Section 8

Cetacean Habitat Loss and Degradation in the Black Sea

Alexei Birkun, Jr.

Laboratory of Ecology and Experimental Pathology, S.I. Georgievsky Crimean State Medical University, Lenin Boulevard 5/7, Simferopol, Crimea 95006, Ukraine - AlexeiBirkun@home.cris.net

Introduction

Early symptoms of progressive deterioration of the Black Sea environment were recorded at the end of the 1960s (Zaitsev 1999). During subsequent decades, the ecological situation in the subregion steadily changed from bad to worse (Mee 1992, 1998, Zaitsev and Mamaev 1997, Zaitsev 1998), and it is only now that the timid gleams of hope appear, suggesting gradual reduction of the environmental distress and partial recovery of the marine ecosystems (Zaitsev 1998, Mee and Topping 1999). No one essential cause of the Black Sea crisis is known, instead manifold human activities in the sea, coastal territories and in the Black Sea basin are identified.

Natural features of the Black Sea environment and ecosystem

Geographical and hydrological peculiarities of the Black Sea and contiguous water bodies have been reviewed repeatedly by authors belonging to different scientific schools and disciplines (e.g. Leonov 1960, Sorokin 1982, Vytkanov et al. 1983, Zaitsev and Mamaev 1997, Kerestecioglu et al. 1998, Readman et al. 1999). Despite numerous factual contradictions, their general attitude on natural features of that maritime area could be briefly summarized as follows.

Geographical properties

The Black Sea is one of the most isolated inland seas in the world (Fig. 8.1). It is situated between southeastern Europe and Asia Minor and has a surface area of 420-436 thousand square kilometres and a volume of 537-555 thousand cubic kilometres of water. The average depth is between 1,240 and 1,315 metres, though it reaches a maximum of 2,212 metres. From east to west the sea measures 1,175 kilometres, and the widest distance from north to south is over 610 kilometres. The total length of the coastline is about 4,020-4,340 kilometres. The shelf is represented by the shelf, continental slope and deep-sea depression. The shelf is significantly wide (up to 200-250 kilometres) in the northwestern part of the sea with a depth varying from zero to 160 metres. In other coastal areas the shelf strip has a similar depth, but considerably less width, from 0.5 to 50 kilometres. Thus, only about one quarter (24-27%) of the sea area has a depth of less than 200 metres. The shelf is slightly inclined offshore; its relief is composed of underwater valleys, canyons and terraces originated due to sediment, abrasive and tectonic activities. The continental slope is tight and steep, descending in some places at an angle of 20-30º. Pelitic muds cover the slope and the deep-sea depression, whereas bottom pebbles, gravel, sand, silt and rocks are common for shelf area. Earthquake epicenters are recorded in the seabed and coastal area on numerous occasions. There are few small islands in the Black Sea; the biggest one and the most distant from the mainland is the Zmeiny isle (0.18 square kilometre) located 35 kilometres offshore. The Crimean peninsula (27,000 square kilometres) protrudes into the sea from the north.

At the northeastern corner, the Black Sea is connected to the Sea of Azov by the Strait of Kerch, which is 41 kilometres long, 4-15 kilometres wide and up to 18 metres deep at its south entrance. Shallow Taman Bay penetrates deep inland in the central section of the eastern strait's shore represented by the Taman peninsula of the Caucasus. The opposite coast of the strait is formed by the Kerch Peninsula which is a constituent part of the Crimea. Sandy Tuzla island at the mouth of Taman bay cuts the Kerch Strait across almost in half and into north (Azov Sea) and south (Black Sea) portions.

The Sea of Azov is about 340 kilometres long and 135 kilometres wide with a surface area of 37-39 thousand square kilometres and a volume of only 320 cubic kilometres. It is the world's shallowest sea with a maximum depth of 13-14 metres in places. The Azov's seafloor, covered by silt and sand, has a generally flat relief. The sea is trapezoid in shape, forming at the northeast the Gulf of Taganrog, a 140-kilometre-long creek with a depth of 0.7 metres. The Arabat Spit, a 112-kilometre-long sand bar, borders the sea at the west. A series of prominent sandy spits is situated on the north coast of the sea. Along the shoreline of both the Black and Azov Seas, mainly on their north and west coasts and in the estuaries of rivers, there are many salty and brackish lakes and lagoons (limans), which are permanently or occasionally connected with the sea through canals and scours perforating the spits. The Sivash Lake, located just to the west of the Arabat Spit and extending longitudinally across almost the entire west coast of the Azov
Sea, is the largest of shallow puddles and marshy inlets linked to the sea.

In the southwest, the Black Sea is connected to the Sea of Marmara (and thus the Dardanelles Strait and the Mediterranean) by the Bosphorus Strait which is over 30 kilometres long, 750-3,700 metres wide and 37-124 metres deep in the midstream. The Sea of Marmara is about 280 kilometres long and nearly 80 kilometres wide. It has a surface area of 11-12 thousand square kilometres and an average depth of 494 metres, reaching a maximum of 1,355 metres in the centre. The sea contains several islands forming two groups. The largest island is Marmara (129 square kilometres) located in front of the entrance to the Dardanelles.

Over 300 rivers flow into the Black and Azov Seas including the second, third and fourth major European rivers, namely the Danube, Dnieper and Don. Some rivers (Danube, Don, Kuban, Kizilirmak and Yeshilirmak) form deltas before their confluence with the sea. The Danube delta (approx 5,920 square kilometres) is the largest wetland in the subregion. According to different estimations, the total catchment area of the Black Sea drainage basin comes to 1,875-2,500 thousand square kilometres covering partially or entirely the territories of 22 countries (Fig. 8.1).

