tons of crude oil was burned, the remaining 64 000 tons was spilled into the sea (BAYKUT *et al.*, 1985). Because of the rapid evaporation of the light components, the spilled crude oil sank rapidly to the bottom. An area of the sea bottom, approximately 5.5 km diameter, was coated with a thick tar coat of a mean concentration of 46 g/m^2. In this area, only nine species of benthos were recorded alive and mortality rate was estimated at 96%.

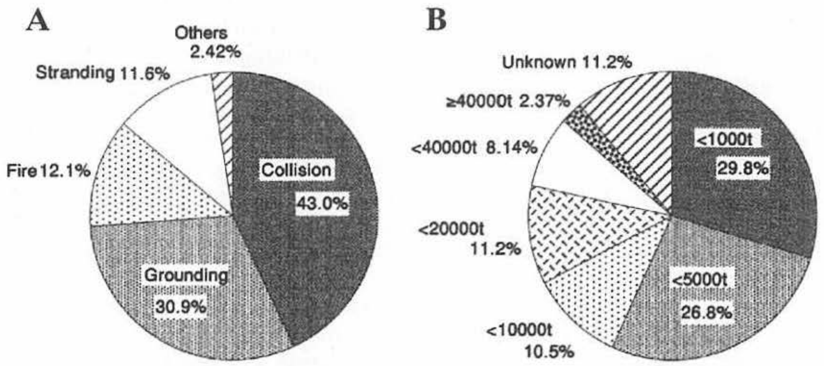

Figure 2 – Sea accidents registered in the Bosphorus strait from May 1982 to April 1994 (modified from OGUZULGEN, 1995). **A**: type of accidents (n = 207). **B**: size (in tons) of the vessels causing accidents (n = 295).

The *Nassia* incident in 1994 resulted in the discharge of 20 000 tons of oil in the Black Sea, Bosphorus and Marmara Sea. The marine environment was greatly affected. Due to the low self-cleaning capacity of the shores of the strait, most bays and beaches were covered with oil and pitch. After this accident, oil levels in the tissues of *Mytilus galloprovincialis* in the Istanbul Strait were as high as 250 μg/g-dry weight (GUVEN *et al.*, 1995).

Another collision provided an example of pollution by a sinking ship. *Rabunion-18* was carrying 20 000 live sheep when it sank after colliding with a Lebanon vessel in the Istanbul Strait in 1991. The sunken sheep decomposed at the bottom of the accident area and caused hypoxia. Due to the hypoxia, the populations of some organisms, such as *Mullus surmuletus,* *M. barbatus, Rapana thomasiana, Mytilus galloprovincialis* and *Crangon crangon,* showed mass mortality. Dissolved oxygen level was measured at 2 mg/l and water transparency value at 0.5 m (YURDUN *et al.*, 1995).

Another major type of accidents in the Bosphorus is grounding (Fig. 2A), often due to failure in maneuvering in the narrow areas, strong currents and mechanical problems. Grounding is dangerous especially for the benthic organisms living in local coastal areas. As shown in Figure 2B more than half of the vessels involved in accidents in the Bosphorus Strait are mainly small to medium size, less than 5 000 t in GRT. While large vessels are relatively rare, they usually impact over a wider zone and a much longer period, as described above. At the same time, these large accidents are relatively well documented compared to small accidents; the environmental consequence of the latter are not studied at all.

FISHERIES

Fishing in the Turkish straits takes two forms, artisanal and industrial (see KOCATAS *et al.*, 1993, for the Marmara Sea). Artisanal type fishing in the Istanbul Strait involves a special lime stone for *Atherina boyeri*, pots for *Gaidropsarus mediterraneus* and also coastal gillnets for *Mullus barbatus, M. surmuletus, Psetta maxima, Scorpaena scrofa* and *Spicara maena maena*. In 1926, DEVEDJIAN counted 52 dalian (coastal bottom setnets) areas in the Istanbul Strait alone. Today there is one dalian left and most traditional fishing is finished. Besides, heavy marine traffic covers the fishing ground in nearly all bays or inlets of the straits, making it difficult to fish.

