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AN INTRODUCTION TO THE BLACK SEA ECOLOGY
Yuvenaly Zaitsev

Foreword

It is hardly an overstatement the assertion that, today, ecology is the most popular of all the natural sciences among the general public. It comes as no surprise because this area of knowledge deals with the interactions between the living creatures (man included) and the natural environment, their dependence on nature, their influence on nature and the consequences of such influence.

Although the term «ecology» was first proposed almost one and a half centuries ago (it was introduced by the German scientist Ernst Haeckel in 1861), ecology as a science still continues to develop and improve as the subject of its study has not stiffen. The relationship between living creatures and their habitat, humans and their natural environment continue to develop and become increasingly complicated. Its consequences become more significant for plants, animals and humans. At the beginning of the XXth century, the prominent Ukrainian scientist V.I. Vernadskyy warned that a time will come when the man's influence on the environment, by its force and consequences, will be commensurable with geological factors.

The discussion about whether ecology is one of the biological sciences, as it was considered initially, or not still goes on. Some authors consider ecology as a part of biology, others are of the opinion that it is the interdisciplinary field of knowledge in which the important and deciding role is taken by biology, but no less important are also physics, chemistry, geography, geology and other sciences, whose objects of study stipulate together the varied complex of processes and phenomena as a result of which are forming this or that state of the environment. Therefore, when speaking about the ecology of aquatic organisms and their communities, the term «hydroecology» (Romanenko, 2001), which is by its content wider than the term «hydrobiology», recently started being applied more and more frequent.

It is not surprising that today ecology is being taught at schools and universities not only to biologists, but also to physicists and chemists, geographers and geologists, historians and lawyers, physicians and literati. Solid knowledge on ecology is required not only to broaden a specialist's range of interests though it is also important, but also because many ecological problems cannot be resolved without the participation of specialists in the different areas of fundamental and applied science.

For all these reasons, this book, devoted to the ecology of the Black Sea, is offered to the

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attention of readers. Studies on this sea have started when the ecological problems were not so actual and vital as they are in our days. The book is entitled «An Introduction to the Black Sea Ecology» because it contains the basic initial knowledge on ecology and is aimed, first of all, to young people interested in the study of ecology. First and foremost, this book is a manual on ecological education and training of the ecological beliefs, but not only. The author is convinced that the more the young people are involved in the issues of marine ecology, the more assistants this science will gain. Hundreds, thousand pairs of young eyes and trained minds can become a serious help in the research of the different ecological processes, especially of those requiring envelopment of vast coastal and water spaces.

This translation is actually a second revised and enlarged edition of the first Russian version.

Acknowledgements

As it frequently happens, the birth of this book involved, besides the author, many other people (teachers, colleagues, students, and friends) whose publications, ideas, personal communications and advice have influenced the formation of the concept of this scientific work. Many of them are cited in the references. I am deeply grateful to all these «invisible co-authors». I would have liked to mention all of them by name, but, unfortunately, it is impossible. Therefore, I will limit myself to a few names.

Professor Ivan I. Puzanov, «the last encyclopedist of the XXth century», as he was called by his contemporaries; a personality of vast knowledge and strong convictions who was the scientific supervisor of my PhD thesis. At the department of Zoology of vertebrates of the I.I. Metchnikov Odessa State University, I worked, supervised by him, in 1950–1956 as laboratory assistant at the marine hydrobiological station. In the 1950s, because of ideological pressure of «Lysenkoism» (neo-Lamarckism), the doctrine that reject the gene theory of inheritance in favour of the inheritance of acquired characters, many biologists (including I.I. Puzanov) were subjected to political persecutions. In that situation, my prospects to engage in science, as a disciple of Puzanov, were more than ghostly. After the successful defense of my PhD thesis in 1956, Professor I.I. Puzanov undertook efforts to leave me at the department of Zoology as his assistant, but administration of the biological faculty disagreed. Thus, I became a junior scientist at the Ukrainian Academy of Sciences.

Professor Constantin A. Vinogradov, famous marine biologist, has willingly employed me at the end of 1956 on a position of junior scientist at the recently created Odessa Biological Station

(OBS) of the Academy of Sciences of Ukraine. C.A. Vinogradov has encouraged in every way the scientific research of young scientists, welcomed new methods, non-ordinary decisions and bold conclusions. He was the scientific consultant of my doctoral thesis, which I defended in 1964. In this scientific establishment, which has been reorganized later in the Odessa division and then into Odessa Branch of the Institute of Biology of Southern Seas of the National Academy of Sciences of Ukraine, I have worked till present. I.I. Puzanov maintained close communications with the OBS and quite often participated in our marine expeditions.

Professor Alexander A. Strelkov, famous zoologist of the well-known St. Petersburg scientific school. With him, I worked in 1965 at the Institute of Oceanology in Havana, Cuba and more than once used his vast scientific knowledge which he was generously communicating. A.A. Strelokov has positively perceived my ideas on marine neuston and its role in marine ecosystem and insistently recommended to accelerate the publication of my monography «Marine Neustonology». This book has been published in Russian in 1970 in Kiev and in 1971 was translated into English and published in the USA and Israel. A.A. Strelkov was glad of this fact not less than the author.

Corresponding Member of the Academy of Sciences of USSR, Professor Veniamin G. Bogorov from the P.P. Shirshov Moscow Institute of Oceanology of the Academy of Sciences of USSR, prominent specialist on marine plankton and marine ecology, heartily supported my attempts to confirm the ideas of the marine neustonology in science. It was very important for me, as not all of the leading domestic scientists had perceived them.

Professor Sigeru Motoda from Japan, prominent marine biologist, author of many original scientific methods, expert on new ideas, and an artist. In 1980 the government agency «Japan Science Society for the Promotion of Science» has invited me to read the course of lectures «Marine Neustonology» at the international Tokay University in Skhimyzu and to give selected lectures on that topic at Tokyo, Hakodate, Tsukuba, Sendai and Nagoya universities. Professor Motoda was my main guide to Japan and introduced to me many leading scientists and sights of the country. During the stay in Japan, on a request of S. Motoda, I have headed and conducted the first scientific expedition on the study of marine neuston in the Suruga Bay not far from the famous Fujiyama Mountain.

Professor John McNeil Sieburth from the Rhode Island University, USA, prominent marine microbiologist, author of many publications on microneuston. Remarkable microphotographies, published by J. Sieburth and, later on, the personal conversations with him have opened for me a «microscopic marine landscape» as he was calling them, proving that, in nature, all multicellular marine organisms, are covered by unicellular algae, fungi and bacteria. It is important to consider this during the realization of *in situ* and laboratory experimental ecological studies.

Academician of the Romanian Academy of Sciences, Professor Mihai Băcescu, prominent marine biologist and ecologist, expert in Black Sea biology, and author of many important scientific publications including co-authorships with foreign scientists. I had many useful conversations with M. Băcescu and was repeatedly turning to his publications during my scientific activity.

The famous French marine explorer Jacques-Yves Cousteau, well known for his discoveries in the submarine world, books and films. In 1950, under the influence of his publications, I made my first aquatic mask and saw for the first time the fabulous world that opens beyond its glass. Later on, interesting conversations with this remarkable personality have strengthened my persuasion in the paramount importance of visual submarine observations for the scientific research. No matter what sophistication has achieved the equipment for instrumental observation and measurements from board of a scientific vessel, the researcher's eye is able to add additional important information.

Academician of the National Academy of Sciences of Ukraine, Professor Gennady G. Polikarpov from the Institute of Biology of Southern Seas in Sevastopol, prominent scientist, founder of radioecology and chemoecology of marine organisms, leader of the world acknowledged school of marine radioecologists. In the beginning, both of us were interested by the fact that in the surface microfilm of the sea is registered not only the large accumulation of marine organisms forming marine neuston, but also the highest concentrations of radionuclides in the pelagic zone. Accumulation in one habitat of living organisms and life-threatening radioisotopes has united our research interests for long years. We have conducted many joint expeditions in seas and oceans and have published quite a lot in domestic and foreign press. Creative and personal friendship with G. Polykarpov has significantly influenced the formation of my views and scientific persuasions.

And, of course, Elena Dmytryevna Kutsyry, my wife, hydrobiologist by education, who selflessly, for over half a century, carries the difficulties and joys of the everyday life of a restless scientist. She constantly creates for me at home that atmosphere without which I would not have succeeded as a researcher. To her, above all, I dedicate this book.

With a huge warmth and gratitude I remember students and colleagues at Odessa Branch of the Institute of Biology of Southern Seas, their good attitude and help in everyday, not always easy and pleasant work. To them I owe my deepest gratitude. Especially, I would like to thank my colleague, talented researcher, Dr Boris G. Alexandrov for his help in creating the electronic version of the text and pictures of this book.

I express my sincere thanks to my old friend, the artist A.M. Karpushkin for creating the cover, title, miniatures and book's layout, and biologist Sergery V. Lagutin for the pictures in the text.

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Yuvenaly Zaitsev

1.1. Among other seas

In the whole World Ocean there are not less then fifty seas. According to the degree of isolation from the ocean, the seas may be classified as enclosed or partly enclosed. Those which are enclosed are also referred to as intercontinental seas, or Mediterranean seas. In the geographical and other specialized literature, «seas» are also called the more or less conditional parts of the World Ocean, such as the Sargasso Sea in the Atlantic Ocean and the Philippine Sea in the Pacific Ocean. It is impossible to name the exact number of seas on Earth since there is no unique criterion for their definition. For example, the Great Soviet Encyclopedia (1974) names 32 major world seas; the Mediterranean Sea being listed among them. However, in the book «Mediterranean Sea. Navigating-hydrographic review», published by the USSR Hydrographical department in 1955, 16 seas are listed as parts of the Mediterranean basin. Among them there are (from west to east): Alboran Sea, Balearic (Iberian) Sea, Ligurian Sea, Tyrrhenian Sea, Adriatic Sea, Ionic Sea, Aegean Sea, Sea of Marmara, and Levantine Sea. In its turn, in some special publications (and that is also enough grounded), the Aegean Sea, is subdivided into the Thracian Sea in the north, the proper Aegean Sea in the center, and the Cretan Sea in the south.

The Black Sea is well isolated geographically, ecologically and biologically, and there were no attempts to subdivide it into smaller marine water bodies. It is a typical example of a semi enclosed, intercontinental sea. It is a Eurasian sea, whose waters, from the west and the north, are washing the coasts of the European countries (Bulgaria, Romania, Ukraine and Russia) and, from the south and the east, the countries of Asia (Turkey and Georgia).

1.2. Geological background of the modern Black Sea ecology

The territory of Europe and Asia, where the Black Sea is presently located, has had a complex geological history. Therefore, in its biology and ecology, we see the legacy of the distant epochs and events that took place on our planet. A simplified geological history of the Black Sea could be presented as follows (Zaitsev, 1998).

In the late Jurassic period of the Mesozoic era (more than 150 million years B.P.*), the Atlantic and the Pacific Oceans have been united by the huge and salty Tethys Sea. It extended from the modern Strait of Gibraltar on the West, through the regions of the presentday Mediterranean, Black and Caspian Seas, the mountains of Caucasus, Copetdag, Tian Shan, Pamir, Himalayas and the South-East Asia on the East. The marine geologist and paleoecologist E.V. Krasnov (2003) called it «the Sea of the Jurassic period». It was inhabited by marine halophilic and thermophilic organisms, in particular by corals. Together with the corals, writes E.V. Krasnov, in this sea were common large Gastropods of the Nerineidae family and bivalves of the Rudistae family that have disappeared later. They were forming the major feature of the Jurassic fauna of the Tethys Sea. It is likely that dinosaurs inhabited the shores of Tethys, but they already belong to terrestrial fauna. The sea, however, was populated by the marine reptiles Ichthyosauria and Plesiosauria, the last probably moving also on land. By the mid Tertiary Period, due to the crust raise and mountain formation, the Tethys Sea became separated, first from the Pacific Ocean, and later from the Atlantic.

In the Miocene (about 7–5 million years ago), the Earth's crust movements continued and resulted in the formation of the Alps, the Carpathians, Balkan and the Caucasian Mountains. As a result, the salty Tethys Sea shrank in size and divided into a number of brackish water basins (with the salinity lower than that in the ocean). One of them, named the Sarmatian Sea (fig. 1A), stretched from the place where today there is the capital of Austria, Vienna, on the west, to the foothills of the Tian Shan Mountains in the Middle and Central Asia on the east. The Sarmatian Sea included the modern regions of the Black Sea, Sea of Azov, Caspian Sea and the Aral Sea. The Sarmatian Sea, isolated from the ocean, was gradually desalinated because of the inflow from large rivers. It is assumed that the salinity in the sea was even lower than in the modern Caspian and Azov Seas. Part of the remaining marine fauna from the Tethys died out. However, typically oceanic animals such as whales, manatees and seals, continued to inhabit the Sarmatian Sea for a prolonged period before they disappeared at the end of Miocene.

*) B.P. – years before the present. 0 B.P. is taken conventionally to be 1950 AD.

Figure 1. Geological past of the Black Sea (from Zaitsev and Mamaev, 1997):

A – Sarmatian Sea, B – Maeotic Sea, C – Pontian Sea-Lake, D – Chaudian Sea, E – Paleoeuxinian Basin, F – Karangat Sea, G – Neoeuxinian Sea, H – modern Black Sea and their hypothetical salinity (‰)

By the late Miocene and the early Pliocene (3–2 million years ago), the Sarmatian Sea has shrunk in and established a communication with the ocean. The water salinity increased and marine species of animals and plants started to appear. This basin was named the Maeotic Sea (fig. 1B). In the Pliocene (2–1.5 million years ago), the connection to the ocean was again fully halted and the salty Maeotic Sea was replaced by the almost freshwater Pontian Sea-Lake (fig. 1C). In this period, the future Black, Azov and Caspian Seas were connected through the present-day territories of the Stavropol and Krasnodar regions and the Northern Caucasus. In the Pontian Sea-Lake, marine fauna and flora left place to a brackish fauna and flora. Its representatives can still be fount to this day in the Caspian and Azov Seas as well as in the areas of the Black Sea with the reduced salinity and in some limans. This part of the modern fauna (flora is less studied in this regard) has received the joint name «pontian relicts», or «caspian relicts», because in the northern part of the Caspian Sea, with the reduced salinity, they are represented by greater number of species.

By the end of Pontian period, due to the rising of the Earth's crust in the region of the North Caucasus, the basin separated from the Caspian Sea. From that period, the Caspian Sea one the one hand and the Black Sea and the Sea of Azov on the other went their separate ways; although temporary links between them were formed from time to time. At last, the shipping Volga-Don channel, built in 1952, set the permanent transport communication between these seas.

In the Quaternary Period, or the Ice Age, the outline of the future Black Sea, its salinity and the species composition of its inhabitants continued to evolve. By the late Pliocene, less than one million years ago, the Pontian Sea-Lake had shrunk in size and got the name of the Chaudian Lake-Sea (Fig. 1D). It was very desalinated, isolated from the ocean and populated by Pontian type fauna. The Sea of Azov did not yet exist at that time.