Hydrological peculiarities

The estimated annual volume of river discharge entering the Black Sea fluctuates from 294 to 480 cubic kilometres. Vast quantities of silt are brought down by rivers (in particular, the Danube expels up to 52 million tonnes of sediments per year) causing low transparency of coastal waters especially in the northwestern Black Sea area and in the Sea of Azov. Impressive figures of river run-off explain the higher water level in the Black Sea in comparison with the neighbouring Sea of Marmara (the difference is 53 centimetres on average). The annual volume of atmospheric precipitations in the Black Sea area (119-300 cubic kilometres) is usually lower than the volume of river inflow, but during the rainy season (autumn-winter) the ratio becomes quite the contrary. The annual level of the evaporation in the Black Sea has been calculated between 232 and 484 cubic kilometres. Besides this the general water balance also depends on the intensity of water exchange through the Kerch Strait and Bosphorus.

There are two counter currents in the Kerch Strait: the surface current flowing from the Azov Sea to the Black Sea (22-95 cubic kilometres of water per year), and the lower one moving in the reverse direction (29-70 cubic kilometres per year). The outflow of Black Sea water through the Bosphorus (the surface current of 227-612 cubic kilometres per year) is approximately twice as large as the inflow from the Sea of Marmara (the lower current of 123-312 cubic kilometres per year). The horizontal circulation of Black Sea superficial waters could be roughly described as the two major ring streams rotating counterclockwise in the western and eastern parts of the basin with a velocity from eight to 18 centimetres per second (Fig. 8.2). The smaller counterclockwise currents are also peculiar to the northwestern shelf area as well as to the Azov and Marmara Seas. The vertical circulation in the Black Sea is extremely slow – it takes hundreds of years for the waters at the surface to be replaced by near-bottom waters from the deep-sea depression. Daily tidal oscillations in the Black Sea do not exceed several centimetres. Severe storms accompanied by waves up to 56 metres high occur most often in winter season.

As a result of huge inflow from rivers, the mean salinity of the Black Sea (18‰, i.e. 18 grammes of solid ingredients per one kilogramme of water) is less than a half that of the Mediterranean. It rises up to 21-27‰ at a depth below 300 metres, however it falls seasonally and even as low as 2-8‰ in some spots of the northwestern area. The presence of a halocline at a depth of 100-200 metres is a distinctive hydrological feature of the Black Sea. Azov's waters are lower in salinity (11.7‰ on average), being almost fresh (1-8‰) in the Gulf of Taganrog. At the same time, the waters in the Marmara Sea are more saline than in the Black Sea, averaging 22‰ at the surface with a gradual increase of salinity closer to the bottom and towards the Dardanelles.

The range of water temperatures at the surface of the Black Sea extends from –1.2ºC in winter to +31ºC in summer with the mean annual level varying from 12ºC in the northwest to 16ºC in the southeast of the basin. The thermocline (7.2-8.6ºC) is situated at a depth between 50 and 150 metres. The waters below 500 metres have a constant temperature of about 9ºC. During frosty winters the shallow waters with low salinity become coated with ice. That is more or less typical for the northwestern coastal area and for the Sea of Azov which sometimes (but not every
Biological diversity (with special reference to metres.

The Black Sea is stratified into the superficial layer of oxygenated waters and the deeper column of anoxic waters saturated by high concentrations (0.2-9.6 milligrammes per one litre of water) of dissolved hydrogen sulphide originating from archaic and actual redox processes and probable past geological cataclysms. A boundary or, rather, a transitional interlayer between those strata is relatively stable, it lies at a depth between 100 and 250 metres with some topographic, seasonal and annual fluctuations. Thus, about 87-90% of the Black Sea water volume forms a "dead" zone unfit for aerobic life and inhabited almost exclusively by specific anaerobic bacteria. Consequently, only the upper 10-13% of the water mass represents the most suitable conditions for most marine organisms and, therefore, sustains biodiversity. This general view on the oxygen-dependent stratification of Black Sea habitats does not necessarily hold entirely true. In particular, some aerobic organisms (nematodes) were found in bottom silt sampled at a depth of 600 and even 2,050 metres (Zaitsev 2,050 metres (Zaitsev et al. 1997). Perhaps, both


Depending on the assumed origin of the species, the Black Sea indigenous biota is classified into four groups (Zaitsev and Mamaev 1997):

- Pontian (Caspian) relics that originated from prehistoric brackish basins that used to exist where the Black Sea is now;
- North-Atlantic or Arctic relics supposedly originating from cold seas;
- Mediterranean immigrants, representing the most numerous part of the Black Sea’s fauna (80% of the total number of animal species); and
- typically freshwater species - discharged to the sea from rivers.

Three species of cetaceans – the harbour porpoise (Phocoena phocoena), the short-beaked common dolphin (Delphinus delphis) and the common bottlenose dolphin (Tursiops truncatus) – and one pinniped species – the Mediterranean monk seal (Monachus monachus) – crown the trophic pyramid of the Black Sea as top predators which have no natural enemies in this basin (Kleinenberg 1956, Geptner et al. 1976, Klinowska 1991, Jefferson et al. 1993).

Harbor porpoises inhabit the waters of the continental shelf around the entire perimeter of the Black Sea. Seasonally they are common in the Sea of Azov and Kerch Strait (Zalkin 1940a, Kleinenberg 1956, Birkun and Krivokhizhin 1998) as well as in the Sea of Marmara and Bosporus (Öztürk and Öztürk 1997). Perhaps, both

year) gets covered almost completely by ice up to 80-90 centimetres thick. Uncommon freeze-up events have been recorded sporadically along the southwestern coast of the Black Sea and even in the Bosphorus.