Until the early 1970s, the straits were biologically the richest and the most productive region. Among the fishes caught, *Pomatomus saltator, Sarda sarda, Trachurus trachurus, Mullus barbatus, M. surmuletus, Lichia amia, Gaidropsarus mediterraneus, Mugil cephalus, Psetta maxima, Scomber japonicus, S. scombrus, Xiphias gladius, Atherina boyeri, Thunnus thynnus* and *Acipenser sturio* were the most numerous. Among these species, *Acipenser sturio, Scomber scombrus, Xiphias gladius, Psetta maxima, Pomatomus saltator, Lichia amia, Atherina boyeri, Gaidropsarus mediterraneus* are disappearing from the Turkish straits system. However, the cause of the decline of the fish populations is not only related to overfishing, illegal fishing methods and vessel originated pollution, but also to organic pollution, changing hydrological regime and other ecological disasters, such as the invasion of *Mnemiopsis leidyi*.

Mussel fishing is also very common in the Istanbul Strait with beam trawls and overfishing (OZTURK and ERGUVEN, (1988). In the Dardanelles Strait, *Mytilus galloprovincialis, Ostrea edulis* and *Ruditapes decussatus* are caught by beam trawls in coastal areas. While trawling is not permitted legally in the straits system, beam trawling which has the same negative effect as trawling on the benthic ecosystem, is permitted and operated widely.

Spongia officinalis is harvested by surface supplied diving in Kemer and Biga areas at a depth of less then 15 m in the Dardanelles. Interestingly, *Spongia* populations in these regions were not affected by the sponge epizootics which covered the whole Mediterranean Sea (VACELET, 1989).

Coastal gill nets are used mainly for *Mullus barbatus, Mullus surmuletus* and *Trachurus trachurus*. Industrial scale fisheries are made by purse seines in the Dardanelles, Marmara Sea and Bosphorus during the peak migration seasons of the Atlantic-Mediterranean pelagic fishes (see Table I). According to RASS (1994), change in stream volume, salinity and pollution in the Bosphorus may affect migration badly by decreasing feeding areas because the life-cycle of some commercial fishes such as *Scomber scombrus, Trachurus mediterraneus, Pomatomus saltator, Sarda sarda* and *Xiphias gladius* requires them to migrate to the Marmara Sea for the winter season and to the Black Sea for their summer feeding. During migration, pelagic fishes are heavily caught; catching fishes on their way to spawning has clearly a large negative effect on the fish stocks of the Black Sea (CELIKKALE, 1994).

Despite large fluctuations, the total catch in the Turkish straits system slightly increased overall in the period of 1980-1993 (Fig. 3). This is likely due to the increasing fishing effort in terms of technology, vessel size and so on. However, the catches of migratory fishes, such as *Pomatomus saltator* and *Thunnus thynnus* and resident fish of the Marmara Sea, such as *Trachurus trachurus*, are lower than in the past.

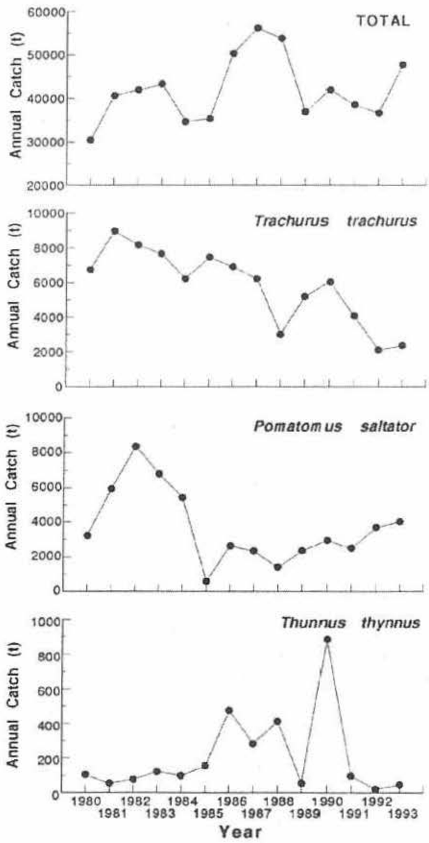

Figure 3 – Total fish catch and catches of some commercially important fishes of the Turkish straits system from 1982 to 1993.

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