As a result of ice melting at the late Mindel Glaciation (some 500,000–400,000 years ago), the Chaudian Lake-Sea was filled with melt water and its outlines started to resemble the modern Black and Azov Seas. It got the name of the Paleoeuxinian Basin (Fig. 1E). On the north-east this basin, through the Kumo-Manych depression, it was connected with the Caspian Sea which at that time was affected by reduced salinity. The fauna of the Paleoeuxinian Basin was of a Pontian type.

A new stage in geological history of the Black Sea came with the beginning of the Riss-Würm

Interglacial Period (150,000–100,000 years ago). Following the formation of the Dardanelles, the connection of the future Black Sea with the Mediterranean formed and the World Ocean and the Karangat Basin (Fig. 1F), or Karangat Sea, appeared. According to the experts' opinion, salinity of its waters could reach 25–30‰. From the Mediterranean and the Atlantic Ocean, many species of typical marine organisms entered the Karangat Sea. Salt water occupied the larger part of the basin, driving back the Pontian species into the bays, river deltas and limans with low salinity. At that time, the halophilic species dominated in the sea. However this marine water body also disappeared.

Some 20,000–18,000 years ago, the Karangat Sea was replaced by the Neoeuxinian Lake-Sea (fig. 1G). This coincided with the end of the last Würm Glaciation in Europe. The sea was again isolated from the ocean, filled with melting waters and desalinated, possibly to the level of 5–7‰. Once again, the halophilic fauna and flora died out and Pontian species outliving the difficult Karangat period in limans and deltas left their refuges and again populated the whole sea. After approximately 10,000, started the last phase of the complicated geological history of the Black Sea (Fig. 13). It did not happen at once. In the beginning, about 7,000 or, according to some authors, 5,000 years ago, the straits of Bosporus and Dardanelles appeared and the water exchange with the Mediterranean and the Atlantic Ocean began. As it took place already in historical time, this event was reflected in some legends and works of ancient authors.

Thus, the ancient Greek geographer and historian Strabo (Leonov, 1960), referring to other ancient authors, writes that in the past the Ponteuxinus, connected with the Caspian Sea, did not have an output to the ocean through Byzantium. However, when rivers inflowing in it highly heaved up its level and broke the Byzantine land, its waters entered in Propontyde and Hellespontus (Sea of Marmara and Dardanelles). There are records of Diodorus that, breaking through the Bosporus, the Pontian waters gushed southward and flooded the Samothraky Island located in the northern part of the Aegean Sea. Apropos of this, nowadays the water level in the Black Sea remains higher than in the Sea of Marmara. Therefore, in the Bosporus, there is a constant surface current flowing from the north to the south, i.e. from the Black Sea into the Sea of Marmara. The reverse flow goes in the bottom layer – from the Sea of Marmara into the Black Sea.

After some time, the water levels of the two connected seas acchives a dynamic equilibrium and a slow salinization of the Black Sea began. At the same time, a gradual lowering of the Earth's crust proceeded in the northern part of the Sea and, as a result, the mouths of rivers were flooded by marine waters and transition freshwater-marine basins which got the name of limans were formed. Ancient navigators considered these basins convenient for the harbours. From here comes their name: in ancient Greek, «liman» stands for «harbor».

It is believed that, within 1,500–2,000 years, the salinity of the Black Sea became sufficient to support a large number of Mediterranean species. They started to populate the Black Sea and presentday are forming the basic component of its biota.

1.3. Dependence on the land

In physical geography, the terms «drainage basin» or «catchment area» are used. They designate that part of the land surface from which the water enters in rivers, lakes and seas. The ratio of the catchment basin surface to the surface of the recipient water body is called specific catchment (SC). The higher is the SC, the more the water body depends on the surrounding territory.

Figure 2. Catchment area of the Black Sea in Europe and Asia from which water drains to the sea

The drainage basin of the Black Sea (Fig. 2) exceeds 2 million 300 thousand km^2 and, entirely or partly, covers the territories of 22 countries in Europe and Asia (Zaitsev, 1998; Zaitsev and Mamaev, 1997). Their number includes 6 already named the Black Sea riparian countries and 16 countries of the Central and Eastern Europe. In accordance with the political map of 2000, these are (in alphabetical order): Albania, Austria, Belarus, Bosnia-Herzegovina, Croatia, the Czech Republic, Germany, Hungary, Italy, Macedonia, Moldova, Poland, Serbia, Slovakia, Slovenia and Switzerland. The contribution of each of these countries to the catchment area of the Black Sea is quite different. Thus, the input of Albania, Poland and Italy is no more than 100–300 km^2, Switzerland – 1700 km^2, Moldova – 33700 km^2, Germany – 58000 km^2, Romania – 226000 km^2, Turkey – 249000 km^2, Ukraine – 600000 km^2. This is a purely statistical layout, but it reflects to a full degree the level of influence of different territories on the Black Sea. As a general rule, the large plain territories located along the lower reaches of rivers have the greater influence on seas.

Large and small rivers, from which more than 300 flow directly into the sea, flow on the catchment basin of the Black Sea. On this area are located huge agricultural regions, large industrial centers, and dozens of large cities, including many state capitals.

1.4. Morphometry of the Black Sea and its coasts

The Black Sea covers an area of 423,000 km^2, occupies a volume of 547,000 km^3 and has a maximum depth of 2,212 m.

Figure 3. Bathymetric map of the Black Sea

According to modern estimations, the length of the Black Sea coastline is 4,838.1 km (Fig. 3). It is distributed as follows among the Black Sea countries: Romania – 245 km, Bulgaria – 378 km, Georgia – 312 km, Russia – 379 km, Turkey – 1695 km and Ukraine – 1829.1 km.

In aquatic ecology, the parameter called «Development of coastline (DCL)» is used for estimation of the biological productivity of natural water bodies. This value is determined according to formula:

$$\text{DCL} = \frac{L}{2\sqrt{S\cdot\pi}},$$

where L – length of the coastline around the periphery,

S – area of water body, π – 3, 14.

High values of DCL signify higher biological productivity of the basin (Dediu, 1989). According to this formula, the DCL of the Black Sea is 1.063. For comparison, the DCL of the Sea of Azov (surface area 39,100 km ^{2} and length of the coastline 2,686 km) (Greze, 1987) is considerably higher: 2.198. It is well known that the biological productivity of the Sea of Azov, determined using other indices, is considered one of the highest among the world seas. The Caspian Sea (surface area 422,112 km^2 and length of the coastline 7,578 km) (Leonov, 1960) has a DCL of 1.857, which also reflects its high level of biological productivity. However, when operating with the DCL index it is necessary to note that it expresses the average data for the whole basin. In different areas of each sea, this index can substantially differ from that for the whole basin.

The coastline of the Black Sea forms many gulfs, bays, peninsulas and prominent capes. The largest gulfs and bays are Burgs and Varna Bays in Bulgaria; Mamaia Bay in Romania; Odessa, Tendrovsky, Yagorliksky, Dzharylgachsky, Karkinitsky, Kalamitsky and Feodosia Gulfs and Sevastopol Bay in Ukraine; Novorossiysk and Gelendzhyk Bays in Russia; Batumi Bay in Georgia; Samsun and Sinop Bays in Turkey. The largest peninsula in the Black Sea is Crimea which is limited by the Tarkhankut peninsula to the west and the Kerch peninsula to the east. The most prominent capes are Kaliakra in Bulgaria; Midia in Romania; Bolshoy Fontan, Tarkhankut, Khersones, Meganom and Chauda in Ukraine; Utrish and Myskhako in Russia; Pitsunda in Georgia; Chum, Bafra, Boztepe, Yndzheburun and Oludzhe in Turkey.

Figure 4. The Zmyiny Island (general view). The ecological role of this single stony island in the open sea on the vast north-western shelf is very important (photo by Yu. Litvinenko)

The Black Sea is not rich in islands of continental origin. The largest is Zmyiny Island (in ancient times – Leuke or Fidonisi), with an area of about 1.5 km^2, a highest elevation of about 42 m, and located at a distance of 37 km from the east edge of the Danube delta (Fig. 4). Another island is Berezan (ancient names Borisfen, Borisfenida or, in Old Russian, Buyan), located at a distance of 2 km south of the mouth of the Berezan Liman. Its area is about 0.5 km^2 and its highest elevation 20 m. The third small island of continental origin, Kefken, is located in the south of the Black Sea, at 1 km from Pasarbashy Cape and 90 km eastward from the Bosporus. There are several other small islands and big rocks in Burgas Bay, near Southern Crimea and in other areas of the Sea.

Sandy islands formed by suspended sediments under the influence of currents are located mainly along the north-western coast of the Sea. These are Tendrovsky Island (Tendrovska Spit) with a length of 65 km and an area about 30 km^2; Dzharylgach Island, length 42 km and area about 25 km^2; Dolgiy Island, area about 3.5 km^2; and some other.

The rivers' runoff entering the Black Sea, besides fresh water, contains different dissolved and suspended matters which serve as nutrients. The volume of the river flow is an important characteristic of the water balance of any inland sea (table 1).

Table 1

Major Rivers of the Black Sea (from Zaitsev and Mamamev, 1997)

Name	Catchment area, km^2	Length, km	Total runoff, $km^3 \cdot year^{-1}$	Sediment discharge, $10^6 t \cdot year^{-1}$
Danube	817 000	2 860	208	51.7
Dniester	71 990	1 328	10.2	2.50
Dnieper	505 810	2 285	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	4 060	221	4.63	2.78
Kodori	2 030	84	4.08	1.01
Bzyb	1 410	-	3.07	0.60
Yesilirmak	36 100	416	4.93	18.0
Kizilirmak	78 200	1 151	5.02	16.0
Sakarya	65 000	790	6.38	n.a.

n.a. Not available

As it appears from table 1, according to the river runoff, the first places belong to the Danube, Dnepr and Rioni and, according to solid load, to the Danube, Yesilirmak and Kizilirmak. The sediment runoff includes silt, sand and pebbles and has an important ecological role, determining the water transparency, silting of the bottom, accumulation of fluvio-marine deposits, development of beaches and their granulometric composition. The liquid river discharge contains nutrients and other dissolved matter, which determine such basic characteristics of marine water such as salinity, density, pH, trophic status (levels of the minerals required by green plants), etc.

Large volumes of fresh water enter the Black Sea with atmospheric precipitations which also contain dissolved and suspended matters. On the other hand, the Sea loses considerable amounts of water because of evaporation from its surface.

Processes related to inflow, outflow and accumulation of water, expressed by the water balance equation, are specific for each sea and have a key ecological significance. The water balance of the Black Sea could be drawn from the data in table 2.

Table 2

Water Balance of the Black Sea (from O.A. Alekin, 1966)

Inflow	Water volume, $km^3 \cdot year^{-1}$	Outflow	Water volume, $km^3 \cdot year^{-1}$
Through the Bosporus	176	Through the Bosporus	340
Through the Kerch Strait	53	Through the Kerch Strait	32
Precipitation	119	Evaporation	332
Drainage from continental area	346	n.a.	n.a.
Total	694	Total	704

n.a. Not applicable

According to the data of other authors, these values change substantially from year to year, in relation to weather conditions and accuracy of measurements. Comparison of published data on this subject shows that, during the last century, the elements of water balance of the Black Sea varied within the following limits:

River discharge from 294 to 480 km^3,

Atmospheric precipitation from 119 to 300 km^3,

Evaporation from 54 to 402 km^3,

Inflow through the Bosporus from 175 to 312 km^3, Inflow through the Kerch Strait from 22 to 95 km3,

Outflow through the Bosporus from 241 to 612 km^3,

Outflow through the Kerch Strait from 29 to 70 km^3

Apart from the weather conditions and accuracy of measurements, variations in the values of the elements of the water balance of the Black Sea are influenced by the irretrievable withdrawal of river water for irrigation and other economic needs. Anthropogenic factors entail a whole chain of changes in the quality of marine water and in the ecological processes developing in it. As evidence could serve the present state of the brackish Aral Sea in Central Asia; reduced, over the last decades, to a small salt lake because of excessive consumption of river water by the use of intensive cotton-growing technologies and other needs. However, the fate of the Aral Sea does not threaten the Black Sea because of the water exchange through the Bosporus Strait linking the Black Sea with the Mediterranean. In addition, the water-consuming agriculture technologies (for example rice cultures) occupy small areas, mainly on the north-western and north-eastern coasts.

For different economic and social reasons, further withdrawal of large volumes of water from the rivers inflowing into the Black Sea was not implemented. Therefore the salinity in the surface layer in the open sea remains virtually at the former level of 17.5–18 ‰. It has risen only in some open limans and in the Sea of Azov, causing the penetration of marine species into these water bodies.

The tides in the isolated Black Sea are practically not registered. The amplitude of these phenomena near Constanta port is about 7 cm, near Odessa – 5.5 cm, near Sevastopol – 1–3 cm, near Poty – about 8–9 cm and everywhere has an irregular semi-diurnal character (Leonov, 1960).

More considerable changes in the sea level take place under the influence of winds. The land winds are driving away into the open sea the surface waters and sometimes lower the water level near the shoreline by 1–1.5 m. During the land winds, a wind upwelling occurs in the coastal zone bringing up waters from the depths of 10–20 m. These waters are more saline than those in the superficial layer (and much colder in summer months). During the warm season, the water temperature at the shoreline can drop by 10–12°C in 24 hours. On these days, in summer and in autumn, waters with the smell of hydrogen sulphide and with dying fish, crabs, shrimps and other bottom animals could come to the shore. It is one of the manifestations of the bottom hypoxia; the reasons and consequences of which will be discussed later on.

Along with the mineral substances (compounds of nitrogen, phosphorus, carbon, etc.) different organic matters are always present in the seawater. As in other seas, their basic sources are the organisms inhabiting the sea, more precisely their vital and postmortal metabolites. In addition to this, river waters, atmospheric precipitations, and winds are sources of organic matter of terrestrial origin (Skopintsev, 1975). According to some estimation, the total mass of the dead organic matter (i.e. beyond the bodies of living organisms) in the pelagic zone exceeds the total biomass of all living inhabitants of the water column. Large amounts of the organic matter are deposited in bottom sediments.

The importance of organic matter for marine organisms is exceptionally high. It makes up an important part of food of all heterotrophic species (that use as a source of food the organic matter produced by other (autotrophic) organisms); from bacteria to fish.

In the most concentrated state, the organic matter is present on the water surface in the form of sea foam.

During the last decades, the quality of river runoff has undergone substantial changes towards the increase of content of many substances of both natural and man-made origin (phenols, detergents, pesticides, and other xenobiotics). The latter do not exist in nature, but man has started to produce them for his own needs. All these substances are causing deep changes in the Black Sea ecosystem, which sometimes is called (however, not fully objectivly) as one of the most polluted in the world. Neither mathematical models nor expert estimations have warned beforehand about these ecological changes. These events came unexpectedly, but they were duly noticed and studied and conclusions were drawn. In one of his papers regarding this subject, one of the best experts in Black Sea ecology, L.D. Mee (Mee, 1992), writes that current research on the ecology of the Black Sea tends towards a reactive rather than proactive approach. Similar situations are observed in all the world seas. Yet, there are no effective mechanisms of prognostics, warning and information about the important forthcoming ecological events. However, in the Black Sea earlier than in other seas, the new phenomena were noticed and studied and their detriment for the sea and for humans was estimated. It was also determined that not all the Black Sea has suffered from anthropogenic influence, but mainly its north-western part and its contour communities. This issue will be discussed later on.