The Black Sea biodiversity is rather confined in comparison, for instance, with the Mediterranean Sea, owing to the higher degree of geographical isolation of the Black Sea, its low water salinity and cooler environment, as well as because of a large amount of anoxic waters enriched with poisonous hydrogen sulphide. As a result, most thermophilous, halophilous, bathypelagic and bathybenthic organisms inherent to the Mediterranean are absent from the Black Sea. Nevertheless, the specific biological productivity of the Black Sea is higher than that estimated for the Mediterranean (Zhakin 1963, Greze 1979, Zaitsev 1998). A total of 3,774 species of multicellular organisms are enumerated in the lists of Black Sea flora and fauna (Zaitsev and Mamaev 1997), including 1,619 species of fungi, algae and higher plants,
small seas are important breeding, calving and feeding areas for the Black Sea population, which is isolated from the nearest one in the northeastern Atlantic. Usually harbour porpoises leave the Azov Sea before winter and come back in spring, but sometimes early and rapid ice formation puts obstacles in the way of their migration causing mass mortality events due to ice entrapment (Kleinenberg 1956, Birkun and Krivokhizhin 1997). Porpoises do not avoid waters with low salinity and transparency; thus, they occur in shallow brackish bays and lagoons, and in the Danube, Dnieper and Don rivers quite far from the sea (Zalkin 1940a, Kleinenberg 1956, Geptner et al. 1976, Selyunina 2001). Similarly to the harbour porpoise, the distribution of common bottlenose dolphins can be found across the Black Sea shelf area (Kleinenberg 1956, Geptner et al. 1976), occasionally they also occur far offshore (Morozova 1981). The presence of bottlenose dolphins in the Bosphorus, Marmara Sea and Dardanelles has been known for a long time (Kleinenberg 1956) and confirmed again recently (Öztürk and Öztürk 1997). These cetaceans are common also in the Kerch Strait (Kleinenberg 1956, Birkun and Krivokhizhin 1998) and sometimes they visit the Sea of Azov (Zalkin 1940b, Birkun et al. 1997). From early spring to late autumn, bottlenose dolphins form compact accumulations in the Kerch Strait and the adjacent Black Sea waters (Kleinenberg 1956, Birkun and Krivokhizhin 1998). Annual autumn migrations of several hundred animals follow from the east towards the south-west along the south coast of the Crimea (Birkun and Krivokhizhin 2000).

Common dolphin herds are distributed predominantly offshore, in the middle part of the Black Sea, and visit inshore waters following seasonal aggregations and mass migrations of small pelagic fishes, mainly sprat and anchovy (Zalkin 1940b, Kleinenberg 1956, Geptner et al. 1976). These cetaceans avoid maritime areas with low water salinity; and this could be an obvious reason why common dolphins do not occur in the Sea of Azov. However, they were observed occasionally in the Kerch Strait (Kleinenberg 1956, Geptner et al. 1976). Common dolphins occur also in the Marmara Sea and Bosphorus from February to November (Öztürk and Öztürk 1997), and it is still a question, where do they come from. Cross-relations including both side movements between Black Sea and Mediterranean populations seem to be possible (Van Beneden 1892, Barabasch 1935, Kleinenberg 1956), although no direct evidence was obtained up to now.

In the last three decades, Black Sea biodiversity has been seriously damaged due to the human-associated degradation of the sea proper and its drainage basin. The species composition of most marine communities was modified with the explosive expansion of some organisms and the depression of many others (Petraru 1997, Komakhidze and Mazmanidi 1998, Konsulov 1998, Zaitsev and Alexandrov 1998, Öztürk 1999). The Mediterranean monk seal has disappeared almost completely from the Black and Marmara Seas. Solitary individuals can still be observed sporadically near the Anatolian coast (Kiraç and Savas 1996, Öztürk 1996, 1999) and, perhaps, in the Danube delta (Zaitsev and Mamaev 1997), although there are probably too few animals to allow for any population recovery. Black Sea dolphins and porpoises, drastically affected by commercial direct killing continued till the early 1980s (see Report Section 6), have also been exposed to modern anthropogenic threats which cause the deterioration of habitats, the depletion of food resources and adversely impact cetacean population health.

**Human impact on the Black Sea environment**

The Black Sea is bordered by six riparian countries - Ukraine to the north, Russia to the northeast, Georgia to the east, Turkey to the south, and Bulgaria and Romania to the west (Fig. 8.2). The Sea of Azov and the Kerch Strait are surrounded by Ukraine and Russia. The Sea of Marmara, Bosphorus and Dardanelles are the internal water bodies of Turkey. Most coastal territories are densely populated and even over-populated especially during the summer season. According to different estimates, based on the national census statistics, permanent human population distributed along the Black Sea shores came to 16-20 millions in the 1990s, and an extra 4-12 million per year were represented by tourists (Petraru 1997, Zaitsev and Mamaev 1997, Bilyavsky et al. 1998, Kerestecioglu et al. 1998, Mazmanidi 1998, Öztürk 1999). However, these figures do not include people inhabiting the coasts of the Azov and Marmara Seas, as well as the citizens of Istanbul, the largest Black Sea urban agglomeration situated on both the European and Asian sides of the Bosphorus and containing the resident population of over 7.3 million people...
Anthropogenic threats to cetacean habitats

The Black Sea and contiguous waters are used for shipping, fishing, aquaculture, mineral exploitation, tourism, recreation, military exercises and waste disposal (Vylkanov et al. 1983, Bilyavsky et al. 1998, Kerestecioglu et al. 1998, Tuncer et al. 1998). In addition, the seabed and the catchment area are under permanent pressure from many other human activities, including urban development, industry, hydro- and nuclear energetics, agriculture and land-improvement. At the moment it seems impossible to prepare a comprehensive assessment of all the anthropogenic threats affecting the habitats of the Black Sea cetaceans. However, principal groups of the threats are generally known and could be listed as follows:

- various kinds of pollution;
- physical modification of the seabed, coasts and rivers; and
- irretrievable direct take of natural wealth including the (over)exploitation of marine living resources.

Some human-associated threats pertinent to the two latter groups are considered in the other parts of this report (e.g., Report Sections 10 and 14).

