Biological Diversity in the Black Sea

A Study of Change and Decline

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GEF Black Sea Environmental Programme

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A Study of Change and Decline

by
Yu. Zaitsev and V. Mamaev

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Global Environment Facility (GEF):
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GEF Black Sea Environmental Programme
Dolmabahce Sarayi, II. Harekat Kosku
80680 Besjkta?, Istanbul
Turkey
Tel: 90-212-227-99-27/28/29/30
Fax: 90-212-227-99-33
Internet: blacksea@dominet.in.com.tr

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Preface

Does man have an ecological memory? If yes, can we hope that it may weigh on political decision-making to the point of overriding short-term economic interests? These are enormous questions, and there is probably no simple answer to them.

Whether through the specialised scientific literature or through the modern mass media, we are continuously showered with nightmarish tales, describing what man's greed and ruthlessness has done to nature, the source and sink of all products - and byproducts- of human creativity.

The good news is so much rarer that it seems that our whole environment is sliding down the one-way street of the second law of thermodynamics: in order to create local organisation and welfare, we destroy, pillage and increase entropy worldwide.

Unless, of course, we begin to change our attitude and begin to pay slightly more than just lip-service to the concept of SD, Sustainable Development. This is not the place to elaborate on the concept itself, but is fair to say that the number of instruments that we have to tackle it on an international scale is limited. There is, in fact, only one major fund that caters for it: the United Nations' Global Environmental Facility, or GEF. But even this fund's resources are far from sufficient to meet demand; which makes it critical that they are spent on the most pressing issues.

The Black Sea qualifies as a GEF-subject. In fact, there are few sites in the world that are better qualified. The current Black Sea basin is part of the physical remains of the ancient Tethys Sea, that ocean which once encircled our planet and only became closed when Arabia hit the Eurasian bloc, raising mountain chains like the Caucasus and Elbruz. Surviving fragments of the Tethys include the southern part of the Caspian basin, and the Black Sea. It is interesting to note that, since its sequestration, the Caspian has never regained contact with the World Ocean. It effectively became a lake; at times saline, at times fresh, but never again with a marine living world. The Pontic basin, however, has had a more eventful history. It may seem strange to some, but the Black "Sea" too was actually a lake for most of its existence. Like the Caspian, its salinity and size fluctuated, and the two sisters were at times separated, at times united, so that their biota was able to flow freely in both directions, creating what is known in biogeography as the Ponto-Caspian flora and fauna. That endemic element still accounts for a significant proportion of their current biodiversity.

The acquisition of a marine facies was a recent event, of Holocene age, which happened as the Mediterranean waters broke through the Bosphorus. It drastically changed the Black Sea's biota, introducing true marine groups, and destroying the entire deep benthos, as meromictic conditions developed.

The authors of this volume, which admirably describes the processes leading to the genesis of the complex biota of the Black Sea, were deeply involved in and made a considerable contribution to the success of the Black Sea Environmental Programme. They deserve to be congratulated for making their great knowledge of the biodiversity of the sea available to a broader audience. The way they describe the microcosm of life forms that develops around a limited number of key species is so incisive and vivid that their case-studies may well be used as school-class examples of the very concept of keystone species.

In addition, their analysis of the multiplicity of causes that have led to the destruction, collapse, or expansion of certain species and communities is lucid and instructive. But the book goes beyond mere analysis. It also proposes a cure for this wounded ecosystem, and the remedies suggested are numerous. But will they also be successful? Much will depend on the consciences of the decision makers in the region. Perhaps the most fundamental lesson to be learnt from the wisdom of this book is that, if the regional political leadership does indeed have an ecological memory, if it remembers the past, with its giant fields of eelgrass, of bottom algae, of oyster banks, of dolphins and tuna, and decides to brush aside pressure from those who want to take even more from the sea without giving anything back, there is still hope and room for recovery. The Strategic Action Plan has been formulated and signed by all the littoral states. We will now wait and see to what extent it can become a reality.

Henri J. Dumont
Professor of Ecology
University of Gent
Belgium.

Introduction

Recent widespread changes in the diversity of life (biodiversity) of the seas are largely due to the effects of human activities. Yet at the same time such biological resources are vital for humanity and its further social development. As a result, there is today a growing recognition that biodiversity is a global asset of tremendous value to current and future generations.

In November 1988 the United Nations Environmental Programme (UNEP) convened the Ad Hoc Working Group of Experts on Biological Diversity, to explore the need for an international convention on biological diversity. The resultant Convention was inspired by the world community's growing commitment to sustainable development. It represents a dramatic step forward in the conservation of biological diversity and the sustainable use of its components.

The Convention was opened for signature on 5 June 1992 at the United Nations Conference on Environment and Development (the Rio "Earth Summit"). It remained open for signature until 4 June 1993, by which time the number of signatories had reached 168. The Biodiversity Convention entered into force on 29 December 1993. All the Black Sea countries have signed and ratified it.

Recently biological diversity has changed from being a purely theoretical concept to become one of the most accurate yardsticks of the health of the environment. This has been emphasised by the resolutions of the United Nations Conference on Environment and Development.

According to Article 2 of the Convention, biological diversity is defined as the variability among living organisms from all sources including, *inter alia,* terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species, between species and between ecosystems.

Article 6 requires each Contracting Party to develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity.

Article 18 requires the Contracting Parties to promote international technical and scientific co-operation in the field of conservation and the sustainable use of biological diversity through, where necessary, the appropriate international and national institutions. Subject to mutual agreement, the Contracting Parties are also required to promote the establishment of joint programmes and joint ventures for the development of technologies relevant to the objectives of the Convention.

The ecological situation in different regions of the world depends on the state of nature in each location and the influence of anthropogenic activities. Over the past few years the Black Sea has increasingly attracted the attention of scientists, governments and •the public at large as a region suffering ecological deterioration. Articles on the subject have appeared in scientific publications, newspapers and magazines all over the world. In assessing the situation, many have expressed apprehension, sometimes panic or even hopelessness. The latter does not reflect the real state of the sea and does not facilitate attempts to find a way out of the present situation.

After several years of negotiation, the Convention for the Protection of the Black Sea from Pollution (Bucharest Convention) was signed in Bucharest in April 1992 by all six coastal countries. By April 1994 the Black Sea Convention had come into force throughout the region.

Under Article 13 of the BucharestConvention, when taking measures in accordance with the Convention for the prevention, reduction and control of the pollution of the marine environment of the Black Sea, the Contracting Parties are required to pay particular attention to avoiding harm to marine life and living resources, in particular by changes to their habitats through fishing and other legitimate uses of the sea, and they are required to give due regard to the recommendations of competent international organisations.

In April 1993 in Odessa a common policy declaration (the Odessa Declaration) was signed by the Environment Ministers from all six Black Sea countries. The Declaration provides a bold calendar of actions aimed at linking all sectors in a joint effort to save and protect the Black Sea environment. The Contracting Parties agreed:

- to encourage the development of comprehensive and coordinated plans for the restoration and conservation of biodiversity in the Black Sea in the spirit of the 1992 Biodiversity Convention;
- to take appropriate measures for the restoration and conservation of biodiversity in the Black Sea in the spirit of the 1992 Biodiversity Convention;
- to establish and improve nature conservation areas in the coastal zone of each of the littoral states before 1996.

In order to give environmental action an early start and to develop a long-term Action Plan, the Black Sea countries requested support from the Global Environment Facility (GEF), a fund established in 1991 under the management of the World Bank, the UN Development Programme and the UN Environmental Programme. In June 1993, a three-year Black Sea Environmental Programme (BSEP) was established with US$ 9.3 million funding from GEF and over US$ 5 million collateral funding from the European Union (Phare and Tacis), the Netherlands, France, Austria, Canada and Japan.

The human population of six coastal countries (Bulgaria, Georgia, Romania, the Russian Federation, Turkey and Ukraine) to satisfy some of its needs for food, transport and recreation uses the Black Sea ecosystem. Unfortunately, it is also used by these and another 11 countries for the disposal of waste from agriculture, industry and domestic activities. The protection of the Black Sea cannot be achieved on a unilateral basis. Almost every use of the sea and its coastal areas has the potential to affect the well-being of neighbouring countries. Even point-source pollution restricted to the vicinity of an industrial plant may affect the economic development of another country by killing juvenile fish which would have otherwise migrated to its coasts. On the other hand, countries may deliberately overexploit their portion of a migrating resource in order to deny access (and advantage) to their neighbours. If such conflicts are to be avoided, the Black Sea countries need to cooperate to ensure the joint management and protection of shared marine living resources. This will create a better sense of ownership of the Sea's resources; and it is well known that "owners" tend to protect their property better than those enjoying a free service. There is a strong need for harmonising legal and policy objectives and for developing common strategies for investment in the control of pollution. Use of the "commons" must be carefully regulated so that one "user" does not deprive another of his/her rights. Only through concerted international action can the biological diversity of the Black Sea be protected.

The purpose of this book is to describe the actual state of the Black Sea ecosystem in general and, using the criterion of biological diversity, to discuss measures that have been planned or are already being implemented in order to improve the ecological situation in the region. This task has been facilitated by the preparation in 1995 by the Black Sea states, under the guidance of the BSEP Programme Coordination Unit based in Istanbul and with the financial support of the World Bank, of national reports on the state of the coastal marine ecosystems in different regions of the sea. The authors of this book have summarised the data contained in these national reports which, together with other published and yet unpublished data, constitute the factual basis of the book.

As for the reliability of biodiversity as the main standard for evaluating the state of the marine environment, this follows from the tenets of classical ecology first formulated by August Thienemann (1950) and which still remain relevant today. One of these tenets says that the more living conditions within a biotope depart from the norm, the poorer the location in terms of the number of species, and the larger the populations of the remaining species. With regard to the Black Sea this sounds fully up-to-date.

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Green, brown, red macro-algae and mussels forming a typical seascape in shallow-water stony bottom areas. They serve as food and offer refuge for many animals, as well as providing a source of oxygen.

1

Peculiarities of the Black Sea as One of the Most Isolated Seas in the World

I. Geological Evolution

Some 50-60 million years ago, before the beginning of the Tertiary Period, a vast oceanic basin extended from west to east across Southern Europe and Central Asia, linking the Atlantic Ocean and the Pacific Ocean. It was the salty Tethys Sea. By the middle of the Tertiary Period, as a result of crust upheavals, the Tethys Sea had become separated first from the Pacific Ocean and later from the Atlantic.

Major crust movements led to mountain-building in the Miocene (from 5 to 7 million years ago) and the formation of the Alps, the Carpathians, the Balkan Mountains and the Caucasus Mountains. As a result the Tethys Sea shrunk in size and became divided into a number of brackish basins. One of them, the Sarmatic Sea (Fig. 1 .a), stretched from the present location of Vienna to the foothills of the Tien Shan Mountains and included the modern Black Sea, the Azov Sea, the Caspian Sea and the Aral Sea. The Sarmatic Sea was separated from the ocean, and gradually its salinity fell as a result of the inflow from rivers. It is assumed that the salinity in the sea was even lower than in the modern Caspian Sea. Much of the marine fauna endemic to the Tethys Sea became extinct. However, it is interesting to note that typically oceanic animals, such as whales, manatees and seals, continued to inhabit the Sarmatic Sea for a long time, before they too disappeared.

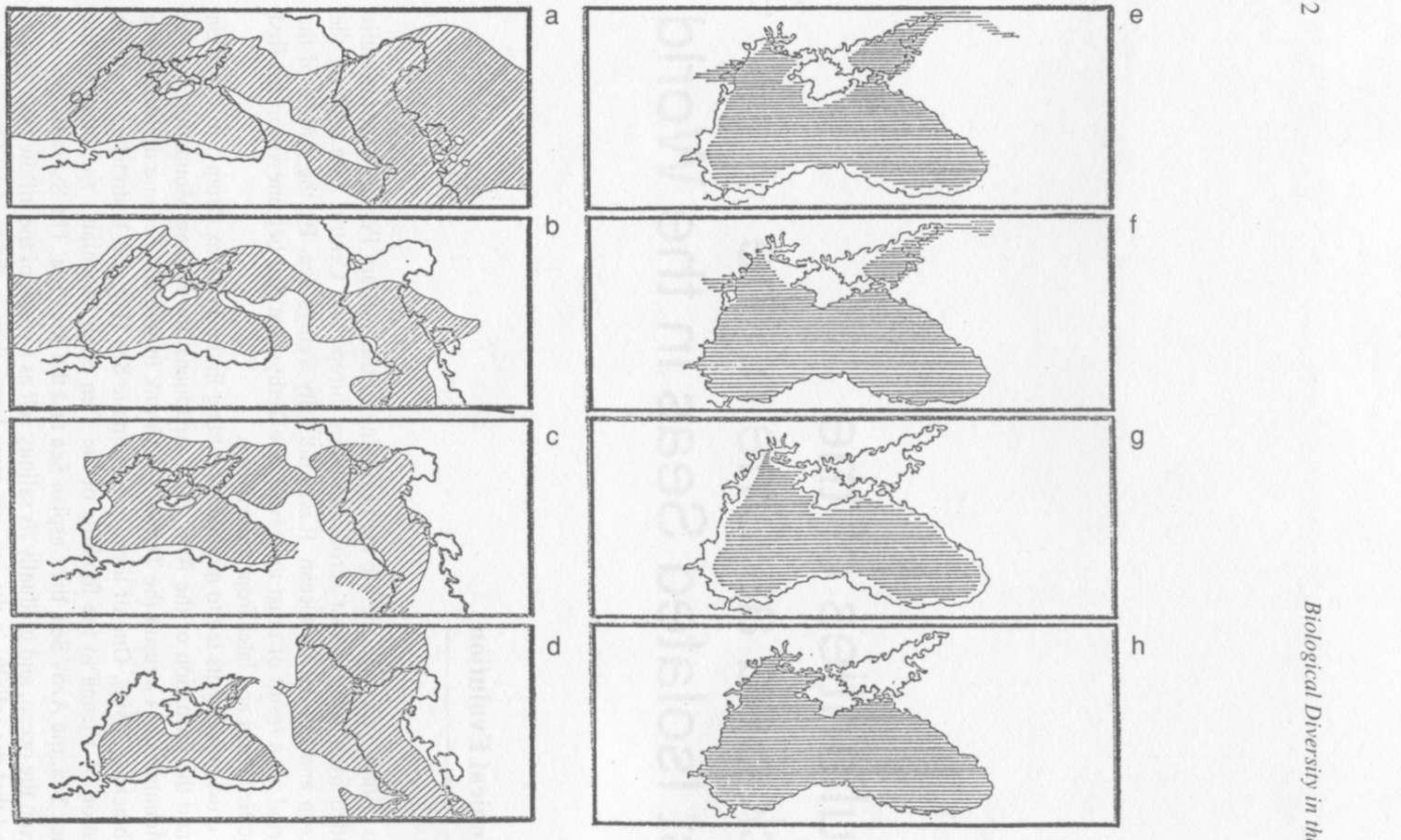

Fig 1. Geological Evolution of the Black Sea (from Zaitsev, 1978)
a) Sarmatic Sea; b) Maeotic Sea; c) Pontian Sea-lake; d) Chaudian Sea-lake;
e) Paleoeuxinian Basin; f) Karangat Sea; g) Neoeuxinian Lake-sea; h) Modern Black Sea

By the late Miocene and early Pliocene (3-5 million years ago) the Sarmatic Sea had shrunk to the size of the Maeotic Sea (Fig. l.b). During that period a link to the ocean was again established, salinity increased and marine species of plants and animals settled in the sea. In the Pliocene (1.5-3 million years ago) the connection to the ocean was again severed, and the salty Maeotic Sea was replaced by the almost freshwater Pontian Sea-Lake (Fig. l.c). Within it the future Black and Caspian Seas were connected through the present-day northern Caucasus. Marine fauna disappeared from the Pontian Sea-Lake and were replaced by brackish-water fauna. To this day its representatives can still be found in the Caspian Sea, the Azov Sea and the regions of the Black Sea with reduced salinities. These species are today referred to Pontian relics or Caspian fauna, since they have been best preserved in the reduced salinities of the Caspian Sea. In the late Pontian stage the Earth's crust began to rise in the northern Caucasus, gradually isolating the Caspian Sea from the basin. From that period onwards the Caspian Sea, on the one hand, and the Black Sea and the Azov Sea, on the other, went their separate ways, although temporary links between them were formed from time to time .

With the onset of the Quaternary Period and the Ice Age the salinity and species composition of the developing Black Sea continued to change, as did the outline of the sea. By the late Pliocene (less than one million years ago) the Pontian Sea-Lake had shrunk to the size of the Chaudian Sea-Lake (Fig. l.d). It had a reduced salinity, was isolated from the ocean and inhabited by fauna of the Pontian type. Evidently, the Azov Sea had not yet come into existence.

When the ice began to melt in the late Mindel (Elsterian) Glaciation (some 400,000-500,000 year ago), the Chaudian Sea-Lake became filled with melt waters and turned into the Paleoeuxinian basin (Fig. l.e). Its outline resembled the modern Black Sea and the Azov Sea. In the north-east it was connected to the Caspian Sea through the Kumo-Manych depression, and in the south-west to the Sea of Marmara through the Bosphorus. At the time, the Sea of Marmara was isolated from the Mediterranean and was also greatly affected by reduced salinity. The fauna of the Paleoeuxinian basin was of a Pontian type.

The Riss-Wurm Interglacial Period (100,000-150,000 years ago) heralded a new phase in the history of the Black Sea. Following the opening of the Dardanelles for the first time since the formation of the Tethys Sea, the future Black Sea became connected to the Mediterranean and the world ocean. The so-called Karangat Basin or Karangat Sea was formed (Fig. l.f), with a salinity higher than that of the modern Black Sea. Various representatives of marine flora and fauna were introduced into it together with ocean waters. They occupied a larger part of the basin, forcing the brackish water and Pontian species into bays, limans and river estuaries with reduced salinities. However, that basin too was to undergo changes.

Some 18,000-20,000 years ago the Karangat Sea was replaced by the Neoeuxinian Lake-Sea (Fig.l.g). This coincided with the end of the last Wiirm Glaciation. The sea was filled with melting waters. Once again it lost its connection to the ocean and its salinity was greatly reduced. The halophilic oceanic flora and fauna also disappeared, while the Pontian

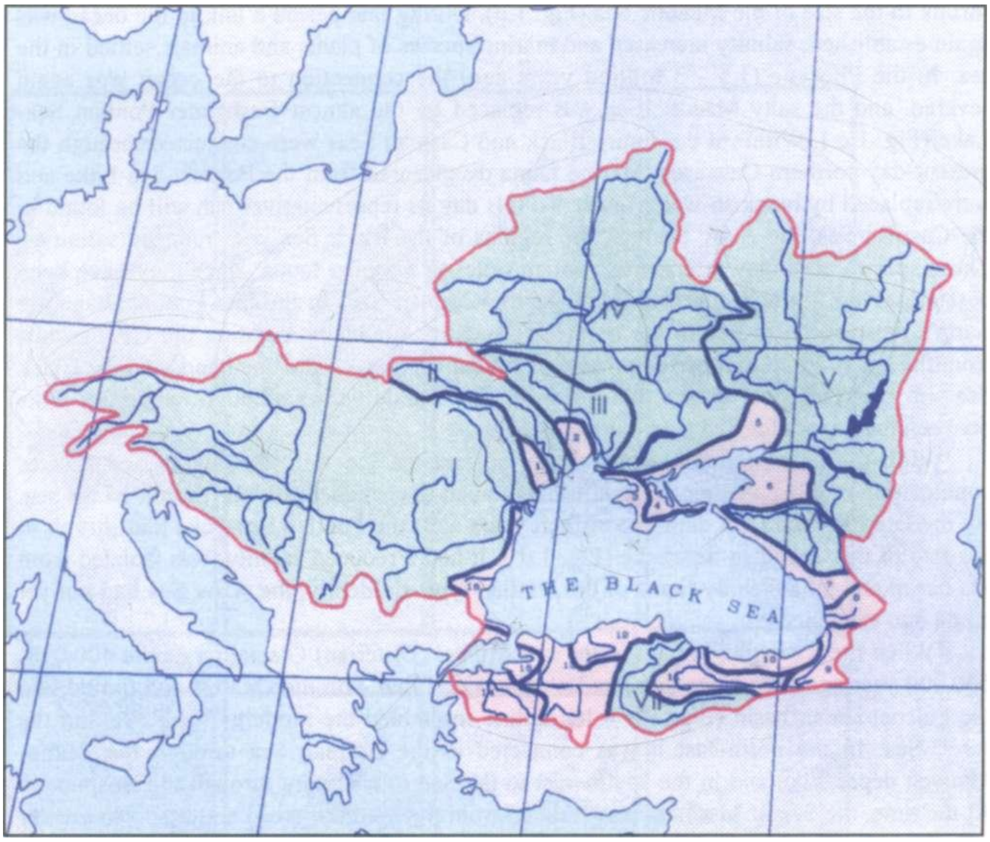

Fig 2. Black Sea Drainage Basin

species that had survived the difficult Karangat period in limans and river estuaries came out of hiding and yet again occupied the entire sea.

After approximately 10,000 years the basin entered its current phase and the modern Black Sea was formed (Fig. l.h). In fact, the word "modern" in this case does not mean that the sea was identical to what it is today. In the beginning, about 7,000 years ago, (although some experts believe that it was even later, about 5,000 years ago) a connection to the Mediterranean and the World Ocean was established through the Bosphorus and the Dardanelles. A gradual salinisation of the Black Sea followed and it is believed that within 1,000-1,500 years the salinity of the sea became sufficient to support a large number of Mediterranean species. Today about 80 percent of the Black Sea fauna are Mediterranean settlers ("Mediterranean immigrants"). The Pontian relics have again moved to the bays and limans with low salinities, as happened during the time of the Karangat basin.

II. Morphometry

Of all the inland seas, such as the White Sea, the Baltic Sea, and the Mediterranean Sea, the Black Sea is the most isolated from the world ocean. Its only tenuous link with other seas is with the Mediterranean through the Bosphorus Strait, the Sea of Marmara and the Dardanelles. The Bosphorus is essentially a narrow, elongated, shallow channel, nearly 31 km long. Its width varies between 0.7 and 3.5 km with an average of 1.3 km at the surface. The width gradually narrows towards the bottom of the channel to an average of 500 m at a depth of 50 m. The depth varies from 30 to 100 m with an average of 50 m along the central section of the channel. In the north, the Kerch Strait connects the Black Sea to the shallow Azov Sea. The Azov Sea has an area of 39,000 km^2 and an average depth of 8 m. The Kerch Strait is a shallow channel (10 m deep in the north, 18 m deep in the south and 5 m deep in the central section) about 45 km long. Its width varies between 3.7 km and 42 km. Such a significant degree of isolation, together with low salinity and low winter water temperatures, has been a decisive factor in shaping the Black Sea flora and fauna.

The catchment area of the Black Sea is over 2 million km^2, entirely or partially covering 22 countries in Europe and Asia Minor. These include the six littoral states (Bulgaria, Georgia, Romania, the Russian Federation, Turkey and Ukraine) and 16 Eastern and Central European states. According to the political map of Europe (1996), these are, in alphabetical order: Albania, Austria, Belarus, Bosnia - Herzegovina, Croatia, the Czech Republic, Germany, Hungary, Italy, Macedonia, Moldova, Poland, Slovakia, Slovenia, Switzerland and Yugoslavia (Fig. 2.). The catchment area contributing water to the Black Sea varies from country to country. In Albania, Poland and Italy it is only 100-300 km^2; in Switzerland 1,700 km^2; in Moldova 33,700 km^2; in Germany 58,000 km^2; in Romania 226,000 km^2; in Turkey 249,000 km^2; and in Ukraine 600,000 km^2.

The surface area of the Black Sea is 423,000 km^2. It contains a total volume of 547,000 km' of water and has a maximum depth of 2,212 m. The sea is located in an east-west intermontane depression (Degens and Ross *et al.,* 1974). To the south of the Black Sea depression are the Pontic Mountains, with a maximum elevation of 3,937 m (Mount Kachkar), and, to the East, the Caucasus Mountains, with a maximum elevation of 5,642 m (Mount Elbrus). The western and northern coastal regions are relatively low (the Black Sea Lowlands). The greatest relief in the north of the Black Sea depression is on the Crimean Peninsula, with a maximum elevation of 1,545 m (Mount Roman-Kosh).

The Black Sea shoreline is about 4,340 km long (the Bulgarian coastline is 300 km long; the Georgian coastline 310 km; the Romanian coastline 225 km; the Russian coastline 475 km; the Turkish coastline 1,400 km and the Ukrainian coastline 1,628 km).

The Black Sea shoreline is not ragged. The only large peninsula is the Crimea, with the Kerch Peninsula linked to it. Several small peninsulas (Capes Ince, Chum, Baba, *etc.)* are located on the Anatolian coast. The largest bays in the north are Odessa Gulf, Yagorliksky Bay, Tendrovsky Bay, Karkinitsky Bay and Kalamitsky Bay; Novorossisk Bay is in the east; Sinop Bay and Samsun Bay are in the south; while the bays of Igneada, Burgas, and Varna are in the west.

The Black Sea shoreline is characterised by a wide diversity of landscapes. There are high mountains, vast lowlands, and valleys with low hills. Some parts of the shoreline are covered by rich subtropical plants, while other sections are poorly vegetated.

The north-western shoreline, from the Danube delta to Sevastopol Bay, is not high. Here the Palaeozoic East-European Platform rises to 10 m above sea level in the south and up to 40-50 m above sea level in the north. It consists of a cover of predominantly sedimentary platform rock from the Neogene Quaternary period. The valley is cut by narrow gorges which end at the coast in a precipitous edge or low spits that cut the sea off from vast salt lakes and limans, which are former river mouths, now covered by sea water. There is a very large number of limans near Odessa. Some limans are completely separated from the sea, others have sporadic access. The limans in the estuaries of large rivers (such as the Dniester , the Southern Bug and the Dnieper) have a permanent connection to the sea. Almost all the large limans (e.g. Dneprovsko-Bugsky, Dnestrovsky, Khadzhibeisky, Kuyalnitsky, Tiligulsky and Berezansky) are shallow, although only a few hundred years ago they still were bays with a depth of 20-30 m.

The shoreline becomes noticeably steeper beyond Sevastopol Bay. Along the southern coast of the Crimean Peninsula, from Cape Feolent to Feodosia there are three parallel ridges of folded Mesozoic Crimean Mountains that thrust precipitous cliffs out into the sea. In some places between Cape Sarych and Yalta the mountains recede from the shore, sloping moderately. Further to the east, the main ridge of the Crimean Mountains retreats from the shoreline, gradually becoming lower; although the mountain slopes near to the sea are precipitous. The shoreline of the Kerch Peninsula is precipitous along almost its entire length.

The north-eastern Black Sea shore from Anapa to Sukhumi is predominantly steep. Here Meso-Cenozoic folded offshoots of the main ridge of the Caucasus Mountains come close to the sea. In some places they form vertical cliff faces; in others well defined terraces. The highest peak is near Sochi (3,000 m), after which the mountains gradually become lower (down to 1,000 m) and retreat from the shoreline (in the vicinity of the Kodori river).

The vast, aggraded Kolkhida Lowland, which forms part of the Meso-Cenozoic depression, is adjacent to the sea between the estuaries of the Kodori river and the Kobuleti river. The large Lake Paleostomi, which was once a sea bay, is located close to the shore to the south of the Rioni river estuary. To the south of the Kobuleti river the shoreline once again becomes mountainous, with ridges in the vicinity of Batumi exceeding 1,500 m.

The southern shore is also mountainous. Meso-Cenozoic folded offshoots of the Pontic Mountains come close to the sea, reaching their highest elevation south and south-west of Batumi. Further to the west they become lower and as they near the Bosphorus decline to less than 450 m. The southern shoreline is precipitous along its entire length. In some places the shoreline slopes towards the sea in terraces and there are low sandy areas with cliffs protruding from the shore.

The shoreline to the west of the Bosphorus is relatively low. To the west of Cape Kaliakra, Mesozoic folded formations of the Balkan Mountains come close to the sea and the capes here are precipitous. The shoreline gradually becomes lower from Cape Kaliakra to the Danube delta. Here, we find a Palaeozoic aggraded platform plain with hills inclining towards the sea.

From the geomorphologic standpoint, the entire Black Sea shore can be regarded as graded and complex. Alternating accumulative areas - sand spits and bars with abrasion sections - are characteristic of this type of shoreline. Lagoon-like and abrasion-landslide types of shore are most widespread in the north-western part of the Black Sea. The abrasion phenomenon is quite characteristic of the whole shoreline and in places takes complex forms.

Landslides and slumps occur periodically on loess and clay shores, which are subsequently washed away by the sea. In such places the cliffs, which have been formed by the surf through abrasion, are almost vertical and relatively high. Extensive landslides develop in locations where Pontic limestone and Meotian clays (abrasion terraces) form the foundation of cliffs.

The higher the shore and the harder the rock, the slower the rate of abrasion. Capes and small peninsulas are formed in such places. The most noteworthy are Tarkhankut, Khersones, Sarych, Meganom, Doob, Pitsunda, Chum, Ince, Baba, Emine, and Kaliakra.

There are no large islands in the Black Sea. The biggest one is Zmeiny (1.5 km^2), located in front of the Danube delta, 37 km off shore. Berezan Island is situated at the mouth of Berezansky Liman; while Kefken Island is just off the southern Black Sea coast, 92 km east of the Bosphorus. All are smaller than Zmeiny. There are several other small islands in Burgas Bay.

The seafloor is divided into the shelf, the continental slope and the deep-sea depression.

The shelf, or continental shoal, is the direct continuation of dry land which has been covered by the sea. It now occupies a large area in the north-western part of the Black Sea, where the shelf is over 200 km wide with as depth ranging from 0 to 100 m, and even reaching 160 m in some places. In other parts of the sea it has a depth of less than 100 m and a width of 2.2 to 15 km. Near the Caucasian and Anatolian coasts the shelf is only a narrow intermittent strip (Fig. 3).

The north-western shelf zone comprises the southern part of the East-European Palaeozoic and Epipalaeozoic Scythian platform. It has a very slight incline and a flat plain abrasion accumulative relief.

The shelf along the Crimean, the Caucasian and Anatolian coasts predominantly consists of an abrasion type of relief, with Meso-Cenozoic folded formations that have been heavily eroded in places.

Underwater valleys and canyons make the even, flat relief of the shelf more complex. Most are winding with well defined slopes, especially on the periphery of the shelf on the edge of the continental slope. The majority are sea extensions of the adjacent river valleys.

The underwater extensions of the Danube, the Dniester, the Dnieper river valleys of and the Southern Bug are on the north-western shelf, a long distance out to sea, approximately 100-120 km from the coast. There are also submarine canyons belonging to rivers such as the Bzyb, the Mzymta, the Rioni and the Coruh near the Caucasian coast.

Well-defined underwater canyons belonging to rivers such as the Yesilirmak, the Kizilirmak and the Karasu can be found near the Anatolian shore.

Submarine terraces, submarine swells in different directions separated by depressions, can be found in different parts of the Black Sea shelf zone. These are the result of changes in the sea level that have occurred at different geological times following tectonic movements in the Earth's crust.

The shelf becomes a rather steep continental slope, descending at an average angle of 5-8° in the north-western part and 1-3° near the Kerch Strait. In some sections the gradient reaches 20-30°.

A network of submarine ridges over 150 km long runs almost parallel to the coast between Sinop and Samsun. The largest submarine ridge lies 60-75 km off shore and is separated from the coast by a series of submarine depressions. The continental slope is also crossed by submarine valleys and canyons. Earthquake epicentres tend to be located on continental slopes and landslides are quite common in these areas.

The centre of the Blacl^Sea depression consists of a deep water basin with a depth of 2,000-2,200 m. The maximum depth is 2,212 m. The bottom of the basin is an aggraded plain formed by diverse formations, which vary both in terms of their age and their geological structure. Most of the Black Sea depressions are located within the boundaries of the Alpine geosynclinal area.

Many scientists believe that the formation of the Black Sea depression is linked to the process of oceanisation of both the continental crust and a relict natural depression, which is represented by a residual basin of the ancient Tethys Sea. The general outlines of the modern depression were already formed in the Oligocene, which was when the folded structures, which gradually separated the depression from the Tethys Sea first appeared in Asia. In the Miocene the Black Sea was part of a system of seas - the lakes of the Sarmatic basin. After a short period during which it was connected to the Mediterranean Sea, the low-salinity Pontian Lake came into existence in the Meotian Age.

Twice during the mid-Pleistocene, the Black Sea was connected to the Mediterranean Sea, and its waters became highly saline. The low-salinity Neoeuxinic Sea was formed during the last Quaternary glaciation. Some 6,000-7,000 years ago it gained access to the Mediterranean Sea and its water acquired a higher salinity.

Coarse detrital deposits, including pebbles, gravel and sand, dominate the coastal zone. Further from the shore they are quickly replaced by fine silt. Shell limestone is widespread in the north-western part of the sea.

Pelitic muds are characteristic of the slope and the seafloor. Their carbonate content increases away from the shoreline, in some places exceeding 50 percent. At depths of up to 2,000 m in the south-east of the sea there are sediments composed of aleurolite and sands carried by turbidity currents.

River run-off means that water levels in the Black Sea are higher than in the Sea of Marmara. The average salinity of the open Black Sea is 17-18 ‰ at the surface and 22-24 ‰ at a depth of 2,000 m.

III. Water Balance

The high degree of isolation from the world ocean, the extensive drainage basin and the large number of incoming rivers all contribute to the unique water balance of the Black Sea. The water balance is an important factor in the Black Sea marine ecosystem. Changes in the water regime have a significant impact on salt and water balances, which are the most vulnerable to any anthropogenic changes, particularly in the shallow, biologically highly productive north-western region. Fresh water input and exchange of Mediterranean water via the Bosphorus are critical elements in the hydrography and ecosystem of the Black Sea. The water balance of the sea has been studied for many years, and there is still considerable controversy over the magnitude of its terms (Table 1.1).

Its major components can be summarised as follows:

- river discharge:
- precipitation;
- evaporation;
- exchange via the Bosphorus, and the Kerch Straits.

River Discharge

The largest volume of river flow entering the Black Sea comes from the north-western part of its basin and from the Caucasus, Turkey and the Bulgarian and Romanian coasts. The total catchment area of all the rivers discharging into the sea is 1,874,904 km^2, including 215,625 km^2 of small river flow. The average total discharge for the period from 1921 to 1988 was 353 km^3 per year (Reshetnikov, 1992).

Drainage from the North-western Coast

The catchment area of the rivers on the north-western coast is about 1,500,000 km^2, including 20,000 km^2 of small river flow. Most of the inflow comes from four principal rivers; namely the Danube, the Dniester, the Dnieper and the Southern Bug (Table 1.2). The average total annual discharge into the north-west of the sea for the period 1921 -1988 was 261 km^3 per year, rising from an average of 153 km^3 in 1921 to 389 km^3 in 1970.

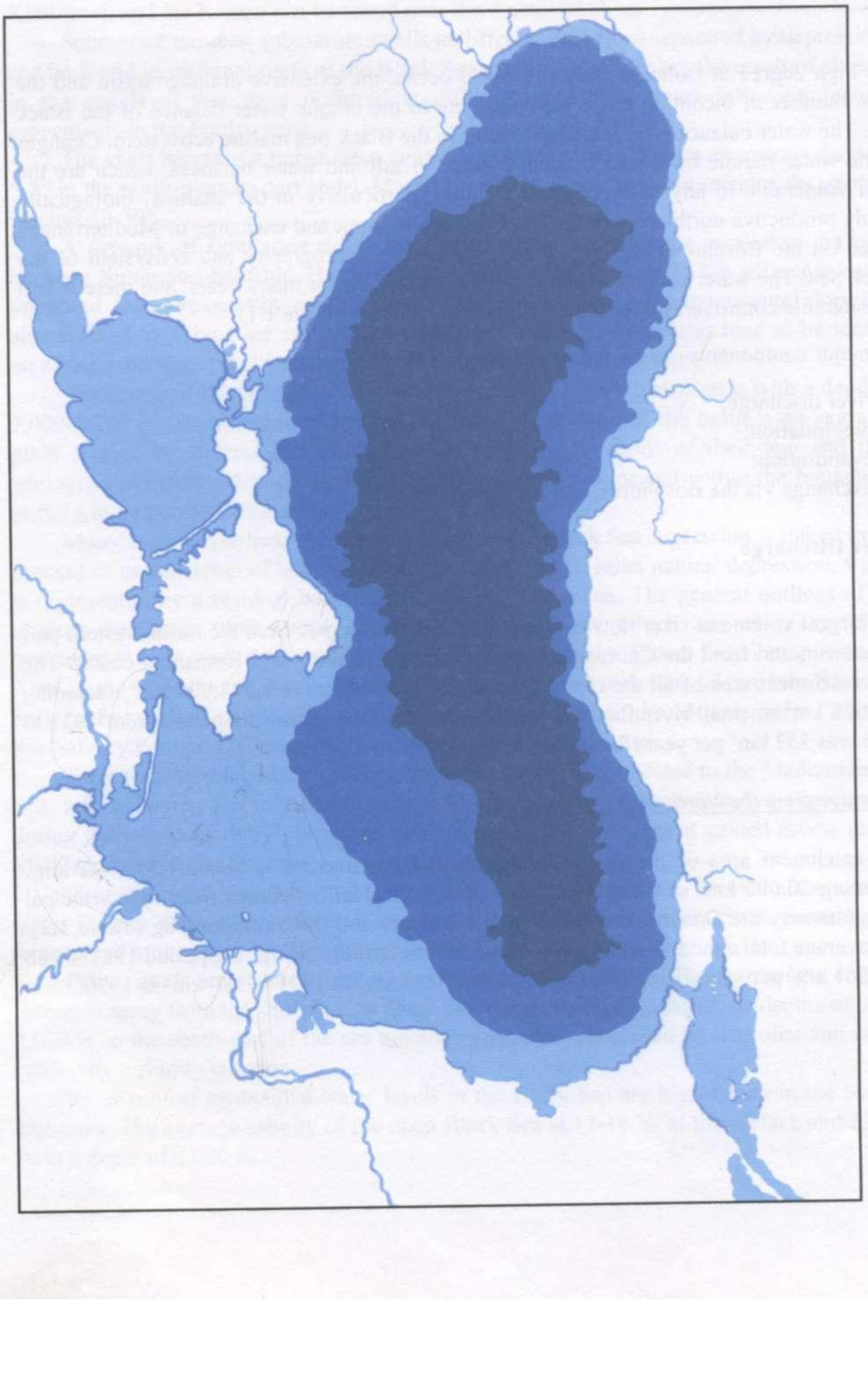

Fig 3. Black Sea Bathymetry

Drainage from the Crimea

The rivers of the Crimea do not play an important role in the water balance of the Black Sea. The largest rivers are the Chernaya, the Belbec, the Al'ma and the Kacha. The total catchment area of rivers running from the Crimean mountains into the Black Sea is only 2,729 km^2. Their average annual flow over the period 1921-1988 was 0.32 km^3, ranging from a minimum of 0.07 km^3 in 1930 to a maximum of 0.67 km^3 in 1968.

Drainage from the Caucasus

The total catchment area of the rivers in the Caucasus is about 75,000 km^2. The major rivers are the Rioni, the Coruh, the Inguri, the Kodori, the Bzyb, the Supsa and the Mzymta (Simonov, and Altman, 1991). The average annual flow during the period under review was 43 km^3, ranging from 31 km^3 in 1969 to 57 km^3 in 1922 (Reshetnikov, 1992).

Drainage from Turkey

Many rivers debouch into the Black Sea along the Turkish coast. Their total catchment area is 259,550 km^2 (Reshetnikov, 1984). The major rivers include the Yesilirmak, the Kizilirmak and the Sakarya. Average annual flow during the period 1930-1986 was 36 km^3, ranging from a minimum of 25 km^3 in 1949 to a maximum of 51 km^3 in 1940.

Table 1.2. Major rivers of the Black Sea

Name	Catchment Area, km^2	Length, km	Total Runoff kmVyear	Sediment Discharge 10^6 t/year
Danube	817 000	2860	208	51,7
Dniester	71 990	1328	10,2	2,50
Dnieper	505 810	2285	51,2	2,12
Southern Bug	68 000	857	3,0	0,53
Rioni	13 300	228	12,8	7,08
Coruh	22 000	500	8,69	15,13
Inguri	4060	221	4,63	2,78
Kodori	2030	84	4,08	1,01
Bzyb	1410	-	3,07	0,60
Yesilirmak	36100	416	4,93	18,0
Kizilirmak	78200	1151	5,02	16,0
Sakarya	65000	790	6,38	-

Table 1.1 Estimates of the Black Sea Water Balance (km^3/yr)

	Rain Fall	Run Off	Evaporation	Net Fresh Water Input	Bosp. Inflow Q2	Inflow From Azov	Total Inflow	Bosp. Outflow	Outflow to Azov	Total Outflow
Shpindler (1896. 1899)	220	474	232	462	-	-	462	416	-	416
Merz (1928)	231	328	54	205	193	-	98	398	-	398
Sverdrup (1942)	240	328	363	205	192	-	397	397	-	397
Zenkevich (1947)	145	320	319	146	202	-	348	348	-	348
Vodyanitski (1948)	280	480	240	520	-	-	520	-	-	-
Rojdestvenskiy (1953)	280	340	240	380	195	-	575	575	-	575
Neumann &Roseman (1954)	240	428	398	270	193	-	463	462	-	462
Caspers (1957)	234	320	354	200	-	-	200	-	-	-
Leonov(1960)	230	309	365	174	193	95	462	392	70	462
Bruevich(1960)	225	350	350	225	175	-	400	400	-	400
Berenbeim(1960)	120	340	280	180	193	59	432	398	34	432
Solyankin (1963)	119	346	332	133	176	53	362	340	32	372
Okeanograf Entsikl. (1966)	-	400	-	-	202	-	-	398	59	457
Tixeront (1970)	181	400	392	189	-	-	400	400	-	400
Ozturgut (1971)	300	352	353	299	249	-	548	548	-	548
Rojdestvenskiy (1971)	254	294	301	247	229	38	514	485	29	514
Sitnikov (1972)	148	423	381	190	-	-	190	190	-	190
Serpoianu (1973)	120	336	340	116	123	53	292	260	32	292
Rozengurt & Sitnikov (1973)	212	406	381	237	-	-	237	241	-	241
Pora and Oros (1974)	254	294	301	247	229	38	514	485	29	514
Fonselius (1974)	230	320	350	200	200	-	400	400	-	400
Entsikl. okean/atm(1983)	234	320	354	200	188	-	388	388	-	388
Altman (1984)	236	338	402	172	181	50	403	366	33	399
Bondar (1986)	119	364	332	151	203	50	404	371	31	402
Altman (1986)	235	338	402	171	-	-	171	-	-	-
Unluata et al. (1990)	300	352	353	299	312	-	611	612	-	612
Altman (1991)	238	338	395	181	176	50	407	371	33	402
Reshetnikov (1992)	225	353	370	208	-	22	230	227	-	227

Drainage from the Bulgarian and Romanian Coasts

The major rivers in Bulgaria are the Duda, Kamchia, Provodiyska, Rezovska, Veleka, Ropotamo and Fakiyska. The total catchment area is 6,292.10 km^2. The total discharge into the sea averages 1.83 kmVyear

The total catchment area of all the rivers debouching along the Romanian coast (excluding the Danube) is 4,589 knr Their total annual discharge is 0.12 km^3 (Simonov, and Altman, 1991).

Precipitation

Precipitation in the Black Sea area is generally caused by cyclonic activity. Cyclones pass mainly from west to east through the southern part of the sea. The eastern and south-eastern regions receive the largest amount of precipitation. The lowest precipitation occurs in the central region, particularly the west. Monthly precipitation over the sea reaches a peak in winter (about 40 percent) and falls to its lowest level in spring and early summer (nearly 15 percent). Along the coast, particularly in the north-west, there is sometimes some summer precipitation caused by thermal convection. In the period under review the average precipitation over the entire surface of the Black Sea was 225 km^3 per year (Reshetnikov, 1992).

The total volume of precipitation is nearly 1.5 times lower than the total volume of river inflow, but its impact on the overall water balance of the sea can vary considerably according to the year and the season. For example, in autumn and winter the volume of precipitation on the surface of the sea exceeds the volume of continental inflow.

Evaporation

A general trend can be observed in the seasonal distribution of evaporation over the surface of the Black Sea. The greatest rate of evaporation occurs in the western and eastern zones between latitudes 44° N and 45° N. These regions usually also have the highest wind velocities as a result of cyclonic circulation due to Black Sea morphometry. The depth of the evaporated water layer in the area bordering the coast of the Caucasus is 1,300 mm per year.

Average evaporation in the Black Sea area during the period under review was 370 km^3 per year, ranging from 484 km^3 in 1951 to 289 km^3 in 1985. The long-term trend of evaporation is negative, particularly over the last 30-40 years, during which time wind velocities have decreased by an average of 0.8-1.3 m/sec per month (Kabatchenko, 1985); and this has been a major factor in the decline in evaporation levels over the surface of the Black Sea. More than 50 percent of annual evaporation occurs during the summer-autumn period. The highest levels of evaporation take place in August, while evaporation are lowest in April. Total evaporation above the surface of the Black Sea in March-June accounts for only 14 percent of the annual total.

Water Exchange through the Bosphorus and the Kerch Straits

The volume of water flowing into the Black Sea through the Bosphorus has been estimated as between 123 kmVyear (Serpoianu, 1973) and 312 kmVyear (Unluata *et ai,* 1990). Estimates for the Bosphorus outflow range from 227 kmVyear (Reshetnikov, 1992) to 612 kmVyear (Unluata. U. *et ai,* 1990). But all authorities agree that the outflow through the Bosphorus is twice as large as the inflow.

There have been attempts to estimate fluctuations in the Bosphorus outflow during the year. Reshetnikov (1992) found that the seasonal flows are irregular, with levels peaking (50-60 km^3) in April-June and falling to their lowest level in September-December (-7/-16 km^3).

The inflow through the Kerch Strait ranges between 22 kmVyear (Reshetnikov, 1992) and 95 kmVyear (Leonov, 1960), while the outflow ranges between 29 kmVyear (Pora and Oros, 1974) and 70 kmVyear (Leonov, 1960).

Fresh Water Balance

For many years the average annual fresh water balance has been positive at 180 km^3, ranging from 441 km^3 in 1980 to -3.7 km^3 in 1950. The values of the components of the fresh water balance have risen during the period under review. There are also seasonal fluctuations, with values peaking in spring and recording their lowest levels during summer. The balance of fresh water in the Black Sea is usually negative in the period from July to October. In some years the balance was also negative in January, June, November, and December. A positive balance of fresh water occurs in the February-May period (Simonov and Altman, 1991). The considerable annual and seasonal fluctuations in the Black Sea fresh water balance are mainly caused by variations in river discharges. Evaporation is a major influence only in the summer.

IV. Hydrogen Sulphide in the Black Sea

As the result of past geological events, its morphometry and specific water balance, nearly 87 percent of the Black Sea water volume is anoxic and contains high levels of hydrogen sulphide (Fig. 4.). The 13 percent of the volume that contains oxygen consists of the shallow surface water and the waters from the shelves. The recent eutrophication of the sea has placed even this 13 percent under severe stress. The introduction of excess nutrient loads has been accompanied by massive phytoplankton blooms (especially flagellates), whose death in turn depletes even the shallow shelf waters of oxygen as the oxidation of organic material consumes valuable oxygen resources. Up to 40,000 km^2 of the north-west shelf of the Black Sea is now subject to hypoxia and the occasional formation of hydrogen sulphide rich bottom waters. The high levels of hydrogen sulphide, both naturally occurring and exacerbated by anthropogenic factors, have considerable socio-economic as well as ecological implications.

Most hydrogen sulphide production is due to redox processes that occur in the water column. There is little evidence of hydrogen sulphide production by geothermal or other crustal processes; although Zaitsev reported that a single source of hydrogen sulphide was observed during bottom sampling on the north-western shelf, analogous to a "black smoker". But the volumes produced by such geothermal sources are negligible compared with the main redox process.

Despite the relatively stable hydrogen sulphide distribution over the last 7,500 years, the level of the interface separating the oxygenated water from the oxygen-deprived lower waters has fluctuated according to the physical oceanography of the region. The hydrogen sulphide layer lies some 100 to 200 m below the surface. There are also seasonal and annual fluctuations in the level at which hydrogen sulphide is first encountered. Seasonal atmospheric variations produce considerable variations in circulation (Oguz *et al.,* 1995). The hydrogen sulphide boundary is usually deepest in summer and shallowest in spring.

Human use of the Black Sea drainage basin has also had a profound impact on the ecology and oceanography of the Black Sea (Aubrey *et al.,* 1996a).

Eutrophication has risen as the nutrient load has increased, leading to hypoxia and occasional anoxia, particularly on the north-west shelf. This anoxia also leads to the formation of hydrogen sulphide in the shelf zones. Garkavaya (unpublished data) recently recorded hydrogen sulphide concentrations of 1.5 to 2.25 ml/1 in the lower water column on the north-western shelf at depths of 10-30 m. This hydrogen sulphide only became apparent in the 1970's as a consequence of increased levels of eutrophication. Yet hydrogen sulphide on the shelf is still transitory, occurring primarily in summer and autumn, as intense water column mixing during winter and spring reoxygenates the bottom waters.

But the zones of hypoxia have definitely expanded in recent years. From 1973 to 1990 the bottom area affected by hypoxia increased from 3,500 km^2 to 40,000 km^2 (Zaitsev, 1993). This undoubtedly led to increases in hydrogen sulphide in the bottom waters, although measurements of hydrogen sulphide are much less abundant than measurements of oxygen levels. Since the north-western shelf is only 64,000 km^2 (limited by the 100 m isobath), the hypoxia has now extended to a significant proportion of the shelf area.

What will happen to the hydrogen sulphide levels in the Black Sea in the future? On the north-western shelf hydrogen sulphide concentrations may decline as measures are implemented to reduce the nutrient loading. But the improvement in the ecosystem will not be immediate. The sequestering of nutrients in bottom sediments on the north-west shelf will continue to provide a source of nutrients through benthic fluxes. No reliable data is currently available on nutrient levels in the sediments or the rates of nitrification and denitrication. Additional research on nutrient sequestering on the shelf and on benthic regeneration, is required in order to make an accurate assessment of future levels of eutrophication on the shelf once nutrient input from the rivers has been reduced to acceptable levels (Aubrey *et al.,* 1996 b).

But what about the deep hydrogen sulphide in the Black Sea? Will the hydrogen sulphide boundary rise? Fortunately, existing data indicate that this boundary is relatively constant. There is no evidence that the average hydrogen sulphide boundary is shoaling over the basin or that it will do so at a later date.

It is clear that the aggressive reduction of nutrient inputs from river and atmospheric sources will have a positive effect on the ecosystem of the north-western shelf and reduce the spread of the hydrogen sulphide across the shelf. But the sequestering of nutrients in bottom sediments means that it is still not possible to predict the response time of the system. In the deep Black Sea the hydrogen sulphide layer appears relatively stable, but large changes in fresh water inflow or physical mixing processes may produce changes in the hydrogen sulphide boundary, which may have a negative impact on the ecosystem as a whole (Aubrey *etal.,* 1996 b).

V. Population in the Coastal Zone

The Black Sea coastal zone is densely populated, containing a permanent population of approximately 16 million and another 4 million visitors during the summer tourist season.

The longest and most densely population Black Sea coastal zones are in Turkey and Ukraine. The total population of the Turkish Black Sea coast is estimated at 6,700 000 (BSEP, ICZM National Report from Turkey). The largest towns in the Turkish coastal zone are: Kocaeli with a population of 1,339,000; Sakarya (815,000); Bolu (576,000); Zonguldak (647,000); Kastamonu (321,000); Sinop (206,000); Samsun (1,199,000); Ordu (925,000); Giresun (457,000); Trabzon (757,000); Rize (256,000); and Artvin (161,000).

The total population of the Ukrainian coastal zone is about 6,800,000, almost half of whom live in large towns such as: Odessa (1,115,000), Nikolaev (503,000), Kherson (355,000), Kerch (174,000), Evpatoria (108,000) and Yalta (89,600).
A total of 1,159,000 people live in the Russian Black Sea coastal zone, many of them in large cities such as Sochi (142,000), Anapa (58,000), Novorossisk (244,000), Gelendgik (52,000) and Tuapse (66,000).

The Bulgarian Black Sea coastal zone is characterised by a large number of resorts, the population of which can more than double during the tourist season. The total permanent population is estimated at 714,000 people. There are only two sizeable towns: Varna (313,000) and Burgas (210,490).

The Romanian coastal zone has a total population of 573,000. The largest town in the coastal zone is Constantza, with a population of 350,000, followed by Mangalia, which has a total population of only 48,000.

The total population of the Georgian coastal zone is estimated at 650,000. The largest towns are Batumi (137,100), Poti (50,900) and Kobuleti (33,700).

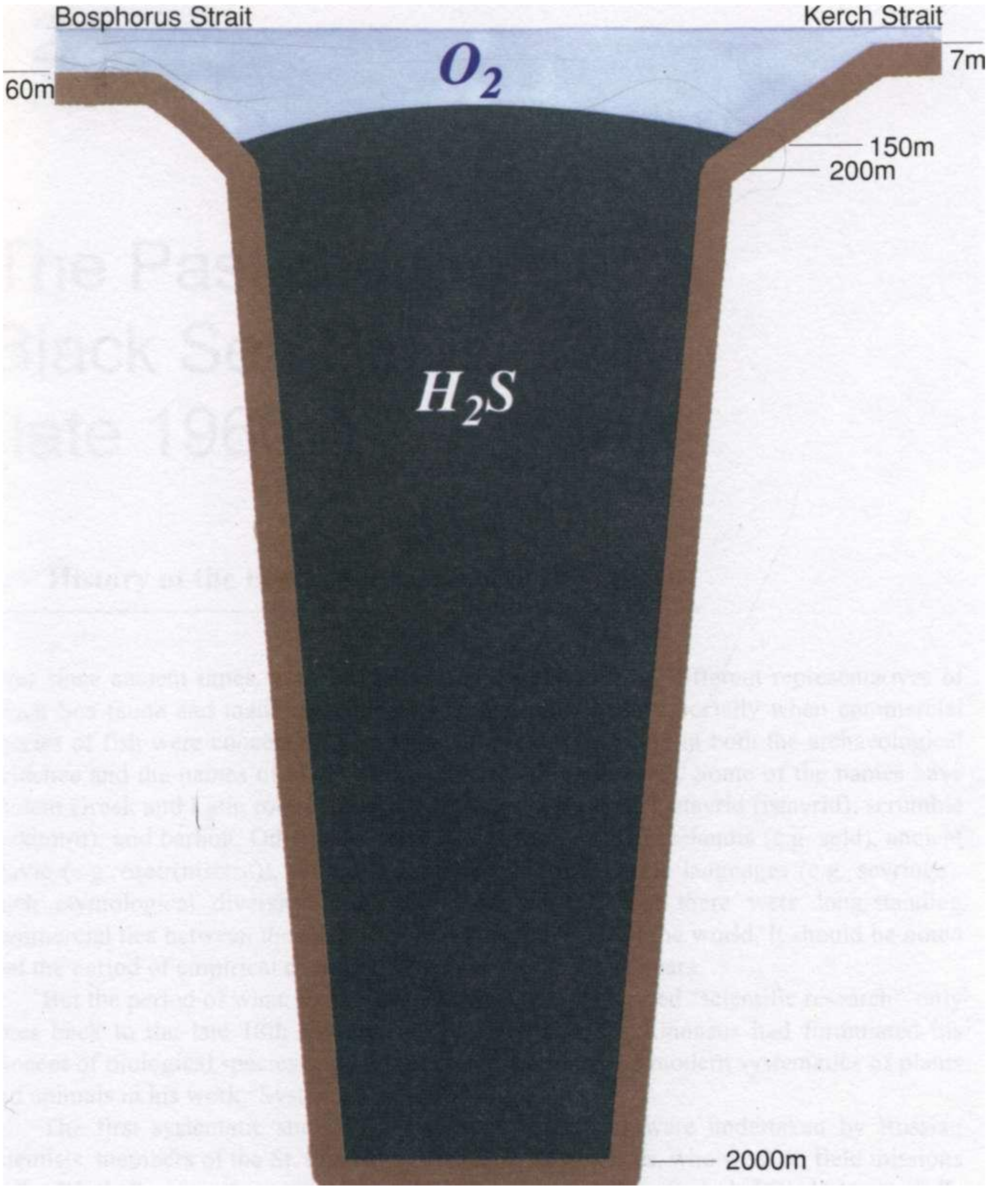

Fig 4. Profile of hydrogen sulphide zone in the Black Sea

The Past State of Black Sea Biodiversity (late 1960s)

I. History of the Black Sea Biodiversity Research

Ever since ancient times, Man has known of the existence of different representatives of Black Sea fauna and made clear distinctions between them, especially when commercial species of fish were concerned. The proof of this can be found in both the archaeological evidence and the names of many of the fish species themselves. Some of the names have ancient Greek and Latin roots, for example: kefal, lufar (liifer); stavrid (istavrid); scrumbie (uskumru); and barbun. Others take their names from ancient Icelandic (e.g. seld), ancient Slavic (e.g.. osetr(nisetru)), Italian (e.g. sardel) and the Turkic languages (e.g. sevriuga). Such etymological diversity also testifies to the fact that there were long-standing commercial ties between the Black Sea region and the rest of the world. It should be noted that the period of empirical cognition lasted for thousands of years.