1.5. Water and bottom

1.5.1. The water column

Physical and chemical features of all natural water bodies, including seas and oceans, are the basic ecological conditions that determine the possibilities of existence of living organisms and stipulate their species composition, numbers, mode of life, ecology and behavior.

As a marine basin, the Black Sea differs from other seas first of all by its low salinity. Salinity is defined as the total amount of dissolved solids in seawater and is denominated in parts per thousand (ppt, ‰) by mass. There are several proposed classifications of salinity of natural waters. According to J.W. Hedgpeth (1951), the salinity of fresh water is less than 0.5‰, of oligohaline waters – 0.5–3.0‰, of mesohaline waters – 3.0–17.0‰, of polyhaline waters – 17.0–30.0‰, and of marine waters – 30.0–40.0‰.

The system of classification of salinity, adopted by the International Limnological Congress in Venice (1959) and often named «Venice System», distinguishes the following categories of natural waters:

freshwater – salinity less than 0.5‰, mixohaline, or brackish water – from 0.5‰ to 30.0‰,

oligohaline water – from 0.51‰ to 5.0‰, mesohaline water – from 5.1‰ to 18.0‰, polyhaline, water – from 18.1‰ to 30.0‰, euhaline, or marine water – from 30.1‰ to 40‰, and hyperhaline, or ultrahaline water – more than 40‰ (Dediu, 1989).

The normal marine salinity is considered to be 35‰ and such it is in most seas. In some inland seas, in which evaporation exceeds the input of the fresh water, salinity can reach up to 37–38‰ (for example, in the eastern part of the Mediterranean), and even 40‰ (in the Red Sea). In the Black Sea, in which the total volume of the river flow and atmospheric precipitations exceeds evaporation by more than one third and which has a limited water exchange with the Mediterranean, the salinity is considerably lower than that of the ocean. In the central Sea areas it is near to 18‰ on the surface and in the north-western part, where are incoming the waters of the large rivers Danube, Dniester and Dnieper, it reduces to 15‰ and less; i.e. corresponds to mesohaline waters according to the Venice System. The salinity of the Black Sea waters increases with depth,and it is near to 20.5‰ at 200 m and 22.4‰ at 2000 m; which corresponds to polyhaline waters.

Such salinity stratification of the water column takes place because the river water and the water from atmospheric precipitations, when reaching the masses of marine waters, spreads on the surface and flows out through the Bosporus into the Sea of Marmara. The near Bosporus area of the Black Sea receives salt water (nearly 30‰) entering with the bottom current from the Sea of Marmara. However this water mass is quickly diluted by the Black Sea water masses and, as a result, the lower 2 km of the Black Sea water column have a salinity of 20.5–22.4‰. Only near the Bosporus mouth, not farther than 5–10 km from the shore, salinities close to 30‰ can be registered and some Mediterranean organisms, which cannot survive in other areas of the Black Sea, can be met.

In spite of the fact that the peculiarities of the currents' system in the Bosporus have since long been attracting the attention of scientists, there are still some information gaps about the physical and dynamical aspects of the water exchange in this strait.

At the beginning of the XVIII century, a little-known but significant work was carried out by the Italian Count Luigi Ferdinando Marsigli. He constructed a current-meter equipped with a propeller to measure subsurface currents and, for the first time, described the current system in the Bosporus. Marsigli's book «The Physical History of the Sea» was published in 1725 with a description of measured undercurrents in the Bosporus and in the adjoining area of the Black Sea (Groves and Hunt, 1980). The ingenious investigations of Marsigli have anticipated the conclusions of the modern theories on the dynamics of convective currents. However, his ideas have not been recognised for the long time. Only after about two centuries, mainly due to the detailed researches of the Russian admiral S.O. Makarov, the erroneous ideas about the bottom Bosporus current based on inaccurate research and incorporation into science of ancient local legends and myths have been removed (Leonov, 1960).

At present it is known that the upper current from the Black Sea into the Sea of Marmara carries a water volume equal to 2–3 annual runoffs of the Danube river and the bottom current into the Black Sea carries a volume the salt water of Mediterranean origin equal on average to one annual flow of the Danube (Zaitsev and Mamaev, 1997). However, there is no certainty whether the influx of water from the Sea of Marmara takes place in a continuous or sporadic manner (Sholten, 1974).

Furthermore, still very little is known about how the salty Marmara waters spread into the Black Sea after their exit from the Bosporus and what is the configuration and area of shelf with the salinity of benthic layer of 30‰. This information could contribute to understanding the process of penetration of Mediterranean Sea species into the Black Sea.

Along with salinity, water temperature is another important ecological factor. In summer, during windless days, coastal waters can be warmed up to 25–26°C and even up to 28–30°C in the shallow gulfs and bays. In the open sea areas, the summer water temperatures at the surface reach 23–24°C. At depth the water is colder and, at a 150 m depth, during the whole-year water temperature is 8.5–8.6°C. Further deep, water temperature is practically stable around 9°C until the bottom. In the water column, between 50–70 m and 100–150 m, there is a so-called «cold intermediate layer» (CIL) with water temperatures from 7.20°C to 7.50°C.

In winter, the water temperature in the southern and south-eastern areas of the Black Sea falls down to 10–13°C and, in the northern areas, to 4–5°C and less. During cold winters, for example in

1954, 1963, 1985, 1996, 2002 and 2006, the water temperature in the Odessa Gulf fell down to 0°C and -1°C. At these times the sea surface was covered by ice, sometimes until the skyline. In exceptionally cold winters, the ice field (continuous ice or floating ice blocks) extends southwards to the Zmyiny Island and, in rare cases, floating ice can arrive to the Bosporus and even block up the channel for a while. Not later than March, all the ice melts and the sea water starts to slowly warm.

Low water salinity and low winter temperatures constitute a serious obstacle for the penetration of the thermophilous species from the Mediterranean Sea into the Black Sea. Another serious obstacle for the settlement of some marine organisms in the Black Sea is the absence of considerable depths suitable for life.

The deeper layers of the Black Sea are contaminated by hydrogen sulphide (H_2S), which is toxic for aerobic organisms. Between the upper (oxygen-rich) and bottom (hydrogen sulphide-rich) layers of the Black Sea there is a thin intermediate layer of up to 10–20 m with coexistence of both gases. In this layer, still could be registered some organisms from the oxygen layer of the Sea. However, about 87% of the Black Sea volume is deprived of oxygen and contaminated by hydrogen sulphide (fig. 5).

Figure 5. Below 200 m the Black Sea water column (87% of the total water volume) contains hydrogen sulfide (from Zaitsev and Mamaev, 1997). No life, except anaerobic bacteria, exists below this level. This is a general opinion, but some new data challenge this postulate and special investigations are needed.

Indeed, the major part of the Black Sea water column is unsuitable for life of most organisms and, in this sense, the Black Sea is a unique sea in the world. In general, hydrogen sulphide is not a rarity in the world seas. It was discovered in the hollows of the Baltic and Caspian Seas, at the bottom of the Arabian Sea and in other areas of the World Ocean. However, in all known cases, the volume of hydrogen sulphide is not great and it is constantly oxidated by the oxygen from the upper layers. The ecological situation in the Black Sea is quite different. Here the great depths are zones of deep stagnation, where each molecule of the near-bottom water can reach the sea surface once every hundred years and more. For comparison, in the Mediterranean which is 2.5 times deeper than the Black Sea, this process takes about 80 years. Therefore, on the bottom of the Mediterranean Sea, the hydrogen sulphide is not registered while in the depths of the Black Sea it is constantly present.

This gas is generated by sulfate-reducing bacteria due to the decomposition of organic matter falling from the sea surface and because of sulphates reduction. Among the specialists continues a discussion concerning what process produces more hydrogen sulphide. However, reasoning ecologically, the important thing is that this gas is accumulated in water layers below 200 m. It is one of the Black Sea peculiarities, marking it out among all other world seas.

Indeed, the uniqueness of the Black Sea is that it contains no algae, invertebrates, or fishes in its deep waters that are not inhabited by any living organisms, except for thiobacteria – the only inhabitants of this enormous/ huge kingdom of cold and darkness. This was considered an axiom, an indisputable truth that does not require any proofs until recently, when some data about which we will talk a bit later have appeared regarding this issue.

Over the last years, in some scientific articles and mainly in mass media, was held a discussion concerning the possibility of changes of the position of the upper limit of the hydrogen sulphide zone in the Black Sea. This gas was for the first time discovered at a depth of 200 m in 1890 during the expedition on the ship «Chernomorets» by the scientists from the Odessa (at that time named Novorossiysk) University: geologist N.I. Andrusov and chemist A.A. Lebedintsev. For a long time the depth of 200 m has been considered in the scientific literature as the upper boundary of the hydrogen sulphide zone in the Black Sea. In the 1920s, the long-term Azov-Black Sea expedition under the supervision of N.M. Knipovich has determined that the upper bound of the hydrogen sulphide zone in the Black Sea is dome-shaped. In practice, it lags beneath the water surface at 150 m and even less in the centers of permanent cyclonic gyres; while on periphery and on the shelves it lowers to 200 m and in some areas to 250 m.

When, in the late 1970s and early 1980s, it was found out that the total number and biomass of plankton in the upper layers of the Black Sea had significantly increased, some authors supposed that the upper limit of the hydrogen sulphide zone must also have raised because of this. It is a quite admissible conclusion, taking into consideration that the increase of biomass of living plankton means intensification of sedimentation of dead organisms on the bottom, decomposition of their bodies, consumption of oxygen dissolved in sea water and production of hydrogen sulphide. But can this fact influence the volume of the hydrogen sulphide zone in the sea, considering that there are proofs that decomposition of organic matter accounts only for a few percents of the total amount of hydrogen sulphide being generated in the stagnant deep waters of the Black Sea?

Scientists have once again analyzed the vast data obtained by oceanographic expeditions. Many prominent experts participated in this work, among them the academician of NAS of Ukraine V.N. Eremeev and the American scientist Dr. D. Aubrey. These scientists found that the hydrogen sulphide zone in the Black Sea was at the same level as before and its upper limit did not reveal any substantial tendency to rising. Atmospheric oxygen together with the oxygen produced by algae is oxidizing the hydrogen sulphide and retains its upper bound at a practically stable distance from the sea surface.

The concentration of the hydrogen sulphide in water depends on depth. At 150 m it makes 0.19 mg per one kilogram of water, at 200 m – 0.83 mg, at 300 m – 2.34 mg, at 1000 m – 8.48 mg, at 2000 m – 9.60 mg.

As for the possibility of combustion of hydrogen sulphide in the Black Sea, about which lately some mass media have beated an alarm causing a public resonance, it was calculated that it would be only possible if the concentration of this gas in water was at least a thousand times higher than at present. This example of alarm around the hydrogen sulphide in the Black Sea shows how «explosive» some ecological problems can be today and how responsibly they should be treated in order to not generate a false agitation in unprepared minds and not to distract the society from real ecological events; participation in which would bring an effective profit.

And now about some riddles related to the hydrogen sulphide zone in the Black Sea.

Studying bottom sediments from different depths of the Black Sea up to 2000 m, some scientists have recorded different metazoan organisms. These were not sulfur bacteria, which would not have caused much surprise, but benthic invertebrates: nematodes, molluscs, crustaceans, etc. (Kiseleva, 1979; Zaitsev *et al*, 1987; Vorobyova, 1999; Sergeeva, 2000), which are quite common in benthos of the oxygenated zone of the sea. They were found despite the presence of hydrogen sulphide and absence of oxygen. How is it possible to explain such paradoxical situation? The simplest way would be to assume that somehow they have «fallen down» from the upper oxygen layer, but the profile of the sea-bottom is not a steep precipice from which it would be possible to «fall» down to a great depth. How long an organism inhabiting an oxygen zone can survive without it in adverse, hydrogen sulphide conditions?

Analyzing this paradoxical situation, the author proposed several hypotheses (Zaitsev, 1998) which do not need to be disputed in this book. General conclusion comes to the fact that the discovery of metazoans (living or not is not yet ascertained) at the maximum depths of the Black Sea, and the recent information about low levels of dissolved oxygen at these depths (however these data were not confirmed), testifies the necessity to conduct special research. Should they confirm the existence of living organisms (besides the sulfur bacteria) or their dormant stages on the bottom of the Black Sea, the deep rooted-in-science name of «azoic» (i.e. lifeless) zone should be revised, though it was considered to be an axiom (Zaitsev, 1998). Recently, for the first time, cultures of aerobic species of fungi and diatoms were obtained from spores collected in bottom sediments of the anaerobic and hydrogen sulphide zone of the Black Sea at depths from 800 to 2100 m (Zaitsev, Polikarpov *et al*., 2007).

Discussion about the hydrogen sulphide in the Black Sea has turned out to be a bit long, but it was impossible to pass over it in silence; this gas being specific for almost 9/10 of the water column.

The problem of the hydrogen sulphide appearing in summer season on the shelf, and which has the anthropogenic origin, will be discussed later.

Among the other ecologically important physical and chemical factors of the marine environment can be named currents, solar radiation, and mineral and organic matter.

Main currents in the Black Sea have circular character and anticlockwise direction (cyclonic currents). In the narrowest part of the sea, between the Southern coast of Crimea and the Kerempe Cape on the Anatolian coast, a part of the water masses coming from the west are turning northward and thus divide the sea into two parts (western and eastern) each with its own cyclonic current (fig. 6). In the centers of cyclonic currents there are the so-called halistatic zones with a relatively stable salinity of about 18.0‰ at the surface.

Figure 6. Main surface currents in the Black Sea (after Neumann, 1942, from Zenkevich, 1963)

The eastern part of the Black Sea has two halistatic zones, which are divided by the branch of cyclonic currents going from the Bafra Cape on the south towards Tuapse area on the Caucasian coast. In the most eastern part of the sea, in the area of the Cape Gonyo (in Greek «gonyo» means «corner»), there is another small circulation of waters but of anticyclonic character (clockwise). In the coastal zone, the directions and speeds of local currents can be influenced by winds, but basic currents are quite stable. For different parts of the cyclonic system of currents encircling all the Sea, the following names were proposed (Leonov, 1960): Anatolian current – between the Bosporus to the traverse of the Kolkhida lowland; Caucasian current – from the traverse of the Kolkhida lowland to the Kerch Strait; Crimean current – from the Kerch Strait to the Tendra spit; and the Rumelian current – from the Tendra spit to the Bosporus Strait.