Pollution

Human-associated contamination of the oxygenated water layer is considered as a primary threat and the greatest environmental problem for the Black Sea region (Mee 1992, 1998, Saving the Black Sea 1993, Strategic Action Plan 1996, Black Sea Transboundary Diagnostic Analysis 1997, Mee and Topping 1999). The main sources of chronic seawater pollution are represented by focal land-based outfalls, river run-off, coastal nonpoint (diffuse) sources, atmospheric fall-out, intentional and accidental inputs from vessels (Table 8.1). According to Mee (1992), the threat to the Black Sea from land-based sources is potentially greater than in any other sea of the world. Many coastal municipalities and industries discharge their wastes directly to the sea with inadequate or no treatment (Fig. 8.2). Nevertheless, the rivers of the basin are responsible for most of the pollution (Tuncer et al. 1998). They are strongly contaminated with industrial and mining wastes (Readman et al. 1999) and transfer a huge amount of nutrients that originate primarily from agriculture (Zaitsev and Mamaev 1997). The impacts of the diffuse coastal, airborne and vessel-sourced pollution are the least investigated, but believed to be significant. Irrespective of sources, anthropogenic pollution of the Black Sea is subdivided into: (a) contamination related to various chemical substances (nutrients, crude oil and petroleum products, persistent synthetic pollutants and trace elements); (b) radioactive contamination; (c) pollution by solid wastes; and (d) biological pollution including microbial contamination and introduction of alien species of marine organisms (Table 8.1). Practically nothing is known about the problem of acoustic (noise) pollution which may cause disturbance of Black Sea cetaceans (see Report Section 14).

Nutrient pollution. In contrast to the Mediterranean, the Black Sea is utterly polluted by organic matter and inorganic nutrients originating from agriculture (fertilizers), animal husbandry, domestic and industrial sewage and from other sources. The excessive loading of sea water with nitrogen- and phosphorus-containing substances is considered as a primary cause of the decline of the shelf ecosystems (Zaitsev 1993, Mee and Topping 1999) and even of the degradation of the Black Sea environment in general (Zaitsev and Mamaev 1997). A large share of nutrients is contributed to the sea by rivers. Some 58% of the dissolved total nitrogen and 66% of the dissolved total phosphorus come from the Danube (Zaitsev and Mamaev 1997). The peak of nutrient inputs has been observed in the 1970s and 1980s. The latter authors, citing Garkavaya et al. (1989), note that by the 1980s the rivers transported to the Black Sea an annual average of 55,000 tonnes of phosphates, 340,000 tonnes of nitrates and 10,700,000 tonnes of organic matter. Four rivers running to the Azov Sea (Don, Kuban, Protoka and Kalmius) discharge every year over 22,000 tonnes of total nitrogen and over 4,500 tonnes of total phosphorus (Black Sea Transboundary Diagnostic Analysis 1997). Detailed additional information on this kind of pollution is presented by Cociasu et al. (1999), Mikhailov (1999), and Topping et al. (1999).
Enormous inputs of nutrients are causing the eutrophication of coastal shallow waters mainly in the northwestern Black Sea shelf area and in the Sea of Azov (Zaitsev 1993, 1998, 1999, Petranu 1997, Zaitsev and Mamaev 1997). This phenomenon includes the production of algal and zooplanktonic blooms (population bursts of dinoflagellates and some other microalgae, and also protozoan Noctiluca miliaris and scyphozoan jelly-fish Aurelia aurita); decline of water transparency; oxygen deficiency in the near-bottom water layer; disappearance of benthic phytocenoses at a depth of 10 metres and deeper; mass mortalities of benthic fishes and invertebrates with associated widespread decay of their remains and seaweed residues. Fish mass mortality events have occurred in the Black Sea since the late 1960s. Blooms of dinoflagellates have become annual events in summertime and autumn since the early 1970s. The areas of eutrophication in the northwestern Black Sea (within Ukrainian, Romanian and Bulgarian waters) expanded from 3,500 square kilometres in 1973 to 40,000 square kilometres in 1990 (Zaitsev 1993) with some reduction of affected areas in the 1990s (Zaitsev 1998). Water hypoxia and anoxia led to sharp depletion of valuable bioresources and decline of biodiversity. It was estimated that between 1972 and 1990 about 60 million tonnes of bottom animals died in the northwestern shelf area due to the lack of oxygen (Zaitsev 1992), and the variety of macrozoobenthic species on the shelf near Danube delta fell from 70 in 1961 to 14 in 1994 (Petranu 1997).

There has been no dedicated research concerning the impact of nutrient pollution on Black Sea cetaceans. The presumed effects of the eutrophication on cetaceans include the depletion of food resources and the collapse of the ecosystem in forage areas (both these effects could be particularly stressful for harbour porpoises and bottlenose dolphins which consume benthic fishes). In addition, the “fertilized” water represents a suitable growth medium for: (a) various bacteria potentially pathogenic for cetaceans, and (b) toxin-producing planktonic species – i.e. Gonyaulax polyedra, Prorocentrum micans and Noctiluca miliaris (Zaitsev 1999) which could cause an accumulation of toxins in cetacean prey.

**Oil pollution** Oil pollution in the Black Sea is concentrated predominantly in the coastal area around stationary sources, such as river mouths, sewerage outfalls, harbour and industrial installations. Accidental and operational spillage of oil and petroleum products from vessels contributes to the pollution in both inshore and offshore areas. According to incomplete data presented in the Black Sea Transboundary Diagnostic Analysis (1997), about 111 thousand tonnes of oil are discharged into the Black Sea every year. Thus, Danube’s outflow values (53,300 tonnes per year) amount to 50% of the estimated total annual load. Officially registered oil spills from accidents at the sea (136 tonnes per year on average) are relatively small in comparison with inputs from other sources. Significant concentrations of total petroleum hydrocarbons and products of oil degradation were detected in sea water and sediments near the Danube delta, close to the ports of Sevastopol, Ilyichevsk, Varna, Kerch, Sochi, Odessa and in the Prebosphoric area (Bayona et al. 1999, Mikhailov 1999, Readman et al. 1999) (Fig. 8.2). Those concentrations are roughly comparable to the values recorded in the Mediterranean, although the levels of carcinogenic polycyclic aromatic hydrocarbons in the Black Sea are lower than in the Mediterranean and other regional seas (Bayona et al. 1999, Readman et al. 1999).

Oil pollution induces deterioration of coastal marine ecosystems and affects the neuston superficial layer causing the elimination of eggs and larvae of mass pelagic fishes (Zaitsev and Mamaev 1997) which constitute a basic diet of Black Sea cetaceans. Fatal experiments on toxic and pathogenic effects of oil (mazout) were conducted on several Black Sea harbour porpoises in the military oceanarium of the former Soviet Union (Lukina et al. 1996, Kavtsevich 2000).