But the period of what, by modern criteria, could be termed "scientific research" only dates back to the late 18th century, already after Carolus Linnaeus had formulated his concept of biological species and laid the foundations for the modern systematics of plants and animals in his work "Systema Naturae".

The first systematic studies of Black Sea organisms were undertaken by Russian scientists, members of the St. Petersburg Academy of Sciences, who went on field missions to the Black Sea or spent many years living by the sea. They included the botanists S.G. Gmelin and C.I. Gablits, and the zoologist and naturalist P.S. Pallas. These pioneering scientists were the first to describe Black Sea plant and animal species according to modern classifications. They also began work on the first ever inventory of Black Sea flora and fauna, an undertaking which is still in progress today.

Initially, these systematicians and taxonomists concentrated on trying to classify fish, algae, molluscs and, crabs. Then they shifted their attention to smaller organisms, such as plankton and benthos, including unicellular organisms and bacteria. At various stages during the research, the results were summarised, lists of plant and animal species compiled and identification guides published. The following gives a brief, simplified history of the main stages of biological research on the Black Sea biodiversity in tabular form (Table 2.1).

There has been an imbalance in the study of Black Sea biodiversity, with considerably more attention being paid to some groups of organisms than to others. For some groups of flora and fauna, all of the representative species have been studied; for others only a few species have been studied; while for a few groups what little research has been done is still only in a preliminary stage.

The list of species that have been more or less fully studied includes: macrophytic algae, sea weeds, mammals, fish, shrimps and crabs (decapods). Additions to the species composition of the Black Sea may follow the completion of research conducted on the Anatolian shelf, the area least studied by systematic biologists. This is particularly true of the Bosphorus region, since it receives high-salinity waters - and its inhabitants - via bottom currents from the Mediterranean.

The species composition of protozoans and many small multicellular organisms (e.g. the turbellarian worms, kinorhynchs, tardigrades, etc.) has also been inadequately studied. It is unfortunate that the biologists currently working in the Black Sea include virtually no experts for a whole range of taxa. Norse was undoubtedly right when he said that the taxonomists who are describing and classifying species should be called an endangered species (1993). According to Norse, there are only 1,500 experts left in the world today, many of them elderly with very few young scientists emerging to take their place. Taxonomists (systematic biologists) are the only experts able to distinguish all the finer points of the biological diversity of living organisms. Their current scarcity represents a major problem for modern biology.

The situation of the biological sciences today is paradoxical. Even though it is now generally agreed that biodiversity is the primary and most reliable method of assessing the health of the environment, that plant and animal species are the planet's irreplaceable genetic fund and that their number (diversity) is dwindling at a faster rate than ever before, the number of taxonomists is appallingly low. As a result, whole regions of the planet have no inventory lists of wild nature. In some cases people are not even aware that part of their biological surroundings has been lost forever.

The reasons for such a situation are well-known, and it is appropriate to mention them in a book such as this, which is dedicated to the biodiversity of the sea. One reason is that scientists have come to realise the advantages of the ecosystematic approach to studying nature; i.e. the study of different parts of the biosphere, such as the seas, the freshwater reserves and their ecological divisions not as an infinite quantity of different living organisms, many of which are yet to be described and classified, but as a certain "higher organism". This higher organism creates organic matter from mineral elements (all plants), consumes these elements as food (all animals), decomposes the organic debris into mineral elements again (all micro-organisms), and thus the cycle is complete. The fact that this really takes place, and in this manner, has been confirmed by measurements of factors such as total photosynthesis, total respiration and decay within the ecosystem.

The crab *Eriphia verrucosa* inhabits stony coastal zones. It is the largest Black Sea crab and can reach up to 9 cm in width.

The sea anemone *Actinia equina* is a sedentary soft-bodied invertebrate with tentacles circling the mouth. It feeds on organisms, ranging from plankton to small fish. The prey is immobilised by numerous nematocysts, or stinging capsules, on the tentacles. It is common in marine shallow-water areas, salt limans and lagoons.

Table 2.1. Some Major Events and Contributions to the Study of Black Sea Biological Diversity JL

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1768-1785	Gmelin S.G. and Gablits C.I. (St. Petersburg Academy of Sciences) describe several species of algae.
1793-1810	Pallas P.S. (St. Petersburg Academy of Sciences) describes 94 fish species in the Black Sea and the Azov Sea.
1837	Nordman A. (Richlieu Lycee, Odessa) describes 24 fish species in the Black Sea and its lagoons not included in the list of Pallas P.S.
1857-1858	Kessler C.T. (Kiev University) studies the fish and invertebrates of the lagoons and river estuaries of the north-western Black Sea coast.
1865	Markuzen I.A. (Novorossisk University, Odessa) describes 47 new species of Black Sea invertebrates.
1868	Mechnikov 1.1. (Novorossisk University, Odessa) publishes the first paper on pelagic fauna (plankton) of the Black Sea.
1868	Chernyavsky V.I. (Kiev University) begins the study of sponges.
1868	Bobretsky N.B. (Kiev University) starts studying polychaetes.
1870	Kovalevsky A.O. (Kiev University) discovers the lancelet, Amphioxus.
1873	Krichagin N.A. (Kiev University) embarks on a study of the copepods.
1873	Grebnitsky N.A. (Novorossisk University, Odessa) studies the oligochaetes.
1880	Repyakhov V.M. (Novorossisk University, Odessa) studies the bryozoans.
1880	Sovinsky V.K. (Kiev University) starts studying the Amphipoda.
1884	Chernyavsky V.I. (Kiev University) studies the decapods.
1886-1891	Pereyaslavtseva S.M. (the Sevastopol biostation) identifies 16 species of Peridiniales and studies foraminiferans and turbellarian worms.
1890	Andrusov N.I. (Novorossisk University, Odessa) discovers the deep-water Modiola mud.
1896	Ostroumov A. A. (the Sevastopol biostation) compiles a key to the identification of the fish of the Black Sea and Azov Sea.
1907	Shishkov G. (Sofia University, Bulgaria) begins a study of the saltwater mites Halacarida.
1908	Zernov S.A. (Sevastopol biostation) establishes the existence of congregations of Phyllophora on the north-western sea shelf (later named Zernov's Phyllophora field).
1908	Voronikhin N.N. (St. Petersburg University) reports on brown, green and red algae.
1910	Kudelin N.V. (Novorossisk University, Odessa) delivers the first report on hydroids.

1913	Zernov S.A. (Sevastopol biostation) is the first to describe Black Sea biocenoses.
1918-1921	Filipjev N.N. (Sevastopol biostation) starts studying the Nematods.
1927	Vodyanitsky V.A. (Novorossisk biostation) starts studying the ichthyoplankton.
1929	Morozova-VodyanitskayaN.V. (Novorosiisk biostation) attempts a quantitative assessment of macrophytes.
1930	Lipsky V.I. (Odessa University) studies the Phyllophora field.
1936	Pusanow I.I (Gorky University) publishes the first book on the anchovy.
1936	Borcea I. (Yassy University. Romania) studies the fish fauna of the western part of the Black Sea.
1939	CSrausu A. (Yassy University, Romania) is the first to classify the insects of the Black Sea.
1941	Antipa Gr. (Natural History Museum, Bucharest) publishes a book on the Black Sea, including its biology.
1957	Valkanov A. (Bulgarian Academy of Sciences) compiles a catalogue of Bulgarian Black Sea fauna.
1958	Zaitsev Yu.P. (Odessa biostation) discovers the marine neuston.
1963	Zenkevich L.A. (Moscow State University) writes a major monograph entitled: "The Biology of the Seas of the USSR".
1964	Svetovidov A.N. (Zoological Institute, Leningrad) writes a monograph on Black Sea fish.
1965	Vinogradov K.A. (Odessa branch, Institute of the Biology of the Southern Seas) formulates the concept of the contact zones of the sea.
1965	Pogrebnyak I.I. (Odessa University) writes a report on the bottom-living vegetation of the limans of the north-western coast.
1965	Zambriborshch F.C (Odessa University) reports on the fish of the limans and river estuaries.
1967	Pusanow I.I (Odessa University) formulates the concept of the mediterranisation of the Black Sea fauna.
1967	Zinova A.D. (the Botanical Institute, Leningrad) compiles a key to the identification of the green, brown and red algae of the southern seas of the USSR.
1967	Grinbart SB. (Odessa University) reports on the zoobenthos of the limans.
1968-1972	Mordukhay-Boltovskoy F.D. (Institute of Inland Water Biology, Borok) edits a guide to the fauna of the Black Sea and the Azov Sea.
1970	Zaitsev Yu.P. (Odessa branch of the Institute of the Biology of the Southern Seas) writes a monograph entitled: "Marine neustonology".
1971	Bacescu M., Muller G., Gomoiu M.-T. (Romanian Academy of Sciences) describe the benthic fauna of the north-western Black Sea and the main biocenoses.
1976	Konsoulov A. (Institute of Oceanology, Varna) monographs the zooplankton of the Bulgarian Black Sea waters.
1976	Petranu A. (Romanian Institute of Marine Research) reviews the infusorian fauna of sandy bottoms.
1978	Konsoulova Ts. (Institute of Oceanology, Varna) reviews the Turbellaria found along the Bulgarian coast.

1979 | Pitsik G.K. (Institute of the Biology of the Southern Seas, Sevastopol) establishes that the Black Sea nhvtnnlanktnn rnrwictc r>f

1979	Pitsik G.K. (Institute of the Biology of the Southern Seas, Sevastopol) establishes that the Black Sea phytoplankton consists of up to 746 species of microalgae.
1979	Kalugina-Gutnik A.A. (Institute of the Biology of the Southern Seas, Sevastopol) lists 304 species of microphyte bottom algae in the Black Sea.
1979	Bodeanu N. (Romanian Institute of Marine Research, Constantza) describes 388 species of macrophyte benthos from the western Black Sea.
1980	Publication of the Red Data Book of the Ukrainian SSR.
1982	Sorokin Yu.I. (Institute of Oceanology, Moscow) publishes a monograph entitled: "The Black Sea".
1985	Publication of the Red Data Book of the Socialist Republic of Bulgaria.
1985	Publication of the Red Data Book of the Russian Federation
1988	Bodeanu N. (Romanian Institute of Marine Research) publishes "L'algoflore unicellulaire dans les eaux du littoral roumain de la Mer Noire". ("Unicellular algoflora of the Romanian coastal waters of the Black Sea.")
1992	Guslyakov N.E. et al. (Odessa University) publishes an atlas of 316 species of benthic diatoms in the north-western Black Sea.
1993	Minicheva G.G., Yeryomenko T.I (Odessa branch of the Institute of the Biology of the Southern Seas) describes the first registered case of the invasion of Black Sea by an exotic species, a macrophyte alga.
1994	First International Symposium on the Marine Mammals of the Black Sea is held in Istanbul.
1994	Publication of the Red Data Book of Ukraine (Second edition).
1995	Preparation of National Biodiversity reports by all Black Sea countries within the BSEP.
1996	Preparation of the Transboundary Diagnostic Analysis, including chapter on Living resources management.
1996	Adoption of the Black Sea Strategic Action Plan

For example, by knowing the quantity of oxygen produced during photosynthesis over a certain time period, or absorbed through respiration, it is possible to calculate the total biomass of plants and animals inhabiting a given body of water or to obtain a fairly accurate picture of the prevalent processes taking place within it.

The second reason is that modern equipment allows us to obtain reliable information from large surfaces of land and water while using only a limited number of personnel. Such personnel do not even have to be very knowledgeable about all the details of the process. The accumulated figures are easy to evaluate quantitatively and formulae can be produced which can be stored into mathematical models, thus facilitating further ecological research'.

The third reason follows from the second: who of the younger generation of biologists and ecologists would voluntarily perform the time-consuming and tedious job of studying the particulars of the fifth pair of copepod's legs under a microscope, or investigate the pharyngeal section of polychaetes or the spiculae of sponges, only to discover the specimen's affinity to a certain other species? Former generations of the scientists' predecessors, who were spared the temptations of automated instruments, computers and models, were expert at this sort of research work. The prospects for somehow making the work of the systematic biologists and taxonomists simpler and easier are not encouraging. At this point we should mention the benefits provided to systematics by electronic microscopy, molecular biology and a number of other achievements of modern science, thanks to which it was possible, in the middle of the 20th century, to initiate a fundamental restructuring of the system of the higher taxa of the organic world. This is why young researchers usually join the ranks of scientists who support the very progressive and effective ecosystematic approach to studying nature.

It is disappointing, however, that many do not fully understand that this ecosystematic approach is a supplement to, not a replacement for, "outdated" morphology, anatomy, systematics, taxonomy and other classic sciences. In the final analysis, the process of photosynthesis in an ecosystem is not the result of some abstract "phytomass", and it is not the "zoomass" or the "ichthyomass" that is breathing, but real plant and animal species, each with their own biological and ecological features.

Take, for example, the fact that there are many species of plants which synthesize organic matter but only one or two that cause water blooms. The process of photosynthesis may be identical for both groups in terms of its aggregate intensity, but in the first group the system will continue to function as usual, whereas it is doomed to hypoxia and starvation in the second. The same is true of respiration and other energy-related parameters. Several different species in a balanced community may consume the same quantity of oxygen per unit of time as, for instance, the ctenophore *Mnemiopsis leidyi* after it has decimated other zooplankton.

That is why, even if it is comparatively easy to make quick and accurate calculations of the integral values of photosynthesis and respiration, there is no avoiding the question of what is directly responsible for that photosynthesis and respiration.

The identification of organisms and the accurate classification of species is, naturally, the final stage of the work of systematic biologists alone. For scientists working in other branches of biology, and in ecology in particular, it is the necessary foundation for their assessments and further research.

The elegant shrimp ***Palaemon elegans,*** one of 12 species of Black Sea shrimp, is a mass bottom crustacean living in shallow waters. It is one of the main food resources for gobies and other benthic fishes.

As regards the process of the scientific cognition of Black Sea biodiversity, it should be noted that the inventory work on many higher taxa of Black sea flora and fauna is virtually complete. In some cases this has taken centuries to accomplish; in others a shorter period of time. It depends on many different factors, including the problems of collecting organisms, determining their affinity to a given species, and, naturally, on the qualifications and diligence of systematic biologists and taxonomists.Table 2.2 contains a general illustration of such a process .

As is evident from Table 2.2, description and inventory work only remains to be performed for flagellates, sarcodines, infusoria, oligochaetes and nemertines; incomplete information is available on turbellarian worms, gastrotrichs, kinorhynchs and tardigrades. Parasitic organisms have been poorly studied.

Nevertheless, the table demonstrates that the Black Sea is an excellently researched sea in terms of the biological diversity of its plants and animals, and may even rank first among the planet's seas in this respect. As for the gaps in our knowledge that still exist, they show us the priorities for the immediate future.

The wrasse *Crenilahrus ocellatus* is one of eight species of the Labridae in the Black Sea. It inhabits shallow-water areas and its strongly adhesive eggs are deposited in a nest of filamentous algae. After giving birth the female is chased away from the vicinity and the nest is protected by the male against prédation by small fish.

Table 2.2 Study of the Species Composition of Some Groups of Black Sea Organisms

Taxa, Groups of Organisms, Biocoenoses	Year and Name of Author of First Specialised Research	Year, Name of Author, and Published Results
Bottom-living algae	1768 Gmelin S.G	1967 Zinova A.D - a guide to the identification of green, brown and red algae of the southern seas of the USSR with a description of 277 species of Black Sea macrophyte algae 1979 Kalugina-Gutnik A.A - a chapter in a book: a total of 304 species of macrophyte algae found in the Black Sea.
Dinophyceae	1886 Pereyaslavtseva S.M	1965 Ivanov A.I. - a guide to the identification of 175 Peridiniales given in the survey "Characteristics of the Qualitative Composition of the Black Sea Phytoplankton". 1979 Pitsik G.K - a chapter in a book: 205 species of Black Sea Peridiniales described.
Diatomeae	1903 Merezhkovsky K.S.	1955 Proshkina-Lavrenko A.I. - a guide to identification entitled "Diatom Algae of the Black Sea Plankton" of 174 species and types of diatoms
Foraminiferida	1886 Pereyaslavtseva S.M	1987 Yanko V.V., Troitskaya T.S. - a description of 94 species of foraminiferans
Spongia	1868 Chernyavsky V.I	1968 Kaminskaya L.D. - a guide to the identification of 26 species of Black Sea sponges

Hydrozoa	1909 Kudelin N.V	1968 Naumov D.V. - a guide to the identification of 26 species of hydrozoans of the Black Sea and Azov Sea.
Nematoda	1918 Filipjev N.N	1968 Platonova T.A. - a guide to the identification of 142 species of roundworms of the Black Sea and Azov Sea.
Polychaeta	1968 Bobretsky N.B	1968 Vinogradov K.A, Losovskaya G.V. - a guide to the identification of 192 species of polychaetes of the Black Sea and Azov Sea
Oligochaeta	1873 Grebnitsky N.A.	1968 Finogenova N.P. - a guide to the identification of 29 species of oligochaetes of the Black Sea and Azov Sea
Bryozoa	1880 Repyakhov V.M	1968 Braiko V.D.- a guide to the identification of 16 species of bryozoans of the Black Sea and Azov Sea
Copepoda	1873 Krichagin N.A.	1969 Dolgopolskaya M.A. - a guide to the identification of 17 species of Calanoida of the Black Sea and Azov Sea. 1969 Dukina V.V. - a guide to the identification of 17 species of Cyclopoida of the Black Sea and the Azov Sea. 1969 Griga R.E. - a guide to the identification of 147 species of Harpacticoida of the Black Sea and Azov Sea. 1988 Apostolov A., Marinov T. - a paper containing a classification of 204 species of Black Sea Harpacticoida 1978-1989 Monchenko V.I. - a classification of 19 species of Black Sea Cyclopoida
Ostracoda	1939 Dubovsky N.V.	1969 Shornikov E.I. - a guide to the identification of 111 species of Ostracoda.

Decapoda	1884 Chernyavsky V.I	1967 Băcescu M. - a paper classifying 37 species of Black Sea decapods 1969 Kobyakova Z.I., Dolgopolskaya M.A. - a guide to the identification of 37 species of decapods of the Black Sea and the Azov Sea
Mysidacea	1882 Chernyavsky V.I	1969 Băcescu M. - a guide to the identification of 19 species of Mysidacea of the Black Sea and Azov Sea
Cumacea	1868 Chernyavsky V.I	1969 Băcescu M. - a guide to the identification of 24 species of Cumacea of the Black Sea and Azov Sea
Isopoda	1868 Chernyavsky V.I	1969 Kusakin O.G. - a guide to the identification of 29 species of Isopoda of the Black Sea and Azov Sea
Amphipoda	1880 Sovinsky V.K	1969 Mordukhay-Boltovskoy F.D, Greze I.I., Vasilenko S.V. - a guide to the identification of 108 species of Amphipoda of the Black Sea and Azov Sea
Halacarida	1907 Shishkov G	1972 Sokolov I.I., Yankovskaya A.I. - a guide to the identification of 27 species of saltwater mites of the Black Sea and Azov Sea
Mollusca	1845 Nordman A	1972 Golikov A.N., Skarlato O.AStarobogatov Ya.I. - a guide to the identification of 203 species of gastropods and bivalves of the Black Sea and Azov Sea
Echinodermata	1892 Ostroumov A.A	1972 Baranova Z.I., Savelyeva T.S- a guide to the identification of 12 species of Black Sea echinoderms
Ichthyoplankton	1927 Vodyanitsky V.A	1954 Vodyanitsky V.A..Kazanova I.I - a guide to the identification of 64 species of Black Sea fish eggs and larvae 1973 Dekhnik T.V. - a monograph entitled "Black Sea Ichthyoplankton" with a description of 103 species of fish eggs and larvae

Pisces	1795 Pallas P.S	1964 Svetovidov A.N. - a paper entitled "Black Sea Fish" with a .description of 150 fish species and subspecies. 1987 Rass T.S. - a review entitled "Modern concepts of the composition of Black Sea ichthyofauna and its changes", including a list of 168 fish species.
Phyllophora biocenosis	1908 Zernov S.A- registration	1954 Shchapova T.F. - determined the boundaries and total biomass. 1967 Vinogradov K.A, Zakutsky V.P. - described the biocenosis 1968 Kalugina A.A., Lachko O.A. - determined the stocks. 1983 Katukov A.V. - established a steep drop in stocks. 1993 Zaitsev Yu.P. - established a degrading of the community
Interstitial meiofauna	1879 Ulyanin V.N.	1992 Vorobyova L.V.*et al.* - a monograph of 66 species pertaining to 12 taxa of the higher invertebrates
Neuston	1957 Zaitsev Yu.P. discovered the biocenosis of neuston in the sea	1970 Zaitsev Yu.P. - a monograph entitled "Marine Neustonology" with a description of the species composition of the community, the methods of adaptation of various species to the ecological conditions of the pelagic surface microlayer

II. The Origin of Black Sea Inhabitants

In the past the region now occupied by the Black Sea was the site of major geological upheavals, many of which have played a major role in the development of the sea's modern character. The Black Sea biota - the historically established combination of flora and fauna - reflects the general processes that have influenced the ecosystem of the sea, particularly those that have taken place over the last 20,000 years.

Research has shown that there are different elements in the Black Sea fauna, comprising groups of biologically distinct species sharing a common origin in a past ecological event. (There has been less research into the extent to which the same can be said of the origins of the Black Sea flora.) These organisms react in a specific way, which varies according to their origin and the marine environmental conditions prevailing in the Black Sea, and consequently occupy different habitats within the sea.

The Black Sea species which had once lived in the Neoeuxinian Lake, the predecessor of the modern Black Sea, should clearly be considered its most ancient inhabitants. The lake-sea came into existence some 18,000 - 20,000 years ago after the end of the VVtirm glaciation during which the whole northern part of Europe had been covered by glaciers. Melting water filled the lake-sea and substantially reduced its salinity. This "sea" was also completely isolated from the Mediterranean. It is believed that its salinity was approximately 5-7 *%o* and that it was inhabited by plants and animals adapted to brackish waters. Its fauna included: bivalves such as *Dreissena, Adacna, Monodacna;* the polychaetes *Hypania* and *Hypaniola;* the crustaceans *Pontogammarus* and *Paramysis;* and fish such as the kilka, *Clupeonella,* many species of goby (Gobiidae), sturgeons (Acipenseridaej and herrings (Clupeidae). These organisms are generally referred to as the "Pontian relics" and occupied dominant positions in the water bodies that existed before the formation of the present Black Sea, Caspian Seas and the Azov Sea. Today they can only be found in waters with low salinity. The largest number of such surviving species inhabit the Caspian Sea, which is why they are also sometimes referred to as "Caspian relics".

A second group consists of marine thermophobic species originating from cold seas. They are referred to by a number of different names, including the "cold-water complex", the "Boreal-Atlantic relics", "Arctic relics" or "Celtic relics". In this book they are called "cold-water relics". Among others they include: the ctenophore *Pleurohrachia;* the copepods *Calanus* and *Pseudocalanus;* the spiny dogfish *Squalm acanthias:* the sprat *Sprattus sprattus phalericus;* the flounder *Platichthys flesus luscus;* the whiting *Merlangius merlangus euximts;* and the Black Sea trout *Salmo trutta labrax.*

It is difficult to be certain when and how these cold-water species were introduced into the Black Sea. They may have entered through the river systems during the time of Neoeuxinian Lake, or at a later date during the early stages of the formation of the Bosphorus, when the Mediterranean Sea was colder than it is today. Whenever they entered the Black Sea, they definitely constitute the second oldest element in the Black Sea fauna.

The Bosphorus is generally believed to have been formed approximately 7,000 years ago, but there are indications that it may have been formed even later, some 5,000 years ago. The Bosphorus established a connection with the Mediterranean, and via the Mediterranean, with the Atlantic Ocean. Gradually, the salinity of the Black Sea began to rise, and it soon reached a sufficiently high level to support many Mediterranean species. These Mediterranean settlers constitute the third, and most populous, element in the Black Sea fauna, comprising up to 80 percent of the total fauna in the Black Sea by species number. Most of them prefer warm, saline waters, and for this reason are predominantly found in the upper layers of the sea, which are not directly affected by the rivers.

- The introduction of saline waters and Mediterranean settlers into the Black Sea put pressure on the autochthonous Pontian relics. They retreated to the brackish regions of the sea and took refuge in limans such as the Dnestrovsky and the Dneprovsko-Bugsky and in estuaries and deltas. But the euryhaline species (which are able to adapt to water with wide ranging salinities), such as the sturgeons and the herrings, can also be found in Black Sea waters with very high salinities. Many species of Pontian relics can also still be found in the Azov Sea.

In the period November-March the cold-water relics can be found near the surface of the pelagic zone, living below the thermocline where the temperature does not exceed 8-10° C. They spawn either during winter and spring near the surface *(Platichthys)* or during the warm season in deeper layers *(Sprattus, Merlangius).*

In summer almost all the Mediterranean immigrants can be found throughout the sea. The only possible exceptions are those species which are unable to live in fresh water. Fish and other animal species spend the winter either in a state of anabiosis, with a much reduced metabolic rate, or in the form of dormant eggs or spores, either on the seabed or in the warmest areas of the Black Sea along the shores of southern Crimea, the Caucasus and Anatolia. After completing their winter migration to these areas they form dense swarms in which they spend the winter. The most thermophilic species (mackerel, bonito, bluefish and tuna) migrate to the Sea of Marmara for the winter. In spring, the overwintering species migrate back to their spawning and feeding grounds.

Mediterranean settlers can be found in all major taxa of the Black Sea biota. They include: most sponges, scyphozoan jellyfish, polychaetes, molluscs, crustaceans, all echinoderms, and over 80 fish species. Some of the Mediterranean settlers have proved so good at adapting to Black Sea conditions that they have formed local subspecies (anchovy, garfish, silverside, red mullet) and even distinct species (turbot). The same phenomenon can also be observed in some cold-water relics (sprat, whiting, flounder).

However, not all species inhabiting the Mediterranean have been able to adapt and become naturalised. Some have been prevented from doing so by low water salinity, some by low water temperatures during winter, and others by the lack of suitable deep water habitats. Some widespread Mediterranean taxa, such as the radiolarians, pelagic foraminiferans, corals, siphonophores, pteropods and cephalopods still do not have a single species in the Black Sea. A comparison between the Mediterranean settlers' complex in the Black Sea and the number of species of different taxa found in Greek coastal waters can be seen in Table 2.3.

Table 2.3. The number of thermophilic marine species of some major taxa in the Mediterranean Sea (the Aegean Sea and Ionian Sea) and the Black Sea. The figures for the Mediterranean are after Bogdanos and Zenetos (1988) and Papaconstantinou, (1988).

Taxa	Mediterranean Sea	Black Sea	% in the Black Sea as compared with the Mediterranean Sea
Spongia	120	26	22
Polychaeta	400	192	48
Mollusca	500	190	38
Bryozoa	200	16	8
Echinodermata	90	12	13
Pisces	447	114	25

The mackerel *Scomber scombrus,* which is widespread in the Atlantic Ocean and the Mediterranean, spawns in the Sea of Marmara but^eeds in the Black Sea, mostly in the north-west where feeding conditions are much better than in the Sea of Marmara. In autumn the mackerel returns to winter and spawn in the Sea of Marmara. It cannot spawn in the Black Sea because the salinity levels prevailing in the oxygenated layers of the Black Sea are insufficient to enable its pelagic eggs to float.

After the 1970s the migration of mackerel from the Sea of Marmara to the Black Sea ceased because of the pollution of its spawning grounds in the vicinity of the Princes' Islands by local sources. A sharp decline in its population followed (Kocatas *et ai,* 1993). There was also an almost complete halt to the migrations of bonito, bluefish, and a number of other species.

The Mediterranean sardine is very close to becoming fully naturalised in the Black Sea. It has often been found in fishermen's nets and there have been isolated instances of its eggs being found in the Black Sea plankton. Reports of the occurrence of *Centracanthus cirrus* fish eggs (Tsokur, 1988) in the west of the sea are another indication of the continuing mediterranisation of Black Sea fauna (Pusanow, 1967).

As a result of the increasingly extensive use of river discharges for irrigation, the inflow of Mediterranean water into the Black Sea will probably increase in the future, with a resultant impact on the salinity of the water and an inevitable shrinkage of the habitats of Pontian relics.

The horse mackerel *Trachurus mediterraneus ponticus,* one of four species in the Carangidae family, is a widespread warm-water Black Sea fish.

The great strugeon *Huso huso ponticus,* one of six species of the Acipenseridae family, is the largest Black Sea fish. It can grow to a size of up to 4 m and a weight of 1,300 kg. However, the maximum length of the great sturgeons caught today does not exceed 2 m. It lives at depths of 100-130 m, feeding on bottom shrimps *Crangon,* crabs, mollucs and fish. It spawns in rivers, especially in the Danube, but dams are an insurmountable barrier to its anandromous migrations.

Fresh-water species are the fourth element in the Black Sea fauna. They have been introduced into the sea in river discharges and are usually found in greatly diluted sea waters during periods when the sea receives maximum river run-off. Their life in saline waters is usually quite limited, often not lasting more than a few days. Many inhabitants of the Dnieper and the Southern Bug can be found in the Odessa Gulf, which is 54 kilometres from Dneprovsko-Bugsky Liman, the main source of fresh water. The phenomenon is most common in spring. Fresh-water species include: large numbers of blue and green algae (e.g. *Microcystis);* many cladocerans (e.g. *Daphnia, Bosmina, Leptodora);* copepods *(Diaptomus);* rotifers and other invertebrates; and many fish species, such as carp, crucian carp, perch, sabrefish, silver carp and grass carp. Occasionally scientists even come across river crayfish with barnacles attached to them, which indicates that they have long been living in the sea.

It has been estimated that the Danube carries from 100,000 to 200,000 tons of freshwater plankton into the sea each year. Some of species have found in the sea at a distance of 100-130 kilometres from the delta, but most of the freshwater plankton dies in the immediate proximity of the delta and sediments to the bottom.

Different freshwater species have been introduced into the Black Sea fauna at different periods in its history. Species such as the carp, crucian carp and perch are clearly as old as the relics; whereas the silver carp and the grass carp could only have entered the sea after adaptation from littoral freshwater areas, which first happened in the 1950s.

The fifth and final element in the Black Sea flora and fauna consists of exotic species. Exotics are plants or animals which are not historically endemic but which have been introduced in one way or another and become resident. A special section (3.3) has been devoted to these species.

It should be noted that exotics are the youngest element in the fauna. The number of exotic species is not large, but some of them have played an extremely important role in the Black Sea ecosystem; for example, the gastropod *Rapcma thomasiana* and the ctenophore *Mnemiopsis leidyi.* Exotic species live in different habitats in the Black Sea, where the salinity, temperature and other ecological factors are similar to those in their place of origin.

A knowledge of the origin of Black Sea inhabitants is a necessary prerequisite for correctly assessing the present state of the ecosystem, formulating ecosystem management practices and forecasting possible changes in biodiversity and other important biotic parameters as the result of anthropogenic and global climatic influences.

The hermit crab *Clihanarius erythropus,* lives in snail shells of *Nassarius* and *Gibhula* on stony bottoms along rocky coasts. It is thermophilous and halophilous, which means that it has almost no representatives in the north-west of the sea. But it is quite common along the coasts of the Crimea, the Caucasus and northern Anatolia.

The goby *Gobius cephalarges* is common on stony bottoms. It is one of 27 species of the Gobiidae family, most of which are Pontian relics.

III. The Main Living Forms and Their Distribution

Living forms, or ecomorphs, are groups of species of plants and animals with similar morphologic features, ecological and physiological distinctions, and biological rhythms reflecting their adaptability to specific environmental conditions.

The water column is inhabited by representatives of two living communities, the plankton and the nekton. The term plankton is a collective name for organisms more or less passively floating in the column of water and being carried by currents. But the passivity is only relative to active swimmers, such as fish. In relation to the size of their bodies, some plankton are quite active. There are many species that perform diurnal vertical migrations of dozens, even hundreds, of metres, upwards from the bottom layers to the surface in the evening and in the opposite direction in the morning. A defining feature of plankton is thus not that it is immobile, but that it cannot swim against currents and is carried by them.

Plankton is divided into three main categories: plant plankton, or phytoplankton; animal plankton, or zooplankton; and bacteria plankton, or bacterioplankton. There may also be subdivisions within these categories; e.g. crustacean plankton or ichthyoplankton (pelagic fish eggs and larvae).

The distinction between euplankton and meroplankton is the amount of time that they spend in the plankton. Euplankton consists of organisms which spend their entire life cycle within the plankton. Meroplankton comprises temporary planktonic organisms, such as the larvae of bottom-living animals that undergo a transformation at the end of the planktonic stage of their life cycle.

Plankton can also be divided into several groups according to the size of the organisms: macroplankton consists of forms larger than 5 mm; mesoplankton comprises forms 1-5 mm in size; microplankton consists of forms smaller than 1 mm.

Nekton is composed of pelagic inhabitants that are active swimmers able to move against currents. The Black Sea nekton consists of by fish and marine mammals.

Neuston is a special pelagic association consisting of plant and animal organisms, as well as of bacteria living near the surface and adapted to the specific conditions of this biotope.

There are distinctions according to distribution within the water column. The hyponeuston comprises the inhabitants of the 5 cm deep microlayer of surface water; while the epineuston consists of the inhabitants of the upper side of the surface film of water. The hyponeuston is predominantly composed of bacteria, some unicellular algae and the eggs and larvae of many invertebrates and fish. The epineuston includes springtails and insects such as water striders.

The bottom-living organisms on the seafloor form the benthos, which is divided into three components: the plant benthos (phytobenthos); the animal benthos (zoobenthos); and the bacterial benthos (bacteriobenthos). Using the interface between the water and the seafloor as a reference, it is possible to distinguish between the epibenthos, which is composed of organisms living on the seafloor, and the inbenthos, the burrowing forms.

Phytobenthic organisms can be classified according to the size of their body, or thallus. Macrophytes are large algae and higher water plants, which form the macrophytobenthos); while the microphytobenthos consist of unicellular algae that live on the seafloor, covering sand, silt, rocks and any other structure, even concrete piles. The phytobenthos is able to reproduce only within the limits of the photic zone (i.e. the sector that receives sunlight in quantities sufficient for the process of photosynthesis). The photic zone is usually several dozen metres deep and extends across the pelagic surface waters. However, in the conditions of eutrophication and declining water transparency currently prevailing in the Black Sea, the lower boundary of the phytobenthos rises to as close as 10 m from the surface, sometimes even closer.

Zoobenthic animals can also be classified according to size. The macrobenthos consists of organisms larger than 2 mm; the meiobenthos comprises organisms 0.1-2 mm; and the microbenthos organisms of less than 0.1 mm. The zoobenthos includes representatives of a wide variety of taxa, ranging from unicellular protozoans to chordates (e.g. sea squirts).

It is often difficult to draw an exact demarcation line between different marine associations, thus supporting the classic thesis of Carolus Linnaeus that nature never makes a leap *(Natura non facit saltus).* For example, it is difficult to determine the exact moment when fish larvae become fully developed and make the transition from plankton to nekton; or to which of the communities the bottom-living goby or the flounder, both of which are strong swimmers, belong. In such instances, scientists utilise conventional divisions (for example, those relating to the speed of movement through water) or resort to terms such as benthonekton or planktonekton.

Organisms form biocenoses, or communities of different species of plants, animals and microorganisms, that are adapted to coexist in their biotope. A biotope is thus a relatively uniform living zone inhabited by a certain biocenosis. The most thoroughly studied benthic biocenoses in the Black Sea are the mussel biocenosis, the *Phaseolina* biocenosis, the *Phyllophora* biocenosis and the eelgrass *(Zostera)* biocenosis.

The biocenosis and the biotope are interrelated and interdependent, forming an ecological system, or ecosystem. Ecosystems vary in dimension and extent and can range from the ecosystem of a small section of the seafloor inhabited, for example, by eelgrass, to the ecosystem of the entire shelf, the pelagic zone ecosystem or the entire Black Sea ecosystem.

Uneven Distribution of Life Forms in the Sea

Living communities are not distributed evenly through all the sections of the oxygenated layers of the Black Sea. There are biologically rich regions and regions where the species diversity is poor and the number of individuals is small. Prominent among the biologically rich regions are shelf zones with depths of up to 50 m and shallow-water areas with depths of up to 5-10 m. Biologically poor regions include the deep water areas of the shelf, bordering the hydrogen sulphide zone at depths of 100-150 m, and corresponding areas in the open sea..

The Black Sea shelf is not homogeneous. The north-western shelf, which is the largest in the Black Sea accounting for over half the surface area of the entire shelf, is of particular interest (Fig. 2). It is the largest low-salinity body of water in the Black Sea and has the most complete representation of Pontian relics. The run-off from the major rivers (e.g. the Danube, the Dniester and the Dnieper) that discharge into this part of the Black Sea supports a salinity of less than 15 %o across vast areas. In the open limans (e.g. Dneprovsko-Bugsky and Dnestrovsky) the salinity is as low as 2-3 %o.

Different environmental conditions on other parts of the shelf mean that they are populated by other sets of organisms. Salinities near the coasts of the south of the Crimea and the Caucasus do not drop below 17-18 %o, while even in winter water temperatures do not fall below 7-10° C; whereas in the north-west the water temperature frequently approaches freezing near the shoreline and an ice cover forms during winter. Representatives of warm-water flora and fauna can thus be found along the southern coast of the Crimea and the Caucasus and many fish species winter there.

Certain areas of the southern shelf along the northern Anatolian coast provide important overwintering sites for fish such as anchovies, mackerel and mullets. The main migration routes and overwintering areas of pelagic Black Sea fish and dolphins are shown in Fig. 5.

A small section of the southern Black Sea shelf close to the Bosphorus stands out as being unique in terms of its biodiversity. It is through this section that bottom currents import salty Mediterranean water (over 30 %o) into the Black Sea. This creates a zone of high salinity and provides living conditions for many Mediterranean species that are not found anywhere else in the Black Sea, such as the sea star, the sea urchin, the sea-plume *Virgularía mirabilis* and other representatives of seas with standard salinity (normal ocean salinity is 35 %o).

Critical Biotopes

One of the most important issues in biodiversity is the concept of "critical biotopes", i.e. areas which are critical to the survival of certain species. If critical biotopes are subjected to pollution or other negative impacts, the result may be the diminution or even disappearance of entire populations of plants and animals. The neuston layer near the surface of the sea, which is a critical biotope for many invertebrates and fish, is particularly sensitive to surface active pollutants, such as crude oil, fat-like elements and different pesticides. High concentrations of these elements kill fish eggs and larvae resident in the neuston.

Sections of the coast from which pollutants are dumped into the sea, or which have been changed in the interests of Man, are critical biotopes for contourobiont species inhabiting the shoreline areas.

If straits are polluted they may become critical biotopes for migratory fish. It is quite significant that fish migrations from the Sea of Marmara to the Black Sea fell sharply between the 1960s and the 1970s, when, according to Turkish scientists (Kocatas *et al.*.

1993), there was a considerable increase in the pollution of the Sea of Marmara by untreated local industrial waste and municipal sewage This undermined the stocks of many fish, including the mackerel, which migrated to the Black Sea to feed in spring and returned to its spawning grounds in the Sea of Marmara in winter. By the end of the 1970s the mackerel population in the Black Sea had become too small to support commercial fishing.

According to Oztiirk and Oztiirk (1996), air pollution caused by funnel gases of vessels and by land-based sources of pollution resulted in the Bosphorus almost closing as a biological corridor.

The blenny *Blennius sanguinolentus*, one of nine species of the family Blenniidae, is a small shallow-water fish living among algae.

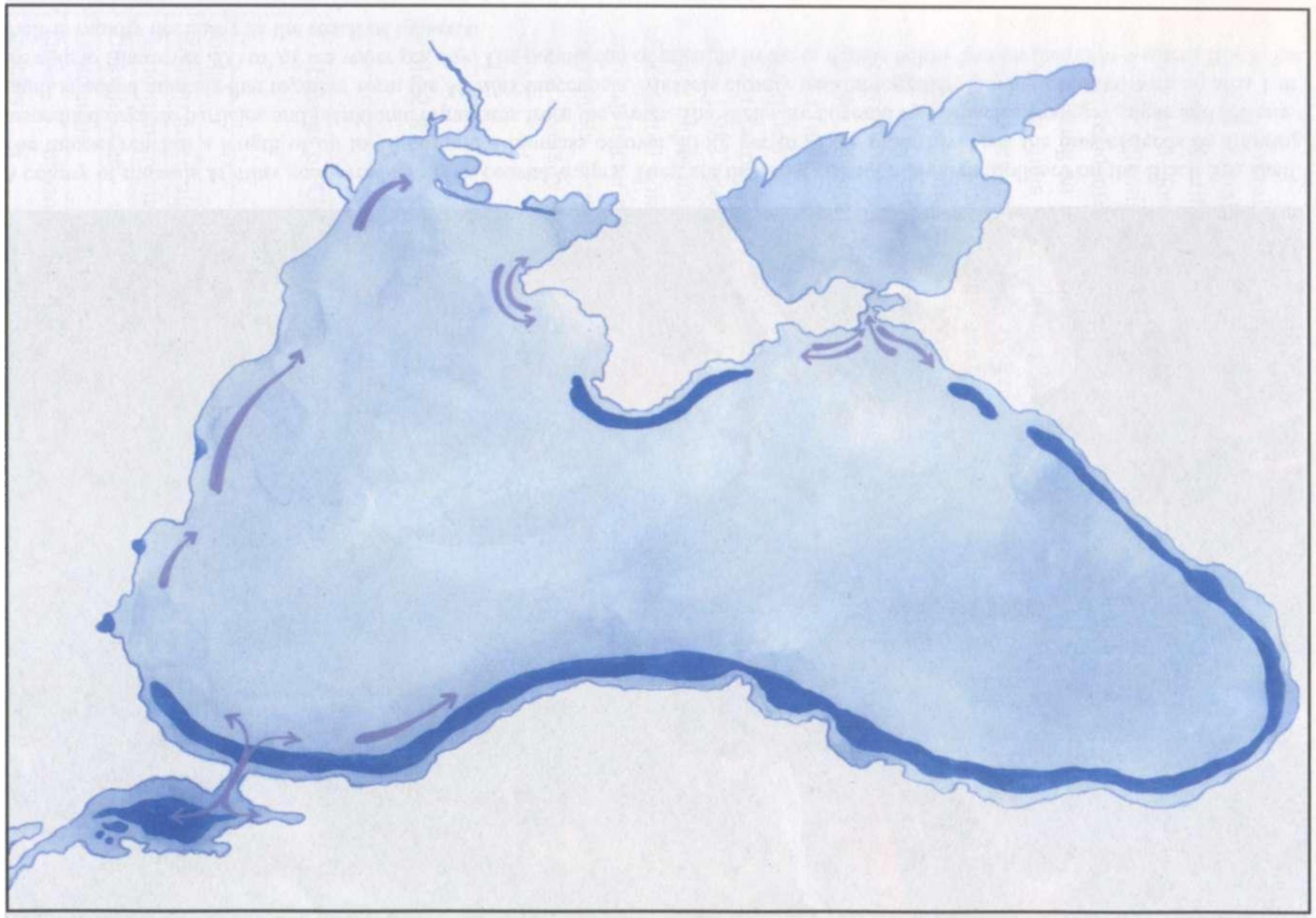


Fig 5. The main migration routes and overwintering areas of pelagic Black Sea fish, such as anchovy, sprat, horse mackerel and grey mullets, and dolphins (migration throughout the Bosphorus represents the situation prior to 1980).

A colony of mussels *Mytilus galloprovincialis* in coastal waters. They are the most common bivalve molluscs on the Black Sea shelf. The mussel reaches a length of up to 14 cm and a biomass of over 20 kg per m^2. Like other bivalves, the mussel feeds by filtering suspended organic particles and planktonic organisms from the water. The shells are covered by barnacles, sponges, algae and different small attached animals that together form the *Mytilus* biocenosis. Mussels closely packed together on a hard bottom with an area 1 m^2 are able to filter over 200 m^3 of sea water per day. The population of mussels living at depths below 8 m on the north-western Black Sea shelf is rapidly declining as the result of hypoxia.

IV. Black Sea Biodiversity in Figures

There are several reasons why it is difficult to provide an extensive list of the species of plants and animals inhabiting the Black Sea. Firstly, not all the organisms that have been found and identified by science can be correctly classified on a species level beyond the shadow of a doubt; e.g. the ctenophore *Mnemiopsis leidyi* and the bivalve *Cunearca.* Secondly, scientists have yet to determine standards for classifying freshwater invaders either as residents of the sea or temporary, accidental intruders which should not included when making an inventory of Black Sea flora and fauna. Thirdly, the mediterranisation of Black Sea biota is continuing, although some species do not yet extend beyond the Bosphorus region. Can they be treated as Black Sea species? Fourthly, the systematics of most species of microorganisms have not yet been determined.

The limitations listed above are a substantial obstacle to an accurate assessment of the number of species resident in the Black Sea. In preparing this summary of Black Sea biodiversity the authors have used the national reports prepared by the Black Sea states under the auspices of the BSEP, together with publications by a number of different authors (Table 2.4). The result is the most comprehensive list of Black Sea flora and fauna yet compiled.

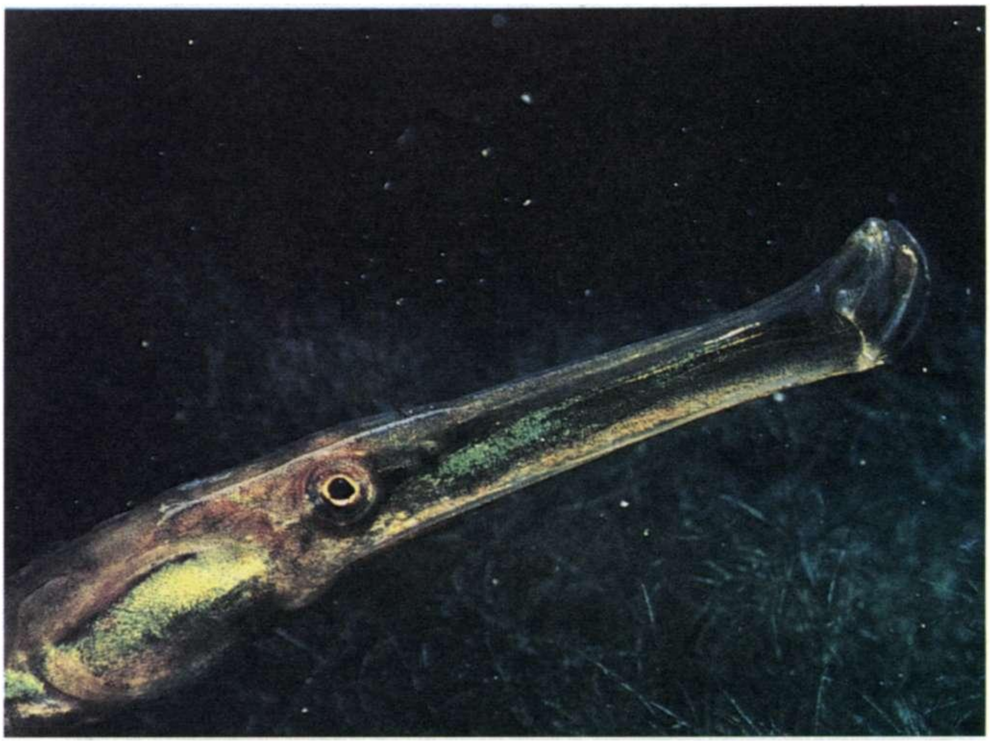
A total of 3,774 species have been identified, including: 1,619 fungi, algae and higher plants; 1,983 species of invertebrates; 168 species of fishes; and 4 species of mammals. But it is impossible to say how far the figures for smaller organisms in particular accurately reflect actual conditions in the Black Sea. The Black Sea is believed to contain a great variety of bacteria, protozoans and other groups of organisms that have yet to be studied by systematists. Nevertheless, the available data makes it possible to assert that, in terms of species diversity, the Black Sea has abundant representatives of all major taxa of plants and animals.

Table 2.4. Black Sea Biodiversity in Figures

Taxons or Groups	Number of species reported	Authors
Fungi	175	Ukrainian National Report, 1995
Bottom macroalgae	304	Kalugina-Gutnik A.A., 1979
Bottom microalgae	388	Romanian National Report, 1995
Dinophyceae	175	Ivanov A.I., 1965
Diatomeae	174	Proshkina-Lavrenko A.I., 1995
Other phytoplankton species	396	PitsikG.K., 1979

Higher marine plants	7	Ukrainian National Report, 1995
Foraminifera	94	Yanko V.V., Troitskaya T.S., 1987
Radiolaria	1	Mordukhay-Boltovskoy F.D., 1972
Other Sarcodina	40	Mordukhay-Boltovskoy F.D., 1972
Tintinnoinea	27	Mordukhay-Boltovskoy F.D., 1972
Other *Infusoria*	200	Mordukhay-Boltovskoy F.D., 1972
Spongia	28	Kiseleva M.I., 1968
Hydrozoa	26	Naumov D.V., 1968
Scyphozoa	3	Naumov D.V., 1968
Anthozoa	4	Naumov D.V, 1968
Ctenophora	*2+L*	Ukrainian National Report, 1995
Turbellaria	103	Kiseleva M.I, 1979
Nemertini	[illegible]	Kiseleva M.I, 1979
Nematoda	142	Pfatonova T.A, 1968
Rotatoria	102	KharinN.N, 1968
Gastrotricha	23	Kiseleva M.N, 1979
Kinorhyncha	10	Romanian National Report, 1995
Sipunculida	1	Mordukhay-Boltovskoy F.D, 1972
Polychaeta	192	Vinogradov K.A, Losovskaya G.V., 1968
Oligochaeta	39	Kiseleva M.N, 1979
Bryozoa	18	Kiseleva M.N, 1979
Kamptozoa	2	Kiseleva M.N, 1979
Phoronidea	1	Kiseleva M.I, 1979
Loricata	3	Starobogatov Ya.I, 1972
Bivalvia	88	Skarlato O.A., Starobogatov Ya.I, 1972
Scaphopoda	1	Starobogatov Ya.I, 1972
Gastropoda	118	Golikov A.N, Starobogatov Ya.I, 1972
Acarina	43	Sokolov I.A, Yankovskaya A.I, 1972
Insecta	11	Kiseleva M.I, 1979
Tardigrada	5	Rudescu L, 1972
Cirripedia	5	Zevina G.B, Dolgopolskaya M.A, 1969
Tanaidacea	6	Makkaveeva E.B, 1969
Branchiopoda	17	Mordukhay-Boltovskoy F.D, 1972
Pantopoda	8	Bacescu M, 1972
Calanoida	17	Dolgopolskaya M.A, 1969
Cyclopoida	19	Monchenko V.I, 1989
Harpacticoida	204	Apostolov A.M., Marinov T.M, 1988
Ostracoda	111	Shornikov E.I, 1969
Decapoda	37	Bacescu M, 1967
Mysidacea	19	Bacescu M, 1967

Cumacea	24	Bacescu M, 1967
Isopoda	29	Kusakin O.G, 1969
Amphipoda	103	Mordukhay-Boltovskoy F.D, Dolgopolskaya M.A, 1969
Chaetognatha	1	Mordukhay-Boltovskoy F.D, 1972
Echinodermata	14	Kiseleva M.I, 1979
Ascidiae	8	Kiseleva M.I, 1979
Acrania	1	Ukrainian National Report, 1995
Pisces	168	Rass T.S, 1987
Mammalia	4	Biodiversity National Reports, 1995



The head of the pipefish *Syngnathus tuphle argentatus*, one of seven species of the Syngnathidae family to be found in the Black Sea. This pipefish is common in the coastal zone and is abundant during the summer season.

The sea horse *Hippocampus ramulosus* among algae *(Cystoseira* and *Codium*). It is the only representative of this genus in the Black Sea.

Main Man-made Impacts on Black Sea Biodiversity

I. Anthropogenic Eutrophication

Anthropogenic eutrophication of shelves and coastal waters has been the most damaging of all the many harmful human influences on the oceans and seas, both in terms of its scale and its consequences. Phenomena such as the decrease in taxonomic diversity of hydrobionts, the population bursts of some species to the detriment of others, declining water transparency, the degradation of benthic macrophytocenoses, hypoxia in the bottom benthic layers, the mass mortalities of the zoobenthos and nektobenthic fish are all directly or indirectly linked to the sharp increase in mineral and organic elements in the run-off, which has had a strong impact on rates of primary production (Odum, 1971).

All the major sources and routes of nutrients entering the sea are already known. They include: fertilisers from fields; discharges from animal husbandry; urban and sewage; and atmospheric fall-out. Different sources of eutrophication may dominate a particular area depending on local conditions. In cases where there is a major city located near a bay or a gulf, municipal sewage tends to be the main source of eutrophication. River run-off is the major factor near estuaries and deltas, whereas in the open sea it is atmospheric fall-out. It is now well established that the content of nitrates and phosphates in rainwater is substantially higher than the levels in the Black Sea (Rozhdestvensky, 1979).

Not all the coastal areas of the world ocean are equally affected by eutrophication. Open coasts, where sea currents and tides ensure a continuous water exchange and where there are no major sources of pollution, are not critically endangered. On the other hand, many bays, gulfs, estuaries and whole inland seas are now suffering from the harsh consequences of excessive water fertilisation. The Black Sea is one of the worst examples (Fig. 6.).

Individual examples of dying benthos were registered along limited sections of the north-western Black Sea in 1967-1969 during a cruise by the Odessa branch of the Institute of the Biology of the Southern Seas aboard the research vessel "Miklukho-Maklai". The first sighting of huge numbers of fish (mostly gobies) approaching the shoreline occurred in July-August 1970 in the vicinity of Odessa Gulf. In September 1973 the research vessel "Miklukho-Maklai" recorded the first mass mortalities of the Black Sea benthos and bottom-living fish in an area of 3,500 km^2 between the Danube delta and Dnestrovsky Liman (Zaitsev, 1977; Salsky, 1977). Total losses amounted to 500,000 tons of zoobenthos and fish. This phenomenon has been attributed to an increase in nutrients in the river discharge, stratification and stagnation of water on the shelf (Tolmazin, 1977), an increase in the volume of phytoplankton and an expansion in the area of water blooms (Nesterova, 1978). In 1975 the average biomass of phytoplankton in the region between the Dniester and the Danube was 1.2 times higher than the maximum prior to the mid-1960s (Ivanov, 1967).

This process may be linked to the increase in mineral and nutrients river discharges. For example, in the 1950s the Danube, the Dniester and the Dnieper annually carried 14,000 tons of phosphates, 155,000 tons of nitrates and 2,350,000 tons of organic matter into the north-western Black Sea (Almazov, 1962, 1967). By the 1980s the rivers were carrying an annual average of 55,000 tons of phosphates, 340,000 tons of nitrates and 10,700,000 tons of organic matter (Garkavaya *et ai*, 1989).

The zones of hypoxia in the north-western Black Sea continued to expand to cover up to 40,000 km^2. Research has shown that the lack of oxygen resulted in the death of 0.3 to 8 million tons of bottom macrofauna per annum. Total losses for the 1972-1990 period have been estimated at around 60 million tons, including 5 million tons of fish (Zaitsev, 1992).

The Varna Bay region, which borders the north-western part of the Black Sea, is influenced by Danube water and, to a greater extent, local discharges. During the summers of 1971-1980, scientists recorded a sharp increase in the number of the peridinean *Exuviaella cordata,* with densities reaching hundreds of millions of cells per litre of water.

Anthropogenic eutrophication affects the diversity of species in a number of different ways. Direct effects on the phytoplankton include the stimulation of the growth of dinoflagellates at the expense of diatoms, whose numbers decline. In the 1950s and 1960s peridineans accounted for 18.8 percent of the phytoplankton biomass (Ivanov, 1967). By the 1970s it accounted for 55 percent (Nesterova, 1987). Extensive water blooms may produce a monoculture with massive blooms of 2-3 species of algae, usually dinoflagellates (Bodeanu, 1988). For example, in the autumn of 1993 Nesterova found only one species of dinoflagellate, *Gymnodinium spiendens,* inhabiting a small eutrophicated brackish lagoon linked to Dnestrovsky Liman. Its population was 3.8 10^6 cells per litre, with a biomass of 92.3 mg.m^{-3}. But not a single diatom was recorded.

Anthropogenic eutrophication directly affects the species composition of bottom-living macrophytes by reducing the number of species with a low level of specific surface

(S/V), even leading to their complete disappearance (as with *Cystoseira* near the north-western coast), and the growth of the number of filamentous species with a high S/V value (Minicheva, 1990).

Anthropogenic eutrophication has a similar indirect effect on the zooplankton through its impact on the phytoplankton. Explosions in the productivity of pelagic microphytes are usually accompanied by a sharp increase in the number of organisms feeding on them (e.g. *Noctiluca scintillans)* and a simultaneous decline in the volume of other zooplankton. In extreme situations the result may be the formation of monocultures or oligocultures.