The sunlight penetrating in the pelagial is absorbed by water layers. The long-wave infrared and red components of the solar spectrum are absorbed first, followed by green and blue ones. The short-wave ultraviolet rays penetrate deeper. For the plants the most important are red rays and their presence determines the possibility of algae and seagrasses development. Because of high concentrations of suspended particles and organisms (phytoplankton, zooplankton, detritus, other organic and mineral particles), the Black Sea waters are less transparent than, for example, the waters of the adjacent Aegean Sea. This is one of the reasons why ancient inhabitants have called the sea «black», while the considerably more transparent Aegean Sea in the Bulgarian, Turkish and Greek languages is called «white».

For the development of plants and some bacteria crucial importance have the compounds of phosphorus, nitrogen, potassium, calcium, sulfur, and magnesium. They are called biogenic elements, or nutrients. Following a deficiency of these matters in water, development of plants is inhibited or even stopped. The main source of nutrients in the Black Sea is river runoff. Consuming inorganic matter, the green plants (in the sea these are first of all algae) use the solar energy absorbed by chlorophyll and other photosynthetic pigments and produce different organic materials, from which are formed the cells and tissues of plants. In the Earth's biosphere, the photosynthesis is the only process leading to an increase of free energy and ensuring the existence of both plants and animals, the latter being able to consume only the organic matter produced by plants.

In natural water bodies, the plants are more abundant in the zones with higher nutrients concentrations. In the Black Sea, these are the coastal shallow waters and especially the north-western part of the sea (NWBS), where the three large rivers Danube, Dnieper and Dniester are inflowing. Here is located the largest shelf of the Black Sea – the north-western shelf (NWS), vividly named the Black Sea «granary» by Professor P.I. Usachev.

1.5.2. Black Sea bottom

Many marine organisms, both plants and animals, inhabit the water column or pelagial during their whole life cycle or during a certain time. They are named pelagic organisms. Other organisms inhabit the sea bottom, or benthal; they are called bottom organisms or benthic. Most species inhabit one or another environment, changing them during their lifecycle (more frequent cases are when larvae are living in pelagial and adult specimens on the bottom) or during the day (in the evening and at night they emerge on the surface of pelagial and in the morning return back to the bottom). Thus, the sea-bottom plays an important role in the life of aquatic organisms. A very specific group of marine water bodies are the coastal wetlands (limans and lagoons), which are especially characteristic of the north-western coast of the Black Sea (Wilson and Moser, 1994).

As habitats (biotopes), the different areas of the bottom differ from each other by geological characteristics (sand, pebbles, stones, shell rocks, silts, etc.) and, related to them, soil's hardness as a substratum for benthic organisms (soft, hard grounds), physicochemical and granulometric characteristics of bottom etc.

Different groups of organisms have adapted during the process of evolution to certain areas of bottom and to specific grounds. In biology and ecology, the term «biotope» means a rather homogeneous site inhabited by a certain community of organisms or biocenosis. Biotopes can be more clearly distinguished on the bottom of each water body, on the basis of the different types of sediments.

Special cases of benthal are the surfaces of different objects that were constructed or left by man on the bottom or in the water column. They are called anthropogenic hard substrates, or anthropogenic biotopes. These are, for example, different hydrotechnical constructions (dikes, traverses, breakwaters, piers and pipes), artificial reefs, and sunken ships. These objects could be from stone, concrete, metal, wood and other materials. With time, their surface is covered by microorganisms, algae, invertebrates, which, at times, develop more successfully on an anthropogenic hard substrate than on natural grounds. Sometimes anthropogenic substrates can be located in the water column or on its surface, as in the case of nets, beacons, buoys, submerged parts of ships, etc. They too become fouled with the aquatic organisms.

In some cases, fouling of anthropogenic substrates could be used as a biological and ecological process useful to the man. On this principle, function the artificial reefs and are fouled the collectors for mollusks growing. In other cases, fouling turns to be a harmful process creating serious problems in the exploitation of marine pipes and in shipping. Therefore, the fight against fouling of submarine objects is one of the prior tasks for a number of branches of human practical activities.

1.5.3. Contour (marginal) biotopes of the sea

1.5.3.1. The Neuston layer (Neustal)

Along with the pelagial and benthal, the contour or marginal biotopes are forming a specific category of habitats in the marine environment. For a long time, these biotopes, located at the sea-atmosphere, sea-shore and sea-river interfaces have not attracted researchers' attention as they were considered of no particular interest. In the scientific literature, it was noted that these peripheral (marginal) biotopes strongly differ from the optimal ones and therefore the organisms that inhabit them cannot successfully compete with those specimens inhabiting optimal biotopes; as they inhabit the so-called «outskirts» or extreme habitats with all the ensuing disadvantages. On the other side, it was known that the marginal zones, where marine, terrestrial and freshwater communities of organisms come into contact, are characterized by a «contour effect»; i.e. high numbers of living organisms (Dediu, 1990). For the land is known the so-called effect of the forest edge; i.e. the forest edge is always inhabited by a higher number of species than the forest itself or a stretch of open land in its vicinity. However, an a priori conviction in the poverty of the sea marginal biotopes has prevailed among marine biologists; in particular with regard to the sea-atmosphere interface. It was considered that here the conditions for marine organisms are most unfavorable and therefore they try to avoid them. As the most dangerous factors were considered the destructive force of waves (especially for the organisms with the soft and unprotected tissues) intensive solar radiation (which is harmful for many species including bacteria) and double «pressure» of predators from below (water) as well as from above (air). All these factors, according to dominating opinion, prove the expediency of marine organisms to be at a distance from the water surface, down in the water column.

For these reasons, the first information that in the upper few centimeters of the Black Sea water column there was a steady accumulation of living organisms, adapted to the specific conditions of this biotope (Zaitsev, 1960, 1961) was not perceived. Later on, when ways of organisms' adaptation to the specific condition of pelagial surface biotope (Zaitsev, 1970, 1974; Tsiban, 1970) have been studied, this attitude changed. Application of special sampling nets has allowed to discover the marine neuston practically in all seas and oceans. Previously, it was considered that the association of organisms of neuston could only develop in small ponds and lakes, protected against wind, but could not exist in large lakes and especially in the seas and oceans.

It was proved that marine neuston is not only a dense concentration of organisms, much denser than the plankton in the water column, but also an accumulation of the early stages of development of invertebrates and fish (i.e. eggs, larvae, fries) that find in this biotope the most favorable conditions for their successful growth and development. These are the high concentrations of dissolved oxygen, presence of infrared and ultraviolet rays of the solar spectrum and abundance of food. Neuston was figuratively called the main «incubator» and sea's «nursery» as many species whose eggs and larvae develop in the near surface biotope inhabit the water column and bottom as adults. In ecological systems, neuston also functions as the «managing link» (Polikarpov and Zaitsev, 1969). If the neuston phase of development goes well, it is possible to expect a productive generation of, for example, grey mullet in the water column or crabs and flounder at the sea-bottom.

Further studies have showed that the evolutionary origin of neuston, with its leading role in the life of the sea, was determined by physical and chemical processes which ensured the formation at the sea - atmosphere interface of such a combination of environmental conditions which were most favorable for the development of a community of organisms responsible for the fate of many marine inhabitants. In scientific literature, this specific biotope of pelagial got the name of neustal (Konstantinov, 1979, 1986; Dediu, 1989).

At present are known the main physical and chemical processes developing in the neustal and they should be named in this book on the ecology of the Black Sea.

The upper layer of 0–1 cm absorbs 20%, and the layer 0–10 cm 50% of the total amount of solar radiation reaching the sea surface. In the upper 10 cm of water, all long-wave radiation (infra-red rays) and also ultraviolet rays within the limits of wave length 300–200 mcm are absorbed.

In the neustal, there is an accumulation of nonliving organic matter of marine and terrestrial origin. From the air, pollen of anemophilous plants, spores, cysts and terrestrial insects fall into the sea. Due to their lightness, lack of moisture and small sizes these particles and organisms could stay for a long time on the water surface serving as an additional source of food for many marine invertebrates and fish (i.e. the main components of neuston).

From the water column to the surface are emerging the dead organisms (the so-called «antirain» phenomenon of dead bodies). Here they remain till their complete decomposition whereupon they accumulate at the bottom. In the layer of 0–5 cm were found accumulations of dead copepods, larvae of barnacles and phytoplankton (Zelezinskaya, 1966; Nesterova, 1968; Roukhiyainen and Senicheva, 1985). Here they continue to decompose, disintegrate in separate fragments and enrich the surface layer with so-called «young» detritus (Krey, 1967) which is most valuable as animal food.

The special mechanism of replenishment of the neustal with organic matter was studied by a number of authors and is related to the air bubbles. These bubbles are originating in the water column because of wave action, photosynthesis, decomposition of dead organisms and other processes. Rising to the surface, these bubbles adsorb dissolved organic matter and transport it to the surface. Thus, in the organic membranes of air bubbles, takes place the change of dispersion of organic matter. From solutions and colloidal suspensions are forming particles, or aggregates, whose chemical composition and dimensions make them suitable as animal food.

An important source of air bubbles is the oxygen dissolved in the water (Ramsey, 1962). The oxygen bubbles, forming because of the fluctuations of water temperature, constantly increase in size and move to the surface carrying adsorbed organic films. It was proved that the bubbles' stability in water is due to the presence of an adsorbed film which plays a role of diffusion barrier containing fatty acids and protein. This barrier prevents the escape of gas from the bubbles into the water (i.e. its destruction) and ensures that they will reach the surface film. The adsorbed organic cover remains here even when a bubble bursts out, releasing the contained gas.

One of the ecologically important consequences of this permanent natural process of bubbling and flotation is the formation of foam on the water surface. Foam is a constituent of superficial biotope and its ecological value is exceptionally high. In foams are contained ten hundred times more organic and mineral matter than in the water, with predominance of surface-active matters. Unsteady (or dynamic) foams and steady (stable) foams are distinguished. The first can be observed in the white horses of wind waves at open sea, in ships' waves appearing in front of the moving ship and left after the stern. The life time of this dynamic foam is measured in seconds. Stable foam appears on the water surface saturated by nonliving organic matter. It could be stable for hours in the form of flakes, bars or fields; which is commensurable with the life-span of bacteria and other microorganisms inhabiting it. However, the foam generated by surfactants, for example by synthetic detergents and saturated by them, is harmful for living creatures.

A.V. Tsyban (Tsyban, 1970, 1971) has registered from thousand to ten thousand times more heterotrophic microorganisms in the foam than in the water at the depth of 0.5 m. Natural sea foam is a biologically active substance. There are data about biologically active properties of excretions of living and dead marine plants and animals (Skopintsev, 1962; Khailov, 1963). They become apparent in the stimulation or suppression (inhibition) of different physiological processes in organisms. For the verification of foams' properties collected at the surface of the Black Sea, different series of laboratory experiments were conducted (Zaitsev, 1967; Chilikina, 1969). The foam samples were collected at the sea surface and precipitated in glass jars until the formation of a thick homogeneous emulsion (colloids) consisting of the membranes of air bubbles at the jar's bottom. This emulsion was diluted to the necessary concentration by the filtered seawater (in experiments with marine organisms) or with the fresh water (in experiments with terrestrial plant). As test objects, marine and terrestrial plants and marine animals have been used. In the control sample, same organisms (terrestrial plants) were kept in the conditions of watering by fresh water or in the filtered sea water without adding of the foam's emulsion.

The results of these experiments, when treated statistically, have shown that 0.5% of the solution of the sea foam emulsion substantially (statistically significant) stimulates the growth of the cyanobacteria *Spirulina tenuissima* and the development of the shrimp *Palaemon adspersus* larvae, accelerates hatching of larvae from the eggs of the goby *Potamoshistus sp*. and prolongs the larvae's life. A female of the copepod *Cyclopoida g. sp*., when placed in a hermetically closed jar (volume 10 cm^3) with undiluted foam emulsion, has moved actively, moulted and, apparently, fed during 98 days. This case could be of interest for the development of technologies of the closed ecological systems. Experiments with the seeds of cereals showed that 0.2% of marine foam solution in fresh water substantially stimulates the development of the root system and growth of the leaves of oat, barley and wheat.

Figure 7. Stable foam at the sea surface or on the sea shore is an evidence of marine ecosystem abnormality (photo Yu. Zaitsev)

These experiments have not received further continuance As, already in the 1970s, the foams collected at the same areas of the north-western part of the Black Sea, at any dilutions of their emulsion, had an inhibiting rather than stimulating on the physiological processes of the plants and animals. This change concurred with the beginning of intensive pollution of the sea by chemical and radioactive matters and with the frequent decline in quantity of many mass organisms of the neuston community (Fig. 7).

Possibly, in the central waters of the Black Sea, foams have preserved their growth-stimulating character, but there are not such data.

When, in the second half of the XXth century, the influence of anthropogenic factor on seas and oceans has sharply increased, the same physical and chemical processes, which allowed formation of favorable conditions for marine organisms in the neustal, have resulted in the accumulation of various harmful substances for the plants and animals. Thus the concentration of many chemical and radio-active matters in the superficial layer 0–5 cm becomes tens, hundreds and even thousands times higher, than in the same volume of water at the depth 0.2–0.5 m.

Examples of the accumulation of different elements and substances in the surface film of water are given in table 3. Samples were taken by S.A. Patin in the Arkashon Bay on the Atlantic coast of France in summer 1977.

Table 3

Vertical distribution of some toxicants at the sea surface (from S.A. Patin, 1977)

	Average concentration, 10^{-6} g		Concentration factor in the surface film
	In surface film 60-100 μm	In water layer at the depth of 0.5 m	
Anionic detergents	850 ± 75	10 ± 1	85
DDT + DDD	95 ± 10	0.10 ± 0.02	950
DDE	86 ± 9	0.10 ± 0.02	860
Lindane	44 ± 8	0.07 ± 0.02	650
Polychlorinated biphenyls (PCBs)	105 ± 15	0.10 ± 0.02	1050

Mercury (Hg)	2750 ± 110	0.5 ± 0.1	5500
Lead (Pb)	2920 ± 118	13.5 ± 3.5	220
Cadmium (Cd)	120 ± 35	0.4 ± 0.1	300
Copper (Cu)	235 ± 15	0.3 ± 0.1	800
Zinc (Zn)	1020 ± 45	22 ± 4	470

During agitation the organic film at the water surface together with the matters accumulated in it gather into the foam.

Spatial coincidence of the accumulation in the biotope of neuston of the extremely sensitive early stages of development of marine organisms from the one side and maximal concentrations of harmful matters from the other has generated one of the most acute ecological problems in the modern World Ocean. The Black Sea makes no exception.

1.5.3.2. Other contour biotopes of the sea

The discovering of neuston in the surface microlayer of the sea has attracted the author's attention to other external interfaces of the pelagic zone bordering with the shore, bottom and river waters. In scientific literature, there are some data concerning the ecological importance of these areas.