**Persistent organic pollutants.** Important synthetic pollutants are represented in the Black Sea by organohalogenes: DDT and its derivatives (DDD, DDE), polychlorinated biphenils (PCBs), hexachlorohexanes (HCHs), hexachlorobenzene (HCB), chlordanes (CHLs), butylin compounds (BTs), heptachlor, heptachlor epoxide, aldrin, dieldrin, endrin, methoxychlor, and mirex which enter the sea mainly from agriculture, industry and municipal sewage (Table 8.1)

---

1 The input from ships sometimes may also be considerable. For instance, in 1976 in Odessa Bay there was an accident involving the vessel “Mozdok” which was loaded with 600 tonnes of DDT and 200 tonnes of HCH (Mikhailov, 1999). Fortunately, most of the freight pre-packed in plastic bags was salvaged from the sunken boat.
there is no evidence of total or widespread contamination of the sea by these substances (most concentrations are comparable with those detected in the Mediterranean), their levels in the sea water and sediments sampled in some coastal areas (near Danube delta, Odessa, Sevastopol, Sochi, close to the Bosphorus and in the Kerch Strait) appear to be quite high (Mikhailov 1999, Readman et al. 1999). The latter publication presents the ranking of organohalogen concentrations in Black Sea surficial sediments as follows: DDTs > HCHs > PCBs > HCB > cyclodiene. A similar ranking has been earlier reported for Black Sea fishes and harbour porpoises (Tanabe et al. 1997 a). The low DDE/DDT values combined with relatively high concentrations indicate current, certainly illegal DDT usage around the Black Sea (Readman et al. 1999) and, particularly, in the Ukraine (Mikhailov 1999) and Turkey (Tuncer et al. 1998).

Persistent organic pollutants are lipophilic and liable to bioaccumulation in food webs attaining maximal concentrations in the fat of top predators including marine mammals. To date the contamination of harbour porpoises is better known than that of the two other Black Sea cetacean species. (Table 8.2). Harbour porpoises appear to accumulate higher concentrations of DDTs, HCHs and HCB than the bottlenose and common dolphins (Birkun et al. 1992, 1993). They also accumulate PCBs (including toxic coplanar congeners), CHLs, BTs, heptachlor, heptachlor epoxide, aldrin, dieldrin, endrin, methoxychlor and mirex (Tanabe et al. 1997 a, b, Madhusree et al. 1997, BLASDOL 1999). The contamination of Black Sea harbour porpoises by DDTs and HCHs is higher than that reported for this species elsewhere in the world (Tanabe et al. 1997a). The concentrations of S DDTs in the blubber of two Black Sea common dolphins that died from morbilliviral disease was about 50 to 100 times higher than the levels in toothed cetaceans from the North Sea, North Atlantic Ocean and Baltic Sea (Birkun et al. 1999).

Trace elements. Contamination by trace elements, including heavy metals, is not a basin-wide problem in the Black Sea but in some coastal areas the surface sediments reveal increased inputs of chromium, lead, copper, zinc, vanadium, cadmium, cobalt, nickel, arsenic, mercury, iron, and manganese (Readman et al. 1999, Windom et al. 1999). Existing values for cadmium, cobalt, copper and nickel show that these metals occur at higher concentrations in the Black Sea than in the Mediterranean (Windom et al. 1999). The known hotspots of trace metal contamination are the outlets of Danube and Dnieper rivers, the areas near Odessa, Sevastopol, Yalta and Sochi cities, the Gulf of Taganrog, the Strait of Kerch and the Black Sea immediately adjacent to the Bosphorus. Elevated concentrations of nickel were also found in the eastern part of the Turkish Black Sea.

The concentrations of cadmium, chromium, copper, iron, lead, nickel, selenium, zinc, mercury and some other microelements have been studied in various tissues of over 100 Black Sea harbour porpoises, but only in five common dolphins and 19 bottlenose dolphins (Table 8.2). Generally, low-to-moderate levels of trace metal contamination are peculiar to Black Sea harbour porpoises. For example, the concentrations of mercury are about one order of magnitude lower than in porpoises from the North Sea (BLASDOL 1999, Jorjis et al. 2001). Low hepatic and renal concentrations of zinc were detected in comparison with harbour porpoises from Belgian coast (Das et al. 2001). Harbour porpoises from the Azov Sea seem to be more contaminated by trace elements than individuals sampled in the Black Sea (Glazov and Zhulidov 2001).

Radioactive contamination. The principal sources of radioactive pollution of the Black Sea are: (a) past nuclear weapon tests, carried out in the air in different points of the world in the 1950s-1960s, and (b) the Chernobyl catastrophe, occurred in the USSR in 1986 (Kulebakina 1992, Polikarpov et al. 1992, Vakulovsky et al. 1994, Osvath and Egorov 1999). As a consequence of those events, the anthropogenic radionuclides (\(^{137}\)cesium, \(^{90}\)strontium, \(^{239}\)\(^{240}\)plutonium, etc.) were introduced to the sea mainly by atmospheric precipitations and rivers, particularly, by the Dnieper and Danube. In the 1990s the Black Sea showed relatively high concentrations of radionuclides in comparison with other marine basins except the Baltic and Irish Seas which were also strongly polluted. Mean concentrations of \(^{137}\)cesium in the water, sediments and fish were one order of magnitude higher in the Black Sea than in the Mediterranean (Osvath and Egorov 1999). Nevertheless, it is considered that the existing levels of radioactive contamination do not represent radiological problem for Black Sea biota and human population (Zaitsev and Mamaev 1997, Osvath and Egorov 1999).
Güngör and Portakal (1996) have measured concentrations of $^{137}$cesium in Black Sea harbour porpoises stranded and by-caught in Turkey. Among samples examined (Table 8.2), the higher levels of the radionuclide (up to 11-12 Bq/kg) were detected in muscles and kidney, but other tissues were also contaminated.