Thus, in mid July 1986 a dense concentration of *Noctiluca scintillans* was recorded in the north-western Black Sea in the zone influenced by the Danube run-off. It occupied an area of over 3,500 km^2 in the surface neuston layer of 0-5 cm. The total population reached 1.5 10^{5} individuals m^{-3} with an average biomass of 125.9 kg m^{-3}. It was the first scientific record of *Noctiluca* occurring on such a scale and can be explained by a coincidence of favourable conditions in the hypertrophic sea zone. It should also be noted that, apart from the *Noctiluca,* the sample contained only two other species of zooplankton, namely *Tintinnopsis cylindrica* and *Coxliella helix var. cochleata.* They had an average population density of 24 10^{6} individuals m^{-3} and a biomass of 72 g.m^{-3} (Zaitsev *et al.,* 1988). *Noctiluca scintillans* comprised 98 percent of the concentration in terms of the number of individuals and 99.9 percent in terms of zooplankton biomass.

The contents of the digestive vacuoles of over 6,400 specimens of *Noctiluca* were studied. On the basis of the least digested remnants it was possible to identify the organisms on which it had fed. They included *Tintinnopsis cylindrica, Coxliella helix,* fragments of different Calanoida, their copepodid stages and eggs, and the cladoceran *Pleopis polyphemoides.* Unidentified detritus comprised the major proportion of the food mass. It was clear that the *Noctiluca* had consumed practically all the zooplankton in the neuston layer.

Obviously, those were extreme circumstances, but they vividly illustrate the possible results of such a process. Similar explosions in the number of the jellyfish *Aurelia aurita* and the ctenophore *Mnemiopsis leidyi* led to a sudden drop in the diversity of zooplanktonic species.

Anthropogenic eutrophication has a number of indirect effects on bottom-living plants, such as reduced water transparency. As a result, only algae adapted to dim sunlight survive at depths of over 15-20 m, thus substantially limiting the species composition of macrophytocenoses on these sections of the shelf.

As for the zoobenthos, its species composition, volume and biomass are highly susceptible to a lack of oxygen near the bottom caused by anthropogenic eutrophication. (Konsoulova, 1993). A good example of this phenomenon is the decrease in mussel biomass (Fig. 7.).

Of the other organisms in the zoobenthos, polychaetes less of all suffer from hypoxia. They are capable of living for over five days in water with oxygen concentrations below 0.5 ml per litre.

Organisms of the meiobenthos react to hypoxia in different ways. Harpacticoida, Ostracoda and the larvae of molluscs are very sensitive to a lack of oxygen.

Fig 6. Zones of moderate (a) and intensive (b) summer phytoplankton blooms in the Black Sea and Azov Sea (Zaitsev, 1991).

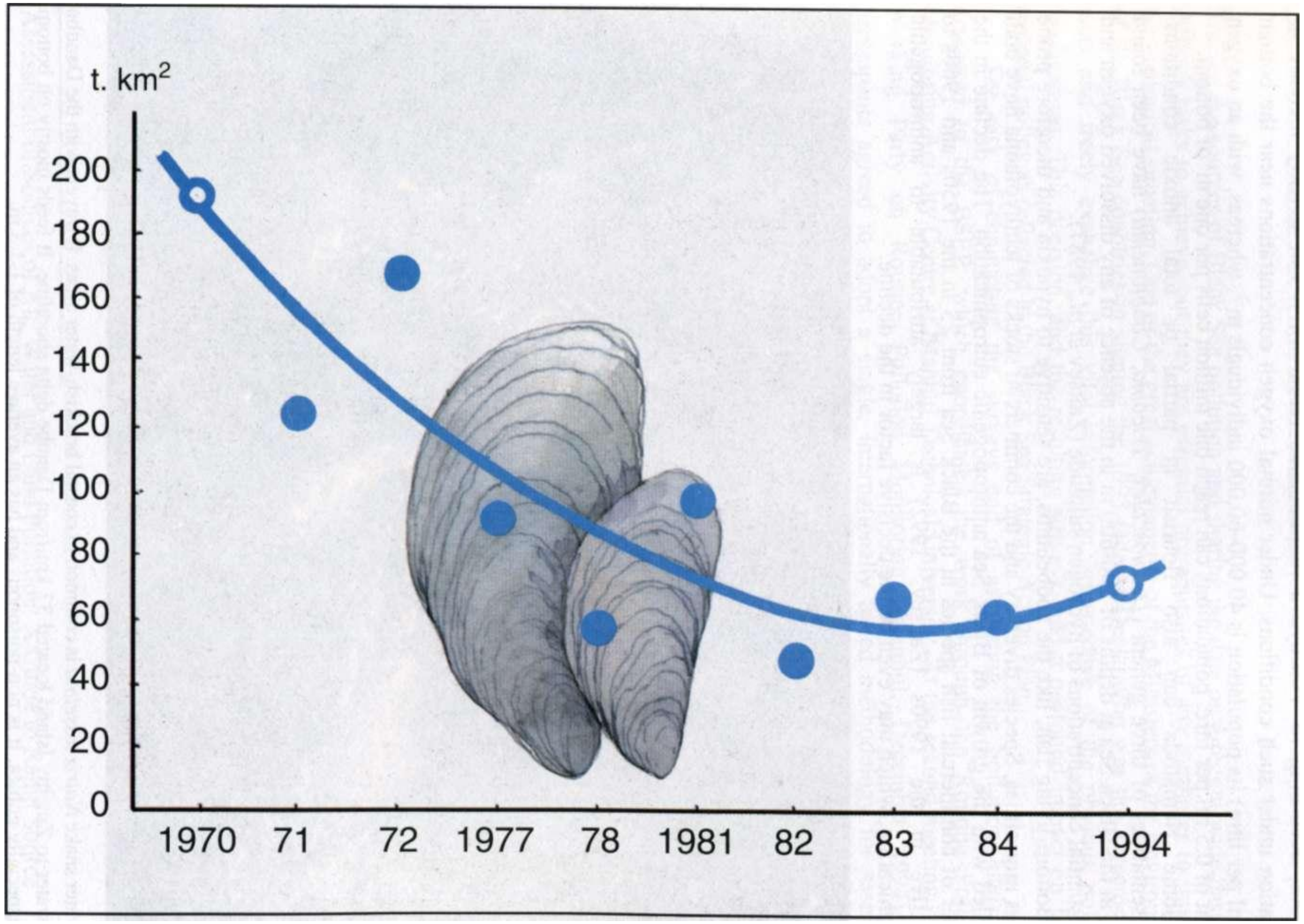


Fig 7. The decline in the biomass of the Mussel *Mytilus galloprovincialis* in Romanian Black Sea waters (Romanian National Report, 1995).

Foraminiferans are also unable to tolerate hypoxia, except for one species. *Ammonia lepida,* which not only survives in water with oxygen concentrations of only 0.5 ml per litre, but, according to Vorobyova (unpublished research), it can quickly increase its population under such conditions. Under normal oxygen concentrations near the bottom (4-7 ml per litre) its population is 40,000-60,000 individuals m^{-2}, whereas, with an oxygen content of 0.5 ml per litre, populations can reach one million cells per one m^2 of bottom.

Some Nematoda can also flourish in partial or total anoxic conditions. Representatives of three genera *(Desmoscolex, Tricoma, Cobbionema)* have been found living in the Black Sea at depths of 500-600 m in the absence of any dissolved oxygen and in substantial concentrations of hydrogen sulphide (Zaitsev *et ai,* 1987).

Bottom-living fish, like the zoobenthos, are sensitive to hypoxia and therefore prone to mass mortalities. Species diversity and the commercial stocks of ichthyofauna have both dwindled with the growth of Black Sea anthropogenic eutrophication. The decline in the number of commercial fish species in the Black Sea from 25 in the 1950s and 1960s to only five in the 1990s (Zaitsev, 1992) is largely attributable to anthropogenic eutrophication, which may even be the decisive factor in the decline.

The water snake *Natrix tesselata* is common in coastal brackish-water areas. It travels with the Danube river water to Zmeiny Island located 37 km from Danube delta shoreline. It feeds mostly on bottom fish, especially gobies. It is non-poisonous and has an average length of 1-1.3 m.

II. Current State of Black Sea Pollution

Tracing the sources of Black Sea pollution and sharing the data on a region-wide basis are difficult tasks to achieve, but they are essential prerequisites of any measures to improve the ecological situation. One of the great achievements of the Ministers of the Environment of the Black Sea countries in signing the 1993 Odessa Declaration was the agreement to meet and freely exchange this vital information, irrespective of the obvious political implications. This decision, and the resulting surveys, had a profound impact on future regional policy as reflected in the Black Sea Strategic Action Plan.

The task of conducting the surveys and of estimating the pollution loads was delegated to the BSEP, which coordinated the work through the Routine Pollution Monitoring Activity Centre at Istanbul Technical University. At the second meeting of the Working Party on Routine Pollution Monitoring (Istanbul, December 1994), the participants agreed to adopt a single, internationally tested methodology for assessing discharges of liquid waste into the environment. This WHO methodology[1] was translated into Bulgarian, Romanian, Russian and Turkish and distributed through the BSEP network. The objective of the study was to develop a rapid inventory of land-based sources of pollution using both existing information and data collected through questionnaires designed by the Working Party. The data covered industrial and domestic sources of pollution. This first study considered both point sources and river inputs to the Black Sea. Diffuse sources, air emissions and surface runoff will be tackled at a later date.

The data revealed striking overall patterns. The influence of international rivers, particularly the Danube, is clearly enormous. International rivers accounted for more than 80 percent of the Biological Oxygen Demand (BOD,) and Total Suspended Solid (TSS) loads; while the Danube alone accounted for about 88 percent of the total riverine BOD_5.

But much better pollution control is also clearly required in the Black Sea coastal region itself. The lists of major sources and their percentage contributions to overall loads revealed that the significant sources are relatively few in number. This was the case for all the countries and for all the discharged substances reviewed. It is obvious that priority must be given to these identified sources. It was also evident that every Black Sea country has major potential sources of pollution. In other words, *nobody is innocent.*

[1] Assessment of Sources of Air, Water and Land Pollution: A Guide to Rapid Source Inventory Techniques and their use in Formulating Environmental Control Strategies. Part One: Rapid Inventory Techniques in Environmental Pollution. WHO, Geneva, 1993

The head of a Black Sea turbot *Psetta maeotica*, the largest Black Sea flatfish, against a sandy bottom background. The turbot is capable of modifying its pigmentation as a protective coloration, enabling it to blend into and become indistinguishable from its environment.

Nutrients

This is clearly the main culprit for the ecological degradation of the Black Sea environment. The present study revealed that some 58 percent of the total nitrogen and 66 percent of the total phosphorus flowing in dissolved form into the Black Sea come from the Danube basin, making the participation of Danubian countries in the clean-up effort of paramount importance. Continued research efforts are also needed through programmes designed to develop scientifically based strategies for mitigation.

Oil Pollution

The Danube river accounts for 48 percent of the 111 10' tons of oil entering the Black Sea each year. Most of the remainder is introduced from land-based sources through inadequate waste treatment and poor handling of oil and oil products. The amount of oil reaching the Black Sea from ballast water discharges by ships is unknown but believed to be considerable.

The concentration of oil was measured in sediments and sea water. The levels were found to be of concern near sea ports (Odessa and Sochi), but on open coasts and in the Bosphorus outflow area the levels were relatively low. The levels of oil and petroleum hydrocarbons in sediments were roughly comparable with those in the Mediterranean. The EROS[2] measurements of dissolved oil recorded relatively high levels of fresh oil, particularly near the discharge of the River Danube. Concentrations in the surface waters of the western Black Sea were one order of magnitude higher than in the western Mediterranean. Concentrations of polyaromatic hydrocarbons (PAH), a group of particularly toxic petroleum hydrocarbon compounds, were generally low. But measures are required to reduce the high concentrations of dissolved oil in the Black Sea.

Sewage

The BSEP pilot survey of microbial contamination of bathing waters was disappointing, largely due to the unwillingness of certain authorities to use standard methodologies and to exchange data. Even so, the data received showed a "fail rate" for samples of between 5 - 44 percent. In other words, between 5 and 44 percent of the samples taken did not meet the sanitary criteria established for the country in question. Of course, not all Black Sea bathing waters are below standard but there are no commonly agreed criteria for informing the public about the relative health risks. In the Black Sea coastal region, approximately 10,385,000 people discharge an estimated 571,175,000 mVyear of sewage into the Black Sea or into downstream stretches of rivers from where it flows into the sea.

The current pilot studies confirmed that there are regular beach closures in many of the Black Sea countries and that, although no cause-effect relationship has been clearly

[2] European River and Ocean Systems

established, there are increasingly frequent outbreaks of serious water borne diseases such as cholera and Hepatitis A. There is a manifest need for better sewage treatment and for greater transparency in the gathering and diffusion of information on the subject.

Pesticides and PCBs

In most cases, concentrations of pesticides and polychlorinated biphenyls (PCBs) were relatively low. Some higher concentrations of lindane were found near the Danube discharge, but most samples were comparable with the Mediterranean. In order to double-check, a " Mussel-Watch" (a survey of the concentrations of chlorinated pesticides and PCBs using mussels as sentinel organisms) was conducted in autumn 1996. But these compounds are certainly not a major concern in the open Black Sea.

Heavy Metals

A large amount of reliable data has been gathered on the concentration of heavy metals in the Black Sea. This data has been analysed in such a manner as to distinguish between metals from natural and anthropogenic sources. It is clear that the Black Sea is generally not polluted by heavy metals. But there are some areas where elevated concentrations occur (near "industrial hot spots") and a more detailed survey of coastal sites needs to be completed. The fact remains, however, that heavy metal concentrations in the Black Sea are virtually indistinguishable from natural levels.

Radionuclides

There is obvious concern regarding the level of radionuclides in the Black Sea and, thanks to the sponsorship and guidance of the International Atomic Energy Agency, a major effort is underway in this area. Certainly, concentrations of some radionuclides are one order of magnitude higher in the Black Sea than in the adjacent Mediterranean. Nevertheless, studies on the radiological consequences of radionuclides in the world ocean and the Mediterranean indicate that radiation doses to humans from anthropogenic radionuclides in the Black Sea are low. Work will continue on this subject under the auspices of the IAEA.

Litter

There is little quantitative information on the garbage problem in the Black Sea. Some municipalities in the south and south-east of the sea are known to be discharging municipal garbage to beaches, to the sea or to river banks discharging into the sea. As a consequence, beaches are highly littered. The situation below the waterline is unknown.

The 1996 BSEPinventory should only be regarded as a first step. Except for the actual measurements provided by the Russian Federation, the estimates used in the current work were derived from typical discharge values given in the WHO methodology and data gathered on individual sources by national focal points. The accuracy of the results is only as good as these literature values and the responses of those answering the questionnaires. The present phase of the study needs following up with site surveys, which should include measurements of the loads based on sampling and analysis. These analyses must be backed by successful intercalibration and intercomparison exercises in order to ensure comparable results in all the participant laboratories. The new data may eventually lead to adjustments in the Strategic Action Plan.

Basin-wide action is needed if eutrophication is to be reduced.. This should include the control of all land-based sources with priority given to the identified major sources (hot spots). Furthermore, in the case of oil, special attention will be need to be paid to sea-based sources (pollution from ships and offshore platforms).

III. Introduced Species

The involuntary (accidental) and intentional introduction of exotic species of plants and animals are among the most important anthropogenic influences on the Black Sea in terms of the consequences both for the ecosystem and its biota.

Accidental Introduction of Exotic Species

Because of its unpredictability, the accidental introduction of species is the most dangerous of anthropogenic influences. It can have considerable biological, ecological, economic and social repercussions.

The Black Sea has become home for a large number of alien plants and animals. There is no doubt that the Black Sea's wide diversity of habitats, both in the sea itself and in the coastal limans, lagoons, estuaries and deltas, and, maybe even the large number of feeding possibilities, has made the Black Sea very susceptible to invader species. Dozens of the thousands, perhaps even tens of thousands, of species that have been accidentally introduced by Man during the 20th century have been able to adapt to Black Sea conditions (Fig. 8.).

The most common way in which new species are introduced is via ocean-going ships. Marine organisms usually travel either as part of the fouling, attached to the hull of ships, or in tanks of ballast water.

Dozens of algal and animal species, both macroorganisms and smaller organisms, are known to travel attached to the hulls of ships. Most of them are attached to the living substrate (algae, clams, barnacles), but active, non-sessile forms can also be found, such as Amphipoda, shrimps, crabs and fish. 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 is pumped into special containers or tanks to stabilise a ship when it is not carrying any cargo. Ships usually fill their ballast tanks in ports or near the coast, and suspended matter and various planktonic organisms also pumped into the tanks with the water. Many organisms survive the trip in the ballast water or in the sediment, sometimes as spore and eggs. Upon arrival at the ship's destination, ballast water is discharged into the sea (if there is no special control inspection) and the organisms find themselves in a new environment. If the conditions are favourable to their particular needs, the organisms may survive and even become naturalised. The huge number of ocean-going ships means that today there are hundreds of examples of exotic species which have survived their introduction into new environments in ballast water.

The Black Sea has a long history of involuntary anthropogenic introduction of hydrobionts. The sea barnacles *Balanus improvisus* and *B. eburneus,* which were introduced into the Black Sea in the 19th century from the coastal waters of North America (Marinov, 1990), are generally considered to be the most ancient settlers. However, this assumption has not been verified by scientific data. During the 20th century the exact dates of the first discoveries of Black Sea exotic species were recorded and it became possible to determine, with a fair degree of accuracy, their origin.

In 1925 the hydromedusa *Blackfordia virginica* (Valkanov, 1936) was recorded near the Bulgarian Black Sea coast. Previously *Blackfordia* had only been found on the Atlantic seaboard of North America. But it has now become abundant in the low-salinity waters of the Black Sea and Azov Sea. Polyp colonies of *Blackfordia* live on water plants at shallow depths while the jellyfish that detach themselves from polyps are found in the surface plankton near the shore. There are no indications that Blackfordia has had any detrimental impact on the local flora and fauna.

The Black Sea has a long history of involuntary anthropogenic introduction of hydrobionts. The sea barnacles *Balanus improvisus* and *B. eburneus,* which were introduced into the Black Sea in the 19th century from the coastal waters of North America (Marinov, 1990), are generally considered to be the most ancient settlers.

However, this assumption has not been verified by scientific data. During the 20th century the exact dates of the first discoveries of Black Sea exotic species were recorded and it became possible to determine, with a fair degree of accuracy, their origin.

In 1925 the hydromedusa *Blackfordia virginica* (Valkanov, 1936) was recorded near the Bulgarian Black Sea coast. Previously *Blackfordia* had only been found on the Atlantic seaboard of North America. But it has now become abundant in the low-salinity waters of the Black Sea and Azov Sea. Polyp colonies of *Blackfordia* live on water plants at shallow depths while the jellyfish that detach themselves from polyps are found in the surface plankton near the shore. There are no indications that Blackfordia has had any detrimental impact on the local flora and fauna.

In 1929 the polychaete *Mercierella enigmática* (Anenkova, after Marinov, 1977) was found in the brackish Lake Paleostomi near Poti in the Caucasus and later in Gelendzhik Bay near Novorossisk. It is believed that *Mercierella* originates in the brackish coastal lakes of India. In 1923 it had been recorded in the Seine estuary in France. It was later carried by ships to the Black Sea, where it colonised low-salinity waters, before penetrating the Caspian Sea. The calcareous tubes of this polychaete are up to 15-20 mm long, and it uses them not only to attach itself to stones, but also to various hydrotechnical structures and the hulls of ships.

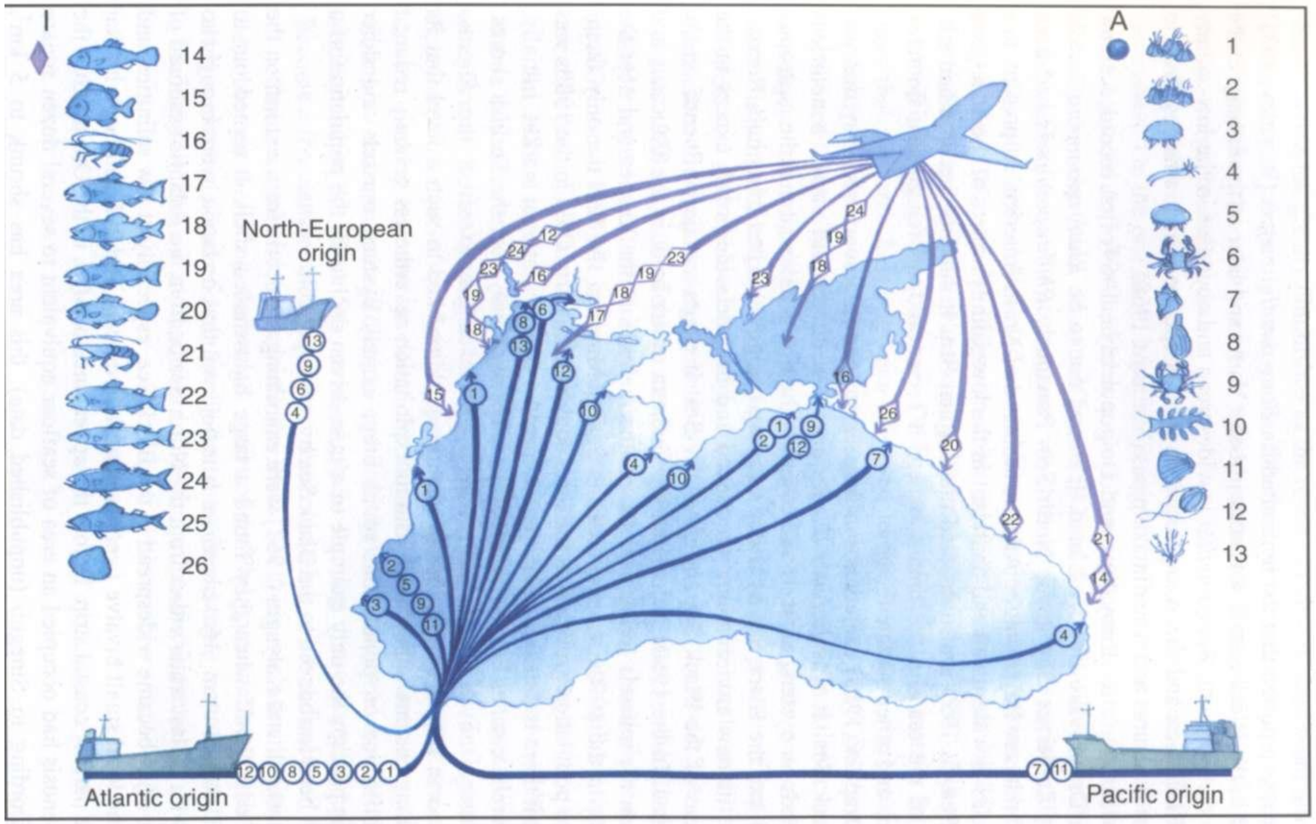


Fig 8. Introduction of exotic species into the Black Sea

Accidental Introduction: 1. Balanus improvisus, 2. Balanus eburneus, 3. Blackfordia virginica, 4. Mercierella enigmatica, 5. Bourgainvillia megas (1933), 6. Rhithropanopeus harrisi tridentata (19837), 7. Rapana thomasiana, 8. Mya arenaria, 9. Callinectes sapidus, 10. Doridella obscura, 11. Cunearca cornea, 12. Mnemiopsis leidyi, 13. Desmarestia viridis.

Intentional Introduction: 14. Gambusia affinis (1925), 15. Lepomis gibbosum (1930), 16. Pandallus kessleri (1959), 17. Plecoglossus altivellis (1963), 18. Roccus saxatilis (1965), 19. Salmo gairdneri (1965), 20. Oryzias latipes (1970s), 21. Penaeus japonicus (1970s), 22. Oncorhynchus keta (1972), 23. Mugil soiuy (1972), 24. Dicentrarchus labrax (1977), 25. Lateolabrax japonicus (1978), 26. Crassostrea gigas (1980).

Mercierella is generally considered a harmful organism and has become widespread in seas throughout the world.

In 1933 it was reported that the hydromedusa *Bougainvillia megas* (Paspalev, 1933) had been found in the Black Sea. It was seen in Lake Varna and later in the estuary of the Ropotamo River. At present, *Bougainvillia* is widespread and abundant in the low-salinity waters of the Black Sea and the Azov Sea. It is a mass species which attaches itself to ships' hulls, port structures and water intake pipes (Naumov, 1968).

In 1937 Makarov (after Kobyakova and Dolgopolskaya, 1969) first recorded a new crab species in Dneprovsko-Bugsky Liman. It turned out to be *Rhithropanopeus harrisi tridentata* from Zuiderzee Bay in the North Sea. Previously *Rhithropanopeus* had been introduced to Zuiderzee Bay from the Atlantic seaboard of North America. At present, this euryhaline species is widespread and abundant in the low-salinity waters of the Black Sea and the Azov Sea. In 1957 it also invaded the Caspian Sea. It inhabits the sand and silt-sand shallows of the sea and the limans, where it serves as food for gobies, flounder, turbot, sturgeons and other benthic feeders.

In 1946 Drapkin (1953) came across a large gastropod in Novorossisk Bay that was new to the Black Sea. It was *Rapana thomasiana* from the Sea of Japan, a notorious predator that feeds on oysters, mussels and other bivalves. It is believed that the gastropod was introduced into the Black Sea by a ship carrying its eggs attached to its hull. *Rapana* adapted well to its new environment, reproduced and became widespread, except in the low salinity areas of the Black Sea and the Azov Sea. It exerts a major influence on the local malacofauna. In the 1950s it depleted the Gudauta oyster bank in the Caucasus and began to feed on the mussels living near the southern shores of the Crimea and near the Bulgarian coast. In the 1970s it penetrated the Sea of Marmara. At first the only factor limiting *Rapana* population growth was the local souvenir industry. Only in the 1980s was it discovered that there is a demand for *Rapana* meat on the international market. Initially, massive commercial catches of the *Rapana* were undertaken only near the Turkish shores. Later, the industry moved to the Bulgarian coast and began to affect the *Rapana* population. In some places the number of gastropods diminished to such a level that its commercial fishing became unprofitable. But its exploitation nevertheless severely reduced the *Rapana's* influence on populations of its prey, namely oysters, mussels and other bivalves. This is perhaps the only example of a man-driven decline in the population of a species that had been introduced to the Black Sea by anthropogenic means.

In 1966 Beshevli and Kalyagin (1967) were examining the debris from astorm on the beach in the Odessa Gulf when they found a large light-shaded shell. It turned out to belong to a soft-shelled clam, *Mya arenaria.* It is believed that its larvae were brought to the Black Sea with ballast water either from the North Sea or from the Atlantic seaboard of North America. *Mya* became widespread in the Black Sea, especially at low salinities, and out-competed the local small bivalve *Lentidium mediterraneum.* Today *Lentidium's* habitat is restricted to a narrow coastal strip. Before the appearance of *Mya,* in the Odessa Gulf the *Lentidium* biocenosis had occupied an area of seafloor equivalent to several dozen square kilometres. According to Sinegub (unpublished data), this area has shrunk to 5 km^2, whereas the *Mya arenaria* biocenosis has captured an area of over 25 km^2.

During the initial stages of its invasion, *Mya* had a biomass of 16-17 kg/m^2. Later its biomass became greatly diminished as the result of hypoxia. However, at a depth of 5-7 m, where there is practically no hypoxia, the clam remains one of the major components of the zoobenthos. Its young serve as a food source for bottom-living fish, gobies, flounder, turbot, sturgeons and others.

Thus, there are two sides to the impact *Mya arenaria* has had on the Black Sea ecosystem. On the one hand, it has had a negative effect factor since it forced out the local bivalve *Lentidium,* which had been an important food source for the fry of many species of fish. On the other hand, *Mya* itself became a food source for fish. Moreover, it became an additional biofilter in the coastal zone, which is quite important ecologically.

The blue crab *Callinectes sapidus* is another Black Sea settler. It was discovered by Bulgurkov (1968) on the Bulgarian coast in 1967. Later, in the 1970s, it was found in Kerch Strait and in 1984 near the Bulgarian coast (Marinov, 1990). But in each case only isolated individuals were observed. Dr. B. OztUrk of Istanbul University (unpublished data) says that this crab has long been observed in the Bosphorus region of the Black Sea. Evidently it is now going through a period of adaptation to Black Sea living conditions. It is believed that the blue crab originates on the North American Atlantic seaboard, where it is subject to commercial fishing; in some places blue crabs are even cultured. The naturalisation of this species to the Black Sea would have a positive effect on both the local environment and the local economy. This process could be accelerated if active measures were taken to introduce large quantities of the blue crab to the Black Sea.

In 1980 a nudibranchiate was found in the north-west of the Black Sea. Later, in 1986, it appeared off the Crimean coast. It was classified as *Doridella obscura* (Roginskaja and Grintsov, 1990). It is a rare mollusc and at this stage it is still too early to make any accurate predictions about its possible role in the Black Sea ecosystem.

In 1982 a research mission undertaken under the supervision of Marinov (1990) in Varna Bay discovered a new and quite numerous bivalve which was initially classified as *Anadara sp.* Several years later the Romanian hydrobiologist M.-T. Gomoiu classified it as *Scapharca inaequivalvis.* Another year later Starobogatov gave it the name *Cunearca cornea,* making it a new species in the fauna of the USSR. Research carried out by V.N. Zolotarev and associates (Zolotarev and Zolotarev 1987) showed that the bivalve was quite widespread in the Black Sea, in some places forming dense populations, and that it had become a frequent component of the macrozoobenthos of silt sediments.

Cunearca was introduced into the Black Sea from the Adriatic Sea, having initially been brought there from the coastal waters of the Philippines in the Pacific Ocean. Its thick shell means that *Cunearca* can hardly become a food source for fish, but its ability to act as a biofilter may make it an important component of benthic biocenoses. ^

The rainbow jelly or Leidy's comb jelly *Mnemiopsis leidyi* is an exotic species accidentally introduced to the Black Sea in the early 1980s. Today it is a mass planktonic species with a total Black Sea biomass of about 1,000,000,000 tons. It feeds on zooplankton, eggs and fish larvae. It grows to a size of up to 10-15 cm.

In 1982 a large (up to 10-11 cm long) ctenophore was recorded off the southern coast of the Crimea, and later in the north-west of the Black Sea. At first it was classified as *Bolinopsis infundibulum* (Zaitsev *et al.,* 1988; Pereladov, 1988), later as *Leucotea multicornis* (Konsoulov, 1990), and still later as *Mnemiopsis leidyi* (Seravin, 1994) or *Mnemiopsis Mccradyi* (Bogdanova and Konsoulov 1993). In the present context the exact classification of this species is not as important (we shall call it *Mnemiopsis leidyi,* like most publications) as its influence on the Black Sea ecosystem. *Mnemiopsis* is believed to have been introduced by ships from the Atlantic coast of North America. It began to reproduce very quickly. By the end of the 1980s its total biomass in the basin was estimated at 1,000,000,000 tons (Vinogradov *et al.,* 1989). It is known that the ctenophore is an active predator, feeding on zooplankton and crustaceans in particular, and also on pelagic eggs and fish larvae (Fig. 9.).

The late 1980s were marked by a sharp decline in the catch of the main commercial fish, the anchovy. Coupled with other evidence, this led many scientists to conclude that *Mnemiopsis* was to blame. After depleting the zooplankton, the main food source for fish, *Mnemiopsis* then turned to anchovy eggs and larvae, decimating stocks(Vinogradov *et al.,* 1989; Mee, 1992; Volovik *et al.,* 1993; Zaitsev, 1993). This interpretation is supported by the clear decline in zooplanktonic populations during the 1980s and a sharp reduction in the number of fish eggs and larvae in the plankton. Towards the end of the 1980s, anchovy catches in the Black Sea and the Azov Sea collapsed. A special working party of GESAMP experts discussed the problem of *Mnemiopsis* in the Black Sea in Geneva in March 1995. The party formulated proposals to fight the ctenophore by increasing the influence of predators which fed on it, including both local species, like the mackerel or the Black Sea scad, which are able to consume jelly-like organisms, and exotic fish and invertebrates.

The experts proposed the following measures:

- the monitoring of opportunistic settlers in the Black Sea ecosystem;
- in situ/ex situ investigations of potential opportunistic settlers predators;
- the development of the effective control of ships' ballast waters and fouling organisms.

A discussion of ways of controlling the ctenophore population lies outside the scope of the present study. Suffice to say that *Mnemiopsis* is undoubtedly the most urgent and most prominent example of the possible impact of exotic settlers on the Black Sea environment.

It may be that *Mnemiopsis* was not the major reason for the decline of the existing Black Sea fisheries. But the example of *Mnemiopsis* and other exotics proves beyond a shadow of a doubt that biological diversity is very fragile. The arbitrary disruption of the ecological balance achieved by plants and animals over the course of a long process of evolution, by, for example, ships taking on and discharging ballast water without any control, can have devastating consequences.

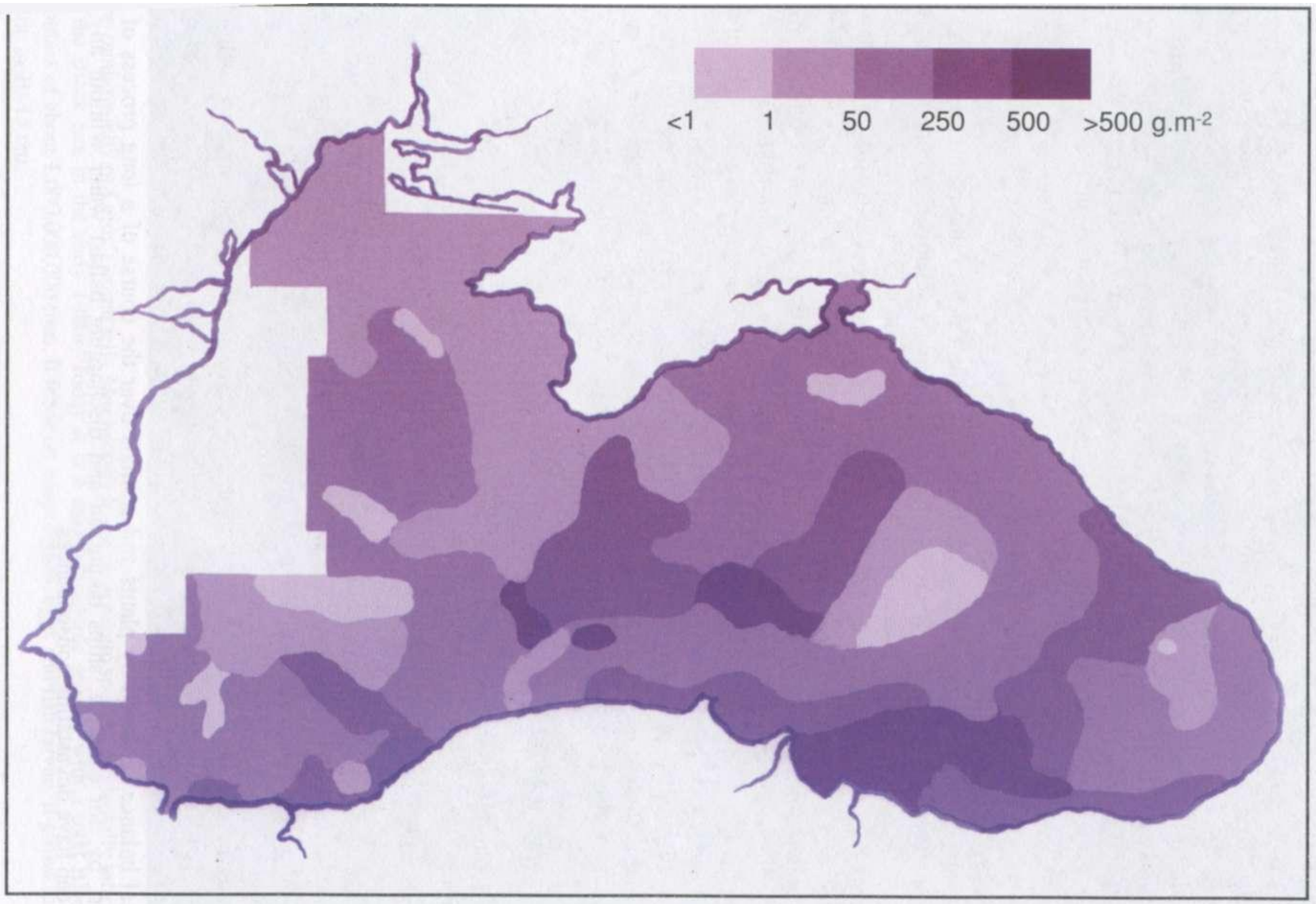


Fig 9. Average biomass of the exotic ctenophore *Mnemiopsis leidyi* (g.m^{-2}) in the Black Sea in summer 1991-1993 (from Mutlu *et al.*, 1994, with additions)

The International Marine Organisation (IMO) has proposed that ballast water should be taken on in centrally located areas of a sea or an ocean where there is far less plankton and no larvae of bottom-living organisms. Such practices require additional effort and expense, but these are insignificant compared with the damage resulting from the introduction of a ctenophore, a toxic phytoplankton or a vibrio comma.

The most recently discovered exotic is the brown alga *Desmarestia viridis,* which was found in the Odessa Gulf in 1990 (Minicheva and Yeryomenko, 1993). In the winter of 1994-1995 it became abundant in the coastal zone. The alga was brought from one of the seas of northern Europe. Its role in the ecosystem has yet to be determined, but it should be emphasised that so far *Desmarestia* is the only known introduction of an exotic macrophyte into the Black Sea. There are far more examples of this sort in the English Channel and the North Sea. Only the future will show whether the reason for this is the nature of the ecological environment or poor algological monitoring practices in the Black Sea.

Intentional Introduction of Exotic Species

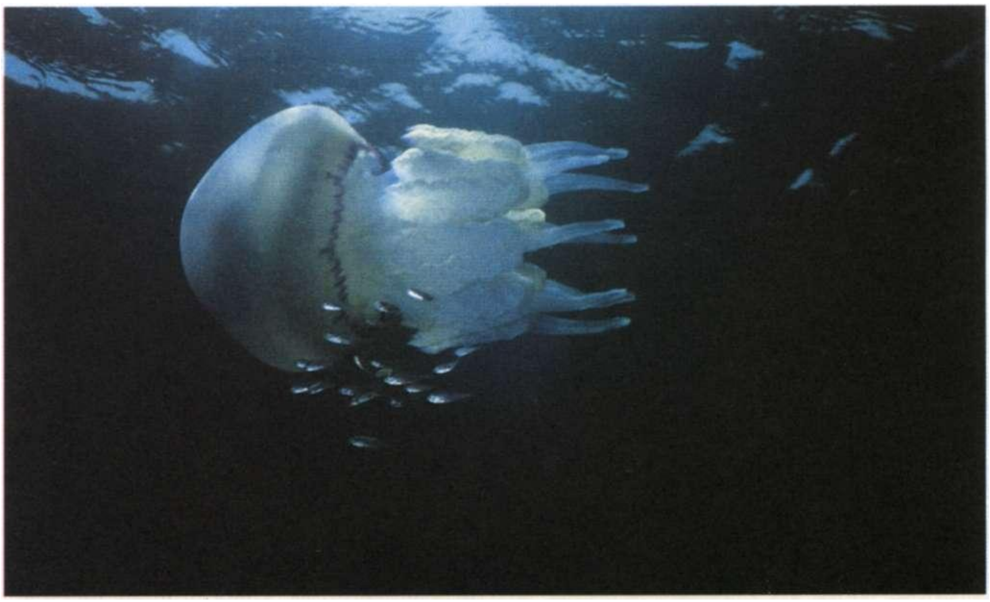
In addition to the involuntary introduction of exotic species to the Black Sea, scientists have been making targeted and experimentally-based attempts to introduce various organisms which are considered necessary for practical purposes. Some of these attempts have been successful and added new species to Brack Sea biota.

In 1925 the small fish *Gambusia affinis* was brought from Italy and introduced to the Kolkhida Lowland to combat the malaria mosquito. *Gambusia* is well known for its ability to feed on neuston larvae and mosquito eggs, including those of species, which transmit malaria.

It adapted, reproduced and, in combination with other biological methods (e.g. the massive planting of eucalyptus trees), led to the elimination of malaria in the region. *Gambusia* turned out to be an euryhaline species, living at salinities of up to 15-17 %o, and it was soon recorded in the Black Sea near river estuaries, which is why it listed among the Black Sea ichthyofauna (Svetovidov, 1964).

At present *Gambusia* is widespread in the Black Sea basin. It is known that, on being introduced to freshwater ponds, *Gambusia* begins to compete for food with the small fry of the carps. An accurate assessment of the role Gambusia plays in the Black Sea environment has yet to made, but, given that it only inhabits estuaries, its significance can hardly be substantial.

In the 1920s aquarists brought a brightly coloured freshwater sunfish *Lepomis gibbosus* from North America to Europe. It soon began to appear in natural conditions. By the 1930s it had already reached the Danube delta, where it became an abundant predator, feeding on the eggs of local fish species, especially carp. As a euryhaline species, the sunfish can also be found in Black Sea areas with low salinities. In 1953 a 12 cm individual was caught in the Odessa Gulf.



The scyphozoan jellyfish *Rhizostoma plumo* and symbiotic organisms, the small fry of the horse mackerel *Trachurus mediterraneus ponticus.*

One of the authors of this book (Yu.P. Zaitsev) put it into a sea water aquarium where it lived together with marine invertebrates and fish for seven months. *Lepomis* is also included in the list of Black Sea ichthyofauna (Svetovidov, 1964), but it is included in the category of rare and accidental species.

In 1959-1964, in an attempt to increase the number of commercial crustaceans, scientists tried to introduce the Far Eastern shrimp *Pandalus kessleri* to the Black Sea (Salsky, 1964). Containers with 500-1,000 shrimps were flown in from Peter the Great Bay in the Sea of Japan, and the shrimps were released in locations such as Khadzhibeisky Liman near Odessa and the Kiziltashsky Limans on the Tamansky Peninsula. The experiment did not succeed.

In the period 1965-72 several thousand fry, 5-6 cm long and weighing 20-30 g, of the striped bass *Roccus saxatilis* were released near the mouth of Dnestrovsky Liman and in Dneprovsko-Bugsky Liman near the Caucasian coast. The fry were bred from fish eggs delivered from the USA. Ichthyologists were interested in *Roccus* because it is tolerant of low salinity water, feeds on small fish, reaches a weight of 30 kg and has a high rate of reproduction.

In the early 1970s anglers caught striped bass individuals each 45 cm long and weighing up to 2 kg, in the north-western Black Sea and along the southern coast of the Crimea (Zaitsev, 1978). But there were no subsequent reports of any *Roccus* individuals being caught. Evidently, the number of individuals was insufficient to reach a critical level for acclimatisation, and the experiment failed.

In 1963 there were attempts to acclimatise the salmonid fish *Plecoglossus altivellis,* which originates in the Sea of Japan. But this attempt also failed. Also unsuccessful was the attempt to introduce the steelhead trout *Salmo gaidneri* from the Atlantic coast of north America.

Since the 1970s there have been recordings of a small aquarium fish, the Japanese medaka *Oryzias latipes,* which is a relative of *Gambusia,* in low salinity waters of the Black Sea and the Azov Sea. Evidently, it was also brought to the region by aquarists..

The Japanese shrimp *Panaeus japonicus* is kept in sea aquaria in the Russian Federation, Ukraine and Romania. The first attempts to acclimatise it to the Black Sea began in the 1970s. Similar experiments have been conducted in France and other European countries. To date there have been no positive results.

Attempts in the 1970s to acclimatise the Far Eastern keta *Oncorhynchus keta* from the Amur River liman also failed. In 1978 there was an abortive attempt to acclimatise the Japanese sea perch *Lateolabrax japonicus* and in 1977-1979 the *Dicentrarches labrax* from the Mediterranean. The giant oyster *Crassostrea gigas* from the Sea of Japan has been bred in aquariums since 1980. There are reports of separate individuals being found near the coast of the Caucasus.

The only successful acclimatisation of an exotic commercial fish species in the Black Sea concerns the haarder *Mugil soiuy.* After prolonged laboratory tests, experimental introductions of haarder fry and small fish caught in the Sukhodol estuary (Primorsky Krai, Russian Federation) were conducted in the Black Sea (1972-1980) and the Azov Sea (1978-1984). Over the course of nine years, 14 containers were flown from the far-east to the Black Sea containing a total of 46,100 individuals, including fry 3-8 cm long and small fish 7-23 cm long. They were released in the Dnestrovsky, Shabolatsky and Tiligulsky limans, and also directly into the north-western Black Sea. A similar attempt was conducted in the Azov Sea, where most of the small fish were released in Molochny Liman. The first reports of haarder spawning in the Black Sea were received in 1982, followed in 1984 by reports of them spawning in the Azov Sea. In the late 1980s and the 1990s haarder became a widespread commercial fish that was caught in Ukraine and the Russian Federation. In winter it is caught near the coast of Turkey and in other locations (Zaitsev and Starushenko, 1996).

According to available data, haarder feeds on small bottom-living organisms, particularly from the meiobenthos and thus does not compete with the local grey mullets.. The grey mullet's small population means that it does not use the full food resources of the shallows of the Black Sea, the Azov Sea or the limans.

The successful acclimatisation of the haarder confirms that the introduction of other species of fish into the Black Sea and the Azov Sea is possible, provided that the ecological and ethological features of the species concerned corresponds to the conditions prevailing in the bodies of water into which it has been introduced. The case of the haarder also demonstrates that, if it is backed by sound scientific research, it is possible to introduce new species into an ecosystem and increase its biodiversity.

The snail *Rapana thomasiana thomasiana* (syn. *R. bezoar, R. venosa)* is originally from the Sea of Japan. It attaches its eggs, enclosed in special chitinous capsules, to rocks and other underwater substrata including ship's hulls and was introduced into the Black Sea by ships in the 1940s. In the Black Sea it grows to 16 cm in size. As a mass bottom-living carnivore, *Rapana* preys on oysters, mussels and other bivalves and has produced a sharp decline in their Black Sea populations. In recent years, fishermen have begun catching *Rapana* for its meat.

IV. Coastline Changes

Coastal erosion is a very serious problem in the Black Sea. A major part of the Black Sea coastline is under-going severe erosion. This is due to the destructive effects of the sea, as well as to man made activity. The building of port structures, concreting of coastal slopes, regulation of river run-off, removal of beach and channel sediment, and many other factors disturb the equilibrium and change the living conditions of marine organisms in the zone, which has ecotone features.

As a biotope, the upper margin of the shore is determined by the limit waves reach during surges; the lower margin by the shoreline during offshore surges. In the Black Sea these borders are respectively located 2-4 m above average sea level on the shore and in the vicinity of the 1.5 m isobath in the sea.

The Black Sea coastal zone can be divided into three main morphodynamic categories (Panin and Kosiyan, 1996).

Low Accumulative Coasts

This type of littoral zone is usually associated with the mouths of big rivers and consists of complex sandy barrier beaches with strong longshore sediment drift systems. These coasts are most strongly influenced by global changes, specifically by sea level fluctuations and changes in the river sediment inputs due to anthropogenic activities. A decrease in sediment supply into the coastal zone and a rise in the sea level could, under certain conditions, result in an active and almost continuous retreat of the beach line (up to 20-30 m/y in some sections of the Danube delta). Examples of this type of coastline include the Danube delta, the coastline between Dniepr liman and Karkinitski Bay, the Tendra spit - Dzharylgatch island section in Ukraine, the Taman-Anapa section in the Russian Federation, the Rioni depression in Georgia and the Kizilirmak, Yesilirmak, and Sakariya deltas in Turkey. In Bulgaria, sandy accumulative beaches are mainly associated with the rivers Dravolska, Kamchiya, Provadyiska and Batova.

Erosive Coasts Within Low-standing Plateaux and Plains, With Active Cliffs

This category may also be affected by erosion processes but the rates of coastline retreat are smaller (only 1-2 m/y). Examples of this type of coast include: the north-western Ukrainian coastal zone between the Danube delta and the city of Ochakov; and the whole of the western Black Sea coastline from Cape Midya in Romania to Cape Kaliakra in Bulgaria.

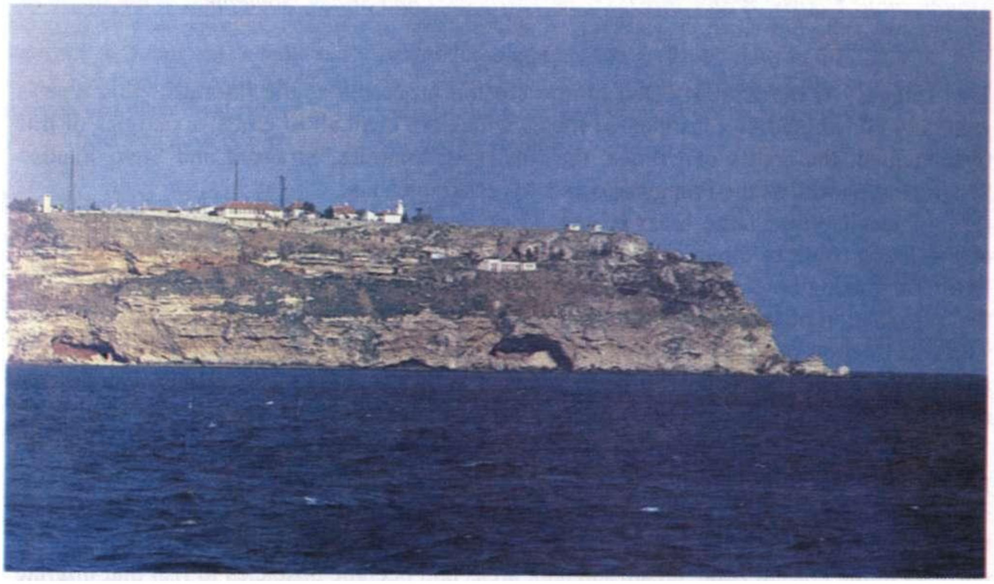
Mountainous Coasts, With Cliffs, Marine Terraces, Land Slides, Sometimes With Sandy or Gravely Beaches

This category is the least affected by the erosion processes as the littoral of this type is generally constituted of consolidated rocks, which are difficult to erode. Examples of this type include: the coasts of Crimea, the Caucasus, Pontides, Strandza and Staro Planina Mountains, as well as the Frangensko and Avrensko plateaux.

In recent years large areas of the Black Sea coastline have undergone significant changes as a result of direct or indirect human influence. The uncontrolled felling of trees, livestock grazing on pastures and ploughing on slopes have led to higher land erosion and the introduction of large quantities of soil particles into rivers and eventually into the sea. The construction of dikes, dams and other hydrotechnical facilities to regulate water flow and create water reservoirs results in reduced solid discharges and means that the sea receives smaller quantities of alluvial materials.

Different coastline protection structures (spur dikes, breakwaters, etc.) are built to protect the coast from landslides, erosion and abrasion caused by waves, currents, adverse ice conditions, as well as from groundwaters issuing from slopes and from surface waters that flow directly from the shore. But such structures may change the existing system of currents in the coastal zone, create stagnant areas and become obstacles to fish that migrate along the shoreline.

Cape Kaliakra, Bulgaria (photo: Yu. Zaitsev)



Cape Tarkhankut, Ukraine (photo: V. Suetin)

Differences in the size of sand particles in artificially created or modified beaches radically change the living conditions of the interstitial fauna. The use of hydraulic dredges in ports and approach channels, and the transportation of soil to dumping locations, produce other ecological and biological problems in the sea.

The coastal zone is very sensitive to anthropogenic changes. It has been suggested that, as a narrow peripheral strip whose area represents only a small fraction of the total surface of the Black Sea, the coastal zone may be ignored when considering measures to protect the sea's biological resources. But such a view is mistaken for two fundamental reasons. Firstly, from the biological point of view the narrow coastal zone is not peripheral, but a focal point containing the highest densities, and the greatest variety of organisms and is home to biological processes of critical importance to life in the sea. Secondly, the coastal zone (e.g. the beaches and shallow-water areas) is the part of the marine environment where people come into direct contact with the sea and where the health of people is directly dependent on the health of the sea.

During the last 20-30 years the Black Sea coastal zone has been affected by a number of direct and indirect anthropogenic influences which have produced a number of biological and ecological responses from the ecosystem.

Large-scale anti-landslide and coast protection works have been undertaken in the vicinity of Odessa. Coastal inclines were made less steep, spur dikes, traverse and breakwaters built, and sand (extracted at a distance from the shore) deposited between them. As a result, destructive landslides have been halted, the beach area increased eight to ten fold, and a recreational infrastructure created.

But these measures created stagnant zones in the sea between the traverse and the breakwaters where the sand became silted and the bottom biocenosis changed. The natural rocks (shell limestone) on the bottom became covered with a layer of sand and the newly built concrete structures became new substrates for attached organisms. In each case the changes in the biota were far from positive.

The sand brought to the beaches proved to be of a different composition (more fine-grained) than the original, which produced a significant deterioration in the living conditions of interstitial fauna. Some previously abundant organisms disappeared from the overwash zone.

The captured underground waters that are discharged into the sea in the beach area have become an additional source of eutrophication of the coastal zone. In a number of cases it became necessary to reconstruct the breakwaters and adopt a new design of biologically-positive hydrotechnical structures for all future construction.

The construction of dams for hydropower stations on several rivers of the Caucasus has led to a sharp reduction in solid discharges. The beaches stopped receiving annual quantities of gravel and became more vulnerable to storm erosion. In areas such as Cape Pitsunda increased erosion has resulted in the destruction of coastal facilities. Even the famous grove of relict pine-trees in Pitsunda is now threatened.

Various projects to change the shoreline are being implemented in the coastal regions of the Black Sea. Among the most dramatic examples is the coastal road from Sarp to Trabzon in Turkey built on the beach for hundreds of kilometers.

One of the most important tasks is to evaluate their ecological impact and introduce corresponding changes into the technology of hydroconstruction. The latter is in the interests not only of the sea and its inhabitants, but also of Man, who has a considerable stake in a healthy marine environment.

Laspi Bay, Crimea, Ukraine (photo: A. Birkun Jr.)
This is how the southern coast of Crimea used to look: bays, steep cliffs, rocks, shinge beaches, slopes covered with juniper and pine woods, pistachio-trees and strawberry groves. Once the woods ran down close to the sea all along the coast. Now, they have receded into the mountains, surviving on the coast in only a few sheltered areas.

Present State of Black Sea Biodiversity

The Black Sea's geographical position and morphometric features make it a classic example of an "ecological target" which has been influenced by human activities. The result has been a transformation of some habitats and significant changes in the biota in terms of population, species, biocenoses and ecosystems.

The first indication of the radical changes taking place in the Black Sea ecosystem was the transformation in the species composition of commercial fish. Mackerel was first to disappear, followed by bonito and bluefish. Yet catches of anchovies and sprats rose. It was only when catches of anchovy, the main commercial fish plummeted and it became apparent that the fisheries had collapsed, there was any consensus that the state of the Black Sea ecosystem had become critical.

But, although they are eye-catching, the changes in the composition and stocks of commercial fish represents only a small part of the radical transformation of the biological diversity of the Black Sea ecosystem, which has much greater ecological, economic and social consequences. However, it is much more difficult to measure and evaluate changes in biodiversity than to record the decline in fish catches, as the former requires special studies throughout the entire sea not only in isolated sections of it.

The establishment of the BSEP in 1993 laid the ground for such integrated studies. The BSEP promoted evaluation studies of different aspects of the Black Sea ecosystem, including its biological diversity. As a result, in 1995, for the first time in almost two centuries of scientific research on the flora and fauna of the Black Sea, the littoral states each prepared National Reports showing the current situation within their borders. These reports formed the basis for the compilation of a regional report on the biological diversity of the Black Sea ecosystem.

Studies have shown that since 1950-1960, which is generally accepted as being the ecological norm, there have been significant changes in Black Sea population, species, biocenosis and the ecosystem as a whole. These changes put an end to centuries of relatively stable ecological balances and marked the beginning of a new era in Black Sea biodiversity, affecting plants, animals, pelagic and benthic inhabitants, mass and rare species and commercially exploited organisms.

The different taxa in the Black Sea have not been studied to the same extent in each of the littoral states. However, the reliable data that does exist is already sufficient for scientists to draw conclusions about the present state of the Black Sea biota, including the main reasons for the changes that have occurred, the regions of the sea that have been subject to varying degrees of anthropogenic transformation, endangered species, populations and communities, major gaps in our knowledge of biological diversity, and possible short- and long-term courses of action to improve the situation.

The confines of space prevent a full description of all the known changes that have taken place over the last three decades in terms of population changes and species diversity. We have decided to concentrate on the biological fate of major life forms and their main representatives in the water column, in the surface microlayer and on the seafloor.

I. Main Changes in the Pelagic Zone

Bacteria

The bacteria inhabiting the pelagic zone constitute the most numerous component in terms of species richness, and the most dynamic component in terms of the physiological activity of the marine biota. At the same time methodological difficulties mean that it is the least studied group of organisms in terms of systematics. As a result, it is impossible to evaluate their species diversity, as has been done with the plankton, the benthos and the fish. Microbiologists usually refer to genera, morphological and physiological groups of bacteria, and only occasionally specify species, whose identification is usually quite difficult. It is not an accident that only two of the National Reports on Black Sea Biodiversity devote much space to bacteria: the Ukrainian Report contains a small chapter on bacteria; while a brief section on bacteria is included in the Georgian Report.