The interfaces of the pelagic zone have a key importance in the conception of the biological structure of the ocean, formulated by the founder of biospherology V.I. Vernadsky in 1926. According to T.A. Aizatullin and coauthors (1979), Vernadsky was obviously taking into consideration the idea of one of the thermodynamics founders, W. Gibbs, about the concentration of all physical characteristics on the borders. However, V.I. Vernadsky operated with large biological structures and differentiated four permanent «condensations of life», or living matter: two films – planktonic and benthonic – and two condensations – coastal (marine) and sargassum. Of particular interest, empahsizes K.A. Vinogradov (1968), is the penetration into the essence of phenomena occuring in the contact (boundary) areas of biosphere at the interface of existing natural media: the surface of seas and oceans and atmosphere, frontal zones of different water masses (especially of different temperature and salinity), neritic zones of seas and oceans and lithosphere.

However, special investigations of the external borders of the sea at a metric and centimetric scale, as it was done in the biotope of neuston, have not yet been conducted. Studies of these areas by the author and his colleagues have revealed certain similarities with the surface film of water. As well as in the neustal, an accumulation of organic and mineral matter that assure mass development of aquatic organisms also occurs at the other boundaries of the pelagic zone. The physical and chemical reasons of this are in principle the same.

In particular, a very important effect of active surfaces of the sea is the activation of different adsorbed substances, acceleration of their reactions (heterogeneous catalysis) by some thousands and ten thousands times. In the contact zone sea – shore, important reactions occur on the surface of solid materials exposed to mechanical impacts. These reactions are studied by mechanochemistry. The major mechanochemistry area on the planet is the zone of waves battering. However, the understanding of this exceptional area still remains a gap in our knowledge (Aizatullin *et al*., 1979).

External borders of the sea are specific areas of transformation and accumulation of matter and energy. The sea shoreline, where all external borders are coming together and interacting, is a kind of unique multi-fold boundary.

As well as the neustal, other external interfaces are inhabited by different organisms with predominance of early ontogenetic stages. As in the case of neustal, these biotopes, in spite of their accessibility for investigation, remain practically out of the researchers' attention. It seems that, such situation is due to a kind of oceanological paradigm which dominates scientific thinking and practical decisions. For example, when planning programs of marine scientific expeditions, studies of deeper layers are sometimes (if possible) foreseen along with the traditional measurements such as physical, chemical and biological parameters of the water column on «standard» horizons (depths). Such immersion into the depths quite often gives new information interesting for science, which authorizes large expenses of time, facilities and intellectual potential during realization of such expeditions. However, this focussing onto the far and deep zones of the sea, forces the researchers to «step over» the very interesting and ecologically important nearest and most accessible areas on the external boundaries of the sea.

These marginal habitats of the sea are named contour biotopes (Zaitsev, 1982, 1986, 1998).
They are inhabited by specific contour biocenoses composed by specific organisms (contourobionts). Taking into consideration the media with which the water mass interacts (fig. 8, 9, 10), the following names have been suggested for other interfaces of the sea: aerocontour (the surface of the sea bordering with the atmosphere), potamocontour (sea-river water masses), psammocontour (sea-sandy shore and sea bottom), lithocontour (sea-rocky shore and sea bottom), pelocontour (sea-muddy shore and bottom).

Each contour biotope has specific groups of organisms adapted to its specific conditions. In all cases, except for the deep-water pelocontour, there is a predominance of early stages of development of invertebrates and fish. Therefore, the contour communities have high values of biological productivity and high quantitative indexes of reproduction of their biomass. Unluckily, these communities are located in zones where man-made impact is strongest.

Figure 8. Contour biotopes of the water column (pelagial) at its external boundaries with the atmosphere (aerocontour – 1), sandy beaches (psammocontour – 2), rocky shores (lithocontour – 3), muddy bottom (pelocontour – 4), and river waters (potamocontour – 5) (from Yu. Zaitsev, 1986).

Figure 9. Sandy contour (psammocontour) in the north-western Black Sea coast. The following main ecological zones can be recognized: supralittoral or spray zone (dry sand), mediolittoral or splash zone (wet sand), upper sublittoral zone (sandy bottom permanently covered by sea water) (photo by Yu. Zaitsev).

Figure 10. Rocky coast of the Zmyiny Island. Below is the splash zone that is subject to wetting by splash from breaking waves. The black film covering the stony surface in this zone is composed by microscopic algae and animals (photo by Yu. Zaitsev).

Summarizing the results of existing investigations on the biology and ecology of the external boundaries of seas and oceans, T.A. Ayzatullin and coauthors (1979) arrived at the conclusion that, in the hydrosphere, they represent active surfaces compared to which the huge water column functionally appears no more than an enormous «dozy giant». Analysing the information about boundary effects, in order to use recent data for the reevaluation of the conception of V.I. Vernadsky, Ayzatullin and coauthors write that «we discovered obvious tracks of a forthcoming revolution in oceanology».

However already a quarter of a century has passed since the publication of this book and the scientific revolution has not yet taken place. Researchers, in most cases, still explore the water column and as a rule do not devote special attention to its surface and coastal contour biotopes. The exception are perhaps the works of the Odessa Branch of Institute of Biology of Southern Seas (OB IBSS) where there is the department of hydrobiology of active surfaces of the sea and the department of radioactive and chemical biology of the IBSS (Sevastopol). Here, under the scientific supervision of academician of NAN of Ukraine G.G. Polikarpov, neuston and other contour communities have been comprehensively studied for longtime. Such an approach and outlet beyond the dominant paradigm in oceanology has allowed to understand better the processes occuring in ecologically critical biotopes of the Black Sea. With their communities, contour biotopes are a kind of «trigger points» of the sea, on which it is possible to judge about the state of the whole ecosystem (Zaitsev and Polikarpov, 2002).

In modern ecology, the concept and term «hot spots» is often used (Norse, 1993). It includes two components. From the one side, this term designate areas with a high species diversity or set of species needing a special attention. From the other side, hot points are the areas of the strongest human impact on the environment. Contour biotopes and organisms inhabiting them fall under the definition of ecological hot spots.

In connection with this, the editor-in-chief of the book «Global marine biological diversity. A strategy for building conservation into decision making» E.A. Norse writes: «At the limited human and financial resources it can be considerably more practical to concentrate them on several hot spots». By analogy with the society, in that degree, in what it is possible to affirm, it is the question of help to those species and communities which need it.

Questions from chapter 1 for seminar (training) in the Black Sea ecology

1. What seas are called inland or internal? Give some examples.
2. Were there the periods of desalination and salination in geological past of the Black Sea? Name them. Have the present Black, Azov and Caspian Seas formed a common marine basin? In what geological periods?
3. What is the catchment (drainage) basin? What area occupies the catchment area of the Black Sea? Territories of what modern countries does it cover?
4. What is the specific drainage basin?
5. Name the major rivers flowing into the drainage basin of the Black Sea. Are there any large cities in the drainage basin of the Black Sea? Give some examples.
6. Name the basic morphometric characteristics of the Black Sea: area, length of the coastline, maximal depth, volume of the water column, major bays, gulfs, capes and islands.
7. What does the term «development of the coastline» mean and how is it determined?
8. What directions have the main currents in the Black Sea?
9. What does salinity of the sea water mean? What is the salinity of the Black Sea water? Does

it differ from the salinity of other seas and oceans? If it differs, explain why.

10. Make an example of classification of the seawater according to its salinity. What is the water temperature in the Black Sea? Could ice be observed on the surface the Black Sea? If yes, then where and when?
11. What is known about the hydrogen sulphide in the Black Sea? How is its origin and permanent presence in the sea depths explained? What part in the water column of the Black Sea is infected by hydrogen sulphide?
12. What is part of the sea called the shelf zone? What is the total area of shelf in the Black Sea? Where is located the main shelf (according to its area) in the Black Sea?
13. Name the basic types of the bottom sediments of the Black Sea.
14. Give the definition of the pelagial, benthal and neustal.
15. What biotopes are called contour, or marginal biotopes of the sea? Give examples.
16. Name the main peculiarities of life conditions in the aerocontour of the pelagial (in the neustal).

2. Inhabitants of the Black Sea

Each sea has its own biota – historically formed community of different species of flora, fauna and microorganisms. The Black Sea, as a specific part of the World Ocean, has its flora and its fauna – the plant and animal components of marine biota. Both flora and fauna are represented by wild species, i.e. undomesticated and uncultivated living creatures. The emphasis is placed on the word «wild» because man when pursuing his own goals, raises the breeds of animals, species of plants, and cultures of microorganisms using possibilities of selection and genetics. As a result, new organisms of existing species, rather than new species, are created by man according to his practical or aesthetic interests. Smallest indoor dog, mastiff, sheep-dog and other domestic dogs belong to one biological species that was raised 10–15,000 years ago from the wild species of wolf (*Canis lupus*). The same is true for the species of birds, fish or plants.

It is impossible to give a clear answer to the simple question of how many species of wild animals and plants are inhabiting the present Black Sea, because nobody knows it.

By estimation of experts, there are from 1.4 to 1.7 million species (excluding bacteria) living on the Earth (Stork, 1988 from Gray). Among them, insects alone comprise about 400,000 species (Heyword and Watson, 1995). It is considered that in seas and oceans there still are from 500,000 (May, 1992) to 10 million undescribed species (Grassle and Maciolek, 1992). Compared to the

300,000 known (described) species of marine creatures, the gaps in our knowledge in the field of taxonomy are clearly considerable.

This fact does not at all indicate a total lag of modern biology, when the human genome and the genomes of other biological species are decoded, living things are recreated from one cell and the rich harvests are collected on the fields. Nevertheless, we do not know the amount of wild species inhabiting Earth.

Till today there is no «register book» of living creatures, without which to redo something at own discretion, to exclude (to annihilate) or to add, or, by other words, to manage, is completely impossible. Nevertheless, man acts according to his own wish, and the fact that his practical activity often does not give the expected result is often due to the huge gaps in fundamental fields of biology such as systematics and taxonomy.

Systematics is the science about the identification of organisms of different species and determination of the relations between them. Taxonomy is the science about principles, methods and rules of hierarchical classification of organisms (kingdom, phylum, class, order, family, genus, species and subspecies), depending on the degree of their relation.

Today's reality is that, in the victorious parade of biological sciences, the systematics and, related to it taxonomy, have remained behind in their development from the time requirements. This lag is more noticeable when not only separate populations of species but whole species are lost because of growing man pressure on the environment. In other words, a species disappears without this being noticed because science did not even know about its existence in nature.

This situation can be explained. Following the founder of modern systematics Carolus Linnaeus (1707–1778), biologists continued to describe biological species according to their anatomy and morphology on the basis of external and internal characteristics that are quite often very difficult to distinguish. This work required not only a thorough, deep knowledge but was also time and assiduity. Well-educated and industrious taxonomists of the XIXth century have succeeded well, although they have committed some errors. Quite often, according to the external and internal morphology, the adult organism sharply differs from its larvae that, in such cases, can be described as separate, independent species. For example, the larva of the fresh water eel looks very different than adult fishes and it was originally described as a species on its own: *Leptocephalus brevirostris.* Later this mistake was corrected, but the larva of the eel continued to be named «*Leptocephalus*». The invention of the electronic microscope and other modern devices, the possibility to use different opportunities of the adjacent sciences (for example the characteristics of the genetic data carrier, DNA), and computer techniques have eased the work of taxonomists, but the lag of this biological science persists.

Most modern young biologists do not adequately appreciate the importance of systematics. They prefer to deal with the quantitative databases concerning the structure and functioning of living organisms. Beyond all doubts, work with numbers is much needed since it allows to estimate not only the modern indexes of biomass, production, destruction etc. of organisms and their communities, but also helps to make prognoses on the future for varying scenarios of development of an ecological systems. However, not enough persons are interested in counting the number of different bristles, cilia, dents and many other structural details of living organisms in order to specify their species affiliation or to identify a new species for the science. Such situation is typical not only for Ukraine, but quite common in other countries. The already mentioned American environmentalist E. Norse alarmingly compares taxonomists to the vanishing species. If systematics, he writes, were the biological species, it would be necessary to classify them as being under the danger of disappearance. In the world taxonomists include about 1500 persons with their majority near to retirement age and few people interested to replace them.

The number of taxonomists is indeed small in the world and almost all of them are acquainted with each other, exchange information and continue their work building the fundamentals of biology. When biologists from the USA needed to know what species of Ostracods (Crustacea) penetrated with the ships' ballast waters from Eastern Europe to North America, they mailed samples to Kiev to the Institute of Zoology of Academy of Sciences of Ukraine. However, there was no specialist in the taxonomy of this rather mass group of benthic animals in Ukraine and samples were readdressed to Kishinev, Academy of Sciences of Moldova. There, the recently retired specialist in the field A.L. Kovalenko returned back to her former laboratory to execute the request of the American colleagues. This more than convincing example supports the sorrowful statement of E. Norse. In Ukraine, for example, there are presently no specialists in the systematics of such large groups of marine organisms, such as foraminiferans, sponges, hydrozoans, combjellyes, turbellarians, gastrotrichs, kinorhynchs, and tardigrades.

The author considers appropriate to talk about the difficulties experienced by taxonomy in this book, which is addressed mainly to young people. Systematics is one of those fundamental areas of biological science where Nature promises a great number of interesting discoveries to the inquisitive mind.

Going back to the book's chapter about the inhabitants of the Black Sea, it should be noted that about them our knowledge is not scarce, as the Black Sea is one of the most studied in the world and many scientists devoted their studies to find out the specific taxonomy of the organisms which inhabit it. Actually, in a book on ecology, it is not necessary to list the all the marine inhabitants of different taxonomic levels, but rather to explain why these species have settled exactly in this sea, while others have not.

To begin with, some information of general character is needed. With all their systematic variety, aquatic organisms form a couple of well-distinguished living forms (Konstantinov, 1986; Khristoforova, 1999), biomorphs or ecomorphs (Aleev, 1986).

2.1. Living forms of aquatic organisms

The water column (pelagic zone or pelagial) (Lincoln *et. al*., 1985) is inhabited by plankton. These are mainly small sized organisms, slowly floating or immobile (pelagic fish eggs) in the water and incapable to resist to currents which freely transport them. Therefore the distribution of plankton in the water column is mainly determined by the system of dominating currents in the area. The plankton community is divided into two main groups: plant plankton (phytoplankton) and animal plankton (zooplankton). Apart from this, plankton is divided according to the size of organisms (Table 4).

Table 4

Size categories of planktonic organisms *)

Category	Size range	Representatives
Femtoplankton	0.02–0.2 mcm	Viruses
Picoplankton	0.2–2.0 mcm	Bacteria, small Flagellates,
Nanoplankton	2.0–20 mcm	Small Flagellates, Coccolithophoridae
Microplankton	20–200 mcm	Protozoans, Diatoms, Dinophlagellates, Silicoflagellates
Mesoplankton	0.2–20 mm	Cladocerans, Copepods, Fish eggs and larvae
Macroplankton	2.0–20 cm	Decapods, Chaetognaths
Megaplankton	0.2–2.0 m	Large Jellyfish

*) Often there is overlap between neighbouring size categories

Besides the plankton, the pelagic zone is inhabited by the organisms of nekton, which includes active swimming animals able to move over long distances, regardless of the speed and direction of currents. Fish, marine mammals and squids belong to nekton. Squids do not inhabit the Black Sea, but fish and mammals do.