**Marine debris.** The Black Sea and its coasts seem to be subject to very high levels of solid wastes, although no formal studies of its extensiveness, sources, patterns and effects have yet been made. Marine dumping of municipal garbage is known in Turkey and Georgia (Mee and Topping 1999). The sites of explosive objects disposal are mapped off the Crimea (Ukraine) and in the Gulf of Taganrog (Russia). Navigation charts reflect also the distribution of sunken vessels and other scrap metal over the shelf area.

Floating litter including plastics and lost fishing nets represent particular threats to cetaceans (Zaitsev 1998) which sometimes ingest inedible things and may get themselves entangled. A number of foreign bodies have been collected from stomachs of Black Sea common dolphins: coal slag, pieces of wood and paper, bird feathers, cherry stones, and even a bunch of roses (Kleinenberg 1956), whereas only pebbles and sand were found in wild bottlenose dolphins and harbour porpoises (Kleinenberg 1956, Krivokhizhin et al. 2000). However, many man-made and natural foreign objects have been recorded ingested by captive individuals of both latter species (Rodin et al. 1970, Belkovich and Gurevich 1971, Vinogradov et al. 1971).

**Microbe/faecal pollution.** Almost all Black Sea cities and settlements currently discharge their effluents (treated, partially treated or untreated) into the marine environment directly or via rivers. The estimated (probably underestimated) total volume of sewage entering the sea comes to over 571 million cubic metres per year (Bartram et al. 1999). Some important sources of faecal pollution were evaluated in the Black Sea Transboundary Diagnostic Analysis (1997) (Fig. 8.2). Between 5% (Bulgaria) and 44% (Ukraine) of seawater samples taken during warm season (May – September) near beaches in different Black Sea countries were significantly contaminated by intestinal bacteria (Bartram et al. 1999). In particular, the number of faecal coliforms exceeded 20,000-100,000 per litre and the number of faecal streptococci exceeded 4,000 per litre. In the late 1980s, the concentration of *Escherichia coli* in the seawater near Odessa sometimes rose up to 2,400,000 microbe cells per one litre (Zaitsev 1998). Wide diversity of enterobacteria (*Escherichia*, *Proteus*, *Edwardsiella*, *Klebsiella*, *Citrobacter*, *Enterobacter* and *Salmonella spp.*) and pyogenic cocci (*Staphylococcus spp.*) have been observed in Georgian coastal waters (Zhgenti 1998). Surface waters in the Romanian nearshore area contained high levels of pathogenic fungi (Apas 1995).

Coprostanol – one of principal sterols in human and animal faeces and, therefore, pertinent indicator of faecal pollution – was detected in all samples of superficial sediments collected from the Black Sea (Readman et al. 1999). The elevated concentrations of this marker have been recorded near Sochi, Danube delta and Bosphorus. Meantime, coprostanol levels in the Black Sea are comparable or perhaps even lower than those generally encountered in other seas including the Mediterranean.

Pathogens associated with land-based discharges, coastal diffuse sources and liquid wastes incoming from ships represent a potential health risk not only to humans (Strategic Action Plan 1996) but also to cetaceans (Birkun 1994). The cetacean-related effects of microbial pollution are described in another chapter entitled “Natural mortality” (see Report Section 16), although the term “natural” in this context is not quite appropriate because of the mainly anthropogenic origin of faecal contamination.

**Introduction of alien species.** The accidental introduction of alien species of animals and plants is a major but poorly manageable anthropogenic threat affecting the Black Sea ecosystem (Zaitsev and Mamaev 1997). Marine organisms, causing this kind of biological pollution, usually arrive in the sea from oceanic vessels either as their external “foulings” or in their ballast waters, which often appear to be discharged without preventive treatment. At this time, several species of exotic crabs, barnacles, jellyfishes, molluscs, one species of a polychaete and one species of brown seaweed are known among the newcomers that have invaded the Black Sea and which have become widely distributed here during the 20th century.

The ctenophore (comb jellyfish) *Mnemiopsis leidyi*, accidentally introduced in the early 1980s from North American coastal waters, has reportedly exerted negative impact on the stocks of Black Sea pelagic fishes (mainly anchovy and scad) and, as a consequence, on Black Sea
cetaceans which feed on those fishes (Vinogradov 1996). Over only a few years, this raptorial invader has become a dominant species in the Black Sea and also spread to the Azov and Marmara Seas. By the end of the 1980s, its total biomass in the basin was estimated at about 1,000 million tonnes (Vinogradov et al. 1989) with a gradual decrease in this value during the 1990s (Mutlu et al. 1994). The outbreak of *M. leidyii* in 1988-1990 has led to the depletion of zooplankton forage sources for pelagic fishes and to the large scale consumption of their eggs and larvae; both effects, combined with overfishing, have resulted in a collapse of pelagic fish resources (Zaitsev and Mamaev 1997). There is therefore considerable reason to regard *M. leidyii* as a form of biological pollution which is able to affect Black Sea cetacean populations through the depletion of their feedings stuff.

Another kind of biological intervention in the Black Sea relates to coastal dolphinaria and oceanaria (Table 8.1) which keep exotic species of marine mammals in the nearshore open-air pens; sometimes those constructions do not prevent escapes of captive animals into the open sea. Such cases have been known since the early 1980s in the former USSR and during the last decade in the Russian Federation and Ukraine (Birkun and Krivokhizhin 1996, 2001). The list of spontaneously released cetaceans and pinnipeds include the white whale (= beluga, *Delphinapterus leucas*), the northern fur seal (*Callorhinus ursinus*), the Steller sea lion (*Eumetopias jubatus*), the harbour seal (*Phoca vitulina*), the Caspian seal (*Phoca caspica*) and, perhaps, one or two other pinniped species. The exact number of irrecoverably escaped alien marine mammals is unknown, but it probably comes to a few tens including two belugas which were observed many times in the wild near the Turkish, Romanian, Bulgarian and Ukrainian coasts in the early 1990s. During the last 12-14 years, solitary individuals of otariids have been recorded in the Black and Azov Seas including Karkinitsky, Kazantipsky, Feodosia and Sevastopol bays, the coast of Kerch peninsula, Arabat Spit and beaches of Sochi and Batumi. In April 1988 and April 1989 two different fur seals were recorded near Ereğli, Turkey (Kırç and Savas 1996). According to the observations of local inhabitants and fishermen, in 1995-1998 two or three individuals of true seals (one of them allegedly had a collar) were seen annually in winter and spring in the Kerch Strait at the coast of Tuzla island (Birkun and Krivokhizhin 2001).