Yet the changes that have occurred in the microbiological component of the Black Sea have attracted as much public attention as, for example, the changes in the composition and stocks of commercial ichthyofauna.

Scientists have shown that as Black Sea eutrophication intensified, the number of saprophytic bacterioplankton sharply increased, particularly the cocci and bacilli (Ukrainian National Report, 1995). This is a result of the higher volume of dissolved and suspended organic matter, which is a source of nutrition for saprophytic microorganisms.

A spawning aggregation of the grey mullet *Liza saliens.* A female (large fish in the centre) is surrounded by nine males. This is a preliminary activity which occurs prior offshore migration. Spawning occurs 10-30 miles offshore.

The grey mullet (Haarder) *Mugil soiuy* originated from the Sea of Japan and become acclimatised to Black Sea conditions. It is an important commercial fish and grows to a length of one metre.

The phenomenon is most pronounced in the coastal zone in the vicinity of large population centres, where the levels of organic pollution are highest (Schultz, 1981) and where an alarming increase in the number of pathogenic microorganisms has been recorded in sea water, bottom sediments and many marine organisms. The main source is the poorly treated sewage water discharged into the sea by the cities. *Escherichia coli. Staphylococcus, Salmonella* and others are now the most widespread pathogenic microorganisms.

The following figures may serve to illustrate this process. Careful sampling was carried out by Khait and Shpilberg (1950) in the shoreline zone of Odessa beaches in the summer months of 1946-1947. They found 10-200 cells of *Escherichia coli* per litre of water. In the 1960s, this figure, known as the coli index, had increased to an maximum of 90,000 cells per litre (Babov *et al.,* 1970). According to Nizhegorodova (unpublished data), in the 1990s the coli index averaged 100,000 cells per litre, and in some cases even 1,000,000 cells per litre.

But *Escherichia* is not the only pathogenic micro-organism in sea water and it has combined with other bacteria to create the conditions for a potential epidemic. Cases of cholera were recorded in Odessa and several other cities on the coast of the Black Sea and the Azov Sea in 1970. The most serious situation arose in the city of Nikolayev in the summer of 1995. As a result, most of Odessa's beaches were closed to the public during the tourist season. The levels of pathogens in sea water only fell to permissible levels days when coastal winds induced offshore surface waters.

The Odessa Gulf is not the only body of water affected by microbiological pollution. The same problems were reported near other large population centres and recreational zones. In the 1980s, for example, a sharp increase in the number of pathogenic microorganisms of the following species and serological types was recorded on the coast of Adzharia, and particularly near Batumi, there was a sharp increase in the numbers of pathogenic micro-organism of the following species and serological types: *Escherichia* - 026, 0111, 0119, 0126, 0127, *Proteus vulgaris, P. mirabilis, Staphylococcus aureus, S. albus, Salmonella typhi murium, Pseudomonas aeruginosa, Klebsiella, Enterobacter, Citrobacter, Edvardsiella* (Georgian National Report, 1995). The number of saprophytic bacteria of different morphological groups has also increased to include: *Bacterium, Chromobacterium, Pseudomonas, Micrococcus* and *Bacillus.*

Bacteria populations, particularly pathogenic organisms, have reacted to changing marine conditions, particularly the rise in the amount of organic matter in the water and bottom sediments, with a sharp increase in numbers and species diversity. Pathogenic organisms are not characteristic of a marine ecosystem in a normal ecological state. But it is worth remembering that the division of the environment into "normal" and "abnormal" or "pathological" reflects an anthropocentric approach to the ecosystem; i.e. whether the situation is, or is not, favourable to Man. The organisms themselves, sea inhabitants in this case, may have quite a different view of the situation. It is probably correct to assume that some of them (e.g. bacteria, Dinoflagellates, *Noctiluca,* jellyfish and others) would claim that the current state of the Black Sea ecosystem is quite favourable.

Naturally, this in no way alleviates the grave ecological problems in the Black Sea. The goal of science is to find a way in which Man can coexist with the diversity of living creatures that have appeared on this planet long before him and which directly or indirectly support his presence in the biosphere.

Phytoplankton

There is no serious divergence of opinion about the causes of the significant qualitative and quantitative changes that have taken place in the Black Sea phytoplankton. It is generally agreed that the primary reason has been the anthropogenic eutrophication of the sea, which intensified sharply in the late 1960s and early 1970s. This rapid increase in eutrophication triggered an acceleration in the primary production of marine plants; and phytoplankton immediately reacted to this impulse. The result was a period of a practically continuous water blooms, interrupted only by the winter months. Blooms had previously been so rare as to merit special academic papers dedicated to such phenomena. For example, there was "A Special Case of Water Blooms in the Black Sea" (Bodeanu and Chirila, 1960) and "An Interesting Case of Surface Water Colouration in the Black Sea" (Skolka and Petranu, 1960). In 1951-1956 water blooms in the north-western part of the Black Sea were registered only near the mouths of deltas of the Danube, the Dniester and the Dnieper, and in water plume areas (Ivanov, 1959). But in August 1974 Nesterova (1979) registered a maximum population figure of 139 10^{6} cells per litre for *Exuviaella cordata* and described the phenomenon as a "red tide". In later years such water blooms became characteristic of the north-western part of the Black Sea, and the area covered by the blooms increased 10- to 30-fold in comparison with the 1950-1960 period.

It is safe to assume that, along with nutrients such as compounds of nitrogen and phosphorus, there were other chemical substances that caused outbursts of phytoplanktonic productivity. It is possible that external metabolites of some representatives of the phytoplankton, which supported the growth of certain species and inhibited that of others, played their role in the "chain reaction" taking place in different species of phytoplankton. Such cases have been recorded in biochemical ecology (Telitchenko and Ostroumov, 1990). However, the issue of chemical interaction in populations and communities of marine organisms, including phytoplankton, has yet to be extensively studied.

At the moment, there is no dispute that all the recent changes in the Black Sea phytoplankton were originally caused by anthropogenic eutrophication and this premise was accepted as a working hypothesis for future discussion. The main manifestations of these changes in the phytoplankton include: an increase in total biomass; more extensive and more regular water blooms; an increase in the number of mass species; a decline in populations of previously abundant species; a growth in the number of species of brackish water and freshwater origin; and changes in the correlation between different taxa of algae (Bodeanu, 1984).

Table 4.1. Systematic groups of phytoplankton in the Romanian Black Sea sector during the period 1960-1980 (Bodeanu, 1984).

Systematic groups	1960-1970		1971-1980	
	Number of species	%	Number of species	%
Bacillariophyta	209	66.6	145	45.6
Pyrrophyta	60	19.1	80	25.2
Chlorohyta	15	4,8	43	13.5
Cyanophyta	11	3.5	27	8.5
Chrysophyta	14	4.7	17	5.3
Euglenophyta	2	0.6	4	1.3
Xanthophyta	j	0.7	2	0.6
Total:	314	100.0	318	100.0

Increase in the Total Phytoplankton Biomass

The increase in the total biomass of phytoplankton has been adequately studied by researchers from Ukraine and Romania, who have taken the north-western Black Sea as an example. They have found that the average biomass of phytoplankton in the Romanian sector of the Black Sea rose from 495 mg m^{-3} in 1959-1963 (Skolka, 1967) to 740 mg m^{-3} in the early 1970s, 2,244 mg m^{-3} in the late 1970s, and 8,770 mg m^{-3} in 1981 (Bodeanu, 1984, 1987-1988).

This increase in absolute values, which is compiled from readings taken at ten day intervals, manifests itself even more clearly north of a line connecting Cape Tarkhankut and Zmeiny Island, where there is a eutrophicating influence, not only from the Danube run-off, but also from the Dniester, the Dnieper and the Southern Bug the 1950s biomass was measured at 670 mg m^{-3} (Ivanov, 1967). By the 1960s it had risen to 1,030 mg m^{-3} (Mashtakova, 1971), by the 1970s 18,690 mg m^{-3} and by the 1980s, 30,000 mg m^{-3} (Nesterova, 1987). The figures for other regions of the Black Sea (such as in the vicinity of the Kerch Strait, in the south-east and the south-west of the sea) may be somewhat different, but the general tendency for an explosive increase in the phytoplankton biomass remains.

Varna Bay borders on the north-western part of the sea and comes under the influence of the Danube and local waste waters. In the summers of 1972-80 a sharp increase was recorded in the number of *Exuviaella cordata* in the region. After 1974 *Exuviaella* and other dinoflagellates underwent regular population explosions. Numbers peaked on 9-10

November 1984 (Petrova-Karadzhova, 1985) when the population of *Prorocentrum micans* and *E. cordata* reached 94.6 million cells per litre with a biomass of 600 mg per litre (wet weight). A strong north-westerly wind that began to blow on 11-12 November 1984 swept the surface waters into the open sea and the bloom patch broke up.

Increase in the Extent and Regularity of Blooms

It has already been noted that phytoplankton blooms changed from being isolated incidents to become annual or interannual events; the only exception was during the winter months.

Seasonal blooms off the Romanian coast have extensively studied by Bodeanu. The diatom *Skeletonema costatum* undergoes a population explosion in the spring, when the number of cells may reach 100 10^6 cells per litre, whereas in the 1960s the maximum did not exceed 18 10^6 cells per litre (Bodeanu, 1969). In comparison, we note that the corresponding figure for the more northern Ukrainian sector was 32 10^6 cells per litre (Ivanov, 1967). The dinoflagellate *Goniaulax polygramma* also developed regular blooms after 1977, reaching a population of 97 10^6 cells per litre (Bodeanu, 1984).

The mass reproduction of the dinoflagellate *Exuviaella cordata* (syn. *Prorocentrum cordata)* takes place in summer. In the 1980s it reached a density of 463 10^6 cells per litre off the coast of Romania, compared with a maximum of only 50 10^6 cells per litre in the 1960s (Skolka and Cautis, 1971). There have even been reports of it reaching densities of 800 10^6 cells per litre (Sukhanova *et al.*, 1986).»In autumn the diatom *Cerataulina bergonii* can produce blooms with a density of 14 10^6 cells per litre, as happened in September of 1980. In the 1960s the highest recorded *Cerataulina* density was only 922,000 cells per litre.

Initially, some authors believed that these phytoplankton and water blooms were positive phenomena, because they produced an increase in biological productivity not only at the phytoplankton level, but amongst zooplankton and plankton-feeding fish as well. As a result, catches of anchovy and sprat rose (Gomoiu, 1982). But there were other factors which may have been equally responsible for the increase in anchovy and sprat catches, namely: the disappearance by that time of large pelagic predators (e.g. mackerel, bonito and bluefish); or the intensification of commercial fishing because of the greater number of fishing vessels and the use of trawls. It is likely that all of the above factors contributed to the temporary increase in the catches of small plankton-feeding fish.

Increases in the Number of Mass Species Within the Plankton

With the arrival of anthropogenic eutrophication, nutrient substances ceased to be a factor limiting the growth of different species. As a result, populations of many representatives of the phytoplankton reached sizes of 100,000 individuals per litre, which is conventionally considered to be the minimum quantitative limit for a mass species.

A **School of sand lance** *Gymnammodytes cicerelus,* **the only representative of the Ammodytidae in the Black Sea.**

A school of silversides *Atherina mochon pontica* **in coastal waters. Aggregations of up to 5,000 individuals per m**^{3} **can be observed in the August-September. They attract such predatory fish as garfish, bluefish and Black Sea salmon to littoral areas.**

During the period 1960-1970, there were 38 such species in the Romanian sector of the Black Sea (Bodeanu, 1978). In 1971-1982 the number rose to 61 (Bodeanu, 1984). The number of species whose abundance was measured in millions of cells per litre increased from nine in 1960-1970 to 24 in the period 1971-1982. At the same time there were reports of a sharp drop in the populations of a number of species that had previously been classified as mass species, including the diatoms: *Rhizosolenia calcar-avis, Leptocylindrus danicus, L. minimus, Detonulla confervacea, Chaetoceros lorenzianus* and *Nitzschia delicatissima* (Bodeanu, 1984).

The fact that these phenomena occurred in the presence of excessive nutrients supports the assumption that anthropogenic eutrophication is the main, but not the only, • reason for the changes that have affected, and are continuing to affect, the Black Sea phytoplankton.

Increase in the Number of Freshwater Species

The rapid rise in anthropogenic eutrophication was followed by an increase in the number of freshwater species. Populations of species such as *Skeletonema subsalsum, Microcystis pulverea* and *Gloeocapsa crepidinium* reached millions of cells per litre (Bodeanu, 1984). It should be emphasised that these species were found dozens of kilometres away from the Danube estuary at salinities higher than 12-T4 %o. The freshwater blue-green algae *Ankistrodesmus* may even be found alive 80-90 kilometres from the Danube estuary at salinities of 17 %o (Zaitsev *et ai,* 1989). Such examples clearly prove that *Ankistrodesmus* can survive and thrive in brackish waters? But they also demonstrate the ability of eutrophicated sea water to provide nutrients for a growing number of pelagic unicellular algae and even other organisms.

Changing Relations Between Taxonomic Groups in the Phytoplankton

We have already drawn attention to the fact that the process of eutrophication is accompanied by a shift in the existing qualitative relations between major taxa. In more general terms, this signifies a relative decrease in the number of diatoms and a relative increase in dinoflagellates, green and blue-green algae. A large number of these are mixotrophic, i.e. capable of using not only mineral substances but also organic matter as nutrients. The relative numbers of different phytoplankton taxa may fluctuate slightly between different Black Sea regions, but a general trend can still be seen. For example, to the north of a line connecting Cape Tarkhankut - Zmeiny Island dinoflagellates accounted for 18.8 percent of the total phytoplankton biomass in the 1950s and 1960s (Ivanov, 1967) but 55 percent in the 1980s (Nesterova, 1987).

Another general change that has affected the phytoplankton since the onset of eutrophication has been the growth in small species. Species with small-sized cells, such as *Exuviaella cordata* and *Prorocentrum micans,* have now become the largest mass species; while populations of large species such as *Rhizosolenia calcar-avis* and *Leptocylindrus* and others have fallen compared with the period before eutrophication. A similar trend has also been observed with species of macroalgae (Minicheva, 1990) and zooplankton (Zaitsev, 1979, 1992b), which appears to demonstrate both a common biological tendency and the importance of biological surface (the body surface of individuals and their populations) in ecological processes.

There have been no incidences of the mass development of toxic species of phytoplankton in the Black Sea, but some cases have been recorded in inland bodies of water. For example, in the summer of 1959, in the brackish Varna Lake, which is connected to the Black Sea by Varna Bay, populations of one species of toxic microalgae, *Prymnesium parvum,* exploded, reaching a density of 150 10^6 cells per litre (Marinov *et al.,* 1984). Simultaneously, all the fish and most of the invertebrates of the benthos died. It appears that *Prymnesium parvum* toxins were responsible, but it is also possible that bottom hypoxia was at least a contributory factor. In the spring of 1964 a large proportion of the fish in Burgas Bay died in similar circumstances (Marinov *et al.,* 1984). A special study of the toxicity of Black Sea phytoplankton found that only one species, *Prymnesium parvum,* is capable of producing toxins. *E. cordata* does not have this ability. (Moncheva, 1991).

Zooplankton

There are parallels between some of the changes that have occurred under cultural eutrophication in the phytoplankton and those that have taken place in the zooplankton. Both include examples of increases and decreases in the number of individuals and their biomass, the expansion of zones of mass development of individual species and changes in the relative numbers of taxa. Naturally these changes have their own algological or zoological uniqueness, but it is evident that the underlying processes remain the same.

A large phytoplankton biomass provides an ample supply of food for the plant-feeding species of zooplankton and for those that feed on algal residues (plant detritus). In recent years there has been a sharp increase in the abundance of *Noctiluca miliaris* (syn. *N. scintillans),* infusoria such as *Mesodinium rubrum,* scyphozoan jellyfish, the brackish water rotifer *Synchaeta baltica,* the cladoceran *Pleopis polyphemoides,* and copepods such as *Oithona minuta* and *Acartia clausi.*

As eutrophication has increased, so the biomass of *Noctiluca* and its share in the overall biomass of zooplankton has steadily risen. In 1951-1969 the average *Noctiluca* biomass in the north-western Black Sea was only 163 mg m^{-3} (Koval, 1984). In 1975-1980 it had increased to 2,356 mg m^{-3} and in 1981-1982 to 10,687 mg m^{-3} (Zaitsev *et al.,* 1988). It has already been mentioned that, under particular circumstances, the biomass of *Noctiluca* in the neuston zone (the surface layer of 0-5 cm) may exceed 100 kg m^{-3} (Zaitsev *et al.,* 1988). For example, on July 1986 a leak from an industrial plant located not far from the Danube delta resulted in a large amount of nitrates being discharged into the Black Sea. This discharge combined with the warm summer water temperatures to provide excellent conditions for a mass development of *Exuviael/a cordata, Noctiluca's* main food source. The result was an explosion in the *Noctiluca* population. A long spell of windless weather and a quiet sea allowed more than 90 percent of the entire *Noctiluca* population to congregate in the surface layer of 0-5 cm. Concentrations reached their peak in the current convergence zone, leading to an extremely high density in the neuston. It was estimated that *Noctiluca* accounted for up to 50 percent of the samples volume taken from the surface 0-5 cm. There were virtually no other representatives of the plankton. This *Noctiluca* bloom occupied an area over 3,500 km^2 and remained intact for several days, before the biomass dropped to 0.5-1 g m^{-3}.

In general, the mass development of so-called gelatinous plankton organisms, whose bodies consist of up to 98-99 percent water, is a characteristic feature of marine zooplankton in conditions of eutrophication (Fig. 10.).

A surprisingly high number of the large scyphozoan *Rhizostoma plumo* was observed in the coastal zone of the north-western Black Sea in the late 1960s and early 1970s. In some cases two to three large *Rhizostoma* (with a umbrella diameter of up to 40 cm) were found in each cubic metre of water. In those years storm surges, which are common in the Odessa Gulf in late summer and early autumn, washed ashore such large numbers of *Rhizostoma* that they formed a bank up to 1-1.5 m high. For some reason this phenomenon was not described in the specialised literature. A similar population outburst of another scyphozoan jellyfish, *Pelagia noctiluca,* was observed over a number of years in eutrophied regions of the Mediterranean Sea, where it was referred to as a "mass invasion" (Rampal, 1985). However, it was not a literal 'invasion', since *Pelagia* has always inhabited the Mediterranean. But under eutrophication, it quickly increased in abundance, as happened with *Rhizostoma* in the Black Sea.

The population of the Black Sea *Rhizostoma plumo* gradually dropped back to its levels in 1973-1974. But, almost immediately, there was an explosion in the population of another scyphozoan jellyfish, *Aurelia aurita,* which was rapidly noticed and appeared in literature. Indeed, this could hardly have been ignored since, unlike *Rhizostoma,* which is a coastal shallow water species, *Aurelia* is distributed throughout the sea and soon began clogging fishing fixed nets, trawls and even the plankton nets of hydrobiologists. The annual increase of *Aurelia* has been closely documented. In the period 1949-1962, 3,146 trawl catches were studied; of which 656 contained jellyfish (Mironov, 1971). The estimated total average biomass of *Aurelia* in the Black Sea during the period was 670,000 tons. In 1976-1981 it rose to an average of 222 million tons (Zaitsev and Polishchuk, 1984). In the late 1980s the total biomass reached 300-500 million tons (Vinogradov *et ai,* 1989). This huge increase in population meant that by the 1980s the mean statistical living space of an individual *Aurelia* had fallen 60-fold in comparison with the 1950s (Zaitsev and Polishchuk, 1984), with a commensurate increase in pressure on *Aurelia's* food source, the plankton. By the late 1980s *Aurelia* alone was devouring up to 62 percent of the annual production of the entire Black Sea zooplankton. The highest populations of *Aurelia* were in areas with the highest concentrations of plankton, such as the north-western Black Sea.

For the first time in the history of the Black Sea population of this cosmopolitan species, individuals were discovered with divergences from the normal tetramerous radial symmetry.

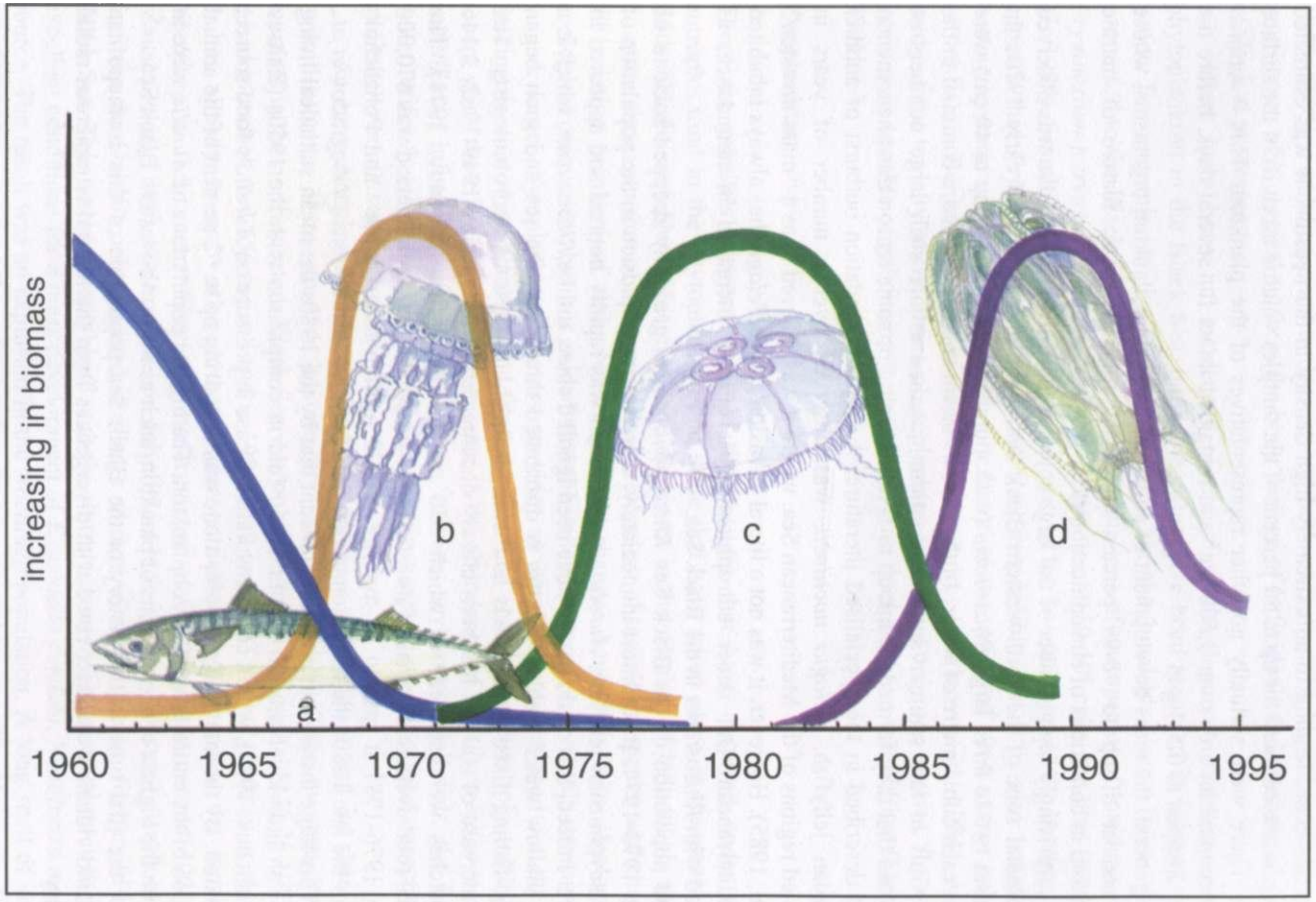


Fig 10. Successive blooms of gelatinous organisms into Black Sea in 1960-1995, after the sharp decline of the population of the jellyfish eating mackerel. a. *Scomber scombrus*, b. *Rhizostoma pulmo*, c. *Aurelia aurita*, d. *Mnemiopsis leidyi*.

These aberrants with 2-, 3-, 5-, **6-** and 7-radial symmetry constituted 2.75 percent of the entire population, but in some samples in the north-west Black Sea, they accounted for up to 25 percent (Zaitsev and Polishchuk, 1984). This phenomenon has yet to be explained.

It is difficult to say what the fate of *Aurelia* would have been, and how its relations with other species would have developed, had not another gelatinous species, the exotic ctenophore *Mnemiopsis,* unexpectedly appeared in the early 1980s. Individual specimens were first reported in 1982. By the late 1980s *Mnemiopsis* had reached a total biomass of close to one billion tons (Vinogradov *et al.,* 1989). The *Aurelia* population collapsed almost immediately, the biomasses of other zooplankton and ichthyoplankton dropped sharply, anchovy catches plummeted and commercial fishing for anchovy in the Azov Sea came to a complete halt (Russian National Report, 1995). The precise role that *Mnemiopsis* played in these events, and whether it was the only culprit, is still to be resolved; but it is usually held responsible for much of what happened.

As stated earlier, the Black Sea has become a favourable habitat for many accidental invaders. Some of these newcomers have become serious competitors for local species or even their enemies, i.e. predators. Presumably, the large volume of phytoplankton and some species of zooplankton that evolved as a result of cultural eutrophication has facilitated the acclimatisation of these exotics.

The central parts of the Black Sea, where river run-off does not directly influence eutrophication, did not undergo the same a hyperproduction of phytoplankton as the shelf zone; although there was an increase in the variety and population of the zooplankton.

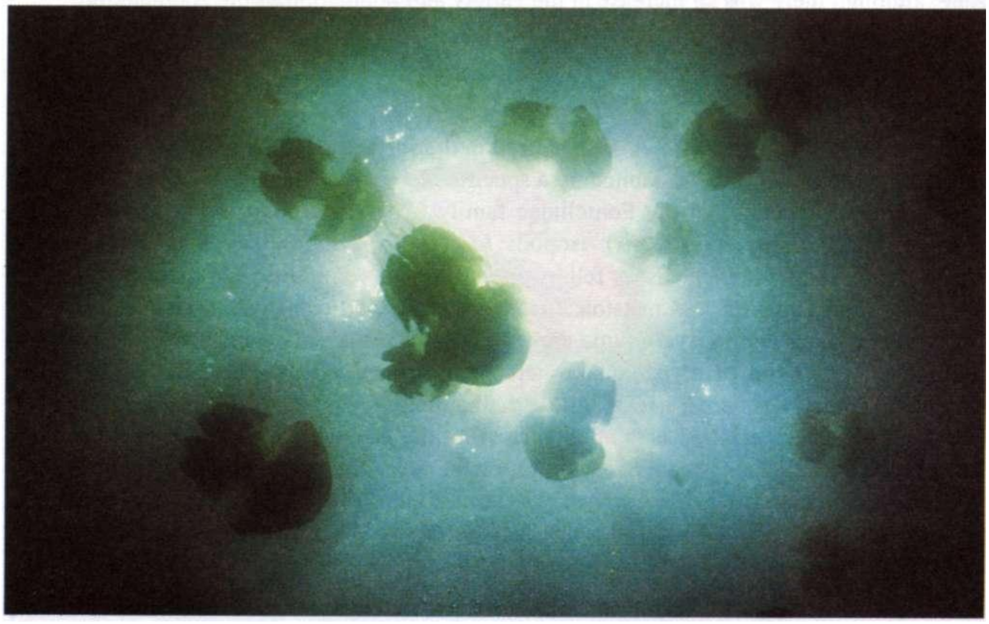
The Neuston

During the 1960s significant changes occurred in the surface layer of the Black Sea pelagic zone (the neustal), which is inhabited by a specific biocenosis, the neuston (Zaitsev, 1970). Populations of copepods of the Pontellidae family *(Pontella mediterránea, Anomalocera patersoni, Labidocera brunescens),* isopods *Idothea ostroumovi,* larvae of shrimps and crabs, grey mullets and other fishes fell by one, or even several, orders of magnitude.

The organisms of the neuston (neustonts) are particularly abundant in current convergence zones and in river«plume areas, where river and sea waters come into contact, forming a small band of transitional waters (hydrofront), which is usually 1-2 m thick, although it sometimes narrows to as little as half a metre.

On 11 September 1963 a sample taken from the Danube hydrofront, no more than 0.5 m wide and 2 m long, contained the following neustons: adult *Pontella mediterránea* (117,760 individuals); *Idothea ostroumovi* (36 individuals); larvae of shrimps and crabs (43 individuals); leaping grey mullet fry *Liza saliens* (61 individuals); striped mullet fry *Mugil cephalus* (2 individuals) (Zaitsev, 1970).

Bloom of the white sea jelly, or moon jelly, *Aurelia aurita*.



The *Rhizostoma pulmo* **bloom.**

The sampling was carried out using a neuston net with a mesh of 0.4 mm, which is why the small neustonts (e.g. nauplii and copepodid stages of copepods, larvae of barnacles, larvae of molluscs, rotifers, infusorians) were not recorded, even though their volume is always far greater than that of the large neustonts. But the 117,902 individuals with a body size not exceeding 1 mm that were caught in 0.05 m' of water (i.e. 50 **x** 200 **x** 5 cm = 50,000 cm^3 or 0.05 m') is evidence of a very high density of neustonts and demonstrates that, with their excellent feeding possibilities, hydrofronts are extremely attractive to neustonic organisms

Sampling with the use of neuston nets in the hydrofronts of other Black Sea rivers during the same period produced similar results. Indeed, under normal conditions hydrofronts are always attractive to hydrobionts, especially for those that live in the neuston. For example, there is a large volume of marine organisms in the hydrofront of the Mississippi River, and densities of copepod nauplii sometimes exceed 1,000 individuals per litre (Dagg and Whitlege, 1991). Large populations of the larvae of menhaden *Brevoortict patronus* can be found in the same hydrofront congregations and are fished. Their food consists primarily of the nauplii of copepods (Dagg *et al.,* 1987).

But over the next 20 years the situation in the Black Sea changed dramatically. By the early 1980s, samples from a similar two-metre bank in the same Danube hydrofront, which did not exhibit any visible signs of change, produced only 15 specimens of pontellids, one or two larvae of shrimps and crabs, not more than one grey mullet fry and not a single isopod. Future research will show whether the reason for this decline was the pollution of the surface microlayer by toxic elements, the poor quality of river water, changes in plankton composition or falling populations of adult individuals, whose larvae grow in the neuston zone.

The National Report of the Russian Federation provides an overview of the population dynamics of some representatives of the Black Sea zooplankton during the 1960-1990 period. The data refer to the north-eastern Black Sea, where the Azov Sea is the main source of eutrophication. Table 4.2 shows that populations of the first four species are increasing, while populations of the others are falling, particularly the neustonic *Centropages, Pontella, Labidocera* and *Gastropoda veliger* (Fig. 11.).

The number of *Pontella* in the north-eastern Black Sea did not grow significantly during 1992-1993. A similar phenomenon was observed during 1993-1995 in the north-western Black Sea. During 1993-1995 there was a modest rise in the number of *Idothea ostroumovi,* megalops of crabs and grey mullet fry in the Danube hydrofront, but the figures are several hundreds lower than those for the 1950-1960 period. It has been suggested that this may be the result of the decrease in industrial activity in the Black Sea catchment area and that this improvement may thus only be temporary.

Table 4.2. Average numbers of some **Zooplankton** species (individuals m~3) in the north-eastern Black Sea. (Russian National Report, 1995).

Species	1967-1975	1980-1985	1989-1991	1992-1993
Noctiluca scintillans	968	10,161	1,974	3,636
Pleopis polyphemoides	1,400	3,778	2,138	9,842
Polychaeta, larvae	204	682	768	4,132
Balanus, nauplii	1,614	5,140	1,776	3,364
Penilia avirostris	15,150	5,142	144	28
Oithona minuta	11,344	37,452	572	20
Paracalanus parvus	7,086	3,032	163	96
Centropages króyeri pontica	5,140	1,668	82	8
Pontella mediterránea	674	136	6	26
Labidocera brunescens	436	28	1	0
Gastropoda, veliger	2,044	10,546	254	202

II. Main Changes in the Benthic Zone

The consequences of cultural eutrophication are felt not only in the water column and on its surface, but also at the bottom, in the benthic zone, where, as in the pelagic zone, they affect the plant and animal world.

Phytobenthos (the algal macroflora)

One of the manifestations of the "eutrophication syndrome" (Gomoiu, 1992) is worsening transparency as the result of greater quantities of phytoplankton, *Noctiluca*, jellyfish, detritus and other organisms and particles suspended in the water of the pelagic zone. In the 1960s the Secchi disk (a white disk used to measure transparency, which is named after the Italian limnologist A. Secchi) was visible at depths of up to 15-18 m in the central north-western shelf. At a distance of one kilometre off shore, visibility had dropped to 6-7 m. By the 1980s transparency had fallen to 7-8 m and 2-2.5 m respectively; and during blooms it declined to less than one metre (Zaitsev, 1992).

The amount of sunlight reaching the bottom is directly dependent on the transparency of the water. In photobiology, the branch of biology investigating the influence of light on living organisms, the concept of compensation point or compensation depth is of fundamental importance.

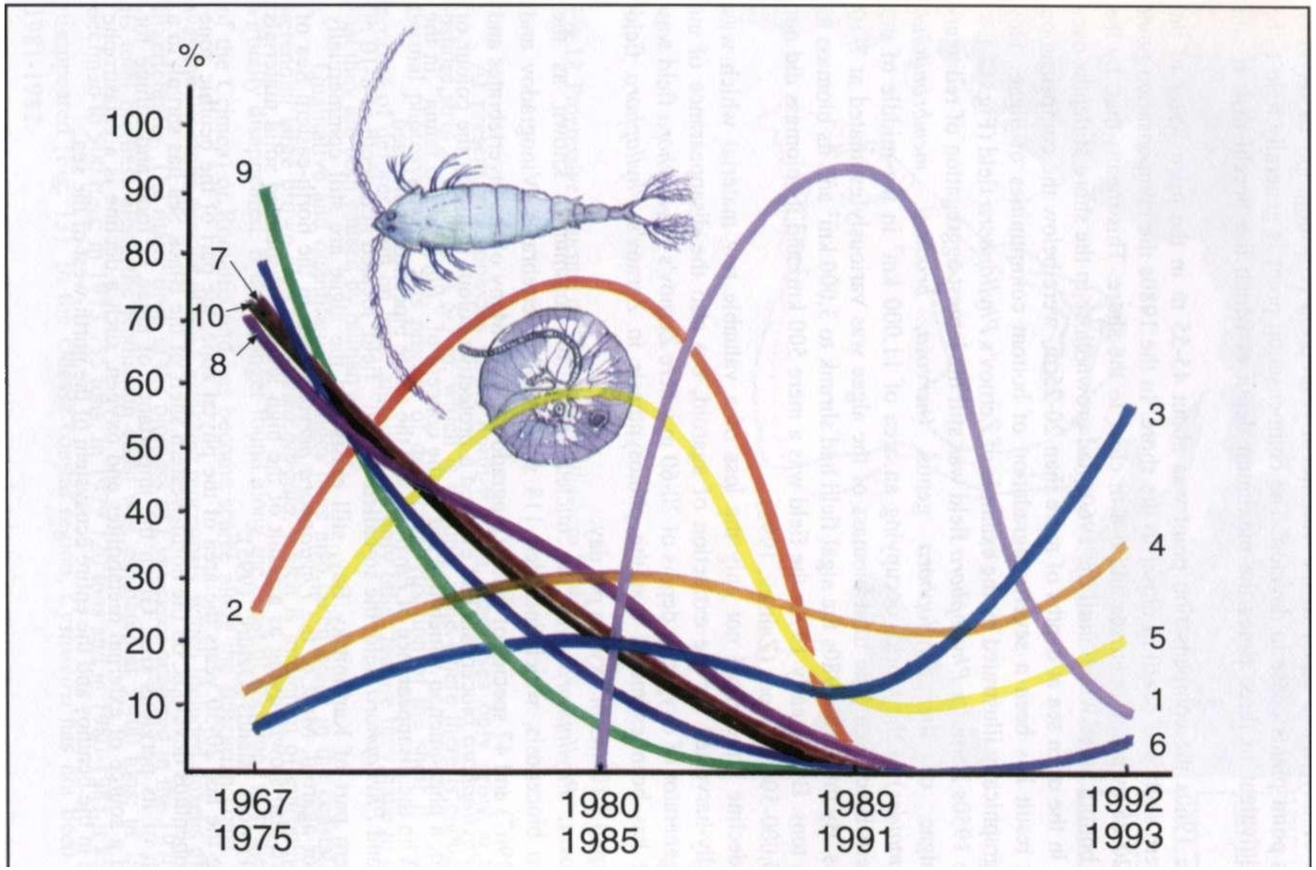


Fig 11. The explosion of *Mnemiopsis leidyi* and the relative abundance of the main Zooplankton species in the north-eastern Black Sea (Russian National Report, 1995). 1. *Mnemiopsis leidyi, 2. Oithona minuta,* 3. *Pleopis polyphemoides,* 4. *Acartia clausi,* 5. *Noctiluca scintillans,* 6. *Pontella mediterránea,* 7. *Penilia avirostris,* 8. *Paracalanus parvus,* 9. *Labidocera brunescens,* 10. *Centropages kroyeri pontica.*

It is the point or depth where the amount of photosynthesis of plants, measured by the production of oxygen, is equal to the volume of respiration (consumption of oxygen). Below this point plants cease to develop. The compensation point is generally held to be roughly equivalent to three times the maximum depth at which the Secchi disk is still visible.

In the 1960s the compensation point was about 45-55 m in the open water of the north-western shelf and 18-20 m closer to the shore. In the 1980s the compensation point shrank to 20-25 m in the open sea and 6-8 m close to the shore. This means that, by the 1980s, the bottom algae which until the 1960s had grown close to the shore at depths over 6-8 m and in the open sea at depths of more than 20-25 m, were below the compensation point. The result has been a severe degradation of bottom communities of algae. This process is graphically illustrated by the example of Zernov's *Phyllophora* field (Fig. 12.).

In the 1950s Zernov's *Phyllophora* field was still the largest aggregation of red agar-bearing algae of the *Phyllophora* genus *(nervosa, brodiaei, membranifolia, pseudoceranoides)* in the world, occupying an area of 11,000 km^2 in the middle of the north-western Black Sea. The total biomass of the algae was variously estimated at 7-10 million tons. By the early 1980s the algal field had shrunk to 3,000 km^2 and its biomass to 1.4 million tons. By the early 1990s the field was a mere 500 km^2 and its biomass did not exceed 300,000-500,000 tons (Zaitsev, 1992).

This decline represented not only the loss of a valuable raw material which was commercially-harvested for the extraction of agaroid, but also the disappearance of an important generator of oxygen at depths of 20-60 m where Zernov's *Phyllophora* field was situated. It has been estimated that the photosynthesis in Zernov's *Phyllophora* field produced up to 2.10 m3 of oxygen per day.

Moreover, *Phyllophora* was the nucleus of a bio-community known as the *Phyllophora* biocenosis, which included 118 species of invertebrates (Vinogradov and Zakutsky, 1967) and 47 species of fish (Vinogradov, 1967). Many of the invertebrates and fish in the *Phyllophora* biocenosis had evolved a protective colour to match the colour of *Phyllophora,* a phenomenon which had led to the concept of "*Phyllophora* fauna" in the literature. With the disappearance of *Phyllophora)* the entire biocenosis collapsed.

A second *Phyllophora* field, the so-called "small" field, located at a depth of 8-10 m in the eastern part of Karkinitsky Bay, still exists and the algae are still commercially harvested for agaroid. Most of the *Phyllophora nervosa* beds in the north-eastern Sea of Marmara are also slowly dying as a result of the high level of suspended solid materials around the Princes' Islands (Oztiirk, 1995).

During the last 20-30 years the area of the phytal zone, the part of the benthic zone where phytobenthos develops, on the north-western shelf of the Black Sea has shrunk to a tiny fraction of its pervious size. Given the importance of algae as food and refuge for animals and a source of external metabolites and oxygen, such a decline is a catastrophe both for life in the benthos and the entire ecosystem of the north-west of the sea.

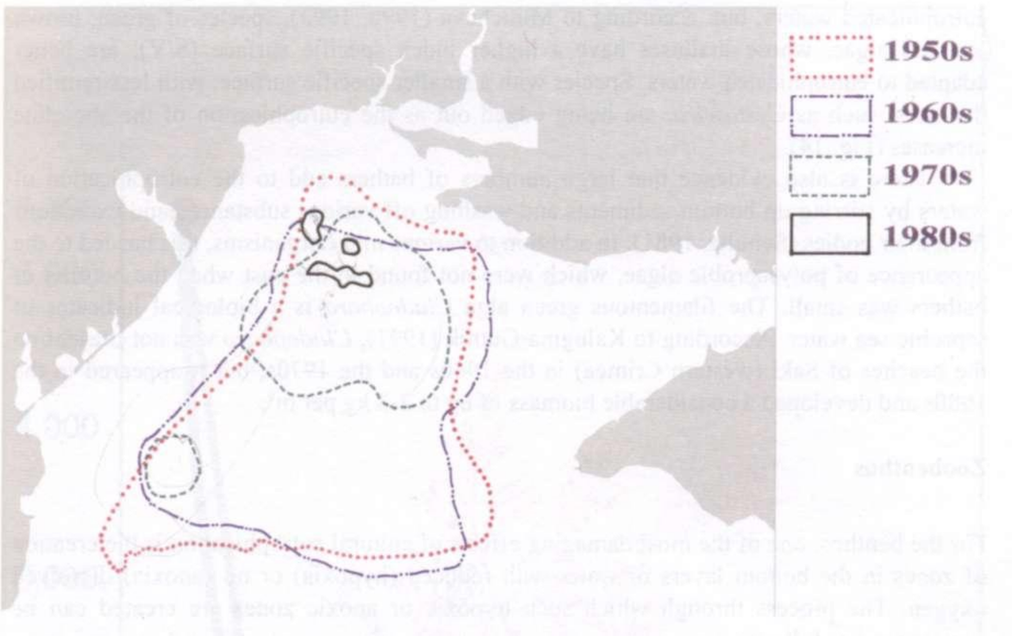


Fig 12. Progressive reduction of "Zernov's *Phyllophora* field."

At present, macrophytes in the north-western Black Sea only grow in the narrow inshore strip at a depth of 5-7 m, which is the only zone where there is enough light for normal photosynthesis, this process of demacrophytisation of the shelf is similar to the process of deforestation on land, although the only other feature they have in common is that they are both caused by human activity.

Qualitative and quantitative changes have also taken place in the coastal zone. The perennial large brown alga *Cystoseira barbata*, which is intolerant of eutrophication, has virtually disappeared. It is no longer found along the coast of Ukraine (with the exception of the Crimea) or Romania and has become scarce along the Bulgarian coast. *Cystoseira* was the keystone species of the *Cystoseira* biocenosis, which included dozens of species of invertebrates. The major drop in the biomass of *Cystoseira* occurred in the 1970s. In 1971 its total biomass along the Romanian coast was estimated at 5,400 tons; in 1972, it had declined to 900 tons; in 1973 755 tons; in 1979 120 tons and in 1980-1981 it had virtually disappeared (Fig. 13). In the Odessa coastal region, *Cystoseira* has not been seen since 1981-1982.

Other species of macroalgae continue to develop intensively along the borders of eutrophicated waters, but, according to Minicheva (1990, 1993), species of green, brown and red algae, whose thalluses have a higher index specific surface (S/V), are better adapted to eutrophicated waters. Species with a smaller specific surface, with less ramified thalluses, such as *Cystoseira,* are being edged out as the eutrophication of the shoreline increases (Fig. 14).

There is also evidence that large numbers of bathers add to the eutrophication of waters by stirring up bottom sediments and washing off various substances and excretions from their bodies (Schultz, 1981). In addition to various microorganisms, this has led to the appearance of polysaprobic algae, which were not found in the past when the number of bathers was small. The filamentous green alga *Cladophora* is a biological indicator of saprobic sea water. According to Kalugina-Gutnik (1991), *Cladophora* was not present on the beaches of Saki (western Crimea) in the 1960s and the 1970s, but it appeared in the 1980s and developed a considerable biomass of up to 2-3 kg per m^3.

Zoobenthos

For the benthos, one of the most damaging effects of cultural eutrophication is the creation of zones in the bottom layers of water with reduced (hypoxia) or no (anoxia) dissolved oxygen. The process through which such hypoxic or anoxic zones are created can be summarised as follows:

At the end of their lifetime, which usually lasts only a few days, phytoplankton cells fall as sediment to the bottom. The amount of phytoplankton sinking to the bottom was once relatively small, but from the 1970s onwards, particularly following the intensification of phytoplankton blooms, this "corpse fallout", as it is sometimes called, has increased several fold.

Algae decay on the seabed, consuming the oxygen dissolved in the water. If the sea surface is calm, as is usually the case in summer, and the column of water is stratified (i.e. divided into layers of different density, with the less salinated at the top), the process of vertical water mixing proceeds slowly. This prevents the exchange of water from the bottom layers with the oxygen-rich water near the surface of the pelagic zone. Under these circumstances the oxygen content of deep water may fall from the normal state (5-7 ml per litre) to 1-2 ml per litre or even zero.

Different species of bottom organisms react differently to low oxygen concentrations. For most of them, including shrimps, crabs and fishes, an oxygen concentration of 1.5-2 ml per litre is lethal, but polychaetes can survive concentrations as low as 0.5 ml per litre.

The bivalve *Cumarca cornea,* which closes its shells tightly and uses oxygen reserves retained in its tissues, can survive for as long as 5-7 days at 0.5 ml per litre of oxygen concentration. Other molluscs, such as mussels, *Mya,* and most other organisms of the benthic zone cannot survive such conditions. Species which are located on the margins of low oxygen zones, and are capable of movement, leave for the shoreline area, where there is always enough oxygen for normal life at a depth of 1-1.5 m.

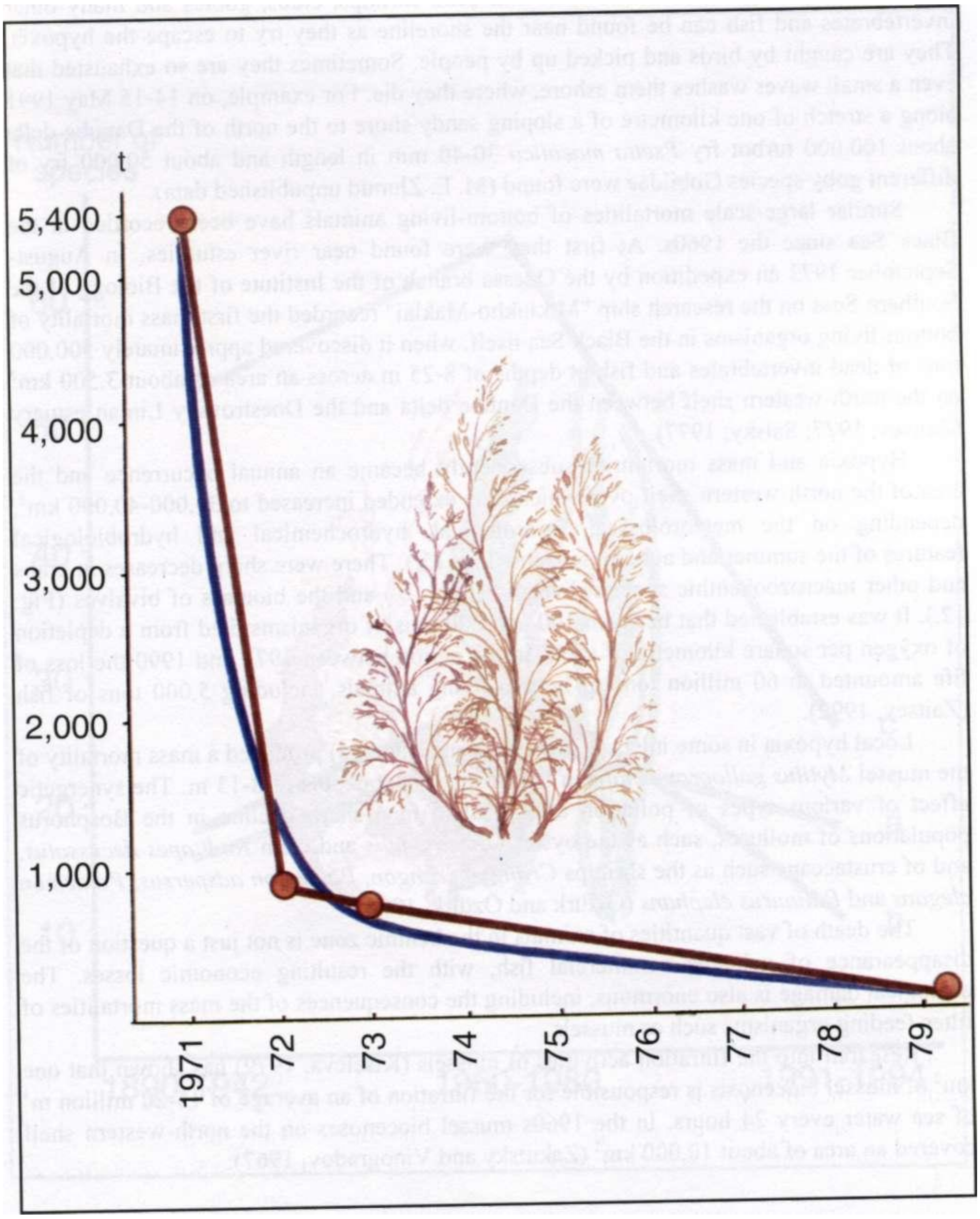


Fig 13. The decline of the brown alga *Cystoseira barbata* total biomass (tons) along coasts in 1971-1979 (from the Romanian National Report, 1995).

At such times, huge concentrations of half-dead shrimps, crabs, gobies and many other invertebrates and fish can be found near the shoreline as they try to escape the hypoxia. They are caught by birds and picked up by people. Sometimes they are so exhausted that even a small waves washes them ashore, where they die. For example, on 14-15 May 1991 along a stretch of one kilometre of a sloping sandy shore to the north of the Danube delta about 100,000 turbot fry *Psetta maeotica* 30-40 mm in length and about 50,000 fry of different goby species Gobiidae were found (M. E. Zhmud unpublished data).

Similar large-scale mortalities of bottom-living animals have been recorded in the Black Sea since the 1960s. At first they were found near river estuaries. In August-September 1973 an expedition by the Odessa branch of the Institute of the Biology of the Southern Seas on the research ship "Miklukho-Maklai" recorded the first mass mortality of bottom-living organisms in the Black Sea itself, when it discovered approximately 500,000 tons of dead invertebrates and fish at depths of 8-25 m across an area of about 3,500 knr on the north-western shelf between the Danube delta and the Dnestrovsky Liman estuary (Zaitsev, 1977; Salsky, 1977).

Hypoxia and mass mortalities subsequently became an annual occurrence and the area of the north-western shelf over which they extended increased to 30,000-40,000 km^2, depending on the meteorological, hydrological, hydrochemical and hydrobiological features of the summer and autumn seasons (Fig. 15.). There were sharp decreases in crabs and other macrozoobenthic species diversity (Fig. 16.) and the biomass of bivalves (Fig. 17.). It was established that between 100 and 200 tons of organisms died from a depletion of oxygen per square kilometre of shelf. In the period between 1973 and 1990 the loss of life amounted to 60 million tons of bottom-living animals, including 5,000 tons of fish (Zaitsev, 1992).

Local hypoxia in some inlets (e.g. Beykoz and Tarabya) produced a mass mortality of the mussel *Mytilus galloprovincialis* in the Bosphorus at depths of 8-13 m. The synergetic effect of various types of pollution also resulted in a sharp decline in the Bosphorus populations of molluscs, such as the oyster *Ostrea edulis* and clam *Ruditapes decussatus,* and of crustaceans such as the shrimps *Crangon crangon, Palaemon adspersus, Palaemon elegans* and *Palinurus elephans* (Oztiirk and Oztiirk, 1996).

The death of vast quantities of animals in the benthic zone is not just a question of the disappearance of valuable commercial fish, with the resulting economic losses. The ecological damage is also enormous, including the consequences of the mass mortalities of filter-feeding organisms such as mussels.

Research into the filtration activities of mussels (Kiseleva, 1979) has shown that one km^2 of mussel biocenosis is responsible for the filtration of an average of 15-20 million m' of sea water every 24 hours. In the 1960s mussel biocenoses on the north-western shelf covered an area of about 10,000 km^2 (Zakutsky and Vinogradov, 1967).

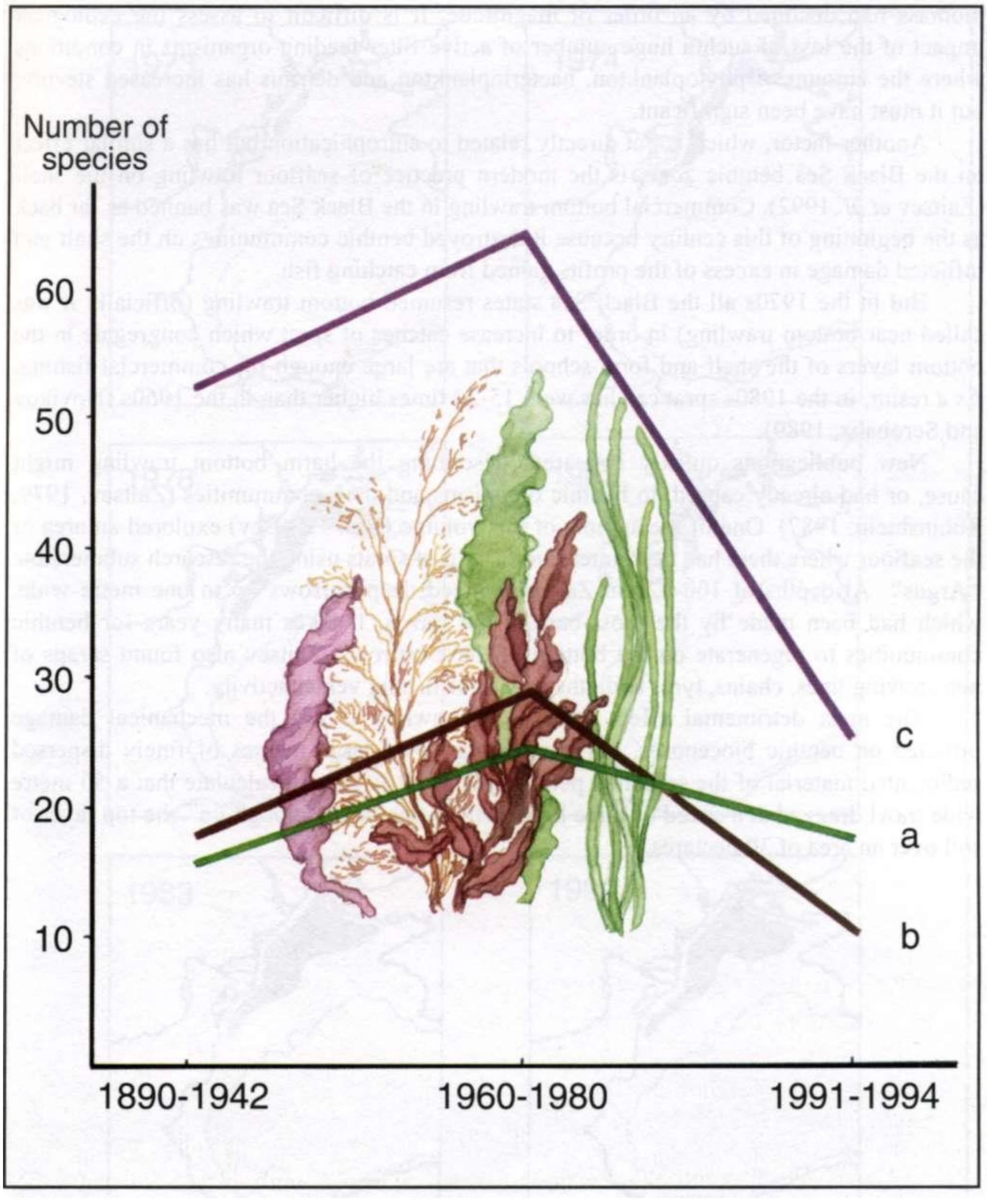


Fig 14. Long-term changes in the number of species of green (a), brown (b) and red (c) bottom macroalgae along the Bulgarian coast in the 20th century (from the Bulgarian National Report, 1995).

By the 1980s this area had shrunk to a fraction of its former size, while the mussel biomass had declined by an order of magnitude. It is difficult to assess the ecological impact of the loss of such a huge number of active filter-feeding organisms in conditions where the amount of phytoplankton, bacterioplankton and detritus has increased steeply; but it must have been significant.

Another factor, which is not directly related to eutrophication but has a similar effect on the Black Sea benthic zone, is the modern practice of seafloor trawling on the shelf (Zaitsev *et ai,* 1992). Commercial bottom trawling in the Black Sea was banned as far back as the beginning of this century because it destroyed benthic communities on the shelf and inflicted damage in excess of the profits gained from catching fish.

But in the 1970s all the Black Sea states resumed bottom trawling (officially it was called near-bottom trawling) in order to increase catches of sprat which congregate in the bottom layers of the shelf and form schools that are large enough for commercial fishing. As a result, in the 1980s sprat catches were 15-20 times higher than in the 1960s (Novikov and Serobaba, 1989).