The sea bottom (benthic zone or benthal) is populated by the organisms of benthos, which are divided into two major groups: the plant benthos (phytobenthos) and the animal benthos (zoobenthos). They also differentiate according to their size.

On the sea surface, in the surface microlayer of water named neustal, live the neuston organisms, which also consist of plants (phytoneuston), animals (zooneuston) and microorganisms (bacterioneuston). Neuston species inhabiting the lower side of the «sea – atmosphere» interface form the hyponeuston, while the inhabitants of the upper side of the surface film form the epineuston. The epineuston is more common in the tropical and subtropical zones.

In tropical seas and oceans, the surface of pelagial is also inhabited by the organisms of pleuston or macroneuston. Their body contains air cavities and, because of this, is semi-submerged in water and is transported by winds. Examples of these organisms are the by-the-wind-sailor (*Velella*) and the Portuguese man-of-war (*Physalia*). Together with them, in a surface towed net, can be collected organisms of neuston. There is no pleuston (macroneuston) in the Black Sea

The living forms of marine organisms are not isolated one from another and have numerous connections. For example, fishes living on the bottom, as flatfishes, belong to both benthos and nekton. Sometimes they are called nektobenthos. The majority of species appertains to different living forms during different stages of their life cycles. For example, larvae develop in the plankton but adult specimens inhabit the sea bottom or the water column as nekton. Many of them accomplish vertical migrations during the day, inhabiting the sea bottom in the day-time and rising higher in the water column or to the surface at night.

Table 5 summarizes the overall picture of the Black Sea species diversity, showing the amount of species belonging to the various phyla and classes. At present, 2028 species, belonging to 22 phyla from the 26 existing marine phyla of animals, are described in the Black Sea. However, many taxons of the animal kingdom are not yet investigated enough, also because of the lack of specialists in systematics and taxonomy. The table is presented in order to show the rather high biological diversity in the Black Sea and to demonstrate that further systematic and taxonomy investigations are needed. In spite of existent gaps in systematization, the Black Sea is considered to be one of the most investigated seas of the World.

Table 5

Numbers of animal species belonging to different phyla and classes registred in the Black Sea

№	Phyla	Classes	Noted in the Black Sea	Numbers of species
1	Protozoans			
		Flagellata	+	No data
	Protozoa	Sarcodina	+	67
		Ciliata	+	227
2	Sponges	Calcarea	+	28
	Porifera	Desmospongia	+	No data
3	Coelenterates	Hydrozoa	+	28
	Coelenterata	Scyphozoa	+	3
		Anthozoa	+	4
4	Comb jellies	Tentaculata	+	1
	Ctenophora	Nuda	+	2
5	Flat worms	Turbellaria	+	103
	Plathelminthes			
6	Nemertea worms	Anopla	+	33
	Nemertea	Enopla	+	No data
7	Nematods	Aphasmidea	+	141
	Nematoda			
8	Hairworms	Gordioidea	+	1
	Nematomorpha			
9	Rotifers	Monogononta	+	102
	Rotatoria			
10	Gastrotrichs	Macrodasyoidea	+	23
	Gastrotricha	Chaetonotoidea	+	No data
11	Kinorhyks	Cyclorhagida	+	10
	Kinorhyncha	Homalorhagida	+	No data
		Conchorhagida	+	No data
12	Entoprocts	Pedicellinida	+	No data
	Entoprocta			
		Urnatellida	+	No data
13	Chaetognaths	Chaetognatha	+	1
	Chaetognatha			
14	Bryozoans	Phylactolaemata	+	20
	Bryozoa			
		Gymnolaemata	+	No data
		Stenolaemata	-	
15	Lamp shells	Inarticulata	-	
	Brachiopoda			
		Articulata	-	
16	Phoronids		+	1
	Phoronidea			
17	Annelid worms	Archiannelida	+	No data

	Annelida			
		Polychaeta	+	192
		Oligochaeta	+	33
		Hirudinea	+	10
		Myzostoma	-	
18	Sipunculans Sipuncula	Sipunculidea	+	1
19	Arthropods Arthropoda	Crustacea	+	540
		Arachnoidea	+	35
		Pycnogonida	+	No data
		Tardigrada	+	5
		Insecta	+	13
20	Molluscs Mollusca	Amphineura	+	2
		Monoplacophora	-	No data
		Scaphopoda	+	1
		Gastropoda	+	113
		Pelecypoda	+	90
21	Echinoderms Echinodermata	Crinoidea	-	
		Holothuroidea	+	8
		Echinoidea	+	1
		Asteroidea	+	1
		Ophiuroidea	+	4
22	Chordate Chordata	Ascidiacea	+	8
		Larvacea	+	1
		Cephalocordata	+	1
		Chondrichthyes	+	5
		Osteichthyes	+	163
		Reptilia	+	2
		Aves	+	No data
		Mammalia	+	4

As it is shown, different animal phyla are unequally represented in the Black Sea, some of them having large numbers of species other a few or single species.

2.1.1. From where did the Black Sea inhabitants originate?

The evolution of the modern Black Sea biota took place from different sources. Part of the aquatic population of the low salinity Pontian Lake-Sea survived till the present time in the brackish water gulfs, limans and deltas of the Black Sea and in the Azov and Caspian Seas. These organisms are united under the name of «pontian relics», or «caspian relics», as they represent the largest number of species in the oligohaline Northern part of the Caspian Sea. Pontian relics are the most ancient element of the Black Sea biota.

In the period of melting of glaciers, the cold waters brought by rivers from the northern seas filled in the ancient Black Sea. It is believed that cold water organisms could penetrate into the Black Sea via northern rivers. Among them there are copepods such as calanus (*Calanus euxinus*) and pseudocalanus (*Pseudocalanus elongatus*), and fishes such as the flounder (*Platichthys flesus luscus*), whiting (*Merlangius merlangus euxinus*), and the Black Sea salmon (*Salmo trutta labrax*). These cold-water or thermophobic species of the Black Sea biota, which are intolerant of high water temperatures, are called «Boreal relics», or «Celtic relics». They inhabit deep waters and can be observed at the surface only in spring and autumn seasons.

After the opening of Bosporus and Dardanelles straits, Mediterranean and Atlantic Ocean species started to enter the Black Sea. They got the name of «Mediterranean immigrants» and are forming the main part of the modern Black Sea flora and fauna, preferring, as a rule, warm and saline waters.

The fourth element of the Black Sea biota is represented by freshwater species of plants and animals. They permanently enter into the sea with river runoff and are most common not far from the river mouth areas. The have a short life in the sea and are generally perishing in salt waters.

The last element of the Black Sea biota is represented by exotic species. These are the plants and animals that were absent in the Black Sea but have been introduced, accidentally or intentionally, as the result of human activities. The Far-Eastern grey mullet (*Liza haematocheila*, syn. *Mugil soiuy*) and silver carp (*Hypophthalmichthys molitrix*) belong to the intentionally acclimatized commercially important species. The number of the accidentally introduced exotic species is much higher. They are mainly entering with ballast waters of ships coming in the Black Sea ports. Some exotic species can cause considerable harm to local species of flora, fauna and fisheries. Therefore the problem of ballast waters is of a great importance and special investigations in this field are carried out by the International Maritime Organization in the frame of the Global Ballast Water Management Programme (GloBallast).

Many indigenous and later introduced species of the Black Sea flora and fauna play an important, and sometimes a determining, role in its ecological processes.

2.1.2. Typical representatives of the Black Sea plants and animals

The key importance of bacteria is well-known both in Nature in general and in the Black Sea in particular. Most bacterial species are heterotrophic, i.e. feeding on organic matter. Part of them is able to grow only in the presence of molecular oxygen (oxybiotic or aerobic species). Another part of bacteria grows or occurrs in the absence of molecular oxygen (anaerobic species). Bacteria play an important role in the turnover of organic matter in the ecosystems, are basic food of many small marine animals, and inhabit all biotopes of the Black Sea; including the huge hydrogen sulphide zone.

The plants of the Black Sea are represented by phytoplankton and phytobenthos. Up to 1000 species of phytoplankton, including many freshwater species entering the sea with the river runoff (Fig. 11), have been described. Among the most common warm-water (termophilic) species of phytoplankton there are the diatoms *Pseudosolenia calcar avis* and *Cerataulina pelagica* and the dinoflagellates *Goniaulax polyedra*, *Prorocentrum cordatum*, *Emiliana huxleyi.* Among the cold-water (termophobic) species, there are the diatoms *Chaetoceros socialis*, *Leptocylindrus minimus*, *Pseudo-nitzschia delicatissima* and the dinoflagellates *Heterocapsa triquetra*, *Scripsiella trochoidea* (Nesterova, 2001).

Figure 11. Some mass representatives of the Black Sea phytoplankton:

1 – Asterionella, 2 – Chaetoceros, 3 – Thalassiosira, 4 – Skeletonema, 5 – Pseudosolenia, 6 – Cerataulina, 7 – Nitzschia, 8 – Prorocentrum, 9 – Peridinium, 10 – Ceratium.

The bottom plants (phytobenthos) include many different one-celled algae from which only diatoms are represented by almost 350 species (Guslyakov, 2002). These microalgae are covering surfaces of submerged stones and other hard substrates forming the microphytobenthos. The large multicellular algae (macrophytobenthos) are represented by more than 300 species belonging to the phyla Chlorophyta (green seaweeds), Phaeophyta (brown seaweeds) and Rhodophyta (red seaweeds). In addition to this, eight species of higher plants or seed plants (Spermatopyta) are living in the Black Sea.

Almost all macroalgae are growing on hard underwater substrates: stones, mollusk shells, different engineering constructions, pipes, nets, and even on submerged part of ships' hulls, if they are not protected by antifouling paints (Fig. 12). Some macroalgae transported by water currents can be found on sandy bottoms. They are most abundant after storms and in autumn; when the vegetative season of most plant species is completed.

Species with the tubular thalli, as the representatives of genus *Enteromorpha* (hollow green weed or grass kelp), are common among the green algae in the Black Sea. Species of the genus *Ulva* (sea lettuce) and *Chaetomorpha* (green hairweed) have lamellar and filamentous thalli respectively. A large variety of species is mentioned among the brown and red algae. Along the rocky shores of the Black Sea, large, abundantly-furcated bushes of the perennial brown alga *Cystoseira barbata* (bearded *Cystoseira*) are very common. Due to the presence of special air bladders, the massive thallus of *Cystoseira* is floating without sinking. In the marine ecosystem, this alga is especially important as a key species of the *Cystoseira* community (biocoenosis) of marine organisms; composed by dozens of species of other micro- and macroalgae, invertebrates and fishes. *Cystoseira* is very sensitive to pollution, especially to eutrophication, and disappears when the amount of nutrients exceed levels acceptable to this alga. In such cases, the whole bioceonsis disappears together with *Cystoseira*.

Figure 12. Some mass representatives of bottom algae and high plants of the Black Sea:
1 – Green alga sea lettuce, *Ulva*, 2 – brown alga, *Cystoseira*, 3 – green alga sea fern, *Bryopsis,* 4 – red alga phyllopohpra, *Phyllophora*, 5 – red alga banded weed, *Ceratium*, 6 – green alga hollow weed enteromorpha, *Enteromorpha,* 7 – red alga laver, *Porphyra*, 8 – higher plant eelgrass, *Zoostera*

Species whose presence or absence indicates a particular habitat, community, or set of environmental conditions are named indicator species or bioindicators (Lincoln *et al*., 1985). *Cystoseira*, together with its whole biocenosis, is a sensitive indicator of pollution by nutrients; especially by nitrogen and phosphorus compounds.

Among brown algae, species of the genus *Ectocarpus* (maiden's hair) with filamentous thalli, *Padina pavonia* (peacock's tail) with an elegant flat fan thallus, species of *Punctaria* with lamellate lanceolate thalli and many others have wide distribution in the coastal waters of the Black Sea.

Species of red algae are also numerous in the Black Sea. In the cold time of the year, large (up to 10–15 cm in diameter), rounded or oval, dark red lamellas of laver (*Porphyra*) are present near the coasts. In summer, species of *Ceramium* and *Callithamnion* with filamentous thalli are common.

Among the red seaweeds, should be especially mentioned some species of the genus *Phyllophora*. Their large, lamellate thalli are attached to the stones, rocks, mussel shells and other hard surfaces. Not having enough elasticity, the thalli of *Phyllophora*, under the wave action, lose separate branches which are carried away by currents and accumulate in the central zones of circular currents. The largest of these accumulations of several species of Phyllophora (*Phyllophora crispa* or *nervosa, P. truncata* or *brodiaei*, and *P. membranifolia)* is formed in the central part of the north-western shelf at depths from 20 to 55 m (Fig. 13). Probably, part of the thalli is carried away and dispersed by the benthic currents, so that it possibly disappears in the hydrogen sulphide zone. However, the largest part of algae is retained by the circular current at the bottom in the central part of the north-western shelf and continues to grow and multiply its biomass unattached to any substratum. This concerns the main species *Phyllophora crispa*; whereas *P. truncata* is attaching to mollusk shells.

By the same natural mechanism, large numbers of floating thalli of the brown alga *Sargassum* (a genus related to the Black Sea *Cystoseira*) are transported away from the Gulf of Mexico by the Gulf Stream to the northeast and are retained by the circular current above the central waters of Atlantic in the vast area called Sargasso Sea.

Accumulation of unattached *Phyllophora* on the bottom of the north-western shelf of the Black Sea was discovered in 1908 by the well-known hydrobiologist S.A. Zernov. This accumulation later got the name of «Zernov's *Phyllophora* field». By the estimation of experts in the 1950s, the area of this «field» achieved 11 thousand km^2 and the total biomass of algae reached up 10 million tons in wet weight. *Phyllophora* proved to be a valuable industrial raw material. In the beginning, it was used as a source of iodine, but in 1930 it started being used to extract the polysaccharide agaroid, one of the best natural gel-forming substances. Agaroid is widely used in microbiology, biochemistry, and in food and other industries.

During many years, the Zernov's *Phyllophora* field was an important component of the shelf ecosystem functioning as a powerful generator of oxygen, food, substratum for spawning and attachment of organisms, and refuge for many animal species. Up to 100 species of invertebrates and 40 species of fishes, the majority of which acquired the protective coloration of body from pink to dark red, inhabit the «jungles» of *Phyllophora*; (for example, amphipods, shrimps, crabs, gobies, dogfishes, clingfishes *et al*). This community of organisms got the name of the biocenosis of *Phyllophora* and its colored animals were united under the common name of «*Phyllophora* fauna». Sharp degradation of the Zernov's *Phyllophora* field (reasons of this man-made succession will be discussed later) took place in the 1970s and 1980s. This event had catastrophic consequences for all the ecological system of the north-western shelf of the Sea. Since the late 1990s, a gradual rehabilitation of the Zernov's *Phyllophora* field was observed, but special investigations of this key area of the Black Sea are needed.

Figure 13. Changes of the Zernov's *Phyllophora* field area on the north-western shelf of the Black Sea between the 1950s and 1980s.