The fate of most accidentally released marine mammals and their possible influence on indigenous Black Sea cetaceans and monk seals remain uncertain. Theoretically, spontaneously released exotic marine mammals can be a potential source of various pathogens including infectious agents and parasites which earlier were not known in the Black Sea.

**List of References**


Tuncer G., Karakas T., Balkas T.I., Gökcay C.F., Aygun S., Yurtari C., Tuncel G. 1998. Land-based sources of pollution along the Black Sea coast of Turkey: Concentra-


Table 8.1. Kinds and sources of pollution in the Black Sea

<table>
<thead>
<tr>
<th>Kinds of pollution</th>
<th>Sources of pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stationary land-based outfalls a</td>
</tr>
<tr>
<td>Contamination with chemicals:</td>
<td></td>
</tr>
<tr>
<td>nutrients and organic matter</td>
<td>+</td>
</tr>
<tr>
<td>oil and petroleum products</td>
<td>+</td>
</tr>
<tr>
<td>persistent organic pollutants</td>
<td>+</td>
</tr>
<tr>
<td>trace elements</td>
<td>+</td>
</tr>
<tr>
<td>Radioactive contamination</td>
<td>+</td>
</tr>
<tr>
<td>Marine debris</td>
<td>+</td>
</tr>
<tr>
<td>Biological pollution:</td>
<td></td>
</tr>
<tr>
<td>microbe/faecal contamination</td>
<td>+</td>
</tr>
<tr>
<td>introduction of exotic species</td>
<td>+</td>
</tr>
</tbody>
</table>

- a – industrial liquid wastes and insufficiently treated or untreated sewage from coastal cities and settlements;
- b – inputs from the agriculture, industry, mining and municipal sewage from the whole Black Sea drainage area;
- c – inputs from the agriculture, animal husbandry and unmanaged tourism mainly through the run-off from land (coastal pluvial effluents and ground waters);
- d – inputs from various sources of air pollution (smokes, fumes, dust, exhaust gases) no matter where in the world;
- e – dumping of solid waste, explosives and dredged matter; discharge of untreated sewage and ballast waters; oil spills; lost fishing nets; introduction of alien marine organisms owing to the biofouling;
- f – escapes or intentional release of captive marine mammals; discharge of untreated pool waters.
Table 8.2. Studies on contaminants and microelements in wild Black Sea cetaceans (in chronological order)