New publications quickly appeared, describing the harm bottom trawling might cause, or had already caused, to benthic organisms and their communities (Zaitsev, 1979; Rubinshtein, 1987). One of the authors of this volume (Yu.P. Zaitsev) explored an area of the seafloor where there had been intensive fishing of sprats using the research submersible "Argus". At depths of 100-120 m Zaitsev noticed deep burrows up to one metre wide, which had been made by the cross-bars of the trawls. It takes many years for benthic communities to regenerate on the bottom of these burrows. Zaitsev also found scraps of nets, towing lines, chains, tyres and other traces of fishing vessel activity.

The most detrimental effect of seafloor trawling is not the mechanical damage inflicted on benthic biocenoses, but the stirring up of large masses of finely dispersed sedimented material of the so-called pelitic fraction. It is easy to calculate that a 50 metre wide trawl dragged at a speed of three knots will in one hour "plough up" the top layer of soil over an area of 30 hectares.

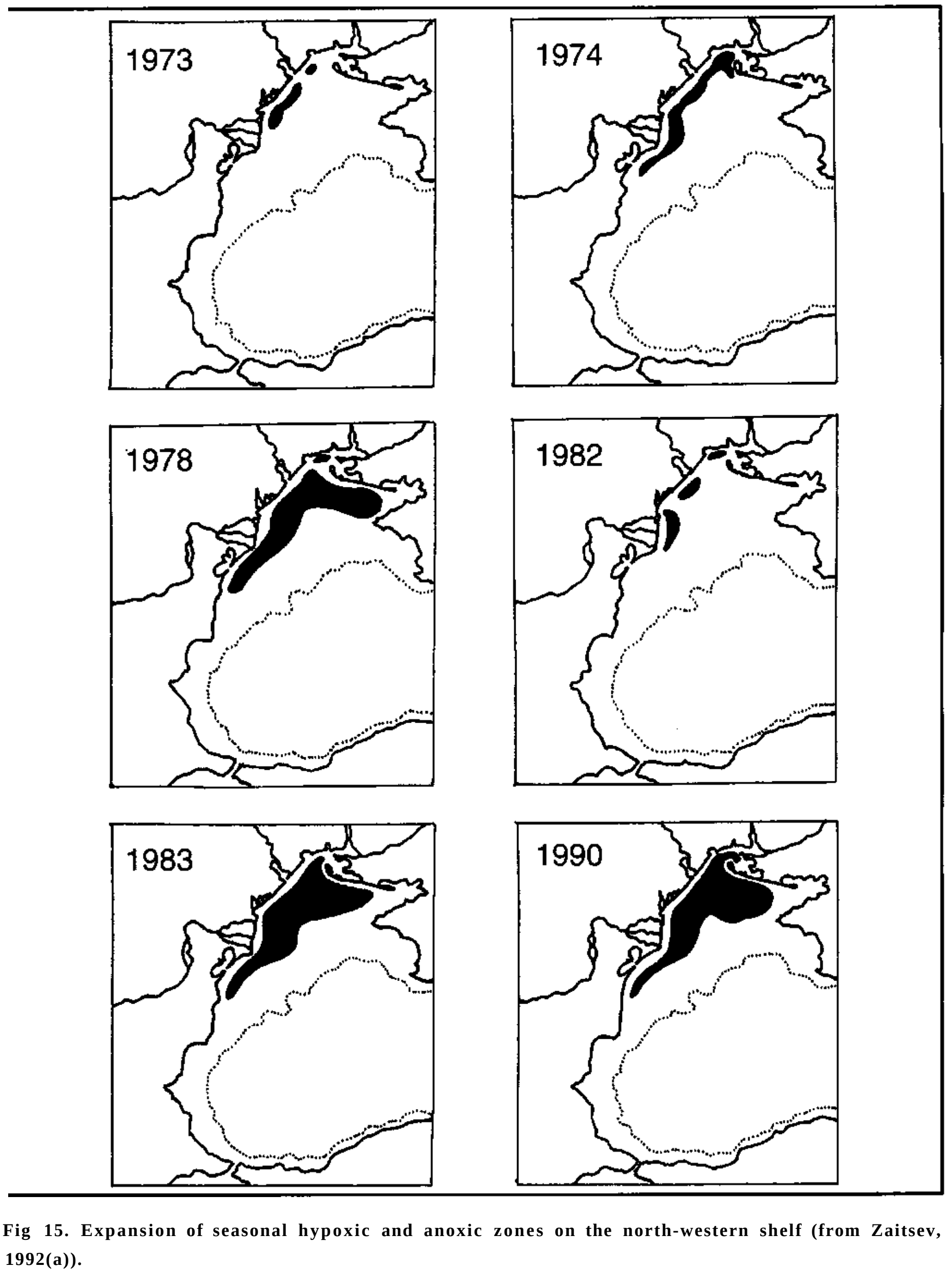


Fig 15. Expansion of seasonal hypoxic and anoxic zones on the north-western shelf (from Zaitsev, 1992(a)).

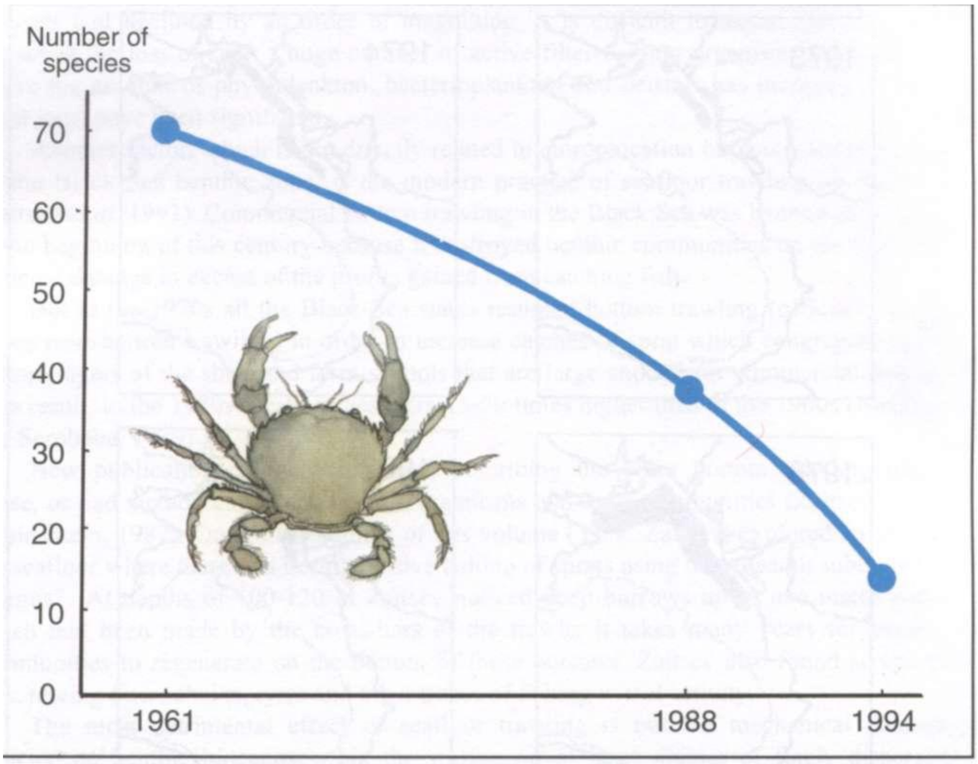


Fig 16. **Specific impoverishment of bottom macrofauna on the Romanian shelf (Romanian National Report,** 1995)

Since there are more than 300 trawlers in the Black Sea and each vessel works for several hours each day. it is clear that the volume of pelitic particles raised into the column of water is sufficient to have a major impact on the marine ecological system.

These particles contain not only minerals but also organic substances, which add to the eutrophication of the pelagic zone, draw toxic substances deposited on the bottom into the water column, reduce transparency and water penetration to the seabed, and silt those areas of the benthic zone where they are carried by currents and redeposited.

The side-effects of seafloor trawling on the north-western Black Sea shelf, where intensive commercial sprat fishing is conducted, were the subject of a special study based on geological and hydrobiological research (Zaitsev *et **al.,*** 1992).

There are two main fishing areas on the largest Black Sea shelf: near Zmeiny Island in the west and off the Tarkhankut Peninsula in the east (Fig. 17). Both regions are situated in the *Modiola* mud zone. The water in this part of the sea circulates in a cyclonic direction; only in the eastern part of Karkinitsky Bay is there a small area with an anticyclonic eddy.

Geological studies have shown that the pelitic particles raised by trawls in the eastern regions are carried by currents over a distance of 150-200 km and deposited in an area of more than 5,000 km^2 at depths of 10 - 50 m. The thickness of the sedimentary layer varies, but in an area of about 3,350 km^2 it exceeds 2-5 cm, increasing in places to 40-50 cm.

The prevailing patterns of movement in the water body mean that pelitic particles which are raised from the bottom in the western fishing area are normally carried to the south towards deep water, and in the eastern region to the north towards the shallow Karkinitsky Bay. The anthropogenic silting of the bottom of Karkinitsky Bay could thus have serious biological consequences for the shelf ecosystem (Fig. 18.).

The silting of sandy bottoms, and the covering of bottom-living organisms with a layer of silt, has resulted in a transformation of benthic communities in the areas affected. In the 1960s, before the onset of trawling, there was a considerable diversity of species of bottom-living organisms and their communities in Karkinitsky Bay (Zakutsky and Vinogradov, 1967). The local benthos biomass averaged 600 mg/m^{2}, rising in places to over 3,000 mg/m . By the 1980s the situation in the now silted bottom areas had changed dramatically. Plant and animal life on the bottom declined both in terms of quantity and diversity. A comparative study of the silted and neighbouring unsifted areas was conducted to assess the losses.

Thirty eight species of macrozoobenthos were found in the regions free of silt. On average 245 individuals with total average biomass of 71 mg/m^{2} were recorded per square metre of seafloor. In adjacent areas covered with a 2 cm thick layer of silt only 11 species of macrozoobenthos were found, at 99 individuals m^{-2} and a total biomass of 3.4 mg/m^{2}. Species diversity in silted areas had thus fallen by 71 percent, abundance by 60 percent and biomass by 95 percent.

The total losses across the 3,300 km^2 of the seafloor of Karkinitsky Bay which is intensively silted has been estimated at 800,000 tons of biomass, the majority of which were mussels.. This represents lost mussel filtering activity of 22-24 10^{9} m^3 of sea water every 24 hours across the 3,300 km^2 of the shelf (Kiseleva, 1979).

Some of what were once the most widespread biocenoses in the region, such as the mussel, the alga *Tolypella nitifica* and some other communities of the sandy and rockshell soils, have now ceased to exist and been replaced by new communities of the polychaetes *Melinna palmata* and *Nepthis hombergii,* which are the main dwellers in loose silt. The disappearance of the old communities has meant that this vast shallow-water area has lost its former function of being a feeding area for the fry and adults of fish such as turbot, sturgeons, flounder, gobies and red mullet. The reduced transparency of the water resulting from the stirring up of silt has also made a contribution to the degradation of Zernov's *Phyllophora* field.

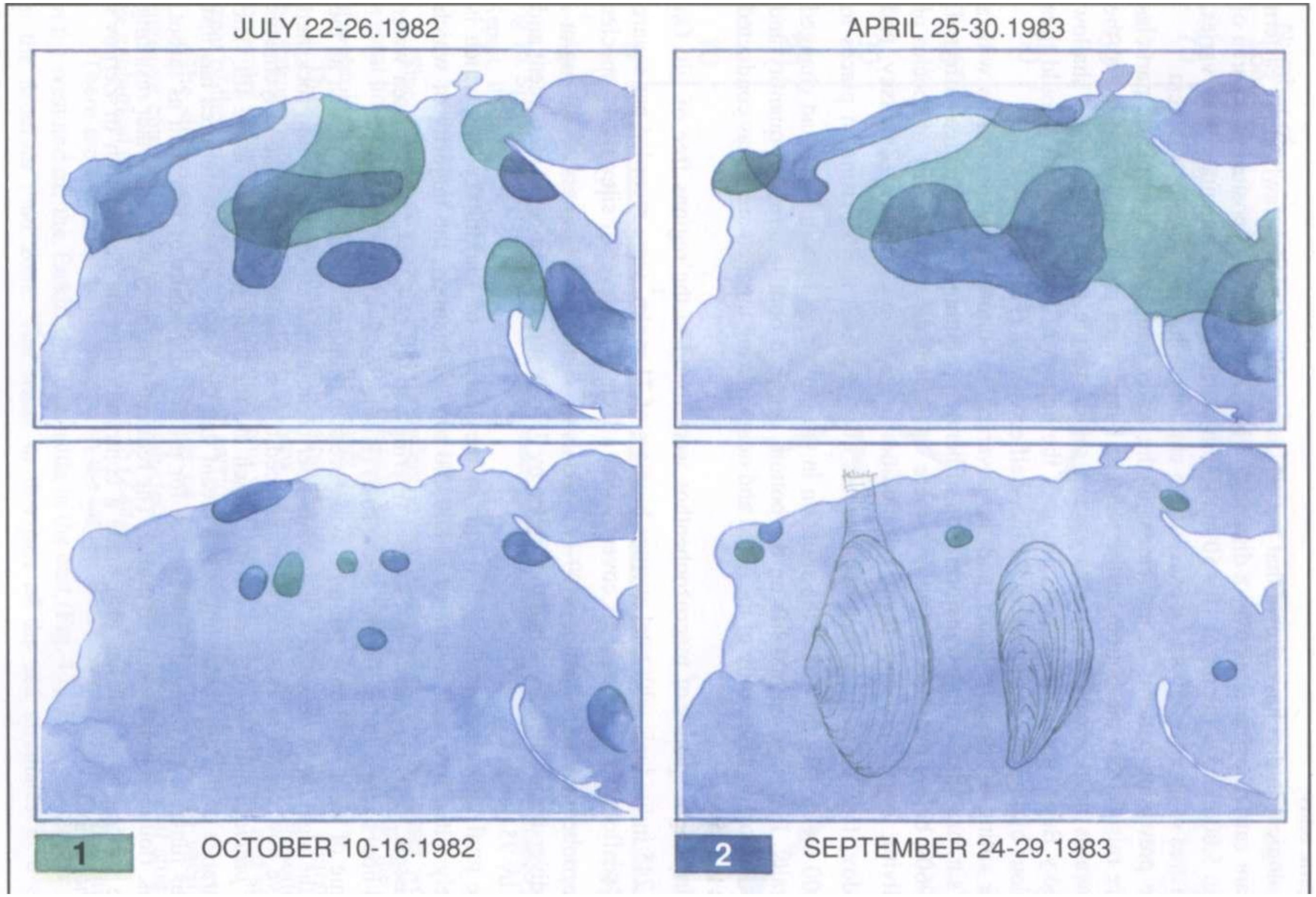


Fig 17. Peaks and collapses in the population of the soft-shelled clam, *Mya arenaria* (1), and mussel, *Mytilus galloprovincialis* (2) in the Odessa Gulf in 1982 and 1983, resulted from seasonal bottom hypoxia.

A comparison of acquisitions and losses resulting from the resumption of seafloor trawling on the Black Sea shelf, shows that it cannot be justified either in economic or ecological terms. Seafloor trawling is currently banned, but its after-effects in the form of the silted and biologically impoverished bottom in Karkinitsky Bay will continue for some time to come.

Meiobenthos

The organisms of the meiobenthos (with a body size of 0.1-2.0 mm) are very sensitive to any change in their habitat. The meiobenthos includes the larvae of most of the species of the macrozoobenthos, which complete their development as part of the plankton or neuston and sink to the bottom. The meiobenthos also includes species-rich taxa of invertebrates such as Turbellaria, Nematoda, Oligochaeta, Harpacticoida, Gastrotricha, Ostracoda, Halacarida, and Kinorhyncha all of the above taxa have been the subject of systematic study, but those on which sufficient data is available demonstrate that they are sensitive bioindicators of changes in their habitat.

During the last decade, typical interstitial species of Halacaridae (such as *Halacarus prozerus, H. capuzinus* and *Actacants pygmaeus)* have disappeared from sandy beaches. Only five of the 19 species of Halacarida recorded in the 1970s remain in the upper sublittoral (depth of up to 2 m) zone today. The most frequent are *Rhombognathus notops, R. paxcens,* and *R. magnirostris,* while less frequent is *Agauopis brevipalpus* (Vorobyova *et al.,* 1992).

Changes in the granulomere composition of the sand, increased quantities of organic substances in bottom sediments, the emergence of stagnant bodies of water resulting from hydrotechnical engineering constructions and other results of human activities have all contributed to the reduction of the diversity of meiobenthic species in the marginal biotopes of the sea.

Hypoxia on the shelf has also had an extremely adverse effect on the diversity of species of the meiobenthos. For example, of the dozens of species of Ostracoda which were recorded on the north-western shelf of the Black Sea in the 1960s and 1970s, only 5-10 species, with very reduced populations, remain today.

All Harpacticoida are very sensitive to hypoxia. Of the Foraminifera only one species, *Ammonia tepida,* is able to support the lowest 0.1 ml per litre oxygen level. However, meiobenthic Polychaeta and Nematoda are relatively tolerant of oxygen shortages. It has already been noted that specimens of three genera of Nematoda, *Desmoscolex, Tricoma, Cobbionema,* have even been discovered at a depth of 400-600 m in the complete absence of oxygen and in the presence of high concentrations of hydrogen sulphide (Zaitsev *et al.,* 1987). This sensational find on the continental slope of the north-western part of the Black Sea has yet to be explained.

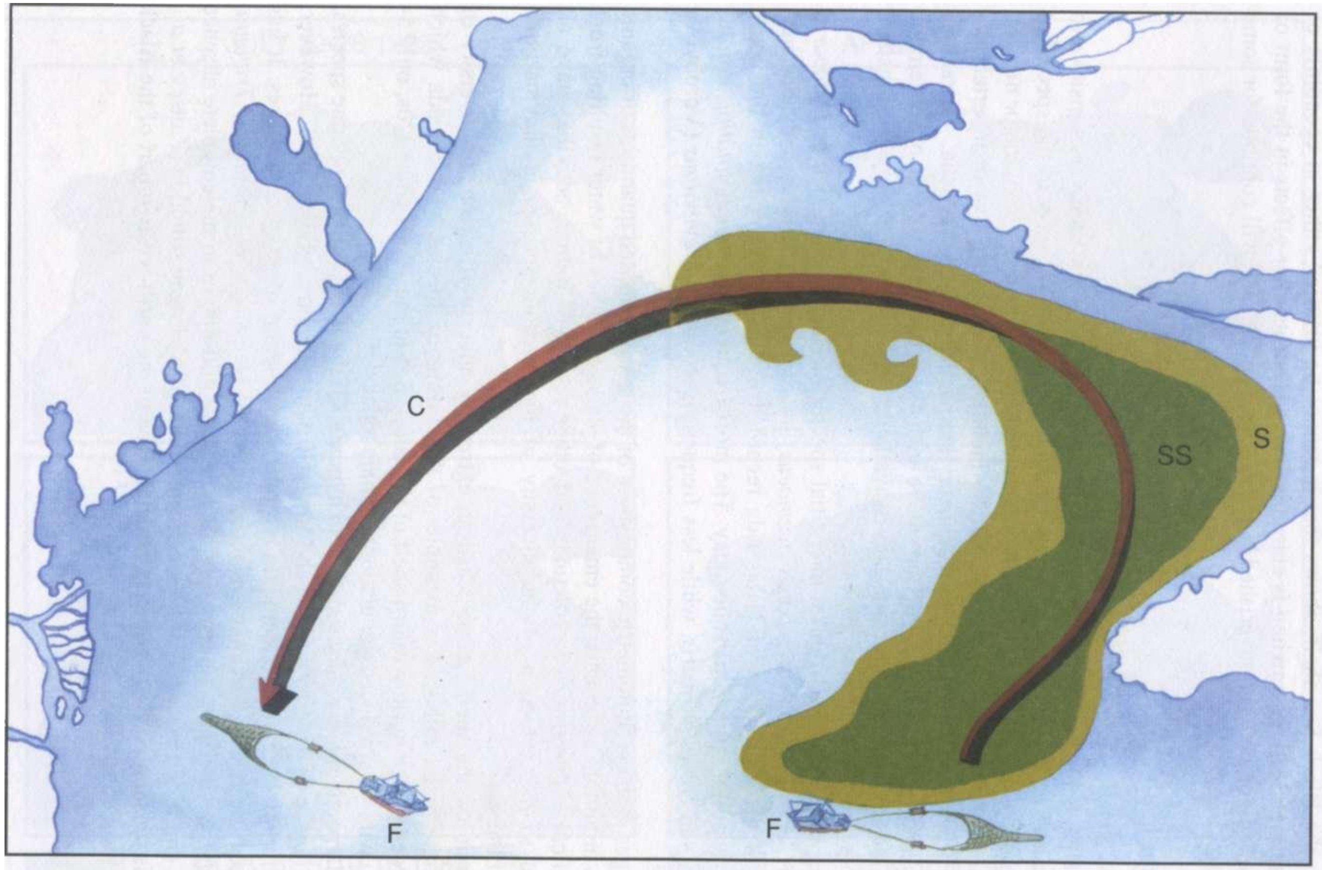


Fig 18. Silting of the north-western Black Sea shelf by bottom trawling (after Zaitsev *et al.*, 1992).

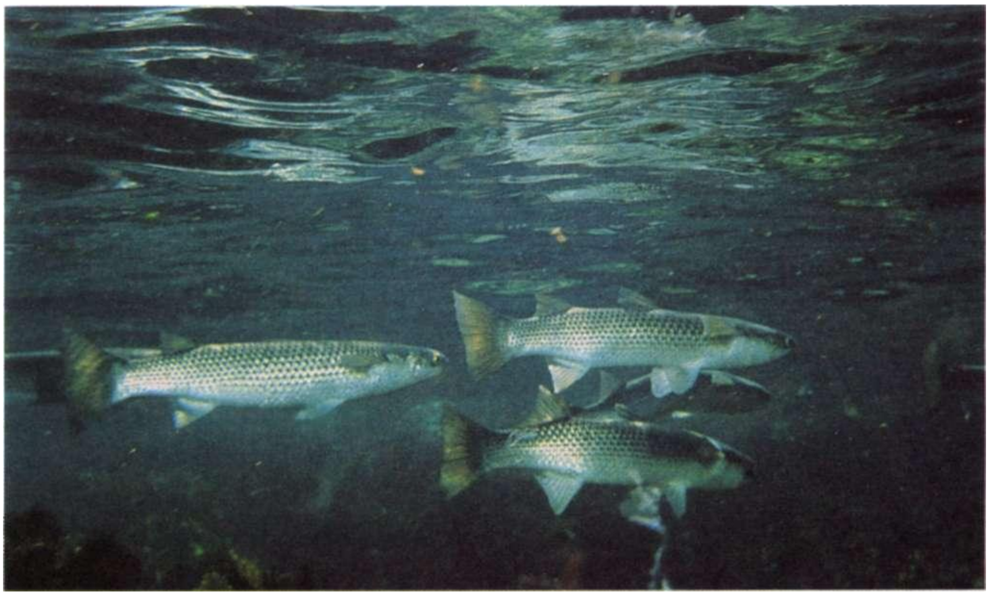
F - main fishing areas
SS - silt deposition, 3.1-50.0 cm layer
S - silt deposition, 1.3-3.0 cm layer
C - integral water circulation

The presence of such living oxybionts in the hydrogen sulphide zone is very unusual. It raises questions about the contention, which has been considered axiomatic, that the deeper waters of the Black Sea are only suitable for thiobionts, which can live in a hydrogen sulphide environment. The same Nematoda which have been discovered in this environment are also quite common in the oxygen zone of the shelf, including shallow waters.

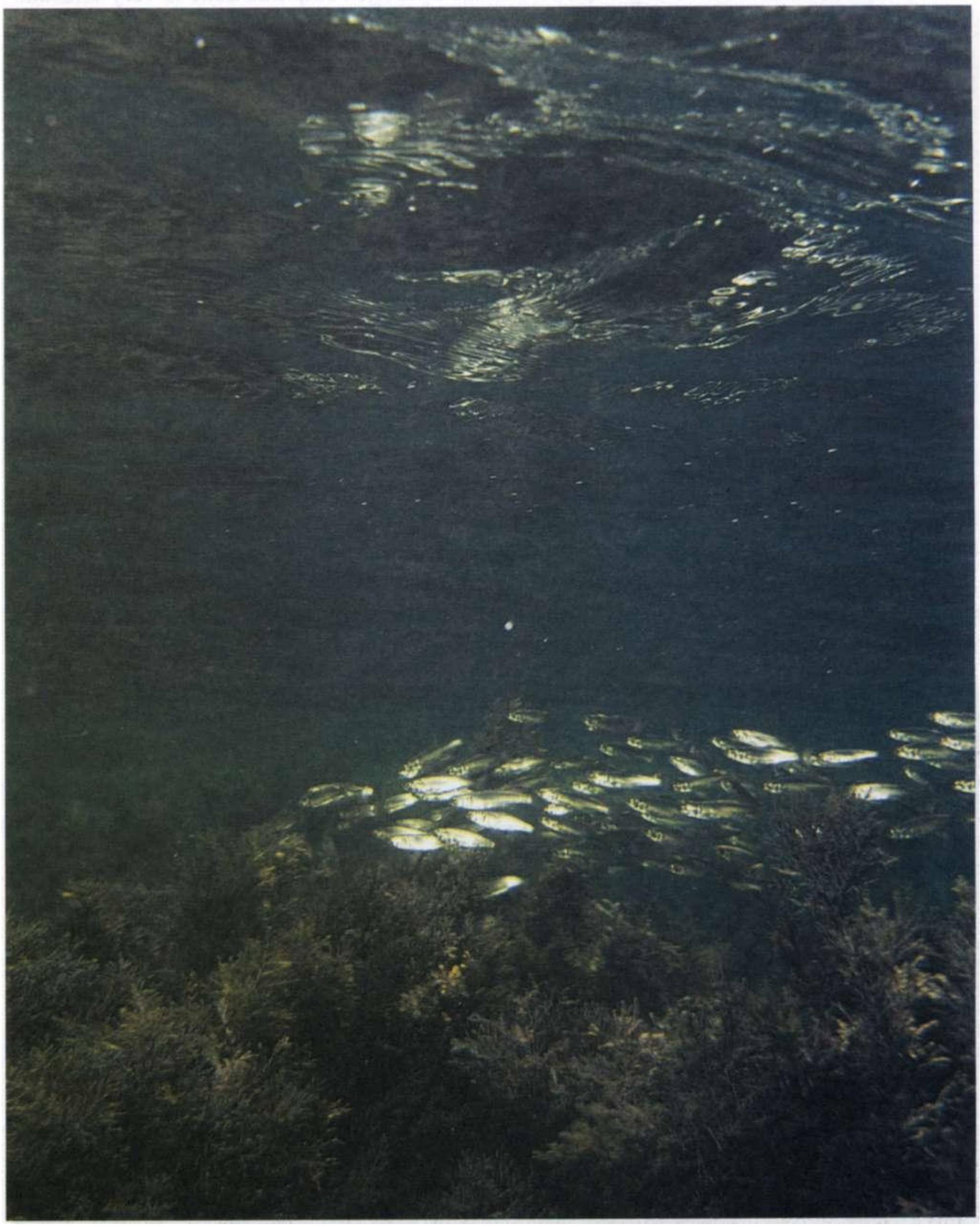
III. Changes in the Ichthyofauna

The composition of the Black Sea ichthyofauna has changed in response to alterations in living conditions in the sea. Some of the changes had an impact on coastal and shelf waters; others on the pelagic zone, affecting common and rare species, fry and adults, commercial and non-commercial species.

A total of 168 fish species have been found in the Black Sea (Rass, 1987). It is fair to say that, in terms of the number of species, the Black Sea fauna has not suffered a decline in biodiversity in recent decades; on the contrary, it has even gained two species. One of them is *Centracanthus cirrus,* which penetrated the sea from the Mediterranean (Tsokur, 1988); thus proving that the process of the mediterranisation of Black Sea fauna is continuing (Pusanow, 1967). The second is the Far-Eastern haarder *Mugil soiuy,* which was brought from the Sea of Japan for acclimatisation to the Black Sea.



A school of grey mullets ***Mugilidae.*** Six species of this family live in the Black Sea.



A school of sprats *Sprattus sprattus phalericus* near the shore, where they congregate when the water is cold.

Changes in the ichthyofaunal composition of the Black Sea have primarily involved alterations in the number of individuals in specific populations. For many species, fish populations have declined so sharply that they have lost their importance for commercial fishing, and remain within the Black Sea ichthyofauna only as zoological representatives of the species. In the period 1960-1970 there were 26 commercial fish species which were caught by the tens or even hundreds of thousands of tons. But by the 1980s only five species were left (Zaitsev, 1992); although they were joined in the early 1990s by the introduced haarder *Mugil soiuy.*

The data presented in the Bulgarian National Report gives an indication of trends in fish catches for the period 1941-1990 (Table 4.3). The diagrammatical representation of the data is presented in Fig. 19.

By the end of the 1970s, commercial fishing for mackerel *Scomber scombrus,* bonito *Sardu sarda,* bluefish *Pomatomus saltator,* as well as for the largest pelagic predators tuna *Thunnus thynnus* and swordfish *Xiphias gladius,* that had been caught in relatively small quantities, had come to a complete halt. *Thunnus thynnus* and *Xiphias gladius* used to migrate into the Black Sea each year through the Bosphorus, but they were never mass species. Nevertheless, schools of tuna numbering 40-50 individuals were observed in the open sea by fishing aviation in the 1950s. The sharp decline in the tuna and swordfish populations also put an end to their regulating influence as predators, and catches of small pelagic fish, such as anchovies and sprats, rose. But by the end of the 1980s their populations had also fallen dramatically (Zaitsev, 1993).

A similar trend can be seen in the fish catches off the Romanian and Bulgarian coasts of the Black Sea (Romanian and Bulgarian National Reports, 1995) (Fig. 20).

The populations of bottom-living fish began to plummet following the onset of mass mortalities on the shelf in the early 1970s. This decline can be clearly seen in the landings of fish such as the turbot *Psetta maeotica.* Turbot catches on the Bulgarian shelf dropped from 334 tons in the 1960s to 172 tons in the 1970s and to as little as 12 tons in the 1980s (Bulgarian National Report). Romanian ichthyologists noted a similar trend in their country. Turbot catches on the Romanian shelf totalled 354.4 tons in 1950-1954, 129.4 tons in 1965-1969, and 70.2 tons in 1970-1974 (Romanian National Report). Commercial fishing of turbot was prohibited in Ukraine in 1980.

The data presented by Georgian ichthyologists clearly illustrates the decline in populations of another group of bottom-living fish, the sturgeons Acipenseridae (Georgian National Report). The number of sturgeon on the Georgian shelf has been estimated on the basis of repeated experimental sample trawlings. There were around 75,000 adult individuals in 1973-1974. By 1978 the population had dropped to 50,000 individuals, in 1984 to 27,000 and in the 1990s to 20,000 (Fig. 21).

There have been no widespread mass mortalities in the benthic zone of this part of the Black Sea. Experts believe that intensive fishing, exceeding the natural increase in stocks, is the main reason for the decline in the sturgeon population, particularly the decision to open the previously closed 5 nautical miles (8 km.) zone between the cities of Poti and Ochamchire to commercial trawling for sturgeons (Georgian National Report).

Table 4.3. Average annual catches of Black Sea commercial fish in Bulgaria 1941-1990 (tons). (Bulgarian National Report, 1995).

Species	1941 1950	1951 1960	1961 1970	1971 1980	1981 1990	1990
Squalus acanthias	0.1	2.0	10	12	5	56
S. sprattus phalericus	795	1,468	1,30	7,551	11619	2,650
Alosa kessleri pontica	112	129	41	49	26.	17
Engraulis encrasicholus ponticus	225	162	177	134	168	-
Mugilidae	-i j j	68	28	11	8	1
Pomatomus saltator	21	69	230	30	8	6
Trachurus mediterraneus ponticus	480	499	444	1,108	777	164
Mullus barbatus ponticus	14	10	2	0.2	-	-
Sarda sarda	653	1,152	945	20	25	17
Thunnus thynnus	1.5	0.4	-	-	-	-
Scomber scombrus	966	543	452	-	-	-
Gobiidae	98	34	25	23	28	14
Psetta maeotica	69	234	334	172	12	-

The change in the fish catches by fixed nets along the Georgian coast in different years accurately reflects the transformation of the Black Sea ichthyofauna. In the period 1969-1979 representatives of 21 species, including eight that were considered mass species, were found in the one kilometre coastal zone. In the period 1989-1991, this figure had fallen to 15 species, including only three mass species, the Black Sea scad *Trachurus mediterraneus ponticus,* the pickarel *Spicara smarts* and the whiting *Merlangius merlangus euxinus.*

In recent years there has been an increase in the populations of some small fish, primarily the silverside *Atherina boyery,* syn. *A. mochon pontica* and the sand lance *Gymnammodytes cicerellus,* in the narrow coastal strip at depths of up to 2-3 m, which is not affected by bottom hypoxia (Zaitsev, 1992). Neither the silverside nor the sand lance are commercial fish and there are no statistics available on their catches. Estimates of their population can only be calculated on the basis of underwater observations and experimental sample catches using small mesh nets. The data collected in this way make it possible to assert that the silverside and sand lance populations in the shoreline strip of the north-western Black Sea have increased not less than 10-fold in the past 10-15 years.

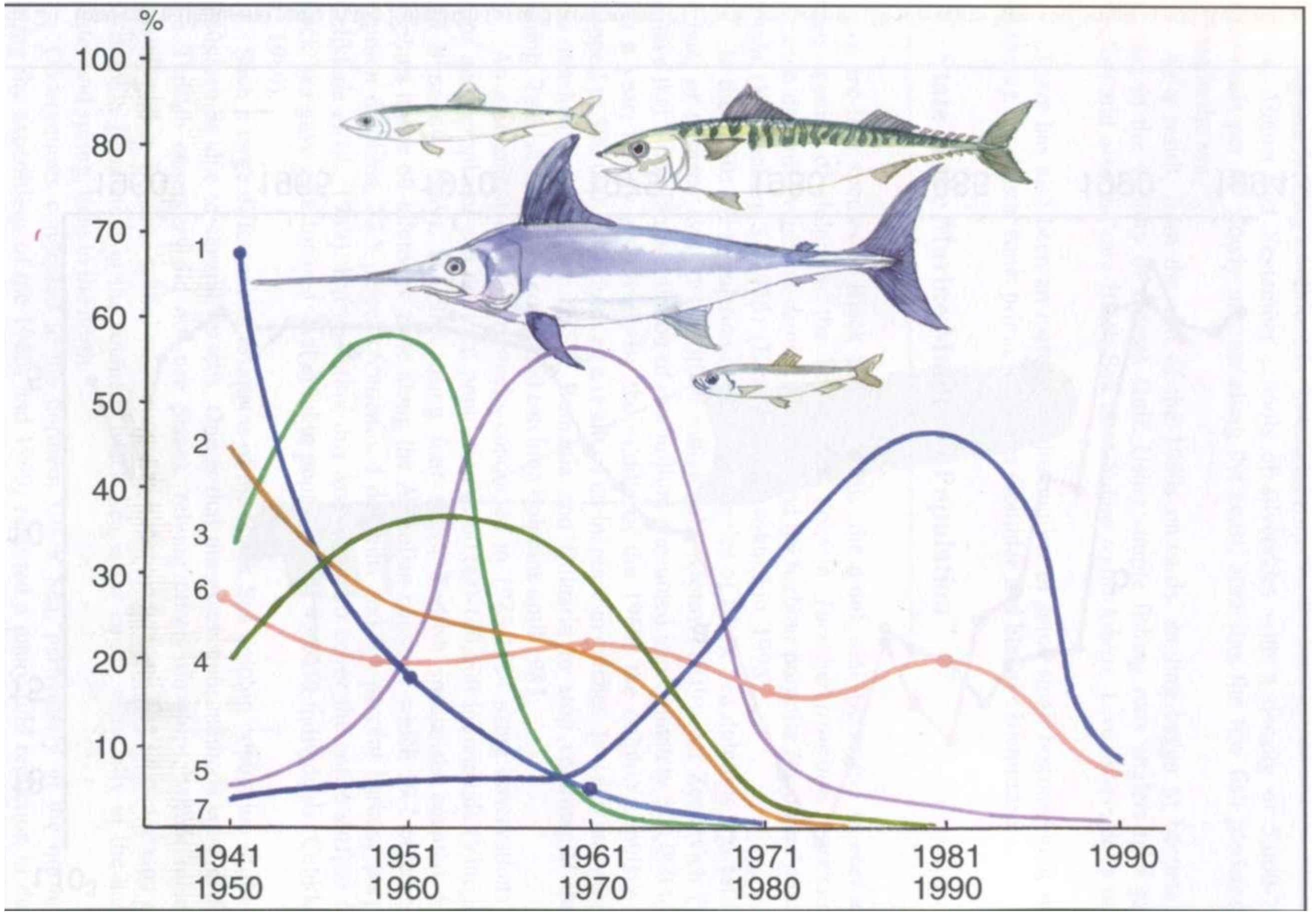


Fig 19. Trends (%) of mean catches per decade of pelagic top predators and forage fishes (anchovy and sprat) in 1941 -1990 in the Bulgarian Black Sea waters: 1. tuna, 2. mackerel, 3. sword-fish, 4. bonito, 5. blue fish, 6. anchovy, 7. sprat (Bulgarian National Report, 1995).

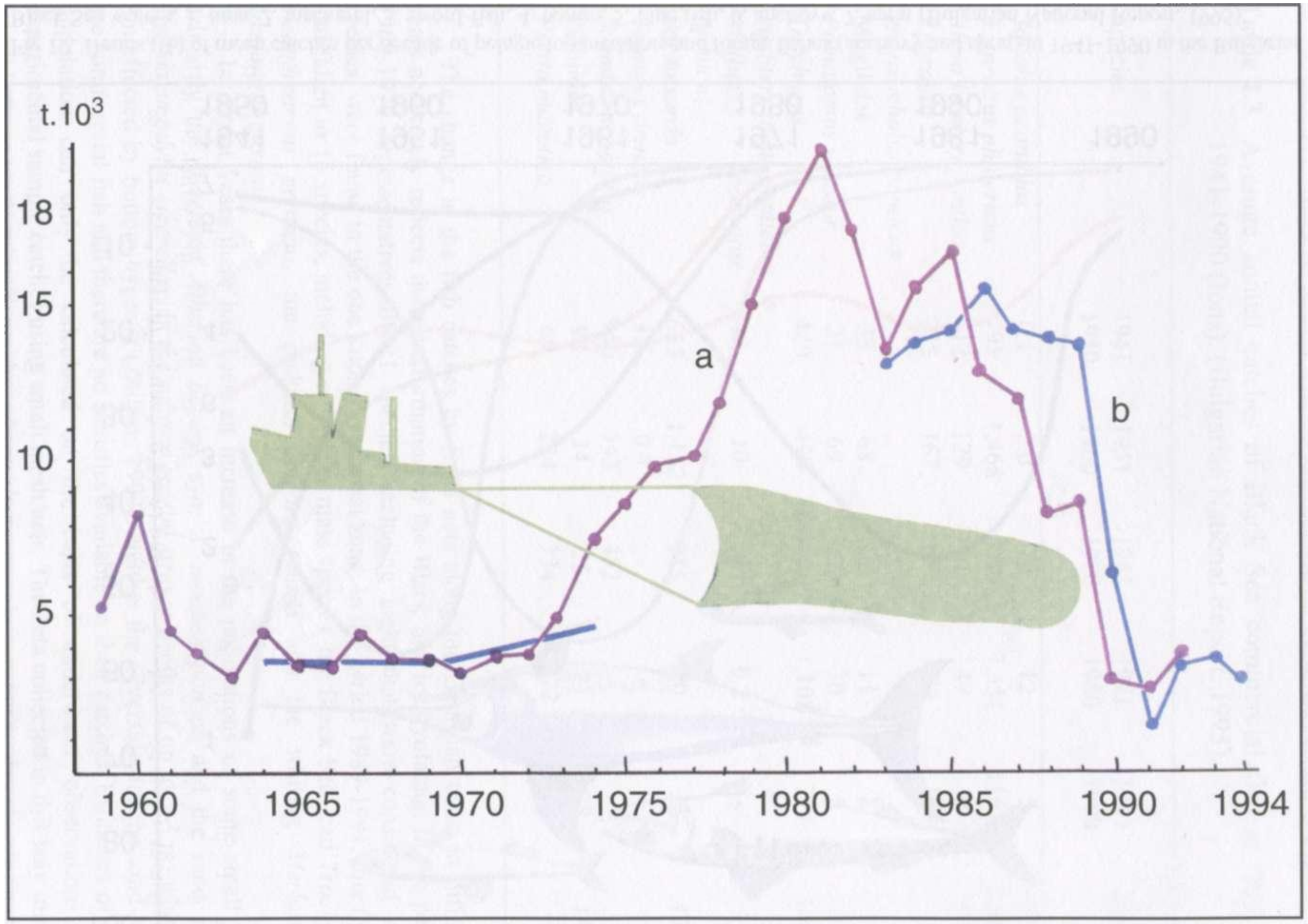


Fig 20. Total catch (thousand tons) in the Bulgarian (a) and Romanian (b) Black Sea sectors (Biodiversity Reports, Bulgaria and Romania).

Such a population increase can be explained by fewer pelagic predators and favourable spawning and feeding conditions in the coastal zone.

In August and September schools of silversides with a density of 5,000-10,000 individuals per m^3 slowly migrate along the coast, attracting the few fish predators that remain in the sea.

As a result, from the end of the 1980s onwards, angling began to become quite popular in the vicinity of Odessa Gulf. Using simple fishing rods anglers take garfish, bluefish and also the rare Black Sea trout *Salmo trutta labrax.* Live silverside is used as bait.

There has also been an increase in the number of some small bottom-living species inhabiting the coastal zone, primarily gobies Gobiidae and blennys Blenniidae.

IV. State of the Marine Mammals Population

There are four species of Black Sea mammals: the monk seal *Monachus monachus* and three species of dolphins, the bottlenosed dolphin *Tursiops truncatus ponticus,* the common dolphin *Delphinus delphis ponticus* and the harbour porpoise *Phocaenaphocaena relicta.* (Kleinenberg S. (1956). (Birkun and Krivokhizhin, 1996).

In the 1950s the population of all three species of Black Sea dolphins was estimated at one, or perhaps even two, million individuals. Krotov (1949) and Zenkevich (1963) believe that a dolphin population of one million consumed approximately 500,000 tons of fish a year, mostly anchovies. By the middle of the 1960s the dolphin population had dropped to 300,000 individuals as a result of an increase in catches. In 1966 an agreement was reached between the USSR, Romania and Bulgaria to stop commercial dolphin fishing. Turkish fishermen continued catching dolphins until 1983.

An assessment of dolphin stocks conducted in 1983-1984 using observations from ships and aeroplanes put the total population at 60,000-100,000 individuals (Vinogradov and Simonov, 1989). In 1987, using four ships, Turkish specialists counted 51,226 dolphins in the 60-kilometre zone along the Anatolian coast, of which 59.1 percent were common dolphins, 32.5 percent bottlenosed dolphins and 8.4 percent harbour porpoises (Celikkale *et a/.,* 1989). Extrapolating this assessment to cover the entire surface of the Black Sea gave an estimated total dolphin population of 454,440 individuals (Celikkale *et al.,* 1989).

Such a large difference in estimates of the Black Sea dolphin population in the mid-1980s can be due to several reasons. One is that the assessment methods were different. The Turkish observers did not use planes, relying purely on ships, which raises the possibility that the same school was counted twice or even more. The second reason is that the dolphin population in the southern Black Sea is far larger, especially in the autumn, winter and spring, than in the north.

Observations conducted in the northern Black Sea, particularly in the north-west, during the expeditions of the 1980s and 1990s reported a many-fold reduction in dolphin populations as compared with the 1960s.

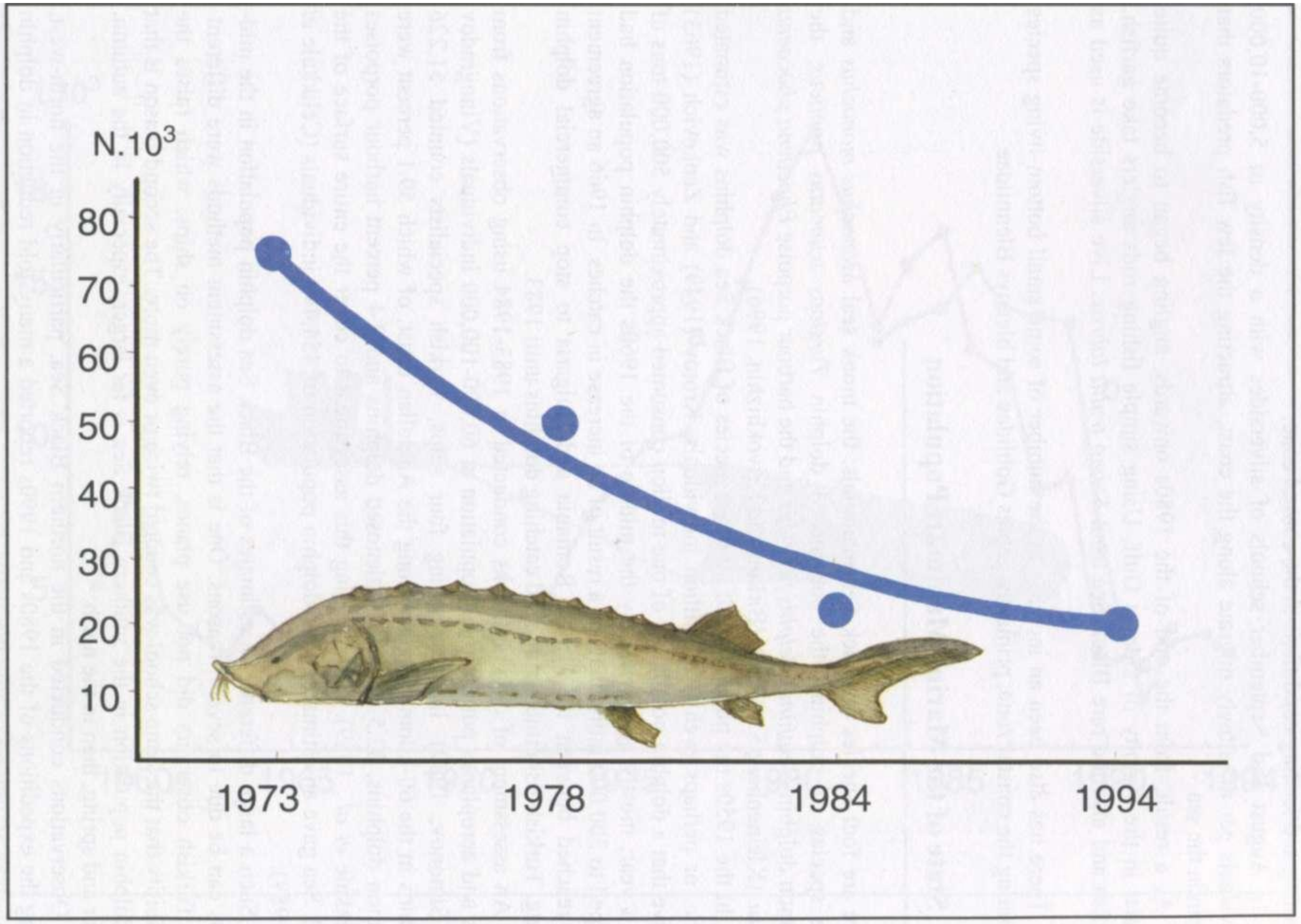


Fig 21. Decline of the total number of sturgeons in the Georgian sector of the Black Sea (Georgian National Report, 1995).

It is therefore almost certain that the figure of a half a million dolphins for the entire Black Sea is a considerable overestimate (Caddy, 1992; Zaitsev, 1993).

Data about Black Sea monk seal population leaves little room for optimism. It is the only seal in the Black Sea and is only found close to the shore or on the shore itself, which is why the exact dates of sightings along different parts of the coast are all on record. The monk seal is easily disturbed and it first stopped appearing in places crowded by people. The first part of the coast from which it disappeared was the southern shore of the Crimea. In 1834 it was sighted for the last time near Nikita Cape, to the east of Yalta, the site of the Nikitsky Botanical Gardens and the Cape Martyan Reserve (Fig. 22). There were sightings of the seal near Cape Khersones, near Sevastopol, until 1880, near Cape Tarkhankut until 1910, and near Cape Zelyony in the vicinity of Batumi until 1933 (Zaitsev, 1978). According to some reports, the seal still lived on Zmeiny Island in 1940 and in the Danube delta in 1950. On 20 May 1950 a monk seal was caught in fishermen's nets, and later died, in the northern part of the delta bordering on Zheriyansky Bay (Salnikov, 1959). It was a large female, 227 cm long and weighing 158 kg. Its stomach contained three kilograms of the digested meat and bones of the turbot *Psetta maeotica*, which approaches the shoreline for spawning in spring.

For many years the largest colony of Black Sea monk seals was located near Cape Kaliakra, Bulgaria. In 1936 the colony consisted of 128 animals, but their numbers fell to 20-30 in 1941-1945 and less than 10 in the 1960s. One of the authors of this book (Yu.P. Zaitsev) had the good fortune to observe two seals near Cape Kaliakra in October 1966. But even then sightings were very rare and they became increasingly infrequent in the years that followed..

The decline in the seal population is shown in Fig. 23. It is a long time since the seal has been observed near Cape Kaliakra or Cape Maslen Nos in Bulgaria. It is hoped that the Anatolian shore, which has numerous desolate caves and underwater grottoes, may serve as a refuge for the last surviving Black Sea monk seals. There are reports that two individuals were observed in Trabzon in 1994. But many believe that this species does not have a future in the Black Sea because its shores are too populated. The same is already true with regard to the Mediterranean. According to Oztiirk (1996), the Black Sea population of *Monachus monachus* is about to become extinct.

Information of recent sightings of the monk seal in the Ukrainian part of the Danube delta is thus of great interest. Dr. M. Zhmud of the Dunaiskiye Plavni Reserve, who has been gathering reliable information about the monk seal for a number of years, has reported several sightings. In September 1992 one seal was observed for half an hour from a distance of 5 m. In July 1994 another animal was observed in the Dunaiskiye Plavni reserve from a distance of 25 m in the marine part of a channel. On 6 July 1995 two staff members of the Reserve observed one seal from a distance of 6 m in the central part of the Reserve, near the marine part of the Bystroe channel, 200 m from the sea. The seal dived several times while crossing the channel.

We would like to express our gratitude to Dr. Zhmud for this valuable information, which confirms that, after an almost 50-year hiatus, the monk seal has again appeared in the Ukrainian part of the Danube delta.

A seven day old monk seal *(Monachus monachus)* pup. This seven days old monk seal pup from the small population on the Aegean coast of Turkey offers hope for the future. There are however, no current photographs of young seals from the Black Sea and serious doubts exist concerning the viability of the remaining population (photo: Cem Kirac SAD/AFAG).

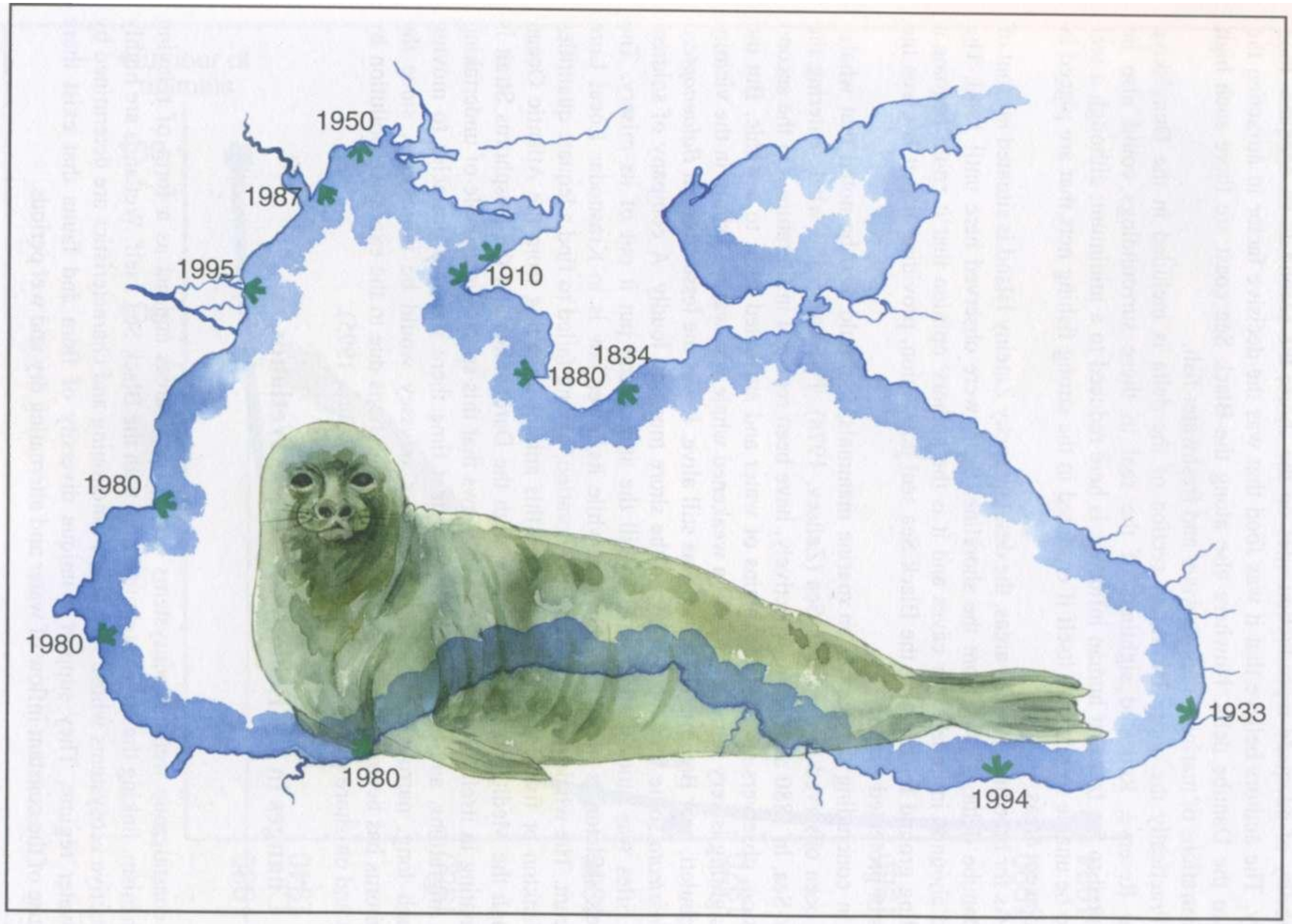


Fig 22. Last observations of the monk seal *Monachus monachus* in different coastal areas of the Black Sea.

Two major factors are critical to the fate of the monk seal population. The first is the availability of adequate reproduction sites on the shore; the second is an adequate food supply. The authors believe that it was food that was the decisive factor in attracting the seals to the Danube delta. Nowhere else along the Black Sea coast are there such high concentrations of marine, brackish water and freshwater fish.

Practically the entire Ukrainian section of the delta is included in the Dunaiskiye Plavni Reserve. Repeated sightings of the seal in these surroundings could also be attributed to the fact that human influence is here reduced to a minimum; although a seal would be unable to extricate itself if ensnared in the strong fishing nets that are placed in the adjacent areas.

As for breeding grounds areas, the desolate rocky Zmeiny Island is situated in front of the Danube delta, 37 km from the shoreline. Seals were observed here until 1940. The island abounds in underwater caves and it is the authors' opinion that it could become a breeding ground for reviving the Black Sea seal population, providing that it is given the status of protected territory.

In concluding the section on marine mammals, it should also be noted that whales have been observed in the Black Sea (Zaitsev, 1978). Two cases of a whale entering the Black Sea, in 1880 and 1926 respectively, have been reported in literature. On the second occasion, observers saw only fountains of water and attributed them to a whale. But the first sighting is very reliable. In 1880 a weakened whale was washed ashore in the vicinity of Kobuleti, near Batumi. The whale was still alive. It was the lesser rorqual *Balaenoptera acutirostrata* some 9 m long. It lay on the shore moaning loudly. A company of soldiers with rifles was quickly summoned to kill the animal and put it out of its misery. The whale's skeleton is in Tbilisi Museum, while its lower jaw is in Krasnodar Local Lore Museum. The whale may have died of starvation, having failed to find adequate quantities of plankton or fish. But the mere fact of this animal travelling from the Atlantic Ocean through the Mediterranean and then through the Dardanelles and the Bosphorus Strait is fascinating in itself. On the one hand, it shows that this species is capable of undertaking long migrations, and on the other, that at that time there were no obstacles to moving through long, narrow straits. Today such an odyssey would be impossible, since the Bosphorus has become a barrier even to fish migrations due to the excessive pollution by ships and on-shore sources (Kocatas *et al.,* 1993; Oztiirk, 1995).

V. Changes in the Ecology of Coastal Wetlands

The coastal zone wetland ecosystems occupy large areas and act as a form of relaying mechanism, linking the huge catchment area with the Black Sea itself. Wetlands are highly productive ecosystems whose formation, functioning and characteristics are determined by the water regime. They support a unique diversity of flora and fauna that exist there because of the constant inflow of water and alternating dry and wet periods.