Besides algae, 8 species of higher plants (Spermatophyta) inhabit the coastal waters of the Black Sea. The most common are two species of eelgrass, *Zostera marina* and *Z. noltii.* Other higher water plants belonging to genera *Potamogeton* (pondweed), *Ruppia* and *Zannichellia* are not as widespread as the eelgrass species. Unlike algae, eelgrass does not grow on stones and other hard substrates, but on sandy and muddy bottoms in shallow zones from 0.5 to 5 m depth (more rarely up to 10 m) in areas protected from waves. Powerful rhizomes develop in ground, and narrow, long leaves (up to 2 m in *Zostera marina*) stretch upwards in water. They are very elastic and easily stand strong water currents. *Zostera* forms dense bushes which become a habitat for dozens of species of marine organisms. Part of them is living among rhizomes (polychaetes, amphipods), others grow on leaves (algae, molluscs, crustaceans) or are freely moving among leaves (shrimps, fishes). All these organisms are members the biocenosis of *Zostera* which is especially characteristic for shallow water bays, gulfs and many coastal limans.

Very diverse is the Black Sea fauna of invertebrates. Here are described the representatives of all taxonomic levels of invertebrates from Protozoans to Echinoderms and Tunicates. At present, more than 2000 species of invertebrates, inhabiting pelagial and benthal zones, are recorded in the Black Sea (Zaitsev and Alexandrov, 1998).

Among the unicellular animals, high numbers were registered for *Noctiluca scintillans* which causes the remarkable phenomenon of water luminescence in the summer period. During the moonless nights, it is possible to see how the floating fish and dolphin, man or ship leave behind a bright luminous strip. The fishermen nets, submarine boats and moving plankton nets are shining and the waves' white caps are sparking. This phenomenon (it is called bioluminescence) is developing because an intracellular enzyme (luciferase) acts on a specific substance (luciferin) which causes luminescence when oxidised. Luciferin is contained in the bodies of many marine organisms, not only the protozoaires, but also worms, crustaceans and fish. Luciferin is activated as a result of mechanical influence on the organism. Due to the high numbers (millions or hundred thousands of individuals per 1 m^3 of water), *Noctiluca* can create huge luminescente areas on the sea surface at night time.

Another mass species of protozoans is the infusoria *Mesodinium rubrum* whose cell contains small unicellular algae of the genus *Erithromonas.* Algae extract from the host's body the different matters needed for activity (in particular carbonic dioxide) and which are produced by infusoria during the respiration process. From their side, infusoria receive from the algae the oxygen produced during the photosynthesis. In addition, during the starvation period, infusoria is able to consume part of these algae as food. Such a mutually beneficial coexistence is named symbiosis. For more effective symbiosis, infusorias rise up to the superficial layer (neustal) for 2–3 hours in the middle of the day so (to give algae the possibility to be «recharged» by the solar energy) and then submerge into the water again. Therefore, in the areas with high densities of *Mesodinium*, the sea surface can be of red and crimson colors during the midday; depending on the color of the pigments of algae inhabiting the infusorian body.

In the seas with the normal water salinity, the pelagic foraminiferans are present in the plankton, but the Black Sea is inhabited only by benthic species of foraminiferans. The radiolarians (Radiolaria), protozoa with a delicate flinty skeleton which are widespread in the other world seas, are absent in the Black Sea (both in the water column and at the bottom), while in the adjacent Mediterranean there are more than 350 species of them registered.

The next level of hierarchical scale after the unicellular protozans is occupied by sponges. As well as all other subsequent groups, sponges belong to the metazoan (multicellular) invertebrates. Sponges are benthic organisms. In the Black Sea, there are described 28 species of sponges, mainly inhabiting the coastal waters at small depths. Only two species of genus *Suberites* could be found up to depths of 100–120 m.

The phylum Coelenterata is known not only among the biologists thanks, first of all, to the large jellyfish (scyphozoan jellyfish), the moon jelly, *Aurelia aurita* and the root-mouthed jellyfish *Rhizostoma pulmo.* However, the species of hydrozoans are much more numerous. These animals pass part of their life cycle fastened to a hard substratum as hydroid polyps which resemble to transparent branches and bushes of different forms. At a certain time of a year, from the hydroid polyps detach small hydrozoans that conduct a planktonic life. Later on, the hydromedusae settle at the bottom and give life to new polyps. In this way, these animals settle around the basin and, in the most favorable biotopes, reach high numbers and biomasses. Among the mass hydrozoans species of genus *Obelia* and *Campanularia* must be mentioned.

At present, about 40 species of coelenterates are described in the Black Sea. According to their taxonomic position, the most close relatives to jellyfish are the comb jellies (Ctenophora). Until 1970s, the sea gooseberry (*Pleurobrachia rhodopis*) was the only species inhabiting the Black Sea. In the early 1980s, the Leidy's comb jelly *Mnemiopsis leidy* was introduced via ships and adapted into the Black Sea, followed, in the late 1990s, by another species: the Beroe's comb jelly *Beroe ovata* (Fig. 14). In the Mediterranean Sea, not less than 17 species of comb jellyes are registered.

Figure 14. Comb jellies of the Black Sea:

1 Sea gooseberry, *Pleurobrachia rhodopis*, a native species;

2 Leidy's comb jelly, *Mnemiopsis leidyi*, an exotic species present since the early 1980s;

3 Beroe's comb jelly, *Beroe ovata*, an exotic species present since the late 1990s.

A vast diversity of species is observed for marine worms and taxonomically related groups. More than 550 species of these organisms are counted in the Black Sea. A numerous group is formed by the flat worms Turbellaria, counting more than 100 species. The small-sized, round worms Nematoda are represented by no less than 160 free-living species; not counting the species parasitizing on other marine animals. The bristle worms Polychaeta are also widespread (more than 190 species). Some polychaeta species inhabit calcareous or muddy tubes, but most of their species are free-living organisms.

Mollusks belong to the mass inhabitants of the Black Sea (Fig. 15).

Figure 15. Representatives of the Black Sea mollusks (not to scale):

1 Venus clam, *Chamelea gallina*:

2 Lamark's cockle, *Cerastoderma lamarcki*;

3 Black Sea scallop, *Flexopecten ponticus*;

4 Coquina, *Donax trunculus*;

5 Donacilla, *Donacilla cornea*;

6 Rapana, *Rapana thomasiana* (*R. venosa*);

7 Soft-shelled clam, *Mya arenaria*;

8 Netted dogwelk, Tritia, *Tritia reticulata*;

9 Mediterranean mussel, *Mytilus galloprovincialis*;

10 Mediterranean lentidium, *Lentidium mediterraneum*;

11 Common oyster, *Ostrea edulis*;

12 Tellina, *Moerella donacina.*

(from A. Vershin, 2003)

The main classes of the Mollusca phyla are bivalves (Bivalvia) and gastropods (Gastropoda). Among more than 90 species of bivalves, the widespread is the Mediterranean mussel (*Mytilus galloprovincialis*) which inhabits different bottom biotopes from the water edge up to the depths of 55–60 m. This mussel is one of the most active filterers of the seawater, which it pass through a branchial filter for straining off of the organisms of plankton, on which it feeds. Mussels' larvae as well as larvae of other mollusks are planktonic. Other bivalves, the clam *Chamelea gallina* and the Lamark's cookle *Cerastoderma lamarcki* inhabit the muddy-sandy bottoms. *Donacilla cornea* is common in the splash zone of unpolluted, coarse-grained sands. The most deep-water bivalve of the

Black Sea is the horse mussel *Modiolus phaseolinus* which ihabits down to 125 m.

Some bivalves were accidentally introduced into the Black Sea with the ship's ballast waters and in other ways. Such are the cases of the soft-shelled clam *Mya arenaria* and of *Cunearca cornea.* The Wood's paper-shell *Sinanodonta woodiana*, a large bivalve with a shell's length of more than 20 cm, is now a mass species in the Danube delta. It was probably introduced into the Black Sea basin as larval stages (glochidia) attached to the gills of the Far-Eastern fresh water fish (e.g. silver carp, white and black amur), which were introduced into the Black Sea in the 1950s for acclimatization as commercially important speies.

About 115 species of gastropod mollusks (the shell of which has a snail-like form) are known in the Black Sea.

On the rocks and stones near the water edge could be found the limpet, *Patella tarentina.* Its shell has a form of small cap and adjusts tightly to the stone surface, being able to withstand the strong wave action. On algal thalli could be found small gastropods of the genus *Hydrobia*, *Rissoa* and *Gibbula.* On soft soils, live conical shells with the 4–5 long finger-shaped sprouts, the pelican's foot shell (*Aporrhais pespelecani*). In the same habitat lives the netted dogwelk, *Tritia reticulata*.

The biggest gastropod of the Black Sea is the rapana, *Rapana thomasiana.* This species was accidentally introduced into the Black Sea from the Sea of Japan.

As well as other seas, the Black Sea is inhabited by many species of crustaceans living in the water column and on the bottom. According to their taxonomy, crustaceans are divided into lower (Entomostraca) and higher (Malacostraca) crustaceans.

Among the lower crustaceans, the highest numbers are typical of the seed shrimps (Ostracoda), which are inhabiting the sandy and muddy bottoms, and barnacles (Cirripedia) which in adult state overgrow the submarine stones and other hard substrates. Among barnacles, the marine acorns from *Balanus* genus are the most well-known. Their larvae develop in neuston and plankton.

Many lower crustaceans inhabit the water column, forming the main part of zooplankton. Especially widespread are copepods. Some copepod species are found in the deep layers of pelagial. These are the cold water *Calanus euxinus* and *Pseudocalanus elongatus.* Others, such as *Acartia clausi* and *Paracalanus parvus*, inhabit the surface warm waters; while *Pontella mediterranea* and *Anomalocera patersoni* are neustonic crustaceans. Unlike copepods inhabiting the water column and having mainly a transparent body, the neustonic species are colored in green and dark blue tones and can be hardly distinguished on a sea surface when looking from above (Fig. 16).

Figure 16. Representatives of the Black Sea neuston:

1 Fry of the little grey mullet, *Liza saliens*;
2 Mediterranean pontella, *Pontella mediterranea*;
3 Larva (megalop) of the green crab, *Carcinus aestuarii*;
4 Larva (zoea) of the crab pisidia, *Pisidia longimana*;
5 Young swimming crab, *Macropipus holsatus*;
6 Larva of the sole *Solea nasuta*;
7 Larva of the small dragonet, *Callionymus belenus*;
8 Fragment of the brown alga *Cystoseira barbata*;
9 Fragment of a eelgrass *Zostera marina* leaf;
10 Fry of the garfish, *Belone belone euxini*

The representatives of Cyclopoida and Harpacticoida are adapted to the bottom life and form a considerable part of the meiobenthos (Vorobyova, 1999).

From higher crustaceans, species of the orders Isopoda, Amphipoda and Decapoda play the most noticeable role in ecological processes.

About 30 species of isopods, inhabiting different biotopes, are described in the Black Sea. The gribbe isopod *Limnoria tuberculata* lives in holes which it drills in wooden materials. The Baltic idotea (*Idotea baltica basteri*) is one of the most widespread algal species in the coastal zone and Ostroumov's idotea, *Idotea ostroumovi*, is a characteristic inhabitant of neustal, including the open waters of the sea.

In the Black Sea, more than 100 species of amphipods are described. They are bottom organisms inhabiting different habitats from the shore line up to the depth of 100 m, but preferring the shallow areas with sandy bottoms and stones covered by algae.

The relict species *Pontogammarus maeoticus* is especially characteristic for the splash zone (mediolittoral), where it can achieve high numbers and biomasses. On shores with the gentel slopes, under the beached algae, high numbers of the species of the genera *Orchestia* and *Talorchestia* consuming the plant residues can be observed. The passages in wood are done by the wood borer, *Chelura terebrans,* which lives in them. The amphipod *Periculoides longimanus* inhabits the bottoms up to 100 m depth.

The order of decapod crustaceans is composed by the floating (Natantia) and creeping (Reptantia) species. This subdivision is a rather relative one, because there are shrimps which usually bury into the soils among the floating species and crabs which are able to float actively in the water column among creeping species.

About 40 species of decapods are described in the Black Sea (Bacescu, 1967). With regard to species diversity, the fauna of decapods of the Black Sea is substantially poorer compared with the Mediterranean Sea, where 178 species are described, and even the Marmara Sea with its 77 species of decapods.

Among the Black Sea shrimps, the sand shrimp, *Crangon crangon*, the common prawn, *Palaemon adspersus* and the elegant shrimp, *P. elegans* are the most common (Fig. 17). The last two species have a local commercial value.

Among the creeping decapods the common are hermit crabs, burrowing prawns and crabs.

Hermit crabs got their name because they hide their unprotected abdomen in the empty shells of marine snails, changing them according to the size of their growing body. The white hermit crab, *Diogenes pugilator*, more frequently use shells of *Cerithium*, *Tritia* and young *Rapana*; while the red hermit crab, *Clibanarius erythropus*, prefers shells of *Gibbula* and *Tritia*.

Figure 17. The elegant shrimp, *Palaemon elegans* on a colony of mussels and barnacles (photo A. Vershin)

The burrowing prawns *Upogebia pusilla* and *Callianassa pestai* inhabit holes burrowed in the bottom of shallow water areas during the day-time, but go out into the water column at night and can even emerge to the water surface.

Among crabs (Fig. 18), the widespread grass crab *Carcinus mediterraneus* (syn. *Carcinus aestuarii*) prefers sandy bottom shallow waters and bushes of the eelgrass *Zostera*. Swimming crabs (*Macropipus arquatus* and *M. holsatus*) skillfully bury in sand, but are also able to float actively due to the adapted, extended, leafed last segments of their fifth pair of legs. The large stone crab, *Eriphia verrucosa*, with its massive armor, inhabits the rocky shore and the marble crab, *Pachygrapsus marmoratus*, can climb on stones 3–5 m higher the water level at night. The small-sized, white-fingered mud crab, *Rhithropanopeus harrisi tridentata*, was accidentally introduced from the North Sea into the Black Sea in the 1930s. It has successfully acclimatized in the Black Sea and has become one of the mass decapod species in the coastal zone, especially in the brackish water bays and coastal wetlands.

Figure 18. Crabs of the Black Sea:

Top left – the green crab, *Carcinus aestuarii*; top right – the swimming crab, *Macropipus holsatus*;

bottom – the stone crab, *Eriphia verrucosa*.

At present it is not clear if the lobster, *Homarus gammarus*, is occurring in the Black Sea. This species is mentioned both in the fundamental Identification Guide of the fauna of the Black and Azov seas (1969) and in the publications of a number of authors from the Black Sea countries, but additional information is needed.

There is no information either about the rivers of the Black Sea in which remain populations of the freshwater crab, *Potamon potamios.* Originating from the sea, this crab has adapted to the life in small rivers and brooks, but, until present, it is unknown where it was saved and what is the number of its populations. At least in the rivers of Crimea, it belongs to the species being under the threat of disappearance.

There is insufficient information about the alien crab species which were observed in the Black Sea during the last years. These are the blue crab, *Callinectes sapidus*, and the Chinese mitten crab, *Eriocheir sinensis*. I hope that such information, which is necessary for science and practice, will come from environmentalists and naturalists working on different areas of the Black Sea coast.