<table>
<thead>
<tr>
<th>Cetacean species</th>
<th>No. of animals</th>
<th>Stranded / By-caught</th>
<th>Period of sampling</th>
<th>Location of sampling</th>
<th>Substances considered</th>
<th>Tissues considered</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harbour porpoise</td>
<td>1</td>
<td>Unknown</td>
<td>1988-1990</td>
<td>Karkinitsky bay, Ukraine</td>
<td>Mercury</td>
<td>Muscle, liver</td>
<td>Svetasheva et al. (1992)</td>
</tr>
<tr>
<td>Common dolphin Bottlenose dolphin Harbour porpoise</td>
<td>2</td>
<td>Stranded</td>
<td>1990</td>
<td>Crimean coast, Ukraine</td>
<td>S DDTs, S HCHs</td>
<td>Blubber</td>
<td>Birkun et al. (1992)</td>
</tr>
<tr>
<td>Common dolphin Bottlenose dolphin Harbour porpoise</td>
<td>2</td>
<td>Stranded</td>
<td>1990</td>
<td>Crimean coast, Ukraine</td>
<td>2,4'-DDE, 4,4'-DDE, 2,4'-DDD, 4,4'-DDD, 2,4'-DDT, 4,4'-DDT, S DDTs, HCB, α-HCH, β-HCH, γ-HCH, δ-HCH, S HCHs</td>
<td>Blubber</td>
<td>Birkun et al. (1993)</td>
</tr>
<tr>
<td>Harbour porpoise</td>
<td>7</td>
<td>Stranded, by-caught</td>
<td>1993</td>
<td>Turkish coast</td>
<td>Cadmium, chromium, copper, zinc</td>
<td>Muscle, liver, kidney, testis, ovary</td>
<td>Bassari et al. (1996)</td>
</tr>
<tr>
<td>Cetacean species</td>
<td>No. of animals</td>
<td>Stranded / By-caught</td>
<td>Period of sampling</td>
<td>Location of sampling</td>
<td>Substances considered</td>
<td>Tissues considered</td>
<td>References</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------</td>
<td>----------------------</td>
<td>--------------------</td>
<td>---------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Harbour porpoise</td>
<td>49</td>
<td>By-caught</td>
<td>1993</td>
<td>Eastern part of Turkish waters</td>
<td>S PCBs, p,p'-DDE, p,p'-DDD, o,p'-DDT, S DDTs, a-HCH, ß-HCH, t-HCH, S HCHs, oxychlordane, cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor, S CHLs, HCB</td>
<td>Blubber</td>
<td>Tanabe et al. (1997 a)</td>
</tr>
<tr>
<td>Harbour porpoise</td>
<td>11</td>
<td>By-caught</td>
<td>1993</td>
<td>Eastern part of Turkish waters</td>
<td>PCB isomers and congeners, S PCBs</td>
<td>Blubber</td>
<td>Tanabe et al. (1997 b)</td>
</tr>
<tr>
<td>Harbour porpoise</td>
<td>27</td>
<td>By-caught</td>
<td>1993</td>
<td>Eastern part of Turkish waters</td>
<td>Butyltin compounds (MBT, DBT, TBT) and S BTs</td>
<td>Liver</td>
<td>Madhusree et al. (1997)</td>
</tr>
<tr>
<td>Common dolphin</td>
<td>2</td>
<td>Stranded</td>
<td>1994</td>
<td>Crimean coast, Ukraine</td>
<td>Cadmium, chromium, copper, iron, lead, mercury (total and organic), nickel, zinc, S PCBs, o,p'-DDE, p,p'-DDT, S DDTs</td>
<td>Liver, kidney, muscle</td>
<td>Holsbeek et al. (1997)</td>
</tr>
<tr>
<td>Common dolphin</td>
<td>2</td>
<td>Stranded</td>
<td>1994</td>
<td>Crimean coast, Ukraine</td>
<td>Cadmium, chromium, copper, iron, lead, mercury (total and organic), nickel, selenium, zinc</td>
<td>Muscle, lung, liver, brain, heart, kidney, lymph node, testis, ovary</td>
<td>Birkun et al. (1999)</td>
</tr>
<tr>
<td>Common dolphin</td>
<td>3</td>
<td>By-caught</td>
<td>1997-1998</td>
<td>Ukraine (Crimea), Bulgaria, Georgia (Ajaria)</td>
<td>Mercury (total and organic), PCB isomers and congeners, S PCBs, p,p'-DDE, o,p'-DDE, p,p'-DDD, o,p'-DDT, S DDTs, HCB, S HCHs, aldrin, dieldrin, endrin, heptachlor, heptachlor epoxide, methoxychlor, mirex</td>
<td>Muscle, liver, blubber, kidney, brain</td>
<td>BLASDOL (1999)</td>
</tr>
<tr>
<td>Cetacean species</td>
<td>No. of animals</td>
<td>Stranded / By-caught</td>
<td>Period of sampling</td>
<td>Location of sampling</td>
<td>Substances considered</td>
<td>Tissues considered</td>
<td>References</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------</td>
<td>----------------------</td>
<td>--------------------</td>
<td>---------------------</td>
<td>-----------------------</td>
<td>-------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Harbour porpoise</td>
<td>4</td>
<td>By-caught, stranded</td>
<td>1993</td>
<td>Western part of Turkish waters</td>
<td>Mercury (inorganic and organic)</td>
<td>Muscle, skin, fat, liver, kidney, testis, vibrissae</td>
<td>Readman et al. (1999)</td>
</tr>
<tr>
<td>Harbour porpoise</td>
<td>46</td>
<td>By-caught</td>
<td>1997-1998</td>
<td>Crimean coast, Ukraine</td>
<td>Cadmium, chromium, copper, iron, lead, nickel, selenium, zinc</td>
<td>Liver, kidney, muscle</td>
<td>Das et al. (2001)</td>
</tr>
<tr>
<td>Harbour porpoise</td>
<td>74, 5</td>
<td>By-caught, Stranded</td>
<td>1997-1998</td>
<td>Ukraine (Crimea), Bulgaria, Georgia</td>
<td>Mercury (total and organic)</td>
<td>Liver, kidney, brain, muscle, blubber</td>
<td>Joiris et al. (2001)</td>
</tr>
<tr>
<td>Bottlenose dolphin, Harbour porpoise</td>
<td>17, 13</td>
<td>By-caught, stranded</td>
<td>1996-1999</td>
<td>Russia (Black Sea coast) Russia (Black Sea and Azov Sea coast)</td>
<td>Cadmium, chromium, copper, lead, manganese, mercury (total and organic), selenium, zinc</td>
<td>Liver, kidney, muscle, skin (epidermis)</td>
<td>Glazov and Zhulidov (2001)</td>
</tr>
</tbody>
</table>
Fig. 8.1. Black Sea drainage basin (after Zaitsev and Mamaev 1997) and a list of twenty two Basin’s countries – potential contributors to Black Sea pollution via their river run-off.

<table>
<thead>
<tr>
<th>Number</th>
<th>City</th>
<th>Number</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tsarevo</td>
<td>17</td>
<td>Anapa</td>
</tr>
<tr>
<td>2</td>
<td>Sozopol</td>
<td>18</td>
<td>Novorossiysk</td>
</tr>
<tr>
<td>3</td>
<td>Bourgas</td>
<td>19</td>
<td>Gelendzhik</td>
</tr>
<tr>
<td>4</td>
<td>Varna</td>
<td>20</td>
<td>Dzhoubga</td>
</tr>
<tr>
<td>5</td>
<td>Balchik</td>
<td>21</td>
<td>Sochi</td>
</tr>
<tr>
<td>6</td>
<td>Mangalia</td>
<td>22</td>
<td>Poti</td>
</tr>
<tr>
<td>7</td>
<td>Constantza and Mamaia</td>
<td>23</td>
<td>Batumi</td>
</tr>
<tr>
<td>8</td>
<td>Odessa and Ilyichevsk</td>
<td>24</td>
<td>Trabzon</td>
</tr>
<tr>
<td>9</td>
<td>Krasnoperekopsk</td>
<td>25</td>
<td>Giresun</td>
</tr>
<tr>
<td>10</td>
<td>Evpatoria</td>
<td>26</td>
<td>Ordu</td>
</tr>
<tr>
<td>11</td>
<td>Sevastopol</td>
<td>27</td>
<td>Samsun</td>
</tr>
<tr>
<td>12</td>
<td>Yalta</td>
<td>28</td>
<td>Bafra</td>
</tr>
<tr>
<td>13</td>
<td>Kerch</td>
<td>29</td>
<td>Gerze</td>
</tr>
<tr>
<td>14</td>
<td>Mariupol</td>
<td>30</td>
<td>Zonguldak</td>
</tr>
<tr>
<td>15</td>
<td>Taganrog</td>
<td>31</td>
<td>Eregli</td>
</tr>
<tr>
<td>16</td>
<td>Rostov-na-Donu</td>
<td>32</td>
<td>Istanbul</td>
</tr>
</tbody>
</table>

*Fig. 8.2* shows the main land-based sources and hot spots of pollution in the Black Sea subregion, with numbers indicating the locations shown on the map. The surficial sea currents are depicted based on Vylkanov *et al.* (1983).