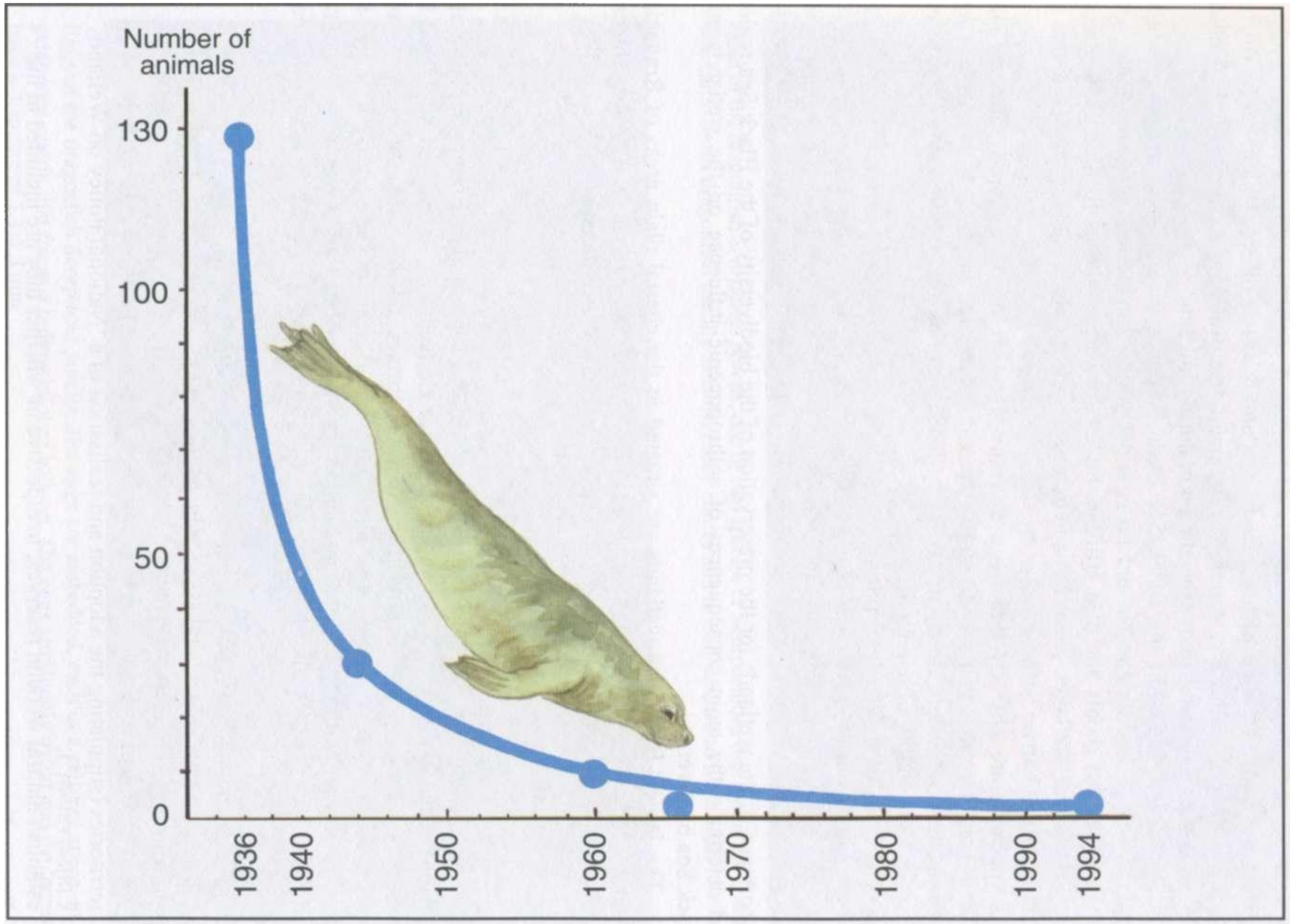


Fig 23. The decline of the number of monk seals *Monachus monachus* in the Black Sea.

The transitory and dynamic nature of wetlands dictates the necessity of a complex approach to their classification. With this goal in mind, the Ramsar Convention[2] proposed defining wetlands as "areas of fen, marsh, peatland or water of either natural or artificial origin, constant or temporary, standing or drainage, freshwater, brackish or salt, as well as areas of the sea with depths not exceeding 6 m during low tide".

Under this definition the Black Sea basin wetlands include reed marshes, forest-dominated river flood-plains, inland lakes and lagoons, limans, deltas, sea lagoons and bays, silt or sand shoals and also artificial bodies of water: such as fish-breeding ponds, rice paddies and salt lakes. Most wetland complexes also include such dry land habitats as sand dunes and barrier islands.

Wetlands are characterised by a diversity of hydrological regimes, salinities and nutrient concentrations that depend on the vast catchment area and semi-isolated sea. They perform many important functions necessary for supporting the region's biodiversity and preserving the quality of human life.

The most complete description of the Black Sea wetlands is given in the book by Wilson and Moser (1994) "Conservation of the Black Sea Wetlands" written on the basis of the results of an international seminar held in Odessa, Ukraine, on 18-22 October 1993 and the national reports of the participating states. This section aims to show the importance of the wetlands for the preservation of the biodiversity of the Black Sea region and determine the main consequences of anthropogenic influence on the wetlands and Black Sea biodiversity.

The largest Black Sea wetlands are situated in the coastal plain areas of Romania, Ukraine and the Russian Federation, in the deltas of such large rivers with vast catchment areas as the Danube, the Dniester, the Dnieper, the Don and the Kuban.

[2] Ramsar Convention - "The Convention on Wetlands of International Importance Mainly as Habitats of Waterfowl" , known as the Ramsar Convention, has entered into force in 1975. This is the only world convention for nature protection that deals specifically with one type of ecosystems, the wetlands. The Convention Bureau (or the Secretariat) works in close cooperation with the International Union for the Conservation of Nature and Natural Resources (IUCN) and the International Waterfowl and Wetlands Research Bureau (IWWRB).

The Ramsar Convention stipulates that the Contracting Parties must:

- provide at least one wetland area for inclusion in the list of wetlands of international significance (the Ramsar list);
- prepare plans in such a way as to promote sensible use of all wetlands on their territories (stipulating the adoption and realisation of a 'National Policy on Wetlands Conservation');
- establish natural wetland reserves, irrespective of whether they are included in the Ramsar list;
- promote international cooperation on issues relating to wetlands.

Head of the dragonfish *Scorpaena porcus*, one of two species of Scorpaenidae that live in the Black Sea. The carnivorous dragonfish usually inhabits rocky shores and is well adapted to its habitat.

Eggs of the dragonfish ***Scorpaena porcus.*** The eggs are embedded, each in a cell-like space, in a thin gelatinous matrix that forms a hollow bilobed balloon. The eggs are slightly ovoid and the largest ones have a diameter of 1.1 -1.3 mm.

Conversely, the wetlands of the Black Sea coasts of Bulgaria, Turkey and Georgia occupy a smaller area and have smaller catchment basins because of the mountainous nature of their surroundings.

The formation, functioning and diversity of Black Sea wetland habitats is determined by their ability to adapt to a whole range of different regimes of water run-off, salinity and nutrient supply. The interaction of water, soil and air ensures a diversity in the wetlands' flora and fauna and the performance of the wetlands' biophysical functions, which necessitate the conservation of these vital regions for mankind.

Limans, lagoons, estuaries and deltas are the most widespread types of wetlands in the Black Sea region. Limans are quite common in the Black Sea. They were formed after the lowering of the Earth's crust and the resulting flooding at the mouth of rivers debouching into the sea and in parts of river valleys.

There are open limans, which have a continuous link to the sea, and closed limans, which are cut off from the sea by a sand bar or sand spit.

Open limans are subject to silting by clay and soil particles carried by rivers. Closed limans turn into swamps dominated by halophyte (resistant to high salinities) vegetation. Salinities greatly increase in closed limans if they are located in a dry climate and there is an insignificant inflow of fresh water. In such cases salinities may greatly exceed the level in the sea and can even reach 200-300 ‰. Such limans are particularly abundant on the Crimean Peninsula.

Limans are characterised by a wide diversity of biotopes, and different plant and animal species originating from the sea, brackish waters and fresh waters. As a rule, limans have a high level of biological production. Shallow waters with their wide diversity of biotopes attract not only a whole range of water-living organisms, but also a variety of land organisms, such as insects, birds and mammals. That is why limans, which are virtually natural laboratories, play such an important scientific role in research in the ecology of water and near-water organisms.

Lagoons are shallow-water regions separated from the sea by bars and spits or other coastal accumulative formations. Lagoons are sometimes linked to the sea by one or more channels, but they are never large. Living conditions in lagoons resemble those in limans, but they are not affected by the freshwater river run-off. Lagoons were formed not because of the flooding of river valleys by the sea, but as a result of the natural isolation of shallow-water gulfs and bays from the sea. As a rule, salinities in lagoons are higher than those in the sea. The natural features of lagoons are similar to those of closed limans. Some limans with relatively stable salinities are even called limans of the lagoon type, like, for instance, Berezansky liman (Moroz, 1990a).

Estuaries are, by definition, bodies of water projecting into dry land but linked to the sea, that receive large amounts of freshwater run-off. The most characteristic ecological feature of estuaries is a cyclical fluctuation in salinity (Lincoln *et al.,* 1985). In their classical form, estuaries are the mouths and lower reaches of rivers that are regularly affected by high and low tides.

High and low tides are practically non-existent in the Black Sea, which is why there are no typical estuaries in the region. Nevertheless, the term is sometimes used with regard

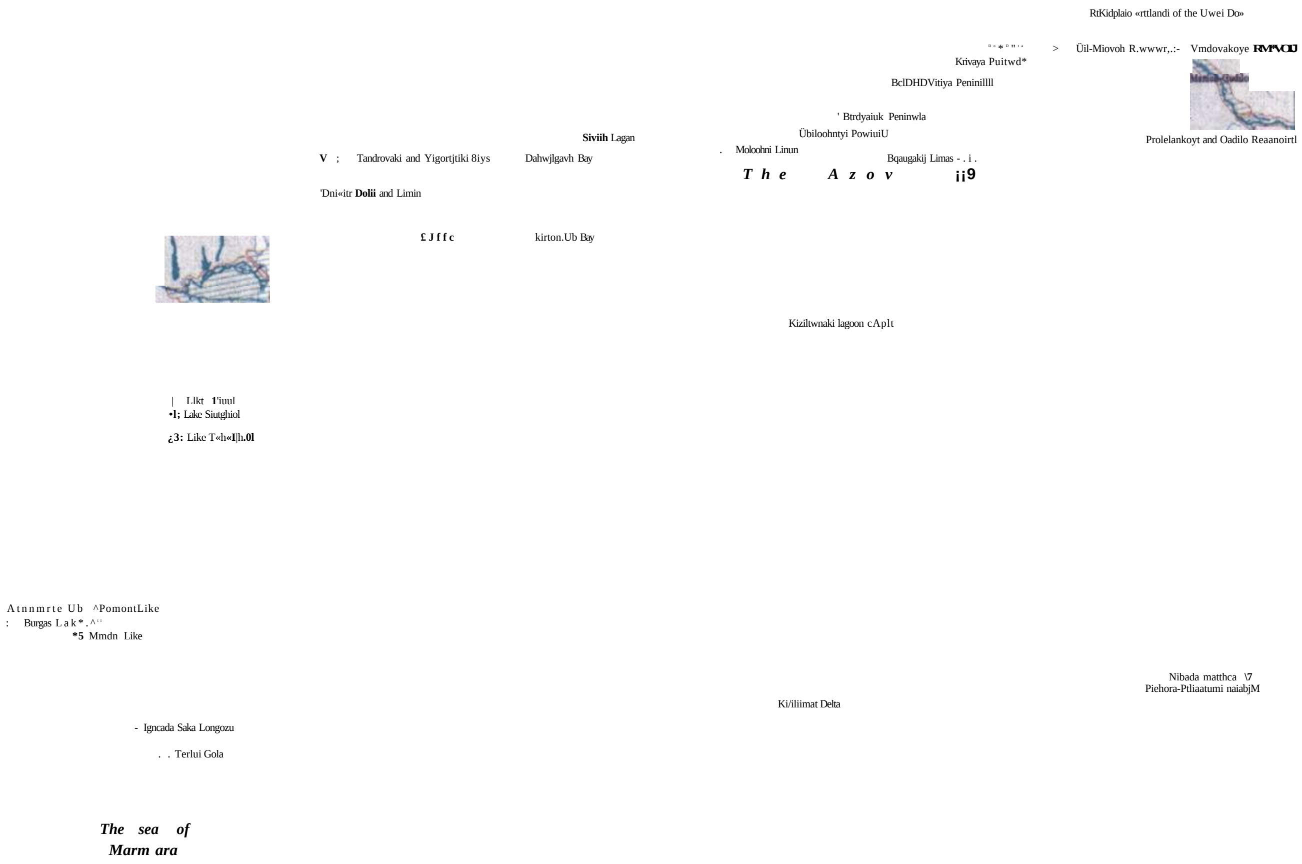


Fig 24. Black Sea Wetlands

to open limans. They are also called estuary type limans (Moroz, 1990). The salinity in limans such as Dnestrovsky and Dneprovsko-Bugsky may change substantially under the influence of sea water surges induced by winds. However, these phenomena, which sometimes have quite serious biological and ecological consequences, do not occur on the regular basis that is the norm in a true estuary. Westerly winds induce surges in Dneprovsko-Bugsky Liman, (Zhuravleva, 1988); while south-easterly winds cause surges in Dnestrovsky Liman, and easterly winds in the Danube delta.

On 31 January 1988 a mighty cyclone produced a strong easterly wind that reached hurricane force, creating waves up to 4 m high in the Danube delta. As a result, near-bottom countercurrents of sea water forced their way into the Kiliya delta of the Kiliya branch of the Danube and filled the bottom cavities where fish were resting during the winter. Alerted by the salt water, the fish took off from the bottom cavities and, using the high water, moved over the flooded coastal strips of land to the shallow-water lakes of the delta which the sea water could not reach. By 1 February the wind had subsided, the water level fallen and the delta lakes became isolated once again. Air temperatures immediately fell to minus 11-13° C and the fish that had taken temporary refuge in the shallow-water lakes of the delta were frozen in ice and died. This winter intrusion of sea water greatly reduced the biological resources of the Danube delta, and its consequences for the populations of fish and other animals continued to be felt for several years.

The different types of limans and lagoons are most evident along the north-western coast of the Crimea and the Tamansky Peninsula. There are over 50 large bodies of water, marked on maps and with a geographic name, along the Black Sea coast from Cape Kaliakra in the west to the city of Anapa in the east, in addition to numerous smaller water bodies. The best known large bodies of water are the Razim-Sinoye lagoon complex in Romania, Sasyk, Shagany, Alibei, Burnas, Dnestrovsky, Khadzhibeisky, Kuyalnitsky, Tiligulsky, Berezansky, Dneprovsko-Bugsky, Donuzlav, the Saki and Tobechik limans, Sivashsky Lagoon in Ukraine, and the Kiziltashsky lagoon complex in the Russian Federation. Coastal salt and brackish water limans of the lake type, such as Burgas, Shabla and Durunkulak in Bulgaria, Paleostomi in Georgia, and Terkos in Turkey, are of great ecological significance and are usually referred to as lakes even though they are not large in size.

River deltas are another category of coastal wetlands. The largest Black Sea deltas are those of the Danube, the Dniester, the Dnieper, the Rioni, the Yesilirmak, the Kizilirmak, the Sakarya, and the Don and the Kuban deltas in the Azov Sea. The Black Sea coastal zone has a rich diversity of habitats and species of international importance. Reed *{Phragmites australis)* marshes are characteristic of many lacustrine and river flood-plains and deltas in the Black Sea region (e.g. the Danube in Romania and Ukraine; the Dniester and the Dnieper in Ukraine; the Kizilirmak and Yesilirmak in Turkey; the Rioni in Georgia; and the Kuban in the Russian Federation). Reed-dominated marshes have an extremely high productivity and provide refuge for many mammals (e.g. the European mink *Mustela lutreola* and the otter *Lutra lutrd)* and nesting birds.

Other unique ecosystem complexes include the peat marshes of the Kolkhida Lowland in Georgia, the vast lagoon system of Karkinitsky Bay near the Ukrainian Black

Sea coast and Sivash Bay in the Azov Sea. All the littoral states have relict steppe habitats near their shores, which provide living conditions for rare reptiles and a great diversity of wild plants.

The tidal zones vary from flat strips of sand to precipitous cliffs, and provide homes and food sources for a variety of benthic communities, including shells, sea anemones and algae. The Black Sea is the only warm water sea resource for the countries of Eastern Europe, and in the past fish catches here were five times more abundant than in the neighbouring Mediterranean Sea. For centuries the coastal marine, lacustrine and flood-plain wetland systems provided highly productive spawning and feeding grounds for fish, including migratory species (e.g. the sturgeon *Acipenser sturid)* and freshwater species (e.g. the carp *Cyprinus carplo,* the pike-perch *Stizostedion lucioperca* and the bream *Abramis bramd).* In the past, the monk seal *Monachus monachus* also inhabited the sea; but only a few individuals have survived to the present day (see section 4.4). Various invertebrates and fish that reproduce in the coastal wetlands are the main food source for the people living in the region. They also support large populations of waterfowl.

The wetlands of the Black Sea basin are a vital link in the network of wetlands that stretch from the Arctic Ocean to South Africa, providing refuge for millions of migrating waterfowl (Fig. 24). The Black Sea wetlands are a winter habitat for many species of birds nesting in the Arctic. At the same time they provide the nesting regions for a variety of herons, terns and gulls that spend the winter in Africa. Five of the 27 European birds that are close to extinction can be found in the Black Sea region either in the summer or the winter, and seven of them live only in the wetlands. The slender-billed curlew *Numenius tenuirostris,* one of the rarest birds of the Western Palearctic, is regularly seen in the Black Sea region during its migrations. The wetlands also support most of the populations of birds nesting in the Palearctic; e.g. the little cormorant *Phalacrocorax pygmeus,* the white pelican *Pelecanus onocrotalus,* the Dalmatian pelican *Pelecanus crispus* and the spoonbill *Platalea leucorodia.* The Danube delta and the lacustrine complex Shabla-Durankulak in northern Bulgaria are the winter habitats of a large number of geese that nest in the Arctic tundra, including the red-breasted goose *Rufibrenta ruficollis* and the lesser white-fronted goose *Anser albifrons,* both of which are considered endangered species.

Impact on the Wetlands

The main types of anthropogenic influences resulting in the loss and degradation of wetlands in the Black Sea region are:

- reclamation of wetlands in the interests of agriculture, forestry and fishing or for home construction;
- deepening river beds, canal construction to ensure navigation and flood control, creating reservoirs and developing coastal regions;
- dumping dredge spoils and solid waste;
- construction of roads, housing and industrial facilities;

- construction of dams, embankments and breakwater structures to protect against storms and floods and to ensure water-supply and irrigation;
- waste discharge (sewage and fertiliser-polluted water) causing eutrophication;
- dumping of toxic pollutants (pesticides, industrial and radioactive waste, heavy metals, organic compounds);
- extraction of peat, sand, gravel and other material from wetlands;
- extraction of oil, gas, underground water and various ores, as a result of which water becomes polluted and land subsides;
- introduction of species;
- overfishing, overhunting of birds and mammals, and overgrazing, which undermine biodiversity and reduce food resources and feeding possibilities for wild animals.

Consequences of the Destruction or Degradation of Wetlands

Wetlands are extremely sensitive ecosystems, particularly those situated on the Black Sea coast because the sea is isolated, the water exchange with the world ocean is minimal and the drainage basin is large. The diversity and productivity of wetland systems depends on the chemical composition of the water and this makes them vulnerable to the slightest changes in the quality of water and the river discharge regime. The intense utilisation and alteration of Black Sea wetlands and their catchments during the 20th century has so changed their character that their ability to provide a wide range of biodiversity, physical and amenity values has been completely destroyed in some areas and severely impaired in others. The cumulative impact of pollution and wetland alteration in the Black Sea region have been staggering.

Some limans were protected from the sea by dams and turned into freshwater reservoirs. Over a number of years salinity fell from 35-36 %o (Khadzhibeisky Liman) or 16-17 %o (Sasyk Liman) to 2 %o or even less, producing radical changes in the flora and fauna in the process. In other cases the closed limans were opened, deepened and turned into sea harbours or virtual sea bays. Thus, Sukhoi Liman, which had been enclosed until the mid-1950s, was converted into part of the port of Ilyichevsk. In the 1970s Grigoryevsky Liman became the sea port of Yuzhny. The flora and fauna in both these limans were transformed as a result.

The disappearance of *Cystoseira* ^cr^ata-dominated areas along the coasts of Ukraine and Romania, and a considerable reduction in its numbers along the Bulgarian coast, has been one of the most striking changes to occur in coastal shallow waters. By the 1990s there were only two locations along the entire north-western Black Sea shelf (near Cape Tarkhankut and Cape Kaliakra where *Cystoseira* could still be found. This may partly explain the catastrophic drop in the populations of the small (40-50 mm long) bottom-living fish *Callionymus belenus*, whose fry develop in the neuston (Zaitsev, 1971). Their pigmentation and body shape closely resemble shreds of Cystoseira thalli that are usually found on the surface of water in the coastal zone in the summer. In the 1960s there were still up to 300-400 adult individuals of *C. belenus* per square metre of sandy seafloor at depths of 0.5-3.0 m.

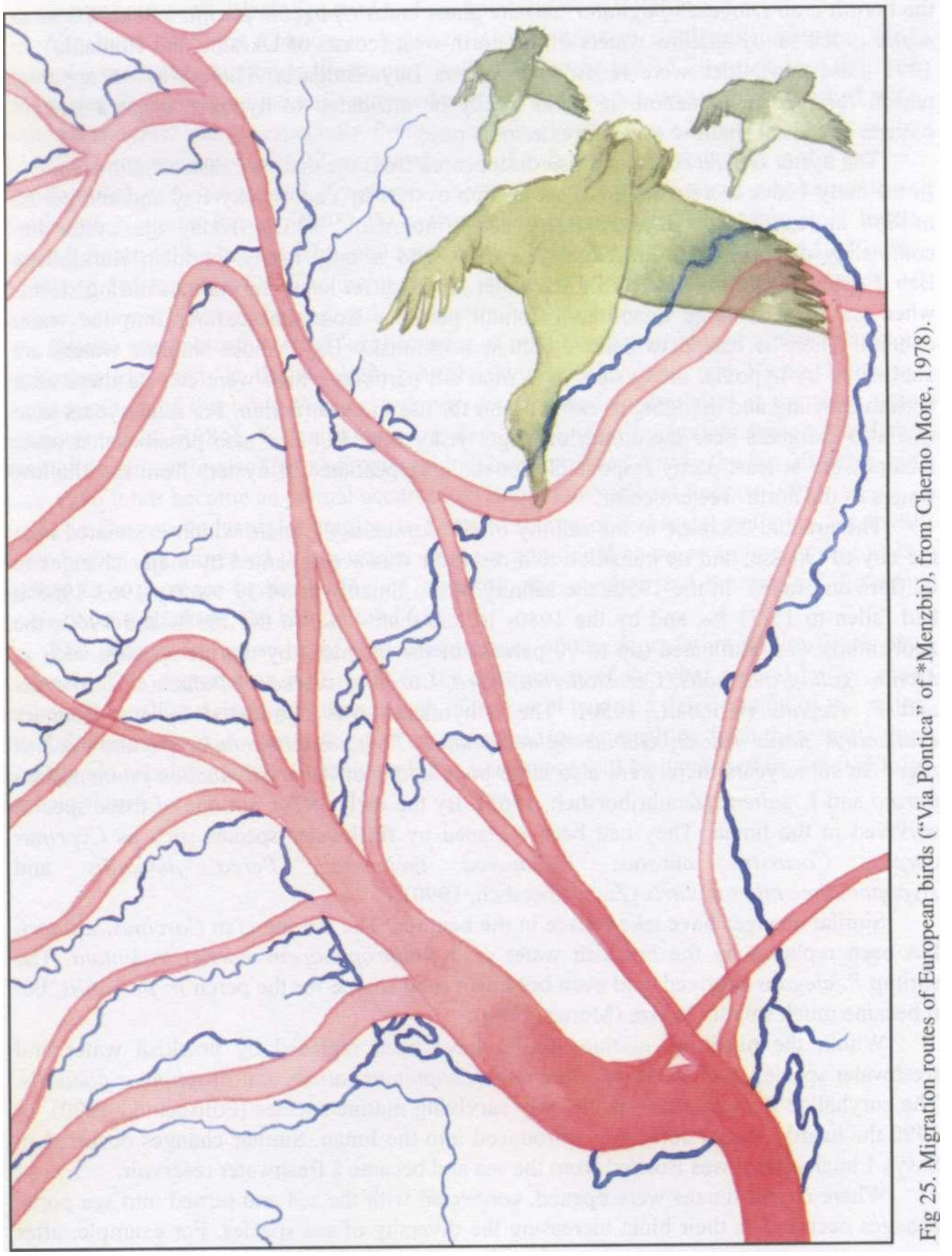


Fig 25. Migration routes of European birds ("Via Pontica" of *Menzbir), from Chermo More, 1978).

The late 1970s and the early 1980s also witnessed a sharp reduction in populations of the hermit crab *Diogenes pugilator* and the ghost crabs *Upogebia pusilla* and *Callianassa pestai* in the sandy shallow waters of the north-west (coasts of Ukraine and Romania). In 1991 mass mortalities were recorded in Varna Bay, Bulgaria. There was no apparent reason for this phenomenon. It could hardly be attributed to hypoxia, since a lack of oxygen in coastal shallow waters is extremely rare.

The oyster *Ostrea edulis* has also disappeared from the marine coastal shallow waters. In the early 1960s there were up to six million oysters in Yagorlytsky Bay and another 62 million in Karkinitsky Bay (Zakutsky and Vinogradov, 1967). Today the oyster has completely disappeared from Yagorlytsky Bay and is only rarely found in Karkinitsky Bay. Oysters cannot tolerate turbid sea water. They suffer heavy mortalities during storms when waves raise large quantities of small particles from the seafloor into the water column. There is reason to believe that in Karkinitsky Bay, whose shallow waters are unaffected by hypoxia, the oysters died from silt particles which were carried there after bottom trawling and dredging to extract sand for use in construction. For many years sand was also extracted near the mouth of Yagorlytsky Bay. But it is also possible that other factors were at least partly responsible for the disappearance of oysters from the shallow waters of the north-western coast.

The gradual decrease in the salinity of Khadzhibeisky Liman, which is situated near the city of Odessa, and its transition to a reservoir was accompanied by major changes to its flora and fauna. In the 1950s the salinity of the liman was 34-37 %o. By 1963-1968 it had fallen to 15-31 %o, and by the 1980s to less than 4 %o. In the 1950s and 1960s the zoobenthos was dominated (up to 90 percent of the biomass) by marine species, such as *Mytilus galloprovincialis, Cerastoderma, Abra, Carcinus aestuarii, Palaemon adspersus* and *P. elegans* (Grinbart, 1950). The icthyofauna was dominated by the flounder *Platichthys flesus luscus, Gobius ophiocephalus, Pomatoschistus microps* and *Gobius niger.* In some years there were also large populations of *Atherina mochon pontica, Liza aurata* and *L. saliens* (Zambriborshch, 1965). By the early 1970s not one of these species survived in the liman. They had been replaced by freshwater species such as *Cyprinus carpio, Carassius auratus, Lucioperca lucioperca, Perca fluviatilis* and *Hypophthalmichthys molitrix* (Zambriborshch, 1990).

Similar changes have taken place in the benthos. The marine crab *Carcinus aestuarii* has been replaced by the brackish water crab *Rhithropanopeus harrisi tridentata.* The shrimp *P. elegans* survived, and even became a food source for the perch *P. fluviatilis,* but it became much smaller in size (Moroz, 1990).

Within the plankton, marine species have been replaced by brackish water and freshwater species, such as *Moina brachiata, Diaptomus salinus* and *Brachionus plicatilis.* The euryhaline *Acartia clausi* is the only surviving marine species (Polishchuk, 1990). In 1990 the haarder *Mugil soiuy* was introduced into the liman. Similar changes occurred in Sasyk Liman after it was isolated from the sea and became a freshwater reservoir.

Where closed limans were opened, connected with the sea and turned into sea ports, changes occurred in their biota increasing the diversity of sea species. For example, after

Grigoryevsky Liman was opened, sea water introduced not only planktonic organisms, but fish such as sturgeons, Black Sea scad and anchovy and even dolphins.

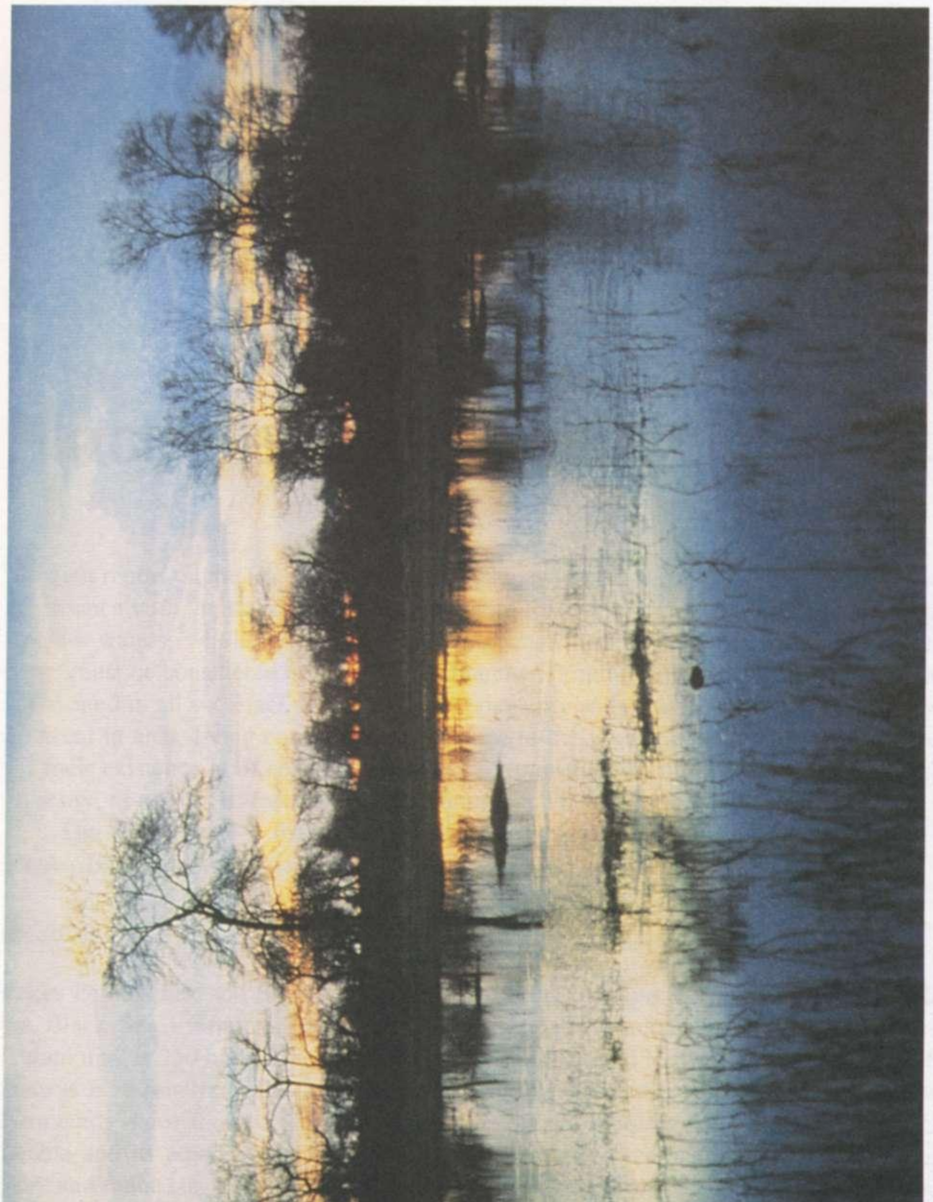
The biota of Sinoe Lagoon in Romania also underwent significant changes. As a result of a gradual reduction in the lagoon's salinity over the last 15-20 years, vast fields of sea grasses *Zostera nana* have disappeared and the *Zostera* biocenosis has vanished with them. Fresh-water plants, especially *Potamogetón pectinatus,* have begun to dominate. In 1950-1952 representatives of 22 marine species of fish were still abundant in the lagoon, including *Belone belone euxini, Trachurus trachurus* and *Engraulis encrasicholus ponticus* (Romanian National Report, 1995). At present marine species of fish can be only found near the mouth of the lagoon. The total catch offish in the lagoon dropped from 1,140 tons in 1981 to 145 tons in 1990. The major part of landings (up to 90 percent) now consists of *Cyprinus carpió, Abramis brama,* and *Lucioperca lucioperca.*

Intense eutrophication from local sources of pollution has produced a phytoplankton population explosion in the brackish coastal lakes Beloslavskoye and Varna, Bulgaria. Large numbers of the toxic *Prymnesium parvum* appeared in the lakes at the same time (Marinov *et al.,* 1984). Water blooms are usually followed by bottom hypoxia and the death of benthic animals. This phenomenon had been recorded during the last 20 years, but since 1986 it has become an annual occurrence (Bulgarian National Report, 1995).

The Devnya Industrial Complex is a major source of industrial pollution for these water bodies. Its untreated waste waters produce additional changes among hydrobionts, leading to a decrease in the biological diversity, the number and biomass of different species of the plankton, the benthos and fish.

The above are just some of the consequences of the degradation of the Black Sea wetlands. This degradation will result in the destruction of the vital natural buffer zone between the polluted rivers and the sea and, in turn, will lead to a deterioration of the entire Black Sea ecosystem. An assessment of the economic losses resulting from the degradation of wetlands is being made. The results of this assessment will be published by the BSEP in the near future.

The rockling *Gaidropsarus mediterraneaus* is a bottom cold-water fish. It is one of two species of the Gadidae family in the Black Sea.



Kizilirmak Delta, Turkey (photo: S. Demircan)

Black Sea Reserves

The first report on the Black Sea coastal wetlands (Wilson and Moser, 1994) shows that, in accordance with the standards laid down by the Ramsar Convention, large areas of marine shallow waters, whole sea bays, limans, lagoons, river deltas and the lower reaches of rivers must be considered areas of international environmental importance. These wetlands are located in all six Black Sea states, but today only some have protected status. They are different in area, living conditions, importance to the Black Sea and adjacent ecosystems, but their existence is of considerable importance in the protection of Black Sea biological diversity, as well as its recreational and commercial fishing resources.

The following is a list of the protected coastal zones of the Black Sea (Wilson and Moser, 1994, with addenda).

Bulgaria

Lakes Durankulak and Shabla, situated to the north of Cape Kaliakra, are separated from the Black Sea by narrow sand bars. Their waters are mostly brackish. The surface of Durankulak is 250 ha and the area of the adjacent protected territory is 100 ha. In addition, there is a 500-metre buffer zone where hunting is prohibited and the use of pesticides on farm lands is not allowed. The same protection regime is effective for the 150-hectare Lake Shabla and its adjacent territory of another 150 ha. Predominantly freshwater species of flora and fauna can be found in these lakes. The carp *Cyprinus carpio* is the most abundant fish species. The lakes have a major impact on the biosphere, as they are home to many endangered species. For example, 90 percent of the world population of red-breasted goose *Rufibrenta ruficollis* is estimated to spend the winter months there. This beautiful small goose nests only in the north of the Russian Federation, particularly in the tundra of Yamal, Taimyr and Gydan. Until recently most of the population used to spend the winter on the shores of the Caspian Sea (Babenko and Kuznetsov, 1986). But, towards the end of the 1980s most of them moved their winter location to the Black Sea coasts of Ukraine, Romania and Bulgaria. Thus, the Bulgarian lakes Durankulak and Shabla are now critical biotopes in the life of this species, which makes their protection a vital necessity of more than regional importance.

The Kamchia Biosphere Reserve, which has an area of 842 ha in the estuary of the Kamchia River, was established to protect sections of the flood-plain forests with their limans. Some marine fishes, such as gobies, are known to enter the river.

Lake Atanasovsko, which has an area of 1,050 ha, is an extremely high salinity body of water with small settling basins for the extraction of salt. Over 250 species of birds from many European countries spend the winter here, including 12 species that are under threat of extinction.

The reserve on the estuary of the Ropotamo River has an area of 1,000 ha and **a** buffer zone of 770 ha. The marshes and its biota are protected. Some representatives of marine fauna can be found near the mouth of the river.

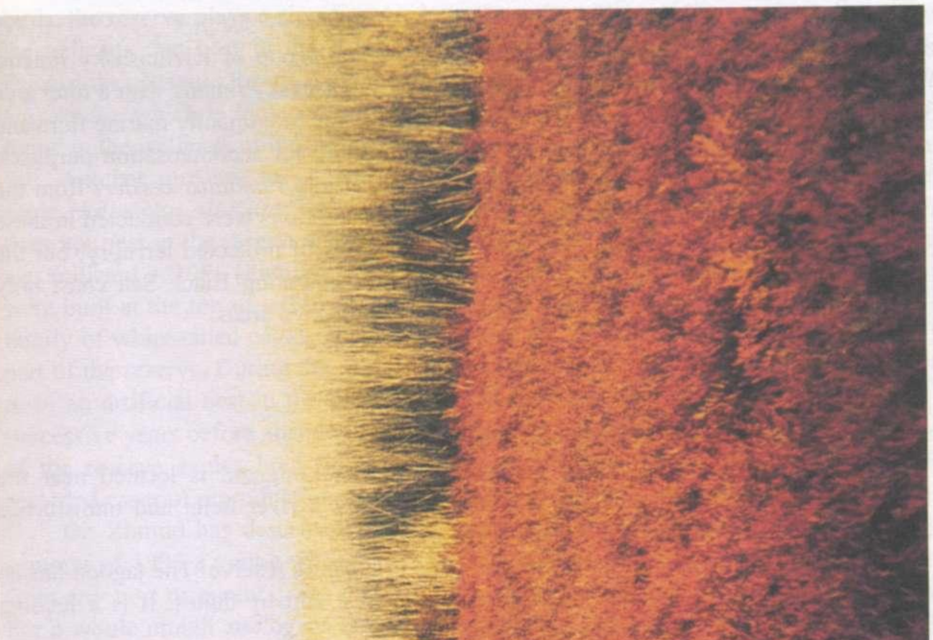
Georgia

A portion of the vast, biologically important Kolkhida Lowlands is under state protection; in particular Lake Paleostomi and the adjacent marshes and forests, which have a total area of 500 ha. Local experts believe that the protected territory is too small to maintain **a** satisfactory level of biological diversity and a normal ecosystem (Georgian National Report, 1995). Georgian scientists believe that the protected territory should be expanded. The Georgian government has recently decided to establish a protected marine zone in the Poti-Ochamchire region, which includes a highly productive shoalbank, containing the major part of the sturgeon population, wintering waters for anchovies (the Black Sea and the Azov Sea subspecies), red mullet and flounder.

Romania

The Danube delta, including the Razelm-Sinoe lake complex, which has an area of 442,000 ha, is the largest coastal wetland complex in Europe. The majority of the Danube delta is a biosphere reserve, which is protected by the Ramsar Convention and the World Convention on Natural and Cultural Heritage.

There are over 80 species of fish in the Danube delta and species such as the sturgeons and carps are very important to the local economy. Two hundred and seventy-five species of birds have been recorded here, including 175 species of nesting birds. Over 50 percent of the white pelican population *Pelecanus onocrotalus* of the entire Palearctic zone and 5 percent of the world population of the Dalmatian pelican *Pelecanus crispus* nest in the Danube delta. The mammals inhabiting the delta include the European mink *Mustela lutreola,* the wild cat *Felis silvestris,* the otter *Lutra lutra* and the wild boar *Sus scrofa.*



Black Sea Wetlands (photo: M. Wilson)

Russian Federation

The wetlands of the Russian Black Sea coast include the group of Kiziltashsky limans, consisting of the Bugazsky, Tsokur, Kiziltashsky and Vityazevsky limans with a total area of 31,300 ha. These lakes have a salinity of 22-80 %o and a predominantly marine flora and fauna. Some of them are used for farming grey mullets and for acclimatisation purposes. For example, experiments on adapting the Far Eastern shrimp *Pandalus kessleri* from the Sea of Japan and the haarder *Mugil soiuy* to Black Sea conditions were conducted in these limans. The Kiziltashsky complex does not have the status of protected territory, but the prospects for this happening are good. In the Russian Federation Black Sea coast only Lake Abrau and Sochi National Park have the status of protected areas.

Turkey

The Turkish Black Sea coast includes six main wetlands:

One of the protected territories, the Igneada Sakha Longozu, is located near the Turkish-Bulgarian border. It includes several small lakes, a river delta and undisturbed sand dunes with their characteristic xerophytic vegetation.

The Sarikum Lagoon near Sinop has the status of a nature reserve. The lagoon has an area of 100 ha and is surrounded by a flood-plain forest and by dunes. It is a feeding ground and a winter habitat for many species of birds.

Some 3,000 ha of the Kizilirmak delta has been granted the status of a hunting reserve. The Simenlik Reserve has been established in part of the Yesilirmak delta. There is a project to establish a reserve for the protection of the breeding grounds of what may be the last individuals of the monk seal *Monachus monachus,* sightings of which were reported until recently.

Ukraine

In Ukraine there are protected territories on the coasts of both the Black Sea and the Azov Sea, encompassing vast areas of marine shallow waters in addition to parts of the shore and wetlands.

The Dunaiskiye Plavni Nature Reserve is situated in the delta of the Kiliisky arm and channels of the Danube. In some areas of the delta a protection regime was introduced as early as 1967. In 1978 the total area of the reserve was increased to 14,851 ha, including 9,251 ha of dry land, 5,600 ha of water and the adjacent 500 metre wide stretch of shoreline (Voloshkevich *et al.,* 1987; Zaitsev, 1990). The reserve has a wide diversity of habitats (freshwater, river channels, channels, marshes and islands) with a corresponding biological diversity of species. Work on compiling an inventory of its flora and fauna is continuing, but even now over 1,500 species of plants and over 5,000 species of animals at all taxonomic levels have already been registered. Many animals are important commercial species, such as the sturgeon, Acipenseridae, the herring, Clupeidae and the carp Cyprinidae. The migratory routes of hundreds of species of birds from Eastern, Central and

Northern Europe cross the reserve and the Romanian part of the Danube delta. For some birds, the reserve plays a significant role in the preservation of their species. For example, the pelicans that nest in the Romanian part of the Danube delta regularly feed in the Dunaiskiye Plavni Reserve. Europe's largest colony of nesting spoonbill *Platalea leucorodia,* which is included in the Ukrainian Red Data Book of endangered species, is found in the wetlands of the reserve's buffer zone.

Another rare species inhabiting the Dunaiskiye Plavni Reserve is the white-tailed eagle *Haliaeetus albicilla,* which is also internationally protected. The white-tailed eagle does not nest in the reserve but a programme to return a nesting population to the reserve was initiated in 1985 (Zhmud, 1995). Four artificial nests, each with a diameter of 1.8-2 m, were built at the top of tall trees. For three years the nests remained vacant, but in 1989 a family of white-tailed eagles occupied one nest on a forest-covered island in the southern part of the reserve. During the same season another family of eagles built a nest within 50 m of an artificial nest in the northern part of the reserve. They reared offspring for two successive years before abandoning the nest and only returned in 1995. In the southern part of the reserve eagles bred in the artificial nest almost every year. There were seven recorded cases of reproduction, and ten young birds successfully left the nest.

Dr. Zhmud has described another incident associated with this rare species. In the summer of 1995 a young white-tailed eagle chick that could barely fly, but was far away from any nest or parents, was picked up by Kiev zoologists in the vicinity of Chernobyl. For a whole month zoologists nursed the chick as it gradually gained in strength. Later it was brought to the Dunaiskiye Plavni Reserve and set free. After a while it was seen accompanied by an adult couple which started to take care of it.

White-tailed eagles regularly nest in the Danube Delta Biosphere Reserve, Romania, especially in the Letea forest. While hunting, these birds often cross state borders, which makes it extremely important to co-ordinate the work of the two adjacent reserves.

In addition to the Dunaiskiye Plavni Reserve, the following nature protection institutions are also located on the Black Sea coast of Ukraine: the Tiligulskaya Peresyp Seasonal Reservation for nesting birds; the Black Sea Biosphere Nature Reserve, which has an area of 87,348 ha in the vicinity of Yagorlytsky and Tendrovsky bays; the Cape Martyan Reserve, which has an area of 240 ha, on the southern coast of the Crimea, and the Karadagsky Nature Reserve, which has an area of 2,855.1 ha, in the eastern Crimea. The Black Sea coastal waters adjacent to these reserves are also protected.

The protected regions of the Azov Sea include 45,700 ha of the Sivash Lagoon and a 154 ha section of the Krivaya spit, which hosts one of the largest colonies of the stilt *Himantopus himantopus.*

Remedial Actions

It is not realistic to hope to restore the entire Black Sea to the same state as it was in the 1950s. The same holds true of the commercial fishing resources.. However, it is quite realistic to bring about a substantial improvement in some biological parameters, including biological diversity, given the corresponding scientific research, technical means and the ability to act not only on a national, but also on an international level; and thus to restore the populations of species with a transboundary distribution.

Most of the negative changes that have taken place in Black Sea ecosystem are the result of the degradation of living conditions for different populations, species or biocenoses. This is why redeeming such biological losses is possible only through the improvement of habitats. This is called the "ecosystem approach" to the protection of wild nature.

However, the question often arises as to whether the Black Sea is a single or several ecosystems. In 1980 M. E. Vinogradov preferred to call a book "The Ecosystems of the Pelagic Zone of the Black Sea", but subsequent books, published in 1987 and 1992 respectively, had been called "The Modern State of the Black Sea Ecosystem" and "The Black Sea Ecosystem".

Which of the titles is correct? The answer is of fundamental importance, for any action to protect nature must have a concrete aim: e.g. who or what should be protected, from whom or from what and where should protection take place?

The term "ecosystem" may mean different things to different authors, but the idea is the same: the community of organisms and the non-living environment functioning together as an ecological system (Odum, 1971; Lincoln ***et ai,*** 1985; Gilyarov, 1986 (ed.); Dediu, 1989). There may sometimes be some confusion when marine ecosystems are referred to in scientific literature, as happened with the titles of the above mentioned books. However, a deeper analysis shows that these apparent contradictions are misleading; in fact all the titles are correct.

A **dying Mnemiopsis at the bottom. The dead animal is decomposed by bacteria in the water and of organic substances.**

For example, the entire Black Sea is the habitat of the dolphins. Therefore they belong to the common Black Sea ecosystem. The same is true of dozens of species of pelagic fish that migrate through the entire sea. The shelf, with its circular configuration, is the only habitat for turbot, gobies, flounder and the entire benthos, which is why these bottom-living organisms belong to the shelf ecosystem. The latter, in turn, is divided into smaller ecosystems, each with specific living conditions and a specific set of organisms that populate them. The ecosystem of the deep-sea shelf, for example, is characterised by low water temperatures and cold-water organisms such as the sponge *Suberites carnosus*, the mollusc *Modiola phaseolina* and the fish *Merlangius merlangus euxinus.* On the other hand, there are ecosystems in shallow sea areas, deltas, limans and estuaries, each with its own type of sediments, other natural conditions and its own set of water organisms.

In the present work the authors have adopted the following hierarchical classification of Black Sea ecosystems according to the level of their organisation and the complexity of their functions (Golubets, 1982 with addenda):

1. A monocoenotic level or a elementary ecological system. Represented by a single biocoenosis with a dominant (key) species and their physical environment interacting as an ecological unit. Examples: *Phyllophora* community, *Cystoseira* community, *Mytilus* community and *Zostera* community.

2. A polycoenotic level. Represented by several biocoenoses with their environment. These may become established in relatively homogeneous areas of a water body or entire small reservoirs which have common characteristics in their structural and functional organisation. This level is represented by the ecosystems of sand, rock and mud sections of the shelf, of lagoons, limans, estuaries, deltas, etc.

3. The biogeosystematic level. Its structural and functional organisation relies heavily on lateral interecosystem connections. Examples: ecosystem of the shelf; ecosystem of the pelagic zone.

4. A landscape geographical level. Its structural and functional features determines large-scale shifts of bodies of water that occur because of both local and planetary factors, and the exchange of elements and energy between the water and the atmosphere. The entire Black Sea is attributed to this level of organisation.

All these chorologic and hierarchical categories of ecosystems exist in nature, which is why it is equally accurate to refer to both a Black Sea ecosystem and Black Sea ecosystems.

In terms of the Black Sea plants and animals that need protection, it should be emphasised that in the initial stage it would be appropriate to work with key species, the nuclei of consortia. The fate of such species is essential to the fate of the dozens of other species that are linked to them by the above mentioned connections. That is why the elevation of the ecological status of the former (for example, from endangered to rehabilitated) automatically leads to positive changes in the populations of the latter.

The ecological status of the Black Sea eelgrass population inhabiting sandy shallow-water bays is considered to be relatively good. Growth of this sea weed is only at risk in locations where there is sand extraction or where there are discharges of waste water containing herbicides from rice paddies. To maintain the ecological state of the eelgrass biocenosis on the present level, it is essential to remove the main negative factors affecting it. Thus, the extraction of sand should be restricted to locations from which currents cannot carry suspended silt particles to eelgrass fields, and rice paddies should have a closed cycle and not release untreated water into the sea.

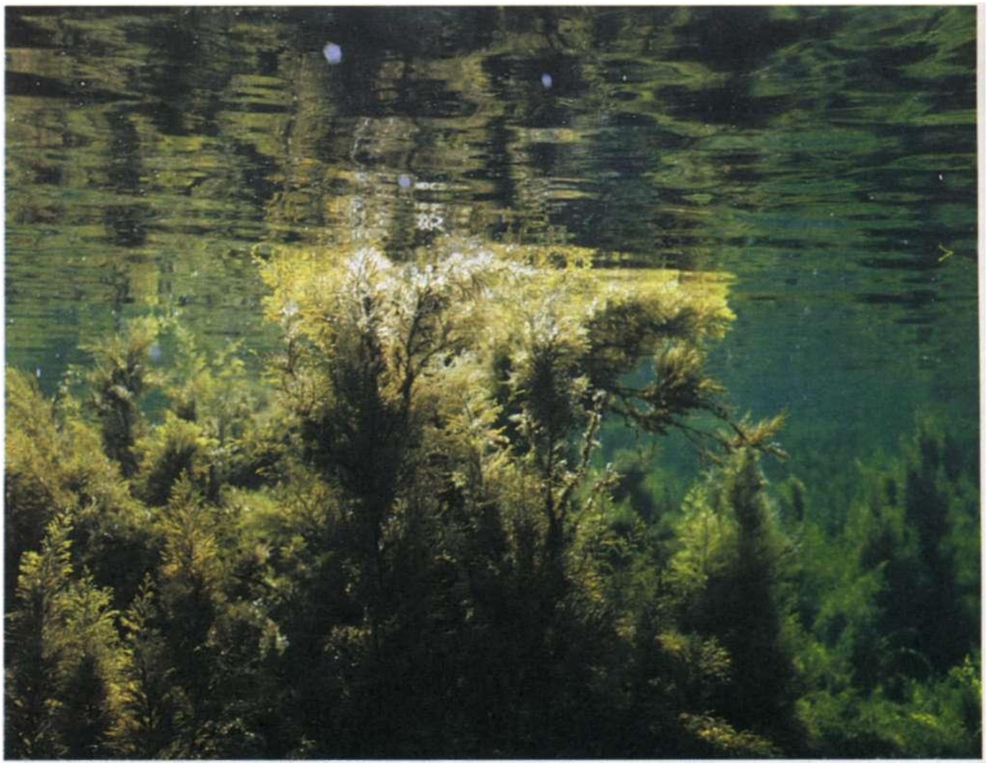
The shrimp *Crangon crangon* is a preferable food of turbot and sturgeons.

The *Cystoseira* inhabiting the rocky coast areas is very sensitive to eutrophication, which is why this alga and its biocenosis have disappeared from the north-western shores of the sea near Ukraine and Romania. On-shore sources of eutrophication have to be controlled if populations of this alga are to be restored. One such source is untreated municipal waste from major cities which is dumped into the coastal zone of the sea.

The Jask of restoring the *Phyllophora* biocenosis is far more wide-reaching and complex. Scientists have recorded a relative improvement in the transparency of sea water during the last three to four years. However, further improvement will be directly dependent on the successful implementation of the Environmental Management Plan for the Danube basin and future similar efforts for other major rivers (Mee, 1992). It is important not just to wait for Black Sea ecosystem to restore itself, but to take the necessary preventive steps such as announcing a five-year moratorium on harvesting *Phyllophora* and prohibiting the use of all bottom fishing equipment in the areas of Zernov's *Phyllophora* field. (Black Sea Strategic Action Plan, 1996)

Another countermeasure could be to introduce complete protection for part of the "small" *Phyllophora* field to the east of **33**°10' E in Karkinitsky Bay, where, the *Phyllophora* biocenosis continues to inhabit depths of less than 10 m. where there is enough sunlight for normal photosynthesis. However, due to a transfer of *Phyllophora* harvesting into the "smaller" field, it is now in danger of over-exploitation. The establishment of a nature reserve would protect the "smaller" field from excessive exploitation and create a reserve fund which may eventually help to restore Zernov's *Phyllophora* field.

The hermit crab *Diogenes pugilator* is one of endangered species of Black Sea shallow waters.



The brown alga *Cystoseira barbata* forms a belt in shallow water. A *Cystoseira* meadow is a Cystoseira biocoenosis, containing several dozen epiphytic algae, invertebrates and fish. This community is disappearing in eutrophicated marine waters.

The mussel *Mytilus galloprovincialis* is widespread at depths of up to 40-50 m on the Black Sea shelf. The largest aggregations can be found at depths of up to 20 m. *Mytilus* is the consortium nucleus (key species) of the mussel biocenosis, which contains over 130 macrozoobenthic species. But the current total mussel biomass does not exceed 30 percent of the levels recorded in the 1960s. The main reason for these dwindling reserves is the annual mortality of a large part of the population due to a lack of oxygen in the bottom layers of water caused by eutrophication. Among the protection measures that are needed to preserve the mussel are reducing the eutrophication of the marine habitat, limiting catches of mussels using bottom fishing equipment, and introducing mussel farming in shallow-water regions of the sea not subject to hypoxia. (TDA, 1996)

The oyster *Ostrea edulis* is not the nucleus of its own biocenosis, but forms part of other communities. Oysters that are attached to rocks form part of the *Cystoseira* or mussel biocenosis. Oysters that grow on the bottom may also be part of the *Mytilus,* or *Venus* biocenoses. The oyster's commercial importance necessitates its protection. The oyster population has suffered a sharp decline in recent decades. In 1932 the number of oysters in Karkinitsky Bay was estimated at 500 million individuals (Nikitin, 1940). By the early 1960s there were 47 million individuals in Karkinitsky Bay, and another 6 million in Yegorlitsky Bay (Ivanov, 1962). The authors estimate that by the 1980s the total number of oysters on the north-western shelf of the Black Sea did not exceed 2-3 million individuals. Hypoxia is not the main reason for this sharp decline, since oysters predominantly inhabit areas above the boundary of the mortality zones on the north-western shelf. It seems that the mobilisation of bottom sediments as a result of sand extraction and the use of bottom trawls has been the decisive factor. Oysters cannot tolerate turbid water and die even during strong storms. Oyster protection measures should therefore include halting all activities that produce extra turbidity in areas with dense oyster populations, including oyster farming areas. Moreover, like other species in need of protection, oysters must be included in the Black Sea Red Data Book which the BSEP has proposed creating.

Molluscs of the genus *Hypanis* belong to endemics and Pontian relics. There are nine such species in the Black Sea and the Azov Sea. The most abundant are *Hypanis caspia grossui, H. colorata* and *H. plicata relicta.* All molluscs of this genus inhabit limans and estuaries in the north-western shelf with the freshest water. They are an important food source for marine and brackish-water bottom-living fish in the Black Sea and the Azov Sea, such as gobies, sturgeons and flat-fish. The reason for a drop in the population of these molluscs is the general deterioration in living conditions in estuaries, limans and deltas as a result of multiple pollution.

There are some 40 species of Decapoda (shrimps and crabs) in the Black Sea. The populations of many of them have declined as a result of deteriorating living conditions (hypoxia, deposition of silt, pollution, etc.). Most of species of Decapoda should be included in the Black Sea Red Data Book, and their habitats should be improved in general, i.e. eelgrass areas, sandy shallow-water areas and the biocenoses of mussel and *Cystoseira.*

Almost all of the fish of the Black Sea shelf need protection, and mass mortalities are the primary threat. Gobies *(Gobiidae)* are one of the most numerous families of bottom-living fish, with up to 30 species and subspecies. The populations of 20 species have dropped substantially, sometimes by over 50 percent. These include such commercial and endemic fish and relics as *Mesogobius batrachocephalus, Neogobius cephalarges, N. fluviatili,* and *N. melanostomu.* Apart from hypoxia, gobies are very susceptible to the destruction of their breeding grounds as a result of hydrotechnical works, sand extraction or deposits of silt. Measures should be taken to protect these breeding grounds. The construction of artificial reefs in sandy shallow-water areas has a noticeably positive effect on the fish of this family and should therefore be encouraged.

Other commercial bottom-living fishes, such as sturgeons, flounder and turbot also need protection. Along with improvements in their living and breeding conditions, it is essential that international agreements be concluded which specify locations and catching methods as well as catch quotas for each of the Black Sea countries. These rules should also apply to pelagic fish, such as anchovy, sprat, horse mackerel and shad, that undertake transboundary migrations to breeding, feeding and wintering areas.

The sharp reduction in the populations of the three species of Black Sea dolphins means that they are currently not caught on a commercial basis. However, there have been repeated cases of dolphins becoming entangled in fishing nets and drowning. As the final link in the marine food chain, dolphins also die from high concentrations of toxic elements that accumulate in their bodies. In the last 20 years the corpses of dolphins floating on the surface of the sea have become a common occurrence. The success of efforts to restore the population of dolphins depends both on an improvement in the quality of Black Sea habitats and on special international actions to protect them in their feeding and overwintering areas.

The monk seal occupies a special place among Black Sea mammals. Only few individuals of this universally protected species remain in the Black Sea today. Two individuals have been observed near the Turkish coast (Turkish National Report). In the summer individual seals may also be found in the Danube delta, an area which is very abundant in fish resources. As with the dolphins, the accumulation of toxic elements in the bodies of monk seals is one of the reasons for the catastrophic reduction in their population in the Black Sea. However, the primary reason is the near total absence of desolate areas of the shore with underwater caves where these animals prefer to mate. Vacationers and tourists have driven the seals away from most of their usual habitats (Fig. 21). For that reason, the few remaining sections of the Black Sea coastline that are suitable for the breeding should be taken under strict control. The Turkish proposal to establish a protected zone for monk seals along part of the Anatolian Black Sea coast (Turkish National Report) deserves wholehearted support. It is interesting to note that Ukraine suggested that Zmeiny Island was suitable as a sanctuary for restoring the population of the monk seal (Ukrainian National Report).

Many species of the plants and animals which inhabit the coastal wetlands are in need of protection. They include algae, invertebrates, fish, amphibians, reptiles, birds and mammals, many of which are included in National Red Data Books or lists of endangered species. The main reasons for their decline are the marked changes in the environment, overfishing and overhunting.

Positive results are achieved when nature reserves are established in the coastal wetlands. But their number and the area they occupy along the Black Sea coastline are insufficient. It is imperative that the network of nature reserves be expanded. Moreover, since the majority of species of fish, birds and other animals have a transboundary distribution, measures to protect them should be implemented at an international level. It is therefore essential that the ecological status of protected species be harmonised throughout the different Black Sea countries.

The creation of a Regional Red Data Book for the Black Sea and the coastal wetlands will greatly assist all the species that are in need of protection and would consolidate efforts to manage the biological diversity of the region.

Another important activity is the development of an Ecological Network in the Black Sea region. This Network will include protected areas, reserves and corridors, which are of great importance for migrating birds.

I. Black Sea Strategic Action Plan

Correcting the decades of destructive use of the Black Sea is a task which will require a huge initial effort during the next decade, to be followed by sustained action on a permanent basis. If governments are to make a commitment to cleaning up the Black Sea, they need reliable information on the causes of the problem and must work together to find the most appropriate long-term strategy for solving them. More than a piece of paper with a theoretical scheme for cleaning up the environment, such a plan has to be a pragmatic and unambiguous statement of common goals and objectives and the means of their achievement. The adoption of a strategic Black Sea Action Plan at a Ministerial Conference on 31 October 1996 was the culmination of three years of BSEP activities.

The first step in creating the Black Sea Action Plan was the completion of a systematic scientific analysis of the root causes of environmental degradation in the Black Sea. Which sectoral activities cause the degradation and how serious is it? What are the information gaps, policy distortions, institutional deficiencies? Information on stakeholders and public involvement was also essential so that economic and social aspects could be included. The analysis of root causes, termed a Transboundary Diagnostic Analysis (TDA) (Annex I), was completed on 22 June 1996. The document was prepared by a group of sixteen leading specialists, drawn from fourteen countries including all six Black Sea countries, together with the PCU specialist staff. They analysed the thematic reports based upon the work of over 100 Black Sea specialists cooperating through the BSEP network. The results were condensed into a series of analytical tables which were employed as a basis for the preparation of the Strategic Action Plan itself.

The results of the TDA clearly demonstrate that the Black Sea environment can still be restored and protected. The BSEP pollution surveys revealed that the Black Sea is not a "deadly soup of toxic waste", as suggested by one international newspaper in 1993. Indeed, contamination by heavy metals and pesticides appears to be limited to a few sites near coastal sources. Furthermore, levels of radionuclides do not represent a health hazard. As mentioned earlier (see 3.2), eutrophication, oil pollution and coastal sewage are more serious problems and require the most urgent action. In order to identify the origins of pollution, careful studies were made of every significant discharge of liquid waste into the Black Sea and the cost of reducing or eliminating the most important sources. Some of the sources can be cleaned up simply by employing more efficient and cost-effective technology; others require investments as large as tens of millions of dollars. Particularly urgent attention needs to given to improving sewage treatment in all six Black Sea countries if human health is to be better protected and the tourist industry fully developed. In the case of nutrients, well over half the load to the Black Sea is transported by the

Danube river. A significant reduction in the problem of eutrophication will require the joint efforts of all seventeen countries of the Black Sea basin.

The TDA examines immediate measures for the protection of the fragile parts of the Black Sea ecosystem. It recommends the urgent creation of a system of protected areas as well as urgent measures to rationalise the exploitation of depleted fish stocks. Furthermore, it shows how aquaculture and tourism can be developed in an environmentally sustainable manner in order to revitalise the Black Sea economy at the same time as protecting the environment. It also highlights the need for a better regulatory framework in all six countries and better involvement of the public in general.

What Can the Strategic Action Plan Achieve?

The Black Sea Strategic Action Plan represents a joint statement of commitment by six governments who are convinced of the need to protect and restore the environment. The ultimate long-term objective is:

> *to enable the population of the Black Sea region to enjoy a healthy living environment in both urban and countryside areas, and to attain a biologically diverse Black Sea ecosystem which includes variable and sustainable natural populations of higher organisms, including marine mammals and sturgeons, and which supports livelihoods engaged in sustainable activities such as fishing, aquaculture and tourism in all Black Sea countries.*

Why marine mammals and sturgeons? Marine mammals and sturgeons are the largest animals sustained by the Black Sea. Their presence is more than symbolic. Both need a healthy, unpolluted and diverse Black Sea ecosystem. Dolphins depend on a healthy connection of the Black Sea to the world's oceans, and sturgeon depend on clean rivers for breeding, as well as a clean Black Sea for feeding and growing. The message is a clear one: the Black Sea offers opportunities for human development in co-existence with its most sensitive ecosystems.

The Strategic Action Plan contains detailed measures for achieving this noble objective in a stepwise and affordable manner. It also makes a powerful request to the Danube basin countries to cooperate by reducing the nutrient loads from agriculture, industry and domestic sources which eventually flow to the Black Sea. Concrete common measures are to be taken in the areas of the reduction and monitoring of pollution, living resources management and sustainable human development.

The Black Sea governments and NGOs cooperated effectively in the design of the Strategic Action Plan. The concept of strengthening existing conservation areas and designing new ones has been warmly embraced. A first large marine conservation area will be created shortly to preserve an area of the north-western Black Sea shelf (near the Ukrainian coast), where the remaining underwater meadows of *Phyllophora* are located. Better wetland management schemes are also planned in all Black Sea countries. In the management of fisheries, which are considered an integral part of the ecosystem, countries are urged to complete the negotiations for a new Black Sea Fisheries Convention and to adjust fishing efforts to the status of the stocks by introducing regional licensing arrangements and a quota system.

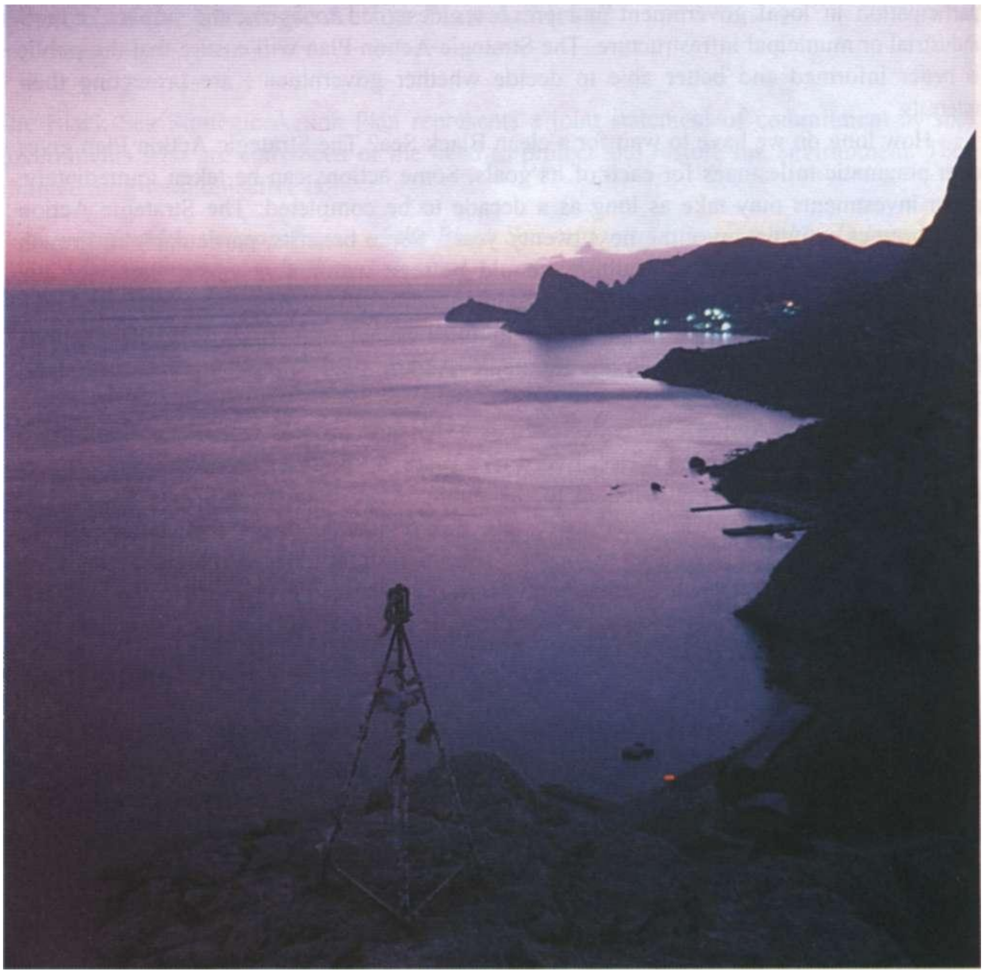
One notable feature of the Strategic Action Plan is the concern for the preservation of the Black Sea landscape. This can be achieved through the adoption and implementation of proper coastal zone management policies, designed to curb unplanned development, and through the creation of a regional strategy for conservation areas. The role of public participation is also stressed, not only through increased awareness of the "real challenges" of protecting and managing the natural environment, but also through active participation in local government and processes designed to assess the impact of new industrial or municipal infrastructure. The Strategic Action Plan will ensure that the public is better informed and better able to decide whether governments are protecting their interests.

How long do we have to wait for a clean Black Sea? The Strategic Action Plan gives clear pragmatic milestones for each of its goals. Some actions can be taken immediately; major investments may take as long as a decade to be completed. The Strategic Action Plan foresees activities over the next twenty years. Some benefits, particularly in growth areas such as tourism and aquaculture, should be seen within five years. Certainly, the control of eutrophication, which requires the cooperation of seventeen countries, will take much longer. Some of the endangered communities cannot wait for two decades; actions for their protection proposed in the Strategic Action Plan should start immediately, otherwise it will be too late.

The Black Sea Action Plan is designed as a dynamic process which can be adjusted from time to time as the need arises. Every five years, a "State of the Black Sea" report will be issued and widely distributed to the public. Consultations and new Ministerial Conferences will be held in order to review progress and correct the course. Donor conferences will also be organised to increase financial support. The Strategic Action Plan will be coordinated by a small international secretariat managed by experts from the Black Sea region and continuing to cooperate with the wide network of specialist institutions and NGOs established by the BSEP.

Towards a Sustainable Future

The sustainable development of the Black Sea will require continued, even enhanced, international cooperation. The Black Sea Strategic Action Plan, together with the Bucharest Convention and Odessa Declaration, will form a comprehensive framework for sustainable regional management. However, success will depend on the thorough implementation of the actions and commitments contained in these agreements. Governments will have to give priority to implementing and enforcing existing laws and policies, and urgent investments will be required. Black Sea coastal and basin countries will need to reaffirm their joint commitment to reducing pollution and over-exploitation of the sea's biological and aesthetic resources. The international community will have to contribute effectively and in a coordinated manner. Perhaps most important of all, local communities will need to see for themselves how their efforts can contribute to a better future. Their sense of pride and ownership will have to be restored. Only in this way will the Black Sea be able to serve as the keystone for the sustainable development of the surrounding coastal economies. Sharing responsibility is more difficult than exchanging blame. Yet, with a concerted effort, the beauty and richness of the Black Sea can be enjoyed by present and future generations alike. We hope that this book will make a small but significant contribution to these noble aims.



Black Sea coast near Sudak (photo: S. Krivokhijin)

Annex I

Black Sea Transboundary Diagnostic Analysis

Fisheries Issues: Status of Stocks and Management of Wild Resources

The following considerations have been developed from information collected, and evaluations performed during fisheries working groups of the General Fisheries Council for the Mediterranean, and through the GEF Fisheries Activity Centre in Romania. They do not pretend to provide a definitive plan of action for Black Sea fisheries. This will have to be developed through more extensive technical consultations between country specialists. It does however provide some main options available at this time for working towards a reconstructed fishery resource base, which places due emphasis on the need for rebuilding of resources where depleted, and opinions that could be taken into account in any joint management action on transboundary fishery resources.

It is clear that the main resources of the Black Sea are transboundary in nature and require cooperative actions. Recent collapse of the fisheries is directly connected with degradation of the water quality and destruction of spawning grounds, opportunistic settler's outbreaks as well as uncontrolled fisheries practices. However, to date, there has been no international agreement on appropriate levels of fishing by each coastal state, and the current distribution of benefits by coastal country does not well reflect the territorial distribution of resources. It is also clear, although precise estimates of the socioeconomic impacts of the collapse of the fisheries are not available in terms of earnings and employment, that annual catch values for the fishery declined by at least $300 million from the mid 1980's to early 1990's. A replacement cost for Turkish fish meal plants alone of $20-$30 million have been estimated, and for the fleet operating in the 1980's, a replacement value of $500 million has been estimated. Much of this investment is now operating at a loss, and much worse, since it is still largely existent, particularly on the southern coast of the Black Sea, presents a constant threat to the recovery of the fishery. This argument has been made on earlier occasions, without action being taken in most countries to remove excess capacity ,although fleet size has declined somewhat in Northern Black Sea countries due to lack of funds for maintenance, as well as a shortages of funding and a fall in purchasing power of the population, and a lack of marketing facilities in others. The partial recovery of the anchovy stock in the last few years has led to a degree of complacency with respect to the state of the resources, which is completely unwarranted, as can be seen from the following tables. It is this circumstance that a less drastic approach to purchase and decommissioning of surplus fleet capacity is proposed: the placing of an upper limit on fleet capacity which is certainly well in excess of needs, but through a license limitation scheme involving all Black Sea countries, could lead to a joint effort to reduce the number of units through market mechanisms; hopefully aided by donor contributions. One tentative estimate suggests that reducing the fleet by 1/3 would generate net returns to the fisheries sector of close to $100 million annually.

The actions proposed here are not intended however to substitute for any future decisions of the proposed Black Sea Fishery Commission, it is emphasized however, that the need for action in cooperative resource management is an urgent one, and cannot be entirely postponed until the Commission is operating; however desirable it is that this should occur in the near future. It must be stressed that cooperative management on transboundary fishery resources throughout the world is based on proper scientific information and analysis, and it is followed by negotiation on overall yield and fishing effort, and appropriate shares of the allowable catch between all parties.

The following general considerations and recommendations are suggested for serious joint consideration by Black Sea countries.

1. Set progressively higher targets for use of small pelagic fish directly for human food; and progressively reduce amounts of fish going to fish meal/oil. Operational target suggested is that the proportion of small pelagic fish going to food should be no less than 50% by the year 2000.

2. We believe it is necessary to license all fishing boats over a total length of (say) 10 m, and issue them with a common Black Sea Fishing License. The number of licenses should be fixed at a level based on the fishing vessels for which there is documentary evidence of operation in the reference year of choice for each countries. No further licenses should be granted without retiring the vessel concerned permanently from the fishery. The intention is that the number of licenses should be progressively reduced during fleet renewal process. A vessel should be replaced with one of equal or lesser fishing power

3. Introduce policies to encourage reduction in the total number of Black Sea licenses and the total fishing power of the Black Sea fleets, to level where risk of economic overcapacity and biological overexploitation are reduced.

4. Encourage sale of licenses between countries with overcapacity and those with needs for fleet rebuilding or replacement (in private sector)

5. There is an urgent need to decide jointly on access areas for national fleets to avoid conflicts.

6. Any common agreement and evaluation of the resource and the fishery will depend on a common database collected and maintained in a standard way, both on the resources and the fishing fleets.

7. There is an urgent need for an equitable system of allocations of either fleet capacity and quotas by fleet/country

B.l.l Summary Tables by Ecological Category of Resource: *The following tables are arranged by ecological category* ^

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Resource Category: *Small Pelagic fish*	State of Stocks	Ecological /Environmental Controls	Fisheries Management Measures	Operational Targets
General comments	Believed that stock size of most small pelagics has partially recovered from Mnemiopsis-caused depletion which began in the early 90's	1. Consider feasibility of keeping Mnemiopsis biomass in check by keeping planktivore biomass high; especially for horse mackerel, believed to be predator on Mnemiopsis. 2. Important to reduce eutrophication of Black Sea. and hence reduce competitiveness of Mnemiopsis	There is an urgent need to decide on a common method of control of fleet size and catch, and decide on access, national allocations of catches, and fishing opportunities.	1. In the absence of a fully operational Black Sea Fisheries Commission, the countries of the region should seek to agree on stock assessments and allocations. 2. They should meet annually to discuss coordinated plans for fishing and for research surveys. 3. A system of arbitration of disputes will be required
Sprat	Have remained high, especially in N./W Black Sea	As above	Could allow some moderate expansion of fisheries for human food	1. See above considerations for use of fish for food, and license limitation. 2. Agreement on level of catch should be made between national authorities made after cooperative acoustic survey and annual meeting of assessment scientists Assistance with regular fishery survey activities of national fleets (fuel, equipment) $400,000 for 3 years; starting 1997-8
Whiting	Ditto	Careful to avoid overfishing of a key prey species for predators such as turbot.	Ditto (by-catch in sprat fishery as well as directed fisheries)	Ditto
Anchovy	Some stock recovery, but restricted by uncontrolled	As for general comments	Negotiate internationally, and introduce, catch or trip limits on national	Ditto (Aim to increase stock size and reduce exploitation rate to achieve

	exploitation. (Evidence of some profound changes in age at maturity and area of spawning as a result of Mnemiopsis)		level	age composition comparable to early I98(fs. with more older fish in the stock) Training of fisheries assessment and management personnel: 6x $30,000 = $180,000 (scholarships/study tours): starting 1998
Horse mackerel	some recovery?	Predator on Mnemiopsis?	Allow only incidental catches	Ditto Aim to double stock size by 2005.

Resource Categories: *Demersal Fish*	State of Stocks	Ecological/Environmental controls	Fisheries Management Measures	Operational Targets
Turbot	Declining to seriously depleted levels	Environmental conditions of shelf waters restrict stock recovery.	1. Essential to decide on national fishing zones	An agreement on joint policing of fishing management measures for turbot should be approached.
			2. Priority to recreational/hook and line fisheries. 3. Consider banning . in most areas, trawls and gill nets	Consider feasibility of closed fishing areas where young fish are predominant. (feasibility study and advice on management of fishery closed areas: location and policing in each country. implementation: $120.000
Spiny dogfish	Slow decline in stocks in most areas	Species relatively immune to Mnemiopsis	1. Fishing effort not to exceed current levels. 2. Take into account migrations in allocating catches	A regular coordination of fishing plans between the countries concerned is strongly recommended. (Advice on preparing a coordinated fishery management plan for a "pilot resource' is proposed for this species, involving national and international consultants: $120.000) Aim to double biomass by 2000 through appropriate joint management measures.

Resource Categories: *Anadromous Fish*	State of Stocks	Ecological/Environmental Controls	Fisheries Management Measures	Operational Targets
Sturgeons	Some species such as giant sturgeon are endangered: Others are depleted, and maintained by hatchery operations where spawning rivers are now unusable	1. Environmental conditions in home rivers, access to spawning grounds, and feeding conditions (benthos) in Black Sea, have all deteriorated . 2. Concern expressed at too high reliance on hatchery operations (and possible genetic modification through mixing with wild stocks) in areas where natural spawning grounds still exist (Danube, Georgian and Turkish rivers)	1. All fisheries for sturgeons to be placed under strict international control, after negotiation of fishing allocations in context provided by International customary law. 2. Adopt strict national measures to reduce poaching.	1. A special international scientific meeting to evaluate sturgeon fisheries and hatchery production in the Black Sea is required. 2. A survey of natural production areas for the key species of sturgeons should be carried out on a Black Sea wide -basis (by 2000, carry out surveys of 2 major spawning rivers of sturgeon and sea trout in Turkey and Georgia: $80,000 international funds. Prior agreement of host country that implementation will be funded nationally within 2000. 3. Aim to double spawning potential from natural recruitment by 2005
		3. For natural stocks, restoration of water quality in home rivers, and protection of spawning areas/runs is a priority	1. A special fishing agreement is needed between countries of Western Black Sea on allocations, in light of international customary law. 2. Stock rebuilding should be encouraged	Plans for stock rehabilitation should be agreed upon by 1998.(See above) Sturgeon spawning and feeding habitat requirements should be integrated into water quality requirements for the Danube and other rivers. (Spawning surveys of the Danube should be carried out under the Danube GEF programme)
Shad	Recovering?	Need to restore water quality in Danube.	Ditto.	Aim to double natural spawning stock by 2005.

Resource Categories: *Indicators of Ecosystem Health*	State of Stocks	Ecological/Environmental Controls	Fisheries Management Measures	Operational Targets
Red algae (Phyllophora)	**(See table B 2.1)**		**Suggest that areas of main Phyllophora beds be closed to dragged fishing gear disturbing the bottom and declared ecological sanctuaries to protect unique associated fauna**	**A marine reserve should be agreed to by 2000 in the area described on the attached map, where no bottom fishing operations with dragged bottom gears such as trawls should be allowed. This area should be kept under continuous monitoring to assess state and extent of seaweed resources.**
Artificial reefs	**Maybe used to increase plant and animal diversity and production in shallow sandy areas**	**Higher populations of mussels, fish and seaweeds may contribute to productivity of the region as well as oxygenation and detritus removal.**	**Assign access rights to local communities**	**Suggest coordinated national projects for constructing reefs in degraded nearshore areas. (Materials, design, location and cost of installation of reefs of at least 1000m2 in waters of each countries should be prepared ($30,000)-1997-8. The likely cost of implementation should be shared between country and international donor. Likely cost per reef of the order of 0.3-S2 million, depending on country- begin before 2000).**
Venus clam	**Declining in many areas**	**Indicator species of clean sandy bottom: very sensitive indicator of hypoxia of shallow shelf**	**Suggest restrict harvesting method - no dredging**	**Operational targets: enter harvesting recommendation into national legislation.**
Blue mussels	**Serious decline of**	**Indicator of bottom hypoxia**	**Suggest (hanging)**	**Designate areas for coastal**

	formerly important biofilter		aquaculture in shallow areas.	aquaculture for the private sector, and promote aquaculture products in markets as substitute for fisheries on wild stocks (Plan for promotion of aquaculture products, common Black Sea marketing organization and promotion of consumer acceptance to be developed: $20.000)- 1997
Native gray/golden mullets	stocks depleted largely due to environmental deterioration	1. Poor condition of many coastal lagoons restricts stock size. 2. Good indicator of healthy lagoon conditions/presence of oil and pesticides reduces range.	Avoid directed commercial fishery.	Draw up plans by 1997 for ecological rehabilitation of coastal lagoons. Each country to suggest one candidate lagoon, for which rehabilitation plans based on pilot sampling will be developed by 1999(5300.000). A cost sharing approach between donors and national governments will begin full scale implementation by 1999. Likely order of cost of dredging, clean up of incoming water, (biological and chemical/water treatment of the order of $1-5 million depending on size and criteria. Transboundary benefits will be reduced outflow of effluents and increased nursery grounds and production of coastal fish) Start clean up implementation by 1999. Aim to increase mullet stock size by 5 times 2005
Red mullet	Very depleted	Indicator of shallow shelf hypoxia	Fisher> moratorium: (by-catch only allowed)	All parties to discuss trawling moratorium in red mullet grounds, (assistance to national survey to evaluate mullet distribution grounds

				and draw up closure plans, implementation: $120,000)
Rays and skates	depleted?	ditto	keep fishery to low levels	
Native salmon-trout	rare	good indicator of clean, unpolluted streams	No commercial fishing	A survey of spawning beds in native streams by 1998 should determine candidates for full restoration of spawning areas. Plans for restoration of stream quality should be drawn up and implemented by 2000. (The costings are similar to those for sturgeon, with which this could be combined)
Dolphins	(See table B 2.1)			

Resource Categories: *Exploitable Species*	State of Stocks	Ecological/Environmental Controls	Fisheries Management Measures	Operational Targets
Rapana snail	Overexploited in Turkey and Bulgaria some potential in Romania.	Well adapted to eutrophic conditions	Fishery has apparently been prohibited in Turkey	1. Important export market will require steady supply 2. Because of it is suggested that national management plans be prepared for this single species fishery, and coordinated regionally. It could also be beneficial to have a common international marketing facility for this and other black sea species: (cost of developing such plans, implementation: $120,000: begin before 2000)
Mya clam	Unexploited; large biomass in some countries	Well adapted to highly eutrophic conditions (Indicator species of eutrophic near shore conditions).	Prohibit dredging (shallow muddy areas).	None
Haarder (exotic grey mullet imported from Far East in 1970's)	Expanding stock area; spreading south from Azov Sea, and beginning to produce commercial landings of several thousand tons throughout the region.	Indicator species for detritus rich conditions near shore. No apparent competition with native mullet. and is consumed by dolphins.	A coordinated decision will have to be taken as to monitor stock expansion.	Undetermined. (Suggested a committee be set up by 1998 to monitor exotic species, with an annual budget for critical investigations and meetings of $20,000)
Blue crabs	Unexploited, but potentially valuable	well adapted to eutrophic conditions	None	Undetermined
Sandlance and Silversides	Unexploited resources now present at much higher biomasses than formerly	Indicators of higher planktonic productivity	None	Undetermined

Resource Categories: *Seasonal Migrants*	State of Socks	Ecological/Environmental controls	Fisheries Management Measures	Operational Targets
Mackerel	Stock heavily fished throughout Mediterranean, Aegean, Marmara, and drastic reduction of immigration into the Black Sea, where it is caught almost exclusively in waters fished by Turkey. It is not clear whether lack of catches in N and W Black Sea is due to penetration north, or lack of fuel for fisheries in countries in transition. A joint stock assessment by countries fishing this stock throughout its range is essential.	1. This species is considered an important potential predator of Aurelia jellyfish and likely also, Mnemiopsis. Its abundance in ihe past was also linked to abundance of the next two species for which it is an important prey. 2. It is important that passage of this and following migrator)' fish species be assured through fishways such as Bosphorus.	Especial ly important that cooperative decisions be made by exploiting countries on stock allocations.	An international working group should attempt to assess this and following stocks throughout their range, with the intention of restoring stock size to higher levels, (assistance to a working group on migratory pelagics: $20,000: 2 meetings).
Bonito	Ditto	Top predator of small pelagic fish	Ditto	Ditto (gill nets for this species may lead to marine mammal bycatch). Cost of monitoring programme for bycatch from fisheries operations: $15,000 per year for 3 years, beginning 1998: $45.000)
Bluefish	Ditto	Ditto	Ditto	Ditto

B. 12 **Opportunistic Settlers**

Issue	Environmental Social impacts	Other Problems	Implementing Authority	Operational Targets Short term	Operational Targets Long Term
Opportunistic settlers	**1. Introduced opportunistic settlers e.g. ctenophore *Mnemiopsis ieidyi* has shown outbreaks and have caused negative effects on fish population and environment.** **2. Some species, which have adapted to the Black Sea environment and replaced indigenous species, are now harvested as living marine resources.**	**1. Risk of exportation of opportunistic settlers from the Black Sea into other seas.** **2. Further introduction of other opportunistic settlers into the Black Sea in the future.**	**1. Ministries of Environment** **2. Ministries of Fisheries** **3. Ministries of Transport**	**1. Monitoring of opportunistic settlers in the Black Sea ecosystem** **2. In situ/ex situ investigations on potential opportunistic settlers predators** **3. Development of effective control of ships ballast waters and fouling organisms**	**1. Manage fisheries so as to enhance populations of indigenous fish competing with or preying on opportunistic settlers** **2. International cooperation to control of unwanted exotic species in ballast water discharges (need IMO to take measures to prevent ballast discharges)** **4. Research network for monitoring of exotic species outbreaks**

Protection of Endangered Species and Their Habitats, Conservation Areas

Recent widespread changes in the biological diversity (biodiversity) of life in the Black Sea are largely due to effects of human activities. Loss or imminent loss of endangered species which have ecological and/or economic value for the Black Sea ecosystem, degradation of coastal wetlands, loss of habitats and communities, degradation of landscape are the most common examples of the response of the Black Sea ecosystem to the man activities. Species listed in Table B.2.1 below are mainly keystone species, and are at the center of communities which are highly characteristic of the local environment, and include threatened endemic as well as relict species. Those communities have dramatically decreased due to the eutrophication caused by inflow of untreated sewage from point and non point sources and otherwise polluted rivers, hypoxia caused by eutrophication, increased turbidity, inter alia due to use of various type of bottom gear, toxic pollution, over-harvesting, destruction of breeding grounds.

Table B.2.2 contains very detailed information regarding current conservation areas and their requirements for proper integration into a Black Sea network. The information, the most up-to-date available at the time of preparation of the TDA should be reviewed periodically. Together with Table B.2.1, it will form the basis of an important holistic strategy for protecting the Black Sea ecosystem.

B. 2.1 Loss or Imminent Loss of Endangered Species in the Black Sea and Its Wetlands

All group of species listed in the table hereunder were selected because of ecological and/or economic value for the Black Sea ecosystem. They include plants which are mainly keystone species, and are at the center of communities which are highly characteristic of the local environment, and include threatened endemic as well as relict species. By protecting those, it is expected that many others will also become protected, including by the creation or improvement of a number of protected areas, specified in table B.3.I. As reference against which to evaluate present population sizes, we used the population sizes for the 1960s.

Taxon	Population size and geographic range	Current legal status of protection	Main threats	Information gaps	Proposed measures in situ/ ex situ*	Implementing authority	Operational targets	Costs
Bottom plant community							Medium term (by the year 2005)	
Red algae: *Phylhphara* community (in which *Phylhphara* itself is the keystone species. providing food and shelter to about 60 animal species many of which are endemic or Ponto-Caspian relicts)	**3% of reference level on Ukrainian shelf**	**None**	**entrophication caused by inflow of untreated sewage and otherwise polluted rivers** **increased turbidity, *inter alia* due to use of various type of bottom gear**	**no quantitative data on standing crop in 1990s** **insufficient information on culturing techniques**	On the short term (2 years) **create a marine protected area as defined on the attached map. East of 33 ' 10' E** **prohibit use of all bottom gear on shelf area, in particular those zones from which water currents would import silt to the reserve** **regulate harvesting elsewhere beginning with a 5 years moratorium on**	**Ministry of EP Ministry of Fisheries of Ukraine Coastal Guard**	**maintain or restore viable populations of about 60 species including fish** **create sustainable use of the presently declining economic resource (agar production)** **improve ecological conditions of the central NWS**	**monitoring 100k $ per year** **enforcement of protection measures, use of boats. running costs and salaries of rangers - 100k $** **development of ex situ culturing techniques- 50k$**

Taxon	Population size and geographic range	Current legal status of protection	Main threats	Information gaps	Proposed measures in situ/ ex situ*	Implementing authority	Operational targets	*p*
					the shelf zone as dellned on the attached map **monitor sensitive areas to assess state and extent of seaweed beds** Medium term (by the year 2005) **reduce nutrient inputs (see section** A.1) **captive cultivation as a precautionary measure to preserve part of the gene pool***			
Brown algae: *('ysio.seiw* community (in which *(\stoseira* itself is the keystone species)	**less than** 1% **of reference level on Romanian and Ukrainian shelf**	**None**	**- eutrophication from point and non point sources and pollution**	**None**	**- reduce eutrophication and pollution by improving quality of riverin input and improve agricultural practices**	**Ministiy of** EP **and Ministry of Agriculture of Ukraine and Romania**	**- save about 40 species** **-save source of sodium alginate production**	
Commercial and/or endemic Animals								

Taxon	Population size and geographic range	Current legal status of protection	Main threats	Information gaps	Proposed measures in situ/ ex situ*	Implementing authority	Operational targets	Costs
Mo Musks								
— S c	**30 % of reference level on NWS**	**None**	**- Hypoxia by eutrophication**	**None**	**- prohibit dredging/trawl i - reduce eutrophication stimulate hanging aquaculture in shallow areas (for details see table C.2)**	**Ministries of Fisheries and Ministries of EP of Ukraine. Romania and Bulgaria**	**- rehabilitate mussel community - restore an economic resource -reduce turbidity by biofiltration**	
Oyster *[Östren eduiis)*	**less than 5% reference level, rocky coasts basin wide**	**Red Data Book listed in Ukraine**	**- Turbidity in shallow zones caused by sand extraction**	**None**	**- as proposed in the red data book - aquaculture (for details see table C.2)**	**Ministries of Fisheries and Ministries of EP of all Black Sea countries**	**- raise biofiltration to reduce eutrophication - restore an economic resource**	
***Hypunis* (3spp)**	**50 % of reference level, brackish waters in Russia and Ukraine**	**None**	**- multiple pollution**	**declining, but reason not clear**	**- reduce pollution of brackish waters**	**Ministries of EP of Russia, Ukraine and Romania**	**- save a unique genome**	
Bottom Crustaceans								
Crabs (about 14 species)	**30-50 % of reference level, shallow water shelf basin wide**	**All in red book**	**Overharvesting**	**None**	**- moratorium on harvesting**	**Ministries of EP of all Black Sea countries**	**- removal, by scavenging, of dead corpses. - reduce microbial pollution**	

Taxon	Population size and geographic range	Current legal status of protection	Main threats	Information gaps	Proposed measures in situ/ ex situ"	Implementing authority	Operational targets	Costs
Shrimps (more than 20 species)	**40 % of reference level, basin wide**	**None**	**Hypoxia Fished for bait**	**Lack of quantitative surveys**	**- regulate fishing - aquaculture recommended for largest species (e.g. Palaemon rectirostris)**	**Ministries of EP and Ministries of Fisheries of all Black Sea countries**	**- create a new economic resource**	
Fish (see table BI.I. for commercial species)								
Gohihkie **(20 species, 10 commercial, all endemic)**	**20 % of reference level. NWS**	**few species protected, 10 exploited**	**- hypoxia on bottom, destruction of breeding grounds (sand covering stony substrates for eggs)**	**- well studied group**	**- more artificial reefs needed (see table B.3) - full protection in breeding seasons**	**Ministries of EP and Ministries of Fisheries of Ukraine and Romania**	**- restore endemic population by 2005, including commercial and recreational species**	**see table on aquaculture**
Wetlands communities (see also table 1131)								
Consisting of plants. invertebrates (mollusks, crayfish. insects), amphibians, reptiles, birds and mammals in	**Variable, but declining**	**Many species already individually protected**	**draining of wetlands eutrophication and pollution mainly from non point sources overfishing.**	**dependent on groups, satisfactory for higher plants and vertebrates**	**protect such areas**	**Ministries of EP of all the Black Sea countries**	**maintain valuable communities and ecosystem services**	**see table B.3.1.**

Taxon	Population size and geographic range	Current legal status of protection	Main threats	Information gaps	Proposed measures in situ/ ex situ*	Implementing authority	Operational targets	Costs
al well over 2000 species			**overhunting**					
Marine mammals								
3 dolphins (endemic subspecies)	**5-10% of reference level, basin wide**	**No hunting allowed. but poor enforcement**	**Biomagnification of various pollutants** **accidental or illegal killing as bycatch in fisheries**	**No recent comprehensive census available**	**reduce pollution** **enforce ban on hunting** **develop a regional rehabilitation center in Batumi to raise public awareness and implement ecotourism. including in the adjacent marine dolphins park in Kolkheti (see table B.3.I.)**	**Ministries of EP and Ministries of Fisheries of all Black Sea countries**	**partial recovery of declining population by 2005 AD**	**300k ECU**
Monk seal	**few specimens left**	**fully protected. but no active enforcement**	**lack of reproduction in coastal areas** **Biomagnification of various pollutants**	**No recent comprehensive census**	**provide sufficient sanctuary area for reproduction in the Bulgarian. Ukrainian and Turkish waters** **reduce pollution** **[recovery of popoulation may no longer**	**Ministries of EP of all Black Sea countries**	**partial restoration of Black Sea population by 2010 AD**	**estimated at no less than 50k $ by country per year**

Taxon	Population size and geographic range	Current legal status of protection	Main threats	Information gaps	Proposed measures in situ/ ex situ"	Implementing authority	Operational targets	Costs
					be possible]			

B. 3.1. Conservation Areas (areas with ecosystem, landscape / seascape, habitat conservation, as well as sustainable development /human use objectives) Management Analysis

Critical Eco-systems, Land-scapes	Coverage by Protected Areas		Name and Status of Management		Legal Level of statutory Designation and Responsible Authority		Sufficiency for Conservation and Sustainable Development		Required Measures		Operational Targets	
Habitats	Count.	Existing Proposed	Category	Size in has	Desig-nation	Resp. Authority	Category	Size	Planning	Imple-mentation	Conser-vation	Human Use
Wetlands	**Ukr**	**Existing** **Danube Delta Nature Reserve**	**Nature Reserve Cat I, Ram sat Site**	**14851**	**1981 Counsel of Ministry**	**N. Acad. Science.**	**Sufficient**	**Insuff**	**Comprehensive Management Plan is required ($ 100 000)**	**Iinprovein ent of law enforcement in the reserve (US$ 40.000 for one year)**	**Ensure the integrity of the reserve. stop poaching and illegal timber exploitation. etc. immediately**	**Promotion of formal and informal education in the reserve.**
		Existing **Chemo-morsky**	**Nature Receive Cat I,**	**87350**	**1927**	**N. Acad. Sen.**	**Sufficient**	**stiff.**	**Comprehensive Management Plan is required ($ 100 000)**	**Improvcm ent of law enforcement in the reserve ($ 10 000 for one year)**	**Ensure the integrity of the reserve. stop poaching and illegal timber exploitation. etc. immediately**	**Promotion of formal and informal education in the reserve.**
		Existing **Mys Marty an**	**Nature Receive Cat I,**	**240**	**1973. by Counsel of Ministries**	**Acad, of Agr. Sen**	**Sufficient**	**stiff.**	**Comprehensive Management Plan is required ($ 40 000)**	**Im provein ent of law enforcement in the reserve ($ 5,000)**	**Ensure the integrity of the reserve. stop poaching and illegal timber exploitation. etc. immediately**	**Promotion of formal and informal education in the reseñe.**
Wetlands	**Ukr**	**Existing** **Karadag**	**Nature Receive Cat. I**	**2855**	**1979 Counsel of Ministries**	**N. Acad Sen.**	**Sufficient**	**Stiff.**	**Comprehensive Management Plan is**	**Improvein ent of law enforceme nt in the**	**Ensure the integrity of the reserve. stop**	**Promotion of formal and informal**

Critical Eco-systems, Land-scapes	Coverage by Protected Areas		Name and Status of Management		Legal Level of statutory Designation and Responsible Authority		Sufficiency for Conservation and Sustainable Development		Required Measures		Operational Targets	
Habitats	Count.	Existing Proposed	Category	Size in has	Desig-nation	Res p. Authority	Category	Size	Planning	Imple-mentation	Conser-vation	Human Use
									required ($ 50 000)	**reserve ($ 8,000)**	**poaching and illegal timber exploitation, etc. immediately**	**education in the reserve.**
		Proposed Cape Tarkhaiiku t	**Nature Receive Cat. I**	**50**	**Non specif.**	**Non specified**	**Sufficient**	**stiff.**	**Non specified**		**Produce Management Plan in one year period**	**Promote public awareness campaign**
		Proposed Bolshoy Fontan Cape	**Nature Receive Cat. I**	**20**	**Non specified**	**Non specified**	**Sufficient**	**stiff.**	**Statutory and Management Planning is required ($ 20 000)**		**Produce Management Plan in one year period**	**Promote public awareness campaign**
		Proposed Zmeniy Island	**Nature Receive Cat. I**	**1700**	**Non specified**	**Non specified**	**Sufficient**	**stiff.**	**Statutory and Management Planning is required ($ 40 000)**		**Produce Management Plan in one year period**	**Promote public awareness campaign**
Wetlands	**Bulgaria**	**Proposed Coketryse Bank**	**Managed Nature Receive Cat. IV**		**Non specified**	**Non specified**	**Sufficient**	**stiff.**	**Statutory and Management Planning is required ($)**		**Produce Management Plan in one year period**	**Promote public awareness campaign**

Critical Eco-systems, Land-scapes	Coverage by Protected Areas		Name and Status of Management		Legal Level of statutory Designation and Responsible Authority		Sufficiency for Conservation and Sustainable Development		Required Measures		Operational Targets	
Habitats	Count.	Existing Proposed	Category-	Size in has	Desig-nation	Resp. Authority	Category	Size	Planning	Imple-mentation	Conser-vation	Human Use
		Proposed Ahtapol Rsova river	**Managed Nature Receive Cat. IV**		**Non specified**	**Non specified**	**Sufficient**	**stiff.**	**Statutory and Management Planing is required ($)**		**Produce Management Plan in one year period**	**Promote public awareness campaign**
		Proposed Primorsko Ropotamo	**Managed Nature Receive Cat IV**		**Non specified**	**Non specified**	**Sufficient**	**suff.**	**Statutory and Management Planning is required ($)**		**Produce Management Plan in one year period**	**Promote public awareness campaign**
		Proposed Byala Shkorilovtzsy	**Managed Nature Receive Cat. IV**		**Non specified**	**Non specified**	**Sufficient**	**suff.**	**Statutory and Management Planning is required (Î)**		**Produce Management Plan in one year period**	**Promote public awareness campaign**
		Proposed Cape Kaliakra Kamen Briaag	**Nature Receive Cat 1**		**Non specified**	**Non specified**	**Sufficient**	**suff.**	**Statutory and Management Planing is required ($)**		**Produce Management Plan in one year period**	**Promote public awareness campaign**
Wetlands	**Turkey**	**Existing kizilirmak Delta**	**Managed Nature Receive Cat.IV**	**11000**	**1985 by Ministry of Forestry**	**Ministry of Forestry**	**Insuff.**	**Insuff**	**Comprehensive statutory and Management Planning is required ($ 100.000)**	**Improvement of law enforcement in the are**	**Ensure the integrity of the reserve, stop illegal exploitation of land and natural resources, etc immediately**	**Promotion of formal and informal education in the area**

Critical Eco-systems, Land-scapes	Coverage by Protected Areas		Name and Status of Management		Legal Level of statutory Designation and Responsible Authority		Sufficiency for Conservation and Sustainable Development		Required Measures		Operational Targets	
Habitats	Count.	Existing Proposed	Category	Size in has	Desig-nation	Res p. Authority	Category	Size	Planning	Imple-mentation	Conser-vation	Human Use
		Existing **Yesilinnak**					**Insuff.**	**Insuff**	**Comprehensive statutory and Management Planning is required <$ 100.000)**	**1mprovein ent of law enfoiceme nt in the area**	**Ensure the integrity of the reserve, stop poaching and illegal timber exploitation etc. immediatelv**	**Promotion of formal and informal education in the area**
		Proposed **Bosphorus**	**Managed Nature Reserve Cat IV**	**Not define d**	**Not defined**	**Not defined**			**Management Plan** is **required (S 100.000)**		**Production of Management Guideline within a year.**	**Promotion of formal and informal education in the area**
Wei **lands Coasts**	**Roman.**	**Existing** **Danube Delta Biosphere Reserve**	**Inretn. Cat. Biosphei Reserve and Ramsar Site**	**48040 0**	**1990 Ramsar Conventio n Secretariat and MAB**	**Ministry of Water. Forest and Environ me ntat Protection**	**Sufficient**	**Suff.**	**Comprehensive Management Plan is required ($ 150 000)**	**Improvem ent of law enfoiceme nt in the reserve { $ 80.000)**	**Ensure the integrity of the reserve. stop poaching and illegal timber exploitation and fishing immediately**	**Promotion of formal and informal education in the reserve.**
		Proposed **Siutghiol Lake**	**Nature Receive Cat. I**	**18000**	**Non Specified**	**Ministry of Water. Forest and Environ-mental Protection**	**Sufficient**	**Suff.**	**Statutory and Management Planing is required ($ 50 000)**		**Produce Management Plan in one year period**	**Promote public awareness campaign**

Critical Eco-systems, Land-scapes	Coverage by Protected Areas		Name and Status of Management		Legal Level of statutory Designation and Responsible Authority		Sufficiency for Conservation and Sustainable Development		Required Measures		Operational Targets	
Habitats	Count.	Existing Proposed	Category	Size in has	Desig-nation	Resp. Authority	Category	Size	Planning	Imple-mentation	Conser-vation	Human Use
		Proposed Techirghio 1 Lake	Managed Nature Receive Cat. IV	10000	Non Specified	Ministry of Water, Forest and Environmental Protection and Ministry of Helth	Sufficient	Sufi*.	Statutory and Management Planing is required ($ 40 000)		Produce Management Plan in one v ear period	Promote public awareness campaign
		Proposed Cape Tuzia	Managed Nature Receive Cat. IV	50	Non Specified	Ministry of Water. Forest and Environmental Protection	Sufficient	Suff	Statutory and Management Planing is required ($ 30 000)		Produce Management Plan in one v ear period	Promote public awareness campaign
Wetlands Coasts	Roman.	Proposed Cape Midya	Nature Receive Cat. I	50	Non Specified	Ministry of Water, Forest and Environmental Protection	Sufficient	Stiff.	Statutory and Management Planing is required ($ 40 000)		Produce Management Plan in one year period	Promote public awareness campaign
		Proposed Mamaia Bay	Managed Nature Receive Cat. IV	4000	Non Specified	Ministry of Water, Forest and Environmental Protection	Sufficient	Suff.	Statutory and Management Planning is required ($ 60 000)		Produce Management Plan in one year period	Promote public awareness campaign

Glossary

Alien species - (also called introduced, exotic, nonindigenous, or settler). A species that has been transported by human activity, intentional or accidental, into a region where it does not naturally occur (e.g. the soft-shelled clam *Mya arenaria,* the snail *Rapana thomasiana,* the comb jelly *Mnemiopsis leidyi* into the Black Sea).

Anadromous - Migrating from salt to fresh water, as in the case of a fish moving from the sea into a river to spawn *(e.g.* sturgeons, shad, *etc.).*

Anoxic - Pertaining to a habitat devoid of molecular oxygen; anoxia.

Anthropogenic - Caused or produced by man. Man-made.

Autochthonous - Produced within a given habitat, community or system. Indigenous.

Autotrophic - Capable of synthesising complex organic substances from simple inorganic substrates.

Ballast water - Water carried by a vessel to improve stability, or the act of adding such weight.

Benthic - Pertaining to the benthos.

Benthos - Those organisms attached to, living on, in or near the bottom.

Biocoenosis (Biocenosis) - A community or natural assemblage of organisms occupying a biotope.

Biological diversity (biodiversity) - The diversity of life often divided into three hierarchical levels: genetic (diversity within species), species (diversity among species), and ecosystems (diversity among ecosystems).

Biological indicator - An organism which is used as an indicator of chemical activity in, or the chemical composition of, a natural system.

Biomass - Any quantitative estimate of the total mass or organisms comprising all or part of a population or any other specific unit, or within a given area; measured as volume, mass (live, dead, dry or ash-free weight) or energy (calories); standing crop; standing stock.

Biota - The total flora and fauna of a given area; bios.

Biotope - The smallest geographical unit of the biosphere or of a habitat that can be delimited by convenient boundaries and is characterised by its biota.

Bloom - A sharp increase in the density of phytoplankton, benthic algae, pelagic or benthic animals.

Blue-green algae - see Cyanobacteria.

Carnivore (Carnivorous) - Flesh eating.

Chlorophyll - A green pigment, present in algae and higher plants, which absorbs light energy used in photosynthesis.

Coastal waters - Marine benthic and pelagic ecosystems which are substantially influenced by the land.

Continental slope - The portion of the continental margin that begins at the outer edge of the continental shelf and descends into the sea (ocean) depths.

Contourobionts - Water organisms and their communities, inhabiting the external biotopes of the sea: sea - atmosphere, sea - shore, marine waters - fresh waters. Due to their location, contourobionts are much more exposed to external factors than the organisms inhabiting the water column (pelagobionts).

Convergence zone - A marine or oceanic region in which surface waters of different origins come together and where the denser water sinks beneath the lighter water.

Cosmopolitan - In biogeography, having an extremely broad or global distribution (e.g. the moon jelly *Amelia aurita).*

Cyanobacteria (formerly known as blue-green algae) - A phylum of single-celled filamentous plant-like, usually photosynthetic. bacteria in which the dominant pigment (c-phycocyanin) imparts a blue, red or black colour.

Cyclonic water circulation - An anticlockwise water rotation.

Demacrophytisation - The permanent reduction of bottom macroalgae due to light insufficiency.

Demersal - Benthic organisms that can swim but spend their time on or near the bottom *(e.g.* shrimps, flatfishes, gobies, *etc.).*

Detritivore (Detritivorous) - Feeding on detritus.

Detritus - Organic remains of plants and animals colonised by bacteria. A major food source in marine ecosystems.

Divergence zone - A zone of marine or oceanic upwelling where deep water rises and spreads out over the surface.

Drainage basin (Catchment area) - An area from which water drains to a particular location such as a main river system, a lake, or a sea.

Dumping - (as defined by the London Dumping Convention) - Any deliberate disposal at sea of wastes or other matter, or any deliberate disposal of vessels or other man-made structures.

Ecology - The scientific study of the interactions of living things and their environment.

Ecosystem - A community of organisms and their physical environment interacting as an ecological unit; the entire biological and physical content of a biotope.

Endemic - Native to, and restricted to, a particular geographical region.

Epiphyte - Any organism living on the surface of a plant.

Estuary - Any semi-enclosed coastal water, open to the sea, having a high fresh water drainage and with marked cyclical fluctuations in salinity. As a tideless sea, the Black Sea does not have estuaries, but its open limans are sometimes referred to as estuaries or estuary-type limans.

Euplankton (Holoplankton) - Those organisms that are permanent members of the plankton.

Eutrophication - Enrichment of a water body with nutrients, resulting in excessive growth of phytoplankton, seaweeds and some animals. This may happen naturally but is often a form of pollution. The algal growth can smother bottom plants reducing light intensity, or cause deoxygenation of bottom layers of water.

Ex situ - Away from the original location.

Exotic species (see Alien species).

Food chain - A sequence of organisms on successive trophic levels within a community, through which energy is transferred by feeding.

Food web - The network of interconnected food chains of a community.

Fouling - An assemblage of organisms growing on the surface of floating or submerged man-made objects (such as pilings or boat-bottoms) that increases resistance to water flow or otherwise interferes with the desired operation of the structure.

Gene pool - The total amount of genetic material within a freely interbreeding population at a given time.

GESAMP - Joint Group of Experts on the Scientific Aspects of Marine Protection.

Herbivore (Herbivorous) - Feeding on plants; phytophagous.

Heterotrophic - Obtaining nourishment from exogenous organic material (all animals).

Hotspot - An area rich in total numbers of species, or an area of especially high pollutant concentrations.

Hypoxia - A state of low oxygen concentration relative to the needs of most aerobic species.

Ichthyoplankton - The ichthyological component of the plankton, typically fish eggs, larvae and fry.

In situ - In the original location.

Interstitial - Pertaining to, or occurring within, the pore spaces (interstices) between sand (sediment) particles.

Invertebrate - Any animal without a backbone or spinal column.

Katadromous - Migration from fresh water to sea water, as in the case of fishes moving into the sea to spawn (e.g. eel).

Keystone species (Key species) - A species that influences the ecological composition, structure, or functioning of its community far more than its abundance would suggest.

Liman - Former mouth of a river now covered with sea water. Open limans are connected to the sea, closed limans are isolated from the sea by a sand bar. The formation of limans is a result of the geological dipping of the earth.

Macrobenthos - The larger organisms of the benthos, exceeding 1 mm in length.

IVIariculture - Controlled cultivation of marine organisms in tanks, ponds, cages, rafts, or other structures.

Meiobenthos-Small benthic organisms that pass through a 1 mm mesh sieve but are retained by 0.1 mm mesh *(e.g.* foraminiferans, nematods, harpacticoids, newly sedimentated larvae of molluscs, etc.).

Meroplankton - Temporary members of the planktonic community.

Microbenthos - Microscopic benthic organisms less than 0.1 mm in length.

Naturalised species - An alien or introduced species that has become successfully established.

Nekton - Aquatic organisms, such as fish and squids, that are powerful enough to swim against currents.

Neuston - Organisms that occur at or just below the air-sea interface and are adapted to its specific environmental conditions.

Oxybiotic (Aerobic) - Growing or occurring only in the presence of molecular oxygen.

Pelagic zone - The water column of the sea or lake.

Perennial - Plants that persist for several years with a period of growth each year *(e.g.* brown alga *Cystoseira barbatd).*

Photic zone (Euphotic zone, Phytal) - The surface zone of the sea or a lake which has sufficient light penetration for photosynthesis.

Photosynthesis - The biochemical process that utilises radiant energy from sunlight to synthesise carbohydrates from carbon dioxide and water in the presence of chlorophyll.

Phytobenthos - Bottom-living plants; Macrophytobenthos - large bottom-living plants; Microphytobenthos - unicellular bottom-living algae.

Plankton - Those aquatic organisms that are unable to maintain their position or distribution independent of the movement of water masses.

Pontian relicts - Type of fauna that first appeared in the brackish to freshwater environments of the Pontian Age (early Pliocene) in south-eastern Europe. The survivors thus are called Pontian relicts by some; others refer to them as "Caspian fauna" because they now occupy the northern part of the Caspian Sea *(e.g.* molluscs pertaining to genus *Hypanis,* crustaceans - to genus *Paramysis,* fish - to genus *Neogobius* and others).

Population - 1. All individuals of one or more species within a prescribed area. 2. A group of organisms of one species, occupying a defined area and usually isolated to some degree from other similar groups.

Primary production - The assimilation of organic matter by autotrophs .

Production (P) - 1. Gross production, the actual rate of incorporation of energy or organic matter by an individual, population or trophic unit per unit of area or volume. 2. Net production, that part of assimilated energy converted into biomass through growth and reproduction by an individual, population or trophic unit, per unit time per unit area or volume.

Productivity - 1. The potential rate of incorporation or generation of energy or organic matter by an individual, population or trophic unit per unit time per unit area or volume. 2. Often used loosely for the organic fertility or capacity of a given area or habitat.

Red tide - Reddish-brown discolouring of surface water coloration of sea water caused by a bloom of dinoflagellate phytoplankton or other microscopically minute plants and animals.

Relic (Relict) species - **1.** Persistent remnants of formerly widespread fauna or flora existing in certain isolated areas or habitats. 2. A phylogenetic relict; the existence of an archaic form in an otherwise extinct taxon.

Salinity - The total amount of dissolved solids in parts per thousand (ppt) by weight. The degree of concentration of salt solutions.

Shelf (Continental shelf) - The edges of continental land masses, now covered with sea water; generally the most productive part of the sea.

Siltation - The settling of fine mineral particles.

Species diversity - The diversity of species in a higher taxon or a particular place; the middle, most familiar level of biological diversity.

Symbiosis - The close relationship between two organisms in proximity with one another, as a result they: both benefit (mutualism); one benefits and the other is not significantly affected (commensalism); or one is harmed (parasitism).

Systematics - The classification of living organisms into hierarchical series of groups emphasising their phylogenetic interrelationships; often used as an equivalent to taxonomy.

Taxon (Taxa) - A taxonomic group of any rank, including all the subordinate groups; taxonomic unit.

Taxonomy - The theory and practice of describing, naming and classifying organisms.

Thallus - A simple plant body which does not exhibit any differentiation into root, stem and leaves.

Thiobiotic - Those organisms inhabiting anaerobic sulphur-rich waters or sediments (e.g. sulphur bacteria, some nematods).

Trophic level - Feeding level in a food chain or pyramid; for example, herbivores constitute one trophic level.

Upwelling - An upward movement of cold nutrient-rich water from sea depths.

Waterfowl - Swans, geese and ducks. Aquatic birds with webbed feet, long necks and broad, flat beaks edged with horny lamellae.

Wetland - An area covered permanently, occasionally, or periodically by fresh or marine water up to a depth of 5 metres.

Zoobenthos - Those animals living in or on the sea bed or lake floor.

Zooplankton - The animals of the plankton.

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Alexandrov, B.G., and L.N. Polischuk, 1994. Pelagicheskie lichinki bentosnykh bespozvonochnykh severo-zapadnoy chasti Chernogo morya (Pelagic larvae of benthic invertebrates of the north-western Black Sea). Dep. V1NITI, N.592-B94, Odessa, pp. 44, (in Russian).

Almazov, A.M., 1962. Gidrohimiya ustyevykh oblastey rek (Hydrochemistry of the river mouth areas). Kiev: Acad. Sci. UkrSSR, pp. 250, (in Russian).

Almazov, A.M., 1967. Gidrokhimiya (Hydrochemistry). In: Biologiya severo-zapadnoy chasti Chernogo morya. Kiev: Naukova dumka , p. 32-43, (in Russian).

Andrusov, N.I., 1891. Predvaritel'nyi otchet ob uchastii v Chernomorskoy glubomernoy ekspeditsii 1890 g (Preliminary account of participation in the Black Sea deepwater expedition). Izv. Russk. geogr. obsh., 26, 2(5), p380-409, (in Russian).

Annenkova, N.P., 1930. Presnovodnye i solonovatovodnye Polychaeta SSSR (Fresh and salty water Polychaeta of the USSR). In: Opredelitel' organizmov presnykh vod (A key to fresh water organisms). Leningrad, 2, (in Russian)*.

Apostolov, A.M., and T.M. Marinov, 1988. Fauna na Bulgaria. Copepoda, *Harpacticoidae* (Fauna of Bulgaria. Copepoda, *Harpacticoidae).* Izd. na Bylgarska Akademiya na naukite. pp. 384, (in Bulgarian).

Aubrey D.G., Moncheva, S., Demirov, E., Diaconu, V., and A. Dimitrov, 1996. Environmental changes in the western Black Sea related to anthropogenic and natural conditions. Journal of Marine Systems, 7, p. 411-425, (in English).

Aubrey D.G., Ivanov, M., and Yu. P Zaitsev, Submitted. Hydrographic alterations and Hydrogen Sulphide in the Black Sea., (in English).

Babenko, V.G. and A. A. Kuznetsov, 1986. Ptitsy krasnoy knigi SSSR (Birds of the Red Data Book of the USSR). Moscow, Pedagogika, pp.144, (in Russian).

Babov, D.I., at al., 1970. Aktual'nye voprosy zdravookhraneniya na vodnom transporte (Actual problems of health protection in water transport). Kiev, Zdorovie, p. 51-51, (in Russian).

Bacescu, M., 1967. Decapoda. In: Fauna Republicii Socialiste Romania. Crustacea. VI(9)., Bucuresti, Rom. Acad. Sci. Publ., pp. 354, (in Romanian).

Bacescu, M., 1969. Otryad kumovye - *Cumacea Kroyer (Cwnacea Kroyer* in the Black Sea). In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna)., Kiev, Naukova dumka, II, p. 381-402, (in Russian).

Bacescu, M., 1969. Otryad mi'zidy - *Mysidacea Boas (Mysidacea Boas* in the Black Sea). In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna)., Kiev, Naukova dumka, II, p. 363-381, (in Russian).

Bacescu, M.C., Muller, G.I., and M.T. Gomoiu., 1971. Cercetari de ecologie bentala in Marea Neagra - analiza cantitativa si comparata a faunel bentale Pontice., Bucuresti, Rom. Acad. Sci. Publ., 4, pp. 352, (in Romanian).

Baranova, Z.I., and T.S. Savel'eva., 1972. Tip iglokojie - *Echinodermata* (Echinodermata - *Echinodermata)*. In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna)., Kiev, Naukova dumka, I, p. 271-291, (in Russian).

Beshevli, L.E., and V.A. Kolyaghin, 1967. O nakhodke molluska *Mya arenaria L.* (Bivalvia) v severo-zapadnoy chasti Chernogo morya (On finding the mollusc *Mya arenaria L.* (Bivalvia) in the north-western Black Sea). Vestnik Zoologii, Kiev, 3, p. 82-84, (in Russian).

Biodiversity of Bulgarian Black Sea Area. National Report, in press. Institute of Oceanology, Varna, pp. 139, (in English).

Biodiversity of Georgian Black Sea Area. National Report, in press. Georgian Institute of Black Sea Ecology and Fisheries, Batumi, pp. 50, (in English).

Biodiversity of the Romanian Black Sea Area. National Report, in press. Romanian Marine Research Institute, Constanta, pp. 323, (in English).

Biodiversity of the Turkish Black Sea Area. National Report, in press. Istanbul University, Underwater Technology Dept., Istanbul, pp.93, (in English).

Biodiversity of the Ukrainian Black Sea Area. National Report, in press. Odessa Branch, Institute of Biology of Southern Sea., Odessa, pp. 268, (in English).

Biodiversity of Water Ecosystems in the Azov-Black Sea Basin. Russian National Report, in press. Azov Sea Research Institute of Fisheries, Rostov-on-Don., pp. 156, (in English).

Birkun, A.A., and Krivokhizhin, S.V., 1996. Kitoobraznye Chernogo Morya: otsenka sostoyaniya populyatscii i problema ikh sokhraneniya (Cetaceans of the Black Sea: population status and problems of protection). In: Krimskiy muzey 1995-1996, Simferopol, Tavria Publ., p. 233-245, (in Russian).

Black Sea Transboundary Diagnostic Analysis, 1996. GEF Black Sea Environmental Programme, Programme Coordination Unit, Istanbul, pp. 104, (in English).

Bobretskyi, N.V., 1868. Shetinkonogie *(Annulata, Chaetopoda)* chervi Sevastopol'skoy bukhty (Setaceous *{Annulata, Chaetopoda)* worms of the Sebastopol bay). Trudy 1 s'ezda russk. Estestvoispytateley, (in Russian)*.

Bodeanu, N., 1969. Cercetari asupra fitoplanctonului din zona de mica adincime de la litoralul rominesc al Marii Negre (Researches on phytoplankton in the shallow-waters of the Romanian shelf of the Black Sea). Ecologie marina, Bucuresti, 3, p. 65-148, (in Romanian).

Bodeanu, N., 1978. Compozitia si dinamica fitoplanctonului si microfitobentosului din apele costiere romanesti ale Marii Negre (Composition and dynamics of the phytoplankton and microphytobenthos of coastal Romanian Black Sea waters). Doctoral thesis, (in Romanian).*

Bodeanu, N„ 1979. Mikrofitobentos (Microphytobenthos). In: Osnovy biologicheskoy produktinovsti Chernogo morya, Naukova dumka, Kiev, p. 109-122, (in Russian).

Bodeanu, N., 1984. Modifications sous l'influence anthropique dans le developement quantitatif et dans la structure du phytoplankton du secteur roumain de la Mer Noire. Trav.Mus.Hist.Nat.Gr.Antipa, Bucuresti, 26, p.69-83, (in French).

Bodeanu, N., 1987. Structure et dynamique de l'algoflore unicellulaire dans les eaux du littoral Roumain de la Mer Noire. Cercetari Marine, 20.(21), p.19-25, (in French).

Bodeanu, N., and V. Chirila, 1960. Un caz aparté de "inflorie" a apei in Marea Neagra in primavara anului 1959 (A special case of water blooms in the Black Sea). Comunicarile Academiei RPR, Bucuresti, N10(8), p. 681-686, (in Romanian).

Bogdanos, C, and A. Zenetos, 1988. Activities of the Benthos Laboratory. National Centre for Marine Research, Athens, p. 50-53, (in English).

Bogdanova, D.P., and A,S. Konsoulov, 1993. On the distribution of the new Ctenophora species *Mnemia mccradyi* in the Black Sea along the Bulgarian coastline in the summer of 1990. Comptes Rendus de l'Académie Bulgare des Sciences, 46, N.3 p. 71-74, (in English).

Borcea, I., 1936. Les Clupeides de la region littorale roumaine de la Mer Noire et des eaux •intérieures. Ann. Sc. Univ. Jassy, 22, p. 306-344, (in French).

Brayko, V.D., 1968. Klass mshanki - *Bryozoa Ehrenberg (Bryozoa Ehrenberg* in the Black Sea). In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna)., Kiev, Naukova dumka, I, p. 406-418, (in Russian).

Bulgurkov, K.I., 1968. *Callinectes sapidus* Rathbun v Cherno more *(Callinectes sapidus* Rathbun in the Black Sea), Izvest. NIORS, 9, p. 97-99, (in Bulgarian).

Caddy, J.F., 1992. Environmental management and protection of the Black Sea. Background document presented at the Technical Experts Meeting, Constanta, Romania 20-21 May, 1992. pp. 22, (in English).

Caddy, J.F., and R.C. Griffiths, 1990. A perspective on recent fishery-related events in the Black Sea. Studies and Reviews. General Fisheries Council for the Mediterranean. N.63,p. 43-71, (in English).

Carausu, A., 1939. *Clunio Marinus Hal.* dans la Mer Noire. Ann. Sc. Univ. Jassy, 25, p. 360-366, (in French).

Celikkale, M.S., Karacam, H., Duzgunes, E., Unsal, S., and H.F. Durukanoglu, 1989. Size and distribution of dolphin populations in the Black Sea. Doga Tu. J. Zoology, 13, 3, p. 189-196, (in English).

Chernyavskiy, V.I., 1867-1868. Materialy sravnitel'noy zoografii Ponta, doljenstvuyushie slujit' osnovaniem dlya genealogii rakoobraznykh (Genealogy of the crawfish of the Black Sea). Trudy 1 s'ezda russk. estest-isp., (in Russian).*

Chernyavskiy, V.I., 1882-1883. Monografiya mizid, preimushestvenno Rossiyskoy imperii *(Mysidaceas* of the Russian Empire), Trudy St. Peterburg. ob-va estest-isp., 12(2), 18(3), (in Russian).*

Chichkoff, G., 1907. Contribution a l'etude de la faune de la Mer Noire. Halacaridae des cotes Bulgares., Arch. zool. exper., 4, VII, (in French).*

Dagg, M.J., and T.E. Whitledge, 1991. Concentrations of copepod nauplii associated with the nutrient-rich plume of the Mississippi River. Continental Shelf Research, 11, p. 1409-1423, (in English).

Dagg, M.J., Ortner, P.B., and F. Al-Yamani, 1987. Winter-time distribution and abundance of copepod nauplii in the northern Gulf of Mexico. Fishery Bulletin, 86, N.2, p. 319-330, (in English).

Dediu, 1.1., 1989. Ecologicheskiy entsiclopedicheskiy slovar' (Ecological encyclopaedic dictionary). Kishinev: Glavnaya redactsya Mold. Sov. Entsyclopedii, pp. 407, (In Russian).

Degens, E.T. and Ross (Eds.), 1974. The Black Sea-Geology, Chemistry and Biology. Amer. Assoc. of Petroleum Geologists. Tulsa, Oklahoma, 633 pp.

Dekhnik, T.V., 1973. Ikhtioplankton Cherogo morya (Ichthyoplankton of the Black Sea), Kiev, Naukova dumka, pp.234, (in Russian).

Dolgopol'skaya, M.A., 1969. Otryad kalanoida - Calanoidae G.O.Sars (Calanoidae G.O.Sars), In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna)., Kiev, Naukova dumka, II, p. 34-48, (in Russian).

Drapkin, E.I., 1953. Noviy mollusk v Chernom more (A new mollusc in the Black Sea). Priroda, 9, p. 92-95, (in Russian).

Dubovskiy, N.V., 1939. Materialy k poznaniyu fauny Ostracoda Chernogo morya (Data on Ostracod fauna of the Black Sea), Tr. Karadag. biol. **St.,** Kiev, 5, p.3-68, (in Russian).

Dukina, V.V., 1969. Otryad tsiklopoida - *Cyclopoidae* G.O.Sars *{Cyclopoidae* G.O.Sars), In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna). Kiev, Naukova dumka, II, p. 48-56, (in Russian).

Filip'ev, I.N., 1922. Novye dannye o svobodnykh nematodakh Chernogo morya (New data on free nematode in the Black Sea). Trudy Stavrop. sel'skokhz. in-ta, 1(17), (in Russian).*

Finogenova, N.P., 1968. Klass maloshetinobye kol'chetsy - *Oligochaeta Grube (Oligochaeta Grube* of the Black Sea). In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna)., Kiev, Naukova dumka, I, p. 372-393, (in Russian).

Garkavaya, G.P., Bulanaya, Z.T., and Yu.I Bogatova, 1985. Znachenie sovremennogo stoka Dunaya v evtrofirovanii Chernogo morya (The contemporary Danube run-off in Black Sea eutrophication). XXI Intern. Iimnological conf. on the Danube studying, Bratislava, sentyabr' 1985, p. 194-198, (in Russian).

Garkavaya, G.P., Zaitsev, Yu.P., and Yu.I. Bogatova, 1987. Iskusstvennye rify kak factor vozdeystviya na gidrokhimicheskie parametry v pribrezhnoy zone severo-zapadnoy chasti Chernogo morya (Artificial reefs as a factor influencing hydrochemical parameters in the north-western Black sea coastal zone). In: Iskusstvenye rify dlya rybnogo hozyaistva. Tez. docl. Vsesoyuzn. conf, Moscow, p. 87-88, (in Russian).

Gilyarov, M.S.,(ed). 1986. Biologicheskiy entsiklopedicheskii slovar' (Biological dictionary). Moskva, Sovetskaya entsiklopediya, pp.831, (in Russian).

Gmelin, S.G., 1768. Historia fucorum. Petropoli, (in Latin).*

Golikov, A.N., and Starobogatov, Ya.I., 1972. Klass brukhonogie moluski - *Gastropoda* Cuvier (Molluscs - *Gastropoda* Cuvier). In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna)., Kiev, Naukova dumka, III, p. 65-166, (in Russian).

Golubets, M.A., 1982. Aktual'nye voprosy ekologii (Actual questions of ecology), Kiev, Naukova Dumka, pp.158, (in Russian).

Gomoiu, M.T., 1982. Tendinte in evolutia ecosistemelor marine costiere din partea de nord-vest a Marii Negre (Trends in the evolution of coastal marine ecosystems of the northwestern Black Sea). Simp.Evolutie si adaptare, Cluj-Napoca, p.59-73, (in Romanian).

Gomoiu, M.T., 1992. Marine eutrophication syndrome in the northwestern part of the Black Sea. In: Science of the Total Environment, Elsevier Sci., Amsterdam, p.683-692, (in English).

Grebnitskii, N.A., 1873. Predvaritel'noe soobshenie o srodstve fauny Chernogo morya s drugimi moryami (Preliminary report on the affinity of the Black Sea fauna), Zapiski Novoross. ob-va estestvoisp., 11, (in Russian)*.

Griga, R.E., 1969. Otryad garpaktikoida - *Harpacticoida* G.O.Sars.(*Harpacttcoida* G.O.Sars). In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna)., Kiev, Naukova dumka, II, p. 56-152, (in Russian).

Grinbart, S.B., 1950. Zoobentos Odesskikh limaniv (Zoobenthos of the Odessa region limans). Pratsy Odesk. Univers., 3, N.3/64, p. 5-13, (in Ukrainian).

Grinbart, S.B., 1967. Zoobentos limanov Severo-Zapadnogo prichernomor'ya I smejnykh s nim uchastkov morya (Zoobenthos of the limans of the north-western Black Sea), Avtoref.diss.dokt.biol.nauk, Odessa, pp.52, (in Russian).

Guslyakov, N.E., Zakordonets, O.A., and V. Gerasimyuk, 1992. Atlas diatomovykh vodorosley bentosa severo-zapadnoy chasti Chernogo morya I prilegayushikh vodoemov (Atlas of the diatom bottom algae of the north-western Black Sea), Kiev, Naukova dumka, pp.252, (in Russian).

Ivanov, A.I., 1965. Kharakteristika kachestvennogo sostava fitoplanktona Chernogo morya (Qualitative classification of the composition of phytoplankton in the Black Sea). In: Vodyanitskiy V.A. (ed), Issledovaniya planktona Chernogo I Azovskogo morey (Plankton studies in the Black Sea and Azov Sea). Naukova Dumka, Kiev, p 17-35, (in Russian).

Ivanov, A.I., 1967. Fitoplankton (Phytoplankton). In: Biologiya severo-zapadnoy chasti Chernogo morya. Kiev: Naukova dumka., p. 59-75, (in Russian).

Ivanov, An.I., 1962. Zapasy I raspredelenie promyslovykh moluskov (midiy I ustrits) u sovetskikh beregov Chernogo morya (Stocks and distribution of the exploited molluscs (mussels and oysters) along the Soviet Black Sea coast). In: Voprosy ekologii, 5, (in Russian).*

Ivanov, O.I., 1959. Pro masoviy rozvitok organizmiv fitoplanktonu v pivnichno-zakhidniy chastini Chornogo morya v 1954-1956 (On the mass development of phytoplanktonic organisms in the north-western Black Sea in 1954-1956). Nauk. zapiski Odeskoi biol. stant., 1, p. 6-24, (in Ukrainian).

Kabatchenko, I.M., 1985. Mezhgodovaya izmenchivost' vetra i vetrovykh voln v Chernom more (Multiannual variability of wind and wind waves in the Black Sea)., Dep. VNIIGMI MTsD, 159, Gm-D82, pp.22, (in Russian).

Kalugina-Gutnik, A.A. and O.A. Lachko, 1968. Sostoyanie zapasov i raspredelenie fillofory v rayone fillofornogo polya Zernova (State of stock and distribution of *Phyllophora* in the area of the Zernov's *Phyllophora* field). Trudy AzcherNIRO. Moskva, 27, p. 121-127, (in Russian).

Kalugina-Gutnik, A.A., 1979. Obshiy sistematicheskiy sostav i ekologicheskaya kharakteristika makrofitobentosa (Systematic structure and ecological characteristics of the macrophytobethos). In: Osnovy biologicheskoy produktivnosti Chernogo morya. Kiev, Naukova Dumka, p. 123-130, (in Russian).

Kaminskaya, L.D., 1968. Klass gubok - *Porifera* (Sponge - *Porifera).* In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna)., Kiev, Naukova dumka, I, p. 35-55, (in Russian).

Katukov, A.V., 1983. Filofornoe pole kak indikator sostoyaniya ekosistemy *(Phyllophora* field as an indicator of the state of the ecosystem). In: Sistemnyi analiz i modelirovanie proscessov na shelfe Chernogo morya (System analysis and modelling of the Black Sea shelf). Sevastopol, MHI, p. 140-145, (in Russian).

Kessler, K.F., 1860. Puteshestvie s zoologicheskoy tsel'yu k severnomu beregu Chernogo morya i v Krym v 1858 g (Zoological journey to the Black Sea and Crimea in 1858). Kiev, (in Russian).*

Khait, K.Z., and G.I. Shpil'berg., 1950. Sanitarno-bakteriologicheskoe issledovanie pribrejnoy morskoy vody i peska morskikh plyajey (Sanitary and bacterial investigations of beaches), Odessa, Gigiena i Sanitariya, 7, p. 39-41, (in Russian).

Kiseleva, M.I., 1979. Zoobentos. Sistematicheskiy sostav (Zoobenthos. Systematic structure). In: Osnovy biologicheskoy produktinovsti Chernogo morya, Naukova dumka, Kiev, p.208-209, (in Russian).

Kiseleva, M.N., 1979. Role of bottom animals in the benthic pelagic system of the Black Sea. Gydrobiological journal., 15, p.54-57, (in English).

Kleinenberg, S.E., 1956. Mlekopitayushie Chernogo i Azovskogo Morey (Mammals of the Black Sea and the Sea of Azov). Moscow, USSR Acad, of Sciences Publ, pp. 288, (in Russian).

Kobyakova, Z.I., and M.A.Dolgopolskaya, 1969. Otryad desyatinogie- Decapoda (The Decapoda order). Opredelitel' fauny Chernogo i Azovskogo morey, 2, Kiev: Naukova dumka., p. 270-306, (in Russian).

Kocatas, A., Koray, T., and M. Kaya, 1993. Review of the Fishery Resources and their environment in the Sea of Marmara. Studies and Reviews. General Fisheries Council for the Mediterranean, N.64, p. 87-143, (in English).

Konsoulov, A., 1976. Zooplankton in the Black Sea along the Bulgarian coast. Ph.D. Inst. Fish., Varna, (in Bulgarian).*

Konsoulov, A., 1990. *Leucotea Multicornis* Eschckoltz - new species for the Black Sea. Oceanology, 19, p.98-99, (in Bulgarian).

Konsoulov, A., 1992. Zooplankton structure and its distribution in the Bulgarian Black Sea coastal eutrophicated zone in summer 1991. Rapp. Comm. int. Mer. Medit., 33, p. 256, (in English).

Konsoulova, Ts., 1978. Turbellyarii *(Turbellaria)* ot Bylgarskogo chernomorsko kraybrejie *(Turbe/laria* along the Bulgarian Black Sea coast), Izv. IRR, 16, p. 87-102, (in Bulgarian).

Konsoulova, Ts., 1993. Marine macrozoobenthic communities' structure and ecological status in relation to some environmental factors. Compt. Rend. Acad. Sci. Bulg., 46(5), p. 115-118, (in English).

Koval', L.G., 1984. Zoo- i nekrozooplankton Chernogo morya (Zoo- and necrozooplankton of the Black Sea). Kiev: Naukova dumka., pp. 127, (in Russian).

Krichagin, N„ 1873. Materialy dlya fauny vostochnogo berega Chernogo morya (Data on the fauna of the eastern shore of the Black Sea), Zap. Kiesk. obshestva estest. 3, (in Russian).*

Krotov, A.V., 1949. Zhizn' Chernogo morya (Life of the Black Sea). Odesskoe oblastnoe izdatelstvo, pp. 127, (in Russian).

Kudelin, N.V., 1909. Gidroidy Chernogo morya (Hydroids of the Black Sea), Zap. Novoross. estest. 33, (in Russian).*

Kusakin, O.G., 1969. Otruad ravnonogie - *Isopoda Latreille (Isopoda Latreille* in the Black Sea)., In: Opredelitef fauny Chernogo i Azovskogo morey (A key to Black Sea and Azov Sea fauna)., Kiev, Naukova dumka, II, p. 408-440, (in Russian).

Leonov, A., 1960. Regionalnaya okeanografia (Regional Oceanography), Part. I, Leningrad, Gidrometeoizdat, 766 pp. (in Russian).

Lincoln, R.**J.,** Boxhall, G.A., and P.F. Clark 1985. A Dictionary of Ecology, Evolution and Systematics. Cambridge, London: Cambridge University Press, pp. 298, (in English).

Linnaeus, C, 1735. Systema Naturae (The system of nature). Lugduni, 13 ed., 1.1-3, (in Latin).*

Lipskiy, V.l., 1932. Iod I agar iz vodorosley Chernogo morya (Iodine and agar from Black Sea algae). Doklady AN SSSR, seria A, 3, p. 61-64, (in Russian).

Marinov, T., 1977. Mnogochetinesty chervi (Polychaeta) (Polychaetes (Polychaeta)). Fauna na Bulgaria,6. Sofia: Bulg. Acad. Sei. Publ., pp.258, (in Bulgarian).

Marinov, T., Petrova-Karadzhova, V.l., and A. Konsoulov. 1984. Sovremenno sostoyanie i nasiki na hidrobiologichnite izsledvanya v Cherno more (Recent state and direction of hydrobiological investigations of the Black Sea). Izvestiya na instituta po rybny resursi, Varna., 21, p. 55-68, (in Bulgarian).

Marinov, T.M., 1990. Zoobentos ot bulgarskya sector na Cherno more (Zoobenthos of the Bulgarian sector of the Black Sea). Sofia: Bulg. Acad. Sei. Publ., pp.196, (in Bulgarian).

Markuzen, I., 1867. Zur Fauna des Schwarzen Meeres. Arch. f. Naturgeschichte, 33, (in German).*

Mashtakova, G.P., 1971. Vliyanie materikovogo stoka na productivnost fitoplanktona v severo-zapadnoy chasti Chernogo morya (Influence of the river runoff on phytoplankton productivity in the north-western Black Sea). Perspectivy razvitiya ribnogo khoziyaystva v Chernom more, Odessa, p, 24-25, (in Russian).

Mechnikov, 1.1., 1868. Zametki o pelagicheskoy faune Chernogo morya (Notes on the pelagic fauna of the Black Sea). Trudy 1-go s'ezda russkikh estestvoispytateley, Sankt-Peterburg, 28 dek.-4 yanv. 1868 g., Moskva, p. 267-270, (in Russian).

Mee, L.D., 1992. The Black Sea in crisis: a need for concerted international action. Ambio, 21, p.278-286, (in English).

Merezhkovskiy, K.S., 1903. Spisok diatomovykh Chornogo morya (List of diatoms in the Black Sea). Bot. zap., 19, S-Peterburg, p. 51-88, (in Russian).

Merz, A., 1928. Hydrographische Untersuchungen in Bosporus und Dardanellen. Bearbeitet von: L. moller, Veroff. Inst. Meereskunde Univ. Berlin, Neue Folge, A, 18, p. 3-284, (in German).

Mihnea, P.-E., 1985. Phytoplankton diversity indices as eutrophication indicators of the Romanian inshore waters. Cercetari Marine- Recherches Marines, 18, p. 139-157, (in English).

Minicheva, G.G., 1990. Prognozirovanie structury fitobentosa s pomoshyu pokazateley poverhnosti vodorosley (Prognostication of the phytobenthos structure by means of the algae surface index). Botanichesky zhurnal. 75, N.l 1, p. 1611-1618, (in Russian).

' Minicheva, G.G., 1993. Structurno-funktsionalnye osobennosti formirovaniya soobschestv morskikh bentosnykh vodorosley (Structural-functional peculiarities of the development of marine benthic algal communities), Algologiya, 3, N.l, p. 3-12, (in Russian).

Minicheva, G.G., and T.I. Eremenko. 1993. Algologicheskie nakhodki v severo-zapadnoy chasti Chernogo morya (Algological discoveries in the north-western Black Sea). Algologya, 3, N.4, p. 83-86, (in Russian).

Mironov, G.N., 1971. Biomassa i raspredelenie meduz *Amelia aurita L.* po dannym tralovykh lovov v 1949-1962 v Chernom more (Biomass and distribution of the jellyfish *Aurelia aurita L.* according to trawl catches in 1949-1962), Biologia morya, Kiev, 24, p. 49-69, (in Russian).

Monchenko, V.I., 1974. Shelepnoroti, sciklopodobni, sciklopi (Cyclopoidae). In: Fauna Ukraini, 27(3), Kiev, Naukova dumka, pp. 437, (in Ukrainian).

Moncheva, S., 1991. On the toxicity of *Exuviaella cordata* Ost. blooming in the Black Sea. Rev.Internationale d'Océanographie, p. 124-126, (in English).

Moncheva, S., Rusev, Ch., and I. Sofronov, 1991. Vliyanie na eutrophikatsiyata varkhu biologicheskata tsiklichnost na phytoplanktonni vidove ot Balgarskoto chernomorsko krajbrezhie (Biological cyclicity of some blooming phytoplankton species along the Bulgarian Black Sea coast). Oceanology, BAS, 21, p.31-38, (in Bulgarian).

Mordukhay-Boltovskoy. F.D., 1968-1972. Opredelitel' fauny Chernogo I Azovskogo morey (Descriptive catalogue of the fauna of the Black Sea and Azov Sea). Kiev Naukova Dumka, I. 2, 3, (in Russian).

Mordukhay-Boltovskoy, F.D., 1969. Otryad amfipody ili raznonogie - *Amphipoda Latreille (Amphipoda Latreille* of the Black Sea). In: Opredelitel' fauny Chernogo i Azovskogo morey (A key to Black Sea and Azov Sea fauna). Kiev, Naukova dumka, II, p. 440-524, (in Russian).

Moroz, T.G., 1990. Formirovanie limanov i ikh klassifikatsiya (Origin of limans and their classification). In: Limany Severnogo Prichernomor'ya. Kiev: Naukova dumka., p. 5-11, (in Russian).

Moroz, T.G., 1990. Macrozoobentos limanov (Macrozoobenthos of limans). In: Limany Severnogo Prichernomorya. Kiev: Naukova dumka., p. 121-141, (in Russian).

Morozova-Vodyanitskaya, N.V., 1930. Sezonnaya smena i migrasciyi vodorosley Novorossiyskoy bukhty (Seasonal changes and migration of algae of the Novorossiysk Bay). Raboty Novoros. Biol.st., IV, (in Russian).*

Mutlu, E., Bingel, F., Gucu, A.C., et al., 1994. Distribution of the new invader *Mnemiopsis* sp. And the resident *Aurelia aurita* and *Pleurobrackia* pilieus populations in the Black Sea in the years 1991-1993. ICES Journ. Mar. sci., p. 1-15.

National Reports "Assessment of Land-Based sources of Pollution in the Black Sea". 1996. Black Sea Environmental Programme. Istanbul, Turkey.

Naumov, D.V., 1968. Class gidrozoi- *Hydrozoa* (Class *Hydrozoa).* Opredelitel' fauny Chernogo i Azovskogo morey, 1, Kiev: Naukova dumka Publ., p. 56-70, (in Russian).

Nesterova, D.A., 1977. Razvitiye fitoplanktona severo-zapadnoy chasti Chernogo morya v vesenniy, letniy i osenniy periody (Development of phytoplankton of the north-western Black Sea in spring, summer and autumn). Biologiya morya, Kiev, 43, p. 17-23, (in Russian).

Nesterova, D.A., 1979. Razvitie peridiney *Exuviaella cordata* i yavlenie "krasnykh prilivov" v severo-zapadnoy chasti Chernogo morya (Development of peridinean, *Exuviaella cordata* and the phenomenon of "red tides" in the north-western Black Sea). Biologiya morya, p.24-29, (in Russian).

Nesterova, D.A., 1987. Peculiarities of phytoplankton succession in the north-western Black Sea. Hydrobiol. J., 23, p. 16-21, (in English).

Nikitin, V.N., 1940. Ustriscy Chernogo morya i ikh promyslovoe znachenie (Oysters of the Black Sea). Rybnoe khozyaistvo SSSR, 10, (in Russian).*

Nordman. A., 1840. Observation sur la faune pontique, (in French).*

Nordman. A., 1845. Versuch einer Monographie des Tergipes Edwardsi, (in German).*

Norse, E. A., (ed.), 1993. Global marine biological diversity: A strategy for buiding conservation into decision making. Island Press, Washngton, DC, pp. 383, (in English).

Novikov, N.P., and I.I. Serobaba. 1989. Sovremennoe sostoyanie i perspektivy ispolzovaniya bioresursov Chernogo morya v usloviyakh antropogennogo vozdeystviya (Recent state and perspectives on the use of the bioresources of the Black Sea in conditions of man-made impact). In: Yuzhnye morya SSSR: geograficheskie problemy issledovaniya i osvoeniya. Leningrad: Geograficheskoe obschestvo SSSR, p. 80-89, (in Russian).

Ocean Color from Space, 1989. Prepared by the NSF/NASA, Woods Hole Oceanographic Institution, Goddard Space Flight Center, University of Miami and University of Rhode Island., pp. 7, (in English).

Odum, E.P., 1971. Fundamentals of Ecology. Third edition. Philadelphia. W.B.Saunders Comp., pp. 574, (in English).

Oguz, T., Malanotte-Rizzoli, P., and D.G.Aubrey, 1994. Wind and thermohaline circulation of the Black Sea driven by yearly mean climatological forcing. Journal of Geophysical Research, (in English)*.

Ostroumov, A.A., 1896. Opredelitel' ryb Chernogo i Azovskogo morey (Key for the fishes of the Black Sea and Azov Sea). Vestnik rybprom. 7, 8, 9, (in Russian).*

Ozturk, B., 1995. The Istanbul Strait, a closing biological corridor. Turkish Straits: New problems, new solutions., Istanbul, ISIS., p. 145-154, (in English).

Ozturk, B., and Ozturk A. A., 1996. On the Biology of the Turkish straits system. Bulletin de PInstitute océanographique, Monaco, No. special 17, CIESM Science Series N.2, p.205-221,(in English).

Pallas, P., 1831. Zoographia Rosso-Asiatica (The zoography of Russian Asia) (in Latin).*

Papaconstantinou, C, 1988. Check-list of marine fishes of Greece. National Centre for Marine Research, Athens, pp. 78, (in English).

Paspalev, G., 1933. Hydrobiologische Untersuchungen uber den Golf von Varna (Hydrobiological researches in the Varna Golf)., Arb. Biol. Meerest. in Varna, 2, p. 29-32, (in German).

Pereladov, M.V., 1988. Nekotorye nablyudeniya za izmeneniem biotsenozov Sudakskogo zaliva Chernogo morya (Some observations of changes in the biocoenoses of the Sudak Gulf in the Black Sea). Tezisy 3 Vsesoyuzn. conf. po morskoy biologii. Sevastopol, p. 237-238, (in Russian).

Pereyaslavtseva, S.M., 1890-1891. Dopolnenie k faune Chernogo morya (New data on Black Sea fauna). Trudy Khar'kovskogo obsh. ispyt. prirody, XXV, (in Russian).*

Petran, A., 1976. Cercetari asupra microfaunei de ciliate psamobionte de la litoralul romanesc al Marii Negre (Researches on microfauna of sandy-bottom living ciliates of the Romanian Black Sea littoral). Ecologie marina, 5, p. 9-84, (in Romanian).

Petran, A., 1986. Remarques sur la structuration des populations zooplanctoniques dans les zones des émissaires d'eaux usees du littoral roumain de la mer Noire. Cercetari Marine-Recherches Marines, 19, p. 55-72, (in French).

Petrova-Karadjova, V.Y., 1985. Cherveniyat priliv ot Prorocentrum micans i Exuviaella cordata vav Varnenski zaliv i po krajbrezhieto prez noemvri 1984g (Red tide of *Prorocentrum micans* and *Exuviaella cordata* in Varna Bay and along the coast in November 1984). Hydrobiology, BAS, Sofia, 26, p.70-78, (in Bulgarian).

Pitsik, G.K., 1979. Sistematicheskiy sostav fitoplanktona (Systematic structure of the phytoplankton). In: Osnovy biologicheskoy produktinovsti Chernogo morya, Naukova dumka, Kiev, p.63-70, (in Russian).

Platonova, T.A., 1968. Klass kruglye chervi - *Nematoda Rudolphi (Nematoda Rudolphi* of the Black Sea). In: Opredelitel' fauny Chernogo i Azovskogo morey (A key to Black Sea and Azov Sea fauna). Kiev, Naukova dumka, I, p. 111-183, (in Russian).

Pogrebnyak, 1.1., 1965. Donnaya rastitel'nost' severo-zapadnogo Prichernomor'ya i sopredel'nykh im akvatoriy Chernogo morya (Bottom flora of lagoons in the north-western Black Sea). Avtoref. diss., Odessa, (in Russian).*

Polishchuk, LV., 1990. Zooplankton limanov severnogo prichrnomor'ya (Zooplankton of the lagoons of the northern Black Sea). In: Limany severnogo prichernomor'ya (Lagoons of the northern Black Sea). Kiev, Naukova dumka, p. 108-120, (in Russian).

Proshkina-Lavrenko, A.I., 1955. Diatomovye vodorosli planktona Chernogo morya (Diatom algae of the Black Sea plankton). Izd. AN SSSR, Moskva-Leningrad, pp.222, (in Russian).

Pusanow, I., 1967. Uber die sukzessiven Stadien der Mediterranisation des Schwarzen Meeres (On the successive studies of Black Sea mediterranisation). Int. Rev. Ges. Hydrobiol., N52(2)., p. 219-236, (in German).

Puzanov, 1.1., 1936. Anchous. Opyt nauchno-promyslovoy monografii (Monograph on the Black Sea anchovy). Uchenye zap.Gor'kovsk. Univ., 5, p. 3-64, (in Russian).

Rampai, J. 1985. Rapport des travaux sur le plankton de la Méditerranée Occidentale. Rapp. Comm. Intern. Mer Méditer., 29, 9, p. 33-35, (in French).

Rass, T.S., 1987. Sovremennye predstavleniya o sostave ikhtiofauny Chernogo morya i ego izmeneniyakh (Present state of Black Sea ichthyofauna composition and its variations). Voprosy ikhtiologii, 27.(2), p. 179-187, (in Russian).

Repyakhov, V.K., 1875. Otchet o zoologicheskikh issledovamiyakh, proizvedennykh **v** Krymu letom 1874g (Zoological investigations in Crimea, summer 1874). Zap.Novorossk. ob-va estest. Ill, (in Russian).*

Repyakhov, V.K., 1880. K morfologii mshanok (On the morphology of bryozoan). Zap.Novorossk. ob-va estest. VI(2), (in Russian).*

Reshetnikov, V.I., 1992. Vodniy balans Chernogo Morya i ego izmenenie pod vliyaniem khozyaistvennoy deyatelnosti (Water balance of the Black Sea and its changes under anthropogenic activities). Moscow State University, Department of Geography, Dissertation, p. 150, (in Russian).

Roginskaya, I.S., and V.A. Grintsov, 1990. Golozhabernyi mollusk *Doridella obscurer.* pervaya nakhodka v Chernom more (Nudibranch mollusc *Doridella obscura:* first record for the Black Sea.) Oceanology, 30.(5), p.855-857, (in English).

Rozhdestvenskiy, A.V., 1979. Khimicheskie osnovy produktivnosti (Chemical basis of productivity). In: Osnovy biologicheskoy produktivnosti Chernogo morya, Kiev, p.34-62, (in Russian).

Rubinstein, I.G., 1987. Zapasy osnovnykh nerybnykh ob'ektov promysla Chernogo morya v usloviyakh antropogennogo vozdeystviya (Stocks of the main Black sea commercial resources (except fish) under the impact of human activities). Geograficheskie i economicheskie problemy izucheniya i osvoyeniya yuzhnykh morey SSSR. Tezisy dokl, 3 Vses. conf. po geografii i cartografirovaniyu okeana. Leningrad: Geografich. Obschestvo SSSR, p. 132-134, (in Russian).

Salnikov, N.E., 1959. Novye dannye o tuleni v Chernom more (New data on the monk seal in the Black Sea). Naukovy Zapiski Odesskoy Biologicheskoy Stantsii., N1., p. 113-126, (in Ukranian).

Salsky, V.O., 1964. Do pitannya pro aclimatizatsyu dalecoshidnogo travyanogo shrimsa *Pandalus kessleri* (P. latirostris) v Khadzhibeyskomu limany (About the acclimatization of the Far-East shrimp, *Pandalus kessleri* (P. latirostris) in the Khadzhibeysky liman). Nauk. zapiski Odesk. biol. stant., 5, p. 107, (in Ukrainean).

Salsky, V.A., 1977. O massovykh zamorakh midiy v severo-zapadnoy chasti Chernogo morya (On mass mortalities of mussels in the north-western Black Sea). Biologiya morya, Kiev, 43, p. 33-38, (in Russian).

Schultz, L., 1981. Nahrstoffeintrag in Seen durch Badegaste (Inputs of nutrients in a water body from beach tourists). Zbl. Bacterid., Abt., IB, 173, N.6., p. 528-548, (in German).

Seravin, L.I., 1994. Reviziya vidovogo sostava grebnevikov roda *Mnemiopsis* (otryad Lobata). 2. Vidovaya prinadlezhnost chernomorskogo mnemiopsisa i vidovoy sostav roda *Mnemiopsis* (Revision of the specific composition of the genus *Mnemiopsis* (ordo Lobata). 2. Specific classification of the Black Sea *Mnemiopsis* and specific composition of the genus *Mnemiopsis).* Zoolog. zhurn., 73, N.l, p. 19-33, (in Russian).

Shchapova, T.F., 1954. Fillofora Chernogo morya *(Phyllophora* of the Black Sea). Trudy In-ta Okeanologii, 2, p. 3-35, (in Russian).

Shornikov, E.I., 1969. Podklass ostrakoda, ili rakushkovye raki - *Ostracoda Latreille (Ostracoda Latreille* of the Black Sea). In: Opredelitef fauny Chernogo i Azovskogo morey (A key to Black Sea and Azov Sea fauna). Kiev, Naukova dumka, II, p. 163-260, (in Russian).

Simonov, A.I., and E.N. Al'tman (eds.), 1991. Proekt "Morya SSSR". Gidrometeorologiya i gidrokhimiya morey SSSR. torn 4. Chernoe more. vypusk 1. Gidrometeorologicheskie usloviya (The project "Seas of the USSR". Hydrometeorology and hydrochemistry of the USSR seas. v.4. The Black Sea. iss.l. Hydrometeorological conditions). GOIN, S.-Peterburg, Gidrometeoizdat, pp. 430, (in Russian).

Skarlato, O.A., and Ya.I. Starobogatov., 1972. Klass dvustvorchatye mollyuski - *Bivalvia* (Bivalvia in the Black Sea). In: Opredelitel' fauny Chernogo i Azovskogo morey (A key to Black Sea and Azov Sea fauna). Kiev, Naukova dumka, III, p. 178-249, (in Russian).

Skolka, H., 1967. Consideratii asupra variatiilor calitative si cantitative ale fitoplanctonului litoralului rominesc al Marii Negre (Considerations about qualitative and quantitative variations of phytoplankton in the littoral Romanian Black Sea zone). Ecoiogie marina, Bucuresti, 2, p. 193-293, (in Romanian).

Skolka, H., and A. Petran. 1960. Un caz interesant de colarare a apei superficiale a Marii Negre (An interesting case of surface water coloration in the Black Sea). St.serc.biol.ser.anim., N12(2), p. 175-180, (in Romanian).

Skolka, H., and 1. Cautis. 1971. Floraison d'*Exuviae/la cordata* Ostenf. et ses consequences sur la peche maritime en Roumanie au cours de I'annee 1969. Cercetari marine, IRCM, Constanta, 1, p. 59-82, (in French).

Sokolov, 1.1., and A.I. Yankovskaya., 1972. Otryad kleshi - *Acarima De Geer* (Black Sea tick - *Acarima De Geer).* In: Opredelitel' fauny Chernogo i Azovskogo morey (A key to Black Sea and Azov Sea fauna). Kiev, Naukova dumka, III, p. 8-32, (in Russian).

Sorokin, Yu.I., 1982. Chernoe more: Priroda i resursy (Black Sea: nature and resources). Moskva, Nauka, pp. 217, (in Russian).

Sovinskiy, V.K., 1880. Ob amfipodakh Sevastopol'skoy bukhty (On apmphipods in Sevastopol Bay). Zap. Kievsk. obshest.estest. 6, 1, (in Russian).*

Strategic Action Plan for the Rehabilitation and Protection of the Black Sea., 1996. GEF Black Sea Environmental Programme, Programme Coordination Unit, Istanbul, pp. 29, (in English).

Sukhanova, I.N., Flint. M.V., Hiebaum, G.H., et al., 1988. *Exuviae/la cordata* red tide in the Bulgarian coastal waters, May-June 1986. Marine biol., 99, p. 1-8, (in English).

Svetovidov, A.N., 1964. Ryby Chernogo morya (Fishes of the Black Sea). Moscow-Leningrad: Nauka Publ., pp. 551, (in Russian).

Telitchenko, M.M., and S.A. Ostroumov, 1990. Vvedenie v problemy biokhimicheskoy ecologii (Introduction to biochemical ecology). Moscow: Nauka., pp. 286, (in Russian).

Thienemam, August., 1939. Grundzuge einer allgemeinen Oekologie. Archiv. Hydrobiol., 35, p. 267-285, (in German).

Tolmazin, D.M., 1977. Gidrologo-gidrokhimicheskaya struktura vod v rayonakh gipoksii i zamorov severo-zapadnoy chasti Chernogo morya (Hydrological and hydrochemical structure of waters in the regions of hypoxia in the north-western Black Sea). Biologiya morya, Kiev, 43, p. 12-17, (in Russian).

Tsokur, A.G., 1988. Pervaya nakhodka ikrinok tsentrakanta, *Centhracanthus cirrus Raftnesque* (Centhracanthidae) v Chernom more (First finding of *Centracanthus cirrus Raftnesque* (Centracanthidae) eggs in the Black Sea). Voprosy ecologii, 28, 2, p. 329-331, (in Russian).

Ul'yanin, V.N., 1879. Resnichnye chervi *(Turbellaria)* Sevastopol'skoy bukhty (Ciliary worms *{Turbellaria)* in Sevastopol Bay), trudy 2-go s'ezda rus. estest., Moskva, 4, p. 1-96, (in Russian).

Unluata ,U., Oguz, T., Latif, M.A., and E. Ozsoy, 1990. On the physical oceanography of the Turkish Straits. In: Physical Oceanography of the straits. J.L.Pratt (ed), NATO/ASI Series, Ibrtrecht, Kluwer Academic Publishers, p. 25-60, (in English).

Valkanov, A., 1936. Belezhki varkhu naskhite brakichny vody (Notes on our brackish waters). God. Sof. Univ, 32, p.1-133. (in Bulgarian).

Valkanov, A., 1955. Katalog na nashta chernomorska fauna (Catalogue of Black Sea fauna). Tr. na morsk. st. v"vv Varna, 19, p. 1-62, (in Bulgarian).

Vinogradov, K.A., 1967. Ikhtiofauna Fillofomogo polya Zernova (Ichthyofauna of the Zernov's *Phyllophora* field). In: Biologiya severo-zapadnoy chasti Chernogo morya. Kiev: Naukova dumka., p. 232-234, (in Russian),

Vinogradov, K.A., and Losovskaya, G.V., 1968. Klass mnogoshetinkovye chervi - *Polychaeta* (Worms *Polychaeta* in the Black Sea). In: Opredelitel' fauny Chernogo I Azovskogo morey (A key to Black Sea and Azov Sea fauna). Kiev, Naukova dumka, 1, p. 251-359, (in Russian).

Vinogradov, K.A., and Zakutskyi, V.P., 1967. Filofornoe pole Zernova (Zernov's *Phylophora* field). In: Biologiya severo-zapadnoy chasti Chernogo morya (Biology of the north-western Black Sea). Kiev, Naukova dumka., p. 158-176, (in Russian).

Vinogradov, K.A.,(ed) 1968. Ekologicheskaya biogeografiya kontaktnykh zon morya (Ecological biogeography of the contact zones of the sea). Kiev, Naukova Dumka, pp. 160, (in Russian).

Vinogradov, M.E., (ed.), 1980. Pelagicheskie ekosistemy Chernogo morya (Pelagic ecosystems of the Black Sea). Moskva, Nauka, pp. 243, (in Russian).

Vinogradov, M.E., and A.I. Simonov, 1989. Izmeneniya v ecosysteme Chernogo morya (Changes in the Black Sea ecosystem). Tretiy Congres sovetskikh oceanologov. Plenarnye doklady, Leningrad, 14-19 December 1987 p. 61-75, (in Russian).

Vinogradov, M.E., and Flint, M.V., (eds.), 1987. Sovremennoe sostoyanie ekosistemy Chernogo morya (Present state of the Black Sea ecosystem). Nauka, Moskva, pp. 240, (in Russian).

Vinogradov, M.E., Sapozhnikov, V.V., and E.A. Shushkina, 1992. Ekosistema Chernogo morya (Ecosystem of the Black Sea). Moskva, Nauka, pp. 112, (in Russian).

Vinogradov, M.E., Shushkina, E.A., Musaeva, E.I., and Yu.P. Sorokin, 1989. Ctenophore *Mnemiopsis leidyi* (A.Agassiz) (Ctenophora, Lobata) - new settlers in the Black Sea. Oceanology, 29.(20), p.293-299, (in English).

Vodyanitskyi, V.A., 1930. K voprosu o proiskhojdenii ryb Chernogo morya (The origins of Black Sea fish), Raboty Novoross. biol. **St.,** 4, p. 3-34, (in Russian).

Vodyanitskyi, V.A., and Kazanova N.N., 1954. Opredelitel' pelagicheskikh ikrinok i lichinok ryb Chernogo morya (A key to pelagic fish eggs and larvae of the Black Sea). Trudy Vsesoyuz.inst-ta morskogo rybn. khoz. I okeanografii, 28, (in Russian)*.

Voloskevich, A.N., Dubyna, D.V., Zhmud, M.E., at al., 1987. Zapovednik Dunayskie plavni (Dunayskie plavni reserve). In: Zapovedniki Ukrainy i Moldavii, Moscow, Mysl', p. 139-153, (in Russian).

Volovik, S.P., Dubinina, V.G., and A.D. Semenov, 1993. Hydrobiology and dynamics of fisheries in the Azov Sea. Studies and Reviews. General Fisheries Council for the Mediterranean, N.64, p. 1-51, (in English).

Vorob'eva, L.V., Zaitsev, Yu.P., and I.I. Kulakova, 1992. Interstitsial'naya meyofauna peschanykh plyazhey Chernogo morya (The interstitial meiofauna of sandy beaches in the Black Sea). Kiev, Naukova Dumka, pp. 140, (in Russian).

Voronikhin, N.N., 1925. Algologicheskie rezul'taty ekskursii prof. S.A. Zernova v Chernom more na parokhode "Meotida" v 1909-1910 gg. I "Gaidamak" v 1911 g (Studies of the algae during Prof. S.A.Zernov's excursion to the Black Sea with the ships "Meotida" in 1909-1910 and "Gaidamak" in 1911). Zhurnal Russk. Botan. Ob-va, 10(1-2), (in Russian)*.

Wilson, A. M., and M. Moser, 1994. Conservation of Black Sea wetlands: a review and preliminary action plan. IWRB publ. N33., pp. 76, (in English).

Yanko, V.V., and T.S. Troitskaya, 1987. Pozdnechetvertichnye foraminifery Chernogo morya (Late Quaternary foraminifers of the Black Sea). Moskva, Nauka, pp. 108, (in Russian).

Zaitsev, Yu.P., 1958. O neobkhodimosti nekotorykh izmeneniy v metodike sbora ikhtioplanktona (Some changes in the methodology for collecting ichthyoplankton samples). Tez. dokl.nauch.sess.Uch.soveta In-ta gidrobiol. AN USSR na Odessk.biost, Odessa, p.37-40, (in Russian).

Zaitsev, Yu.P., 1971. Marine Neustonologie. Jerusalem: Israel Program for Scientific Translations, pp. 207, (in English).

Zaitsev, Yu.P., 1977. Severo-zapadnaya chast' Chernogo morya kak ob'ekt sovremennykh gidrobiologicheskikh issledovaniy (The north-western Black Sea as an area of hydrobiological investigations). Biologiya morya, Kiev, Naukova Dumka, 43, p.3-7, (in Russian)

Zaitsev, Yu. P., 1978. Eto udivitel'noe more (This wonderful Sea). Mayak, Odessa., pp. 159, (in Russian).

Zaitsev, Yu.P., 1979. Problèmes biologiques de la partie nord-west de la Mer Noire, Recherches marines, Constanta, N.12, p. 7-32, (in French).

Zaitsev, Yu.P. 1990. Gosudarstvenniy zapovednik Dunayskie plavni (Dunayskie plavni State Reserve). Biologiya morya, N 2, p. 74-77, (in Russian).

Zaitsev, Yu.P., 1992(a). Ekologicheskoe sostoyanie shelfovoy zony Chernogo morya u poberezhya Ukrainy (obzor) (Ecological state of the Black Sea shelf zone, Ukrainian coast (a review)). Gidrobiolog.zhurnal, 28.(4), p.3-18, (in Russian).

Zaitsev, Yu.P., 1992(b). Recent changes in the trophic structure of the Black Sea. Fish. Oceanogr., 1.(2), p. 180-189, (in English).

Zaitsev, Yu.P., 1993. Impacts of eutrophication on the Black Sea fauna. General Fisheries Council for the Mediterranean. Studies and Reviews, Rome, FAO, 64, p.63-86, (in English).

Zaitsev, Yu.P., and L.N. Polishchuk, 1984. Vspyshka chislennosti meduzy *Aure/ia aurita* (L.) v Chernom morye (The increase in the number of *Aurelia aurita* (L.) in the Black Sea). Ekologiya morya, 17, p.35-46, (in Russian).

Zaitsev, Yu.P., Ansupova, L.V., Vorob'eva, L.V., Garkavaya, G.P., Kulakova, 1.1., and E.M. Rusnak, 1987. Nematody v glubokovodnoy zone Chernogo morya (Nematodes in the deep zone of the Black Sea). Doklady AN Ukr.SSR, ser.B, 11, p.77-79, (in Ukrainian).

Zaitsev, Yu.P., Fesyunov, O.E., and I.A. Sinegub, 1992. Vliyanie donnogo tralovogo promysla na ekosistemu chernomorskogo shelfa (The impact of bottom fish trawling on the ecosystem of the Black Sea shelf). Doklady AN Ukr.SSR, 3, p. 156-158, (in Russian).

Zaitsev, Yu.P., Garkavaya, G.P., Nesterova, D,A., and L.N. Polishchuk, 1989. Dunay kak osnovnoy istochnik evtrofirovaniya Chernogo morya (The Danube as the main source of Black Sea eutrophication). Gidrobiolog.zhurnal, 25.(4), p.21-23, (in Russian).

Zaitsev, Yu.P., Polishchuk, L.N., Nastenko,E.V., and G.M. Trofankhuk, 1988. Sverkhvysokie contsentratsii nochesvetki *Noctiluca miliaris* Suriray v neystali Chernogo morya (Very high concentrations of *Noctiluca miliaris* Suriray in the neustal layer of the Black Sea). Doklady Acad, nauk Ukr.SSR, 10, p.67-69, (in Russian).

Zaitsev, Yu.P., Vorob'eva, L.V., and B.G. Alexandrov, 1988. Novyi vid Ctenofory v Chernom more (New species of Ctenophora in the Black Sea.) Moscow, VINIT1, 35, p. 1-5, (in Russian).

Zaitsev, Yu.P., and L.I. Starushenko, 1996. Pilengas *(Mugil soiuy* Basilewsky, 1855)-novaya promislovaya riba v Chernom i Azovskom moryakh (The haarder *{Mugil soiuy* Basilewsky, 1855)- a new commercial fish in the Black Sea and Azov Sea). Gidrobiologichesky Zhurnal (at press), (in Russian).

Zakutsky, V.P., and K..A. Vinogradov, 1967. Macrozoobentos (Macrozoobenthos). In: Biologiya severo-zapadnoy chasti Chernogo morya. Kiev: Naukova dumka., p. 146-157, (in Russian).

Zambriborsh, F.S., 1965. Ryby nizoviya rek I primorskikh vodoemov severo-zapadnoy chasti Chernogo morya I usloviya ikh sushestvovaniya (Fish of the river deltas and semi-enclosed water bodies of the north-western Black Sea). Avtoref.diss.dokt.biol.nauk.,Odessa, pp.46, (in Russian).

Zambriborsch, F,S., 1990. Ikhtiofauna limanov i ikh rybokhozyaistvennoe ispolzovanie (lchthyofauna of limans and their commercial use). In: Limany Severnogo Prichernomoriya. Kiev: Naukova dumka., p. 170-185, (in Russian).

Zenkevich, L.A., 1963. Biologiya morey SSSR (Biology of the USSR seas), Moskva, Izd. Akademii Nauk SSSR, pp.739, (in Russian).

Zernov, S.A., 1909. Fatsiya fillofory (Algae *Rhodophyceae).* Fillofornoe pole v severo-zapadnoy chasti Chernogo morya (The facies of *Phyllophora* (Algae *Rhodophyceae). Phyllophora* field in the north-western Black Sea). Ejegodn. Zool. muzey Akademii nauk, XIY, p. 181-191, (in Russian).

Zernov, S.A., 1913. K voprosu ob izuchenii jizni Chernogo morya (On the question of life in the Black Sea). Zap. Imp. Akad. Nauk, St. Petesb., VII, 31(1), pp. 299, (in Russian).

Zhmud, M. E., 1995. Orlan-belokhvost v delte Dunaya (The white-tailed eagle in the Danube delta). Newspaper "Nashe vremya", N90 (24 September 1995), (in Russian).

Zhuravleva, L.A, 1988. Gidrokhimiya ustievoy oblasti Dnepra i Yujnogo Buga v usloviyakh zaregulirovannogo rechnogo stoka (Hydrochemistry of Dnieper and Southern Bug deltas region under regulation of river flow). Kiev, Naukova Dumka, pp. 176, (in Russian).

Zinova, A.D., 1967. Opredelitel' zelenykh, burykh I krasnykh vodorosley yujnykh morey SSSR (Key for green, brown and red algae of the southern seas of the USSR). Moskva-Leningrad, Izd. Nauka, pp.398, (in Russian).

Zolotarev, V.N., and P.N. Zolotarev, 1987. Dvustvorchaty mollyusk *Cunearca cornea* - novy element fauny Chernogo morya (The bivalve mollusc *Cunearca cornea* as a new element of the Black Sea fauna). Doklady AN SSSR, 297.(2), p.501-503, (in Russian).