Close to the class of crustaceas, the class of insects in the Black Sea is represented by few species of chironomids, or chironomid midge (Chironomidae). The larvae of these insects inhabit mainly the coastal brackish waters and some coastal wetlands. Among them the midge tendipes, *Chironomus plumosus*, is well known. On the contrary, the larvae of a related species, the saline midge, *C. salinarius*, prefer salt waters and could even inhabit such saline wetlands as the Sivash lagoon in Crimea and Kuyalnitsky liman nearly Odessa wth salinity up to 100‰. The bright red larvae of *C. salinarius* are cultivated and used as food for aquarium fish. The species *Clunio marinus* and *C. ponticus*, even in adult stage, live on the Black Sea water surface, freely moving on it and probably feeding on the organic matters from superficial film and foams. These insects represent the upper (aerial) part of marine neuston – the epineuston.

Another class of the Arthropoda phylum is formed by marine mites. They inhabit the Black Sea and enter in the composition of meiobenthos. At present more than 40 species of marine mites from the Halacaridae family are described in the Black Sea (Gelmboldt, 2003, 2006).

One of the most highly organized phylum of invertebrates is represented by the species of Echinodermata. In the Black Sea 14 species are described, while no less than 50 species are known for the Mediterranean Sea. The Black Sea Echinodermata, living in unfavorable conditions for the representatives of this phylum, are much smaller than in the Mediterranean Sea and oceans and do not achieve high numbers. They include 8 species of sea-cucumber (Holothuroidea), 4 species of brittle stars (Ophiuroidea) and one species of starfish and sea-urchin, which are registered only in the area near the Bosporus.

The most highly organized animals belong to the phylum Chordata, to which belong vertebrates; including mammals. Only the species of salps and amphibians are absent in the Black Sea; the other classes are represented at least by single species.

From the class of sea squirts (Ascidiacea), 8 species of single (*Ciona intestinalis*) and colonial (*Botryllus schlosseri*) sea squirts are present. Both species are bottom organisms.

From the class Appendicularia, *Oikopleura dioica*, which is a common component of plankton, is the only species inhabiting the Black Sea.

From fish, representatives of both cartilaginous (Chondrichthyes) and bony (Osteichthyes) fishes are recorded in the Black Sea.

According to the review of T.C. Rass (1987), the Black Sea is inhabited by 146 species of marine and brackish water fish species, excluding anadromous and freshwater species. When counting sturgeons (5 species), herrings (5 species), the Black Sea salmon, thornback and no less than 20 other freshwater species (sometimes recorded in the sea at a distance of dozens kilometers from the river mouths) as well as new findings, the number of fish species in the Black Sea achieves 180 species (Fig. 19, 20).

Figure 19. Pelagic fish of the Black Sea:

1 Black Sea anchovy, *Engraulis encrasicholus ponticus*;
2 Black Sea shad, *Alosa kessleri pontica*;
3 Black Sea sprat, *Sprattus sprattus phalericus*;
4 Black Sea silverside, *Atherina mochon pontica*;
5 Black Sea garfish, *Belone belone euxini*;
6 Stripped grey mullet, *Mugil cephalus*;
7 Haarder, *Liza haematocheila*;
8 Dogfish, *Squalus acanthias*;
9 Mackerel, *Scomber scombrus*;
10 Bluefish, *Pomatomus saltatrix*;
11 Black Sea horse mackerel, *Trachurus mediterraneus ponticus*;
12 Bluefin tuna, *Thunnus thynnus*.

Figure 20. Benthic fish of the Black Sea:

1 Black Sea red mullet, *Mullus barbatus ponticus*;
2 Black Sea whiting, *Merlangius merlangus euxinus*;
3 Star sturgeon, *Acipenser stellatus*;
4 Scorpionfish, *Scorpaena porcus*;
5 Russian sturgeon, *Acipenser guldenstadti colchicus*;
6 Thornback ray, *Raja clavata*;
7 Toad goby, *Mesogobius batrachocephalus*;
8 Flounder, *Platichthys flesus luscus*;
9 Round goby, *Neogobius melanostomus*;
10 Black and Azov Seas turbot, *Psetta maeotica*.

Among the Black Sea fish species, there are the representatives of pontian relicts including many species of gobies (Gobiidae) and common kilka, *Clupeonella cultriventris cultriventris*; and boreal relicts (sprat, *Sprattus sprattus phalericus*, *w*hiting *Merlangius merlangus euxinus*, European flounder *Platichthys flesus luscus*). However, the main part of the Black Sea ichthyofauna is composed by species of Mediterranean origin (so-called Mediterranean immigrants). Among them there are important commercial species such as anchovy (*Engraulis encrasicholus ponticus*), horse-mackerel (*Trachurus mediterraneus ponticus*), turbot (*Psetta maeotica*), four species of grey mullets (Mugilidae), etc.

From the class of reptiles (Reptilia), the water snake, *Natrix tesselata*, is recorded in the Black Sea. In 1840, the famous zoologist A.D. Nordman wrote that the water snakes are common in the Black Sea where they are hunting on gobies even on the Odessa beaches. Nowadays this fact is not observed anymore, but in some estuaries and on marine side of the islands of the Danube delta it is possible to meet up to two or three dozens of water snakes per one kilometer. They are able to swim to the Zmiyni (Snake) Island which, already in ancient times, got its name from the presence of snakes of this species in its coastal waters and on its shores.

From the class of mammals (Mammalia), three species of dolphins and one species of seal (Birkun jun.and Krivokhizhin, 1996) presently inhabit the Black Sea. Dolphins species are the harbour porpoise (*Phocoena phocoena relicta*), bottlenosed dolphin (*Tursiops truncatus ponticus*) and the common dolphin (*Delphinus delphis*); and the only species of seal is the Mediterranean monk seal (*Monachus monachus*) (Fig. 21).

Figure 21. Dolphins of the Black Sea:

Top left – the bottlenosed dolphin, *Tursiops truncates ponticus*; top right – the common dolphin *Delphinus delphis*. Bottom – the harbour porpoise, *Phocoena phocoena relicta*.

Among the representatives of the class of birds (Aves), there are no species which are spending their whole life-cycle in the sea. Even the non-flying penguins are nesting on land. However there are a lot of bird species which are feeding in the sea and nesting on the sea shore. Such birds play an important role in marine ecology, especially in the coastal zone, and their typical representatives will be presented in this book. On the Black Sea shores, there are no famous bird colonies like on the rocky shores of the Barents Sea or the Sea of Okhotsk, but in some zones of the coast the birds numbers is rather high (Fig. 22, 23).

According to published data and author's direct observations, representatives of 9 orders can be named among the most characteristic birds of the Black Sea:

1) Order Gaviiformes. They build their nests in the north of Europe and winter on the Black Sea. Example: the black-throated diver (*Gavia arctica*).

2) Podicipediformes. They nest in the coastal wetlands. In winter, especially after freezing of the freshwater basins, they live in the sea. Example: the red-necked grebe (*Podiceps grisegena*) and great-crested grebe (*Podiceps cristatus*).

3) Procellariiformes. They nest in the islands of the Aegean Sea and the Sea of Marmara. The most part of the year feed on the Black Sea. Example: the Manx shearwater (*Puffinus puffinus*).

4) Pelecaniformes. They nest in the Danube delta and other Black Sea coastal areas. Feed in the coastal shallow waters. Example: the White pelican (*Pelecanus onocrotalus*), Dalmatian pelican (*Pelecanus crispus*), Cormorant (*Phalacrocorax carbo*), Shag (*Phalacrocorax aristotelis*).

5) Ciconiiformes. They nest in wetlands, feed in wetlands and in the sea coastal zone. Example: the Great white egret (*Egretta alba*), Little egret (*Egretta garzetta*).

6) Anseriformes. They nest in coastal wetlands, feed on the fields, fresh waters and the marine coastal zone. Example: Mute swan (*Cygnus olor*), whooper swan (*Cygnus cygnus*), shelduck (*Tadorna tadorna*), mallard (*Anas platyrhynchos*) tufted duck (*Aythya fuligula*).

7) Falconiformes. They nest in wetlands; hunt in wetlands and in the marine coastal zone. Example: Osprey (*Pandion haliaetus*), white-tailed eagle (*Haliaeetus albicilla*).

8) Gruiformes. They nest in wetlands, in winter feed in the sea coastal zone. Example:Coot (*Fulica atra*).

9) Charadriiformes. They nest in wetlands and on sandy islands. Feed on fields, in wetlands and and the marine coastal zone. Example: Kentish plover (*Charadrius alexandrinus*), Oystercatcher

(*Haematopus ostralegus*), Black-winged stilt (*Himantopus himantopus*), Avocet (*Recurvirostra avosetta*), Mediterranean gull (*Larus melanocephalus*), Black-headed gull (*Larus ridibundus*), Herring gull (*Larus argentatus*).

Certainly, this list could be considerably completed by scientific information of ornithologists. However, till present, the collaboration between specialists on birds and marine organisms remains, much to our regret, at traditionally low level.

Figure 22. Birds feeding in wetlands, marine coastal zone and in open waters of the Black Sea:

1 Manx shearwater, *Puffinus puffinus*,
2 White pelican, *Pelecanus onocrotalus*,
3 Cormorant, *Phalacrocorax carbo*,
4 Black-headed gull, *Larus ridibundus*,
5 Dalmatian pelican, *Pelecanus crispus*,
6 Little egret, *Egretta garzetta*,
7 Herring gull, *Larus argentatus*,
8 Shelduck, *Tadorna tadorna*.

Figure 23. Birds feeding in wetlands and in the Black Sea coastal zone:

1 White-tailed eagle, *Haliaeetus albicilla*,
2 Osprey, *Pandion haliaetus*,
3 Black-winged stilt, *Himantopus himantopus*,
4 Kentish plover, *Charadrius alexandrinus*,
5 Oystercatcher, *Haematopus ostralegus*,
6 Avocet, *Recurvirostra avosetta*.

Questions from chapter 2 for training in the Black Sea ecology

1. What is a living form of aquatic organisms?
2. What living forms are known among the organisms inhabiting the Black Sea?
3. What is the difference between the planktonic organisms (planktonts) and other inhabitants of the sea?
4. In which groups are subdivided the planktonts?
5. Name several representatives of the phytoplankton of the Black Sea.

6. Name several representatives of the zooplankton of the Black Sea.
7. Is it possible to consider species of fish as planktonic organisms?
8. What distinguishes the organisms of the benthos from the other inhabitants of the sea?
9. In which groups are subdivided the organisms of the benthos?
10. Name several representatives of the bottom algae of the Black Sea.
11. Name several representatives of the bottom animals of the Black Sea.
12. Is it possible to consider species of fish as benthic organisms?
13. How do the organisms of nekton differ from the other inhabitants of the sea?
14. Which groups of animals of the Black Sea belong to nekton?
15. Name the mass representatives of plankton, benthos and nekton of the Black Sea.
16. Who causes the sea «luminescence»?
17. How many species of comb jellies inhabit the modern Black Sea?
18. Name the largest fish of the Black Sea.
19. How many species of fish are known for the Black Sea?
20. Name the species of the Black Sea marine mammals.

3. Ecology of aquatic organisms

3.1. Soft bottom as a habitat

Soft bottoms (geologists commonly use the term «bottom sediments») are composed by different particles which, initially, had angular outlines, but received different degrees of circularity due to abrasion. Considered as a whole, as in the case of bottom sediments, these particles have interstices (pore spaces among them) that make up to 30–40% of the total volume of sediment. If particles have a spherical shape, the correlation (volume ratio) between the solid body and pores is expressed as 76:26. The pore spacing system, or interstices, can be filled by water, air, detritus or living organisms. The forces of surface tension and capillary pressure retain water in the sediments. Fresh water originates from superficial or underground streams, that sometimes can come out from the sea-bottom at a considerable distance from the shoreline. In this case, we speak about the deep discharge of the fresh waters into the sea. In the interstices of sandy beaches, the salt and fresh water could be in different proportions. These waters do not undergo such considerable changes of salinity and temperature as the water masses in the adjacent coastal zone of the pelagial.

Granulometric composition of sand and mud influences other parameters of the soft bottom habitat; including the total volume of pore spaces and their dimensions. The admixtures of small particles, such as clay or sponges spicules (silicon dioxide bodies which form the supporting skeleton of many sponges), radically change the size of pore spaces and this, in its turn, changes the processes of drainage of the bottom sediments and the mechanisms of seepage (percolation) of water through the sediment.

Oxygen content of interstitial water sharply reduces when more than 30% of hard particles have a size less than 200 mcm. Almost all bottom sediments become anaerobic at a certain depth below their surface. This depth is determined, along with the granulometric characteristics of sediment, by the hydrodynamic regime of the bottom waters, by organic matters and by the population of an area of the bottom.

On muddy sediments, the anoxic layer extends, as a rule, very close to the surface. In the open shore beaches it can start at a depth of 1 m and more, but it is determined by tides, wave action and granulometric composition of sediments.

All kind of soft bottoms are populated by different benthic organisms and their species composition and numbers are determined by the physical and chemical characteristics of each habitat.

As a rule, the number of bacteria in soft bottom is increased along with the decrease of the size of hard particles. This is due to the increase of the total surface of particles in fine-grained sediments, since more than 90% of benthic bacteria are attached to either mineral particles or particles of detritus. For example, there are data that in one gram of sand from the coastal about 200 million bacteria have been found and in one gram of mud up to 5 billion bacteria. The bacterial biomass was 5.5 g and 57.0 g per 1 m^2 of the bottom respectively.

Along with bacteria, soft bottoms are inhabited by cyanobacteria (procaryote) that are quite often developing in high numbers. Thus, species of the genera *Beggiatoa* and *Oscillatoria* can form continuous mats on the bottom surface; such mats play an important share in the fixation of nitrogen. It is known that the third most abundant inorganic species in marine water, after natrium and chlorine, is sulphate. Therefore the reduction of sulphates plays an important role in the chemistry of the soft bottoms; many microorganisms taking part in this process.

The process of primary production in bottom sediments is mainly ensured by diatoms (for example, *Nitzschia*) and dinoflagellates. Many unicellular algae are able to move and their vertical migrations in the sediments are marked by coloration of bottom surface in olive-brownish and greenish tones. The rhythms of these diurnal migrations depend on the intensity of sunlight and their biological reason is to ensure the position of unicellular algae in optimal light conditions. These migrations weaken or stop when the algae approach to the surface of bottom, where they would be threatened by the waves' action and, in extreme cases, desiccation.

A great number of species of heterotrophic flagellates and infusorians inhabit the soft bottoms. Their majority feeds on bacteria, other flagellates and diatoms, although there are detritophagous species among them.

Macrophytic algae are not common on soft bottoms, but some species have free-floating physiological forms, and can be found on sandy and muddy bottoms. Free forms are known for species of the *Ectocarpus* and for red alga *Phyllophora nervosa*.

Unlike algae, sea grasses are common on soft bottoms in shallow water areas. In the Black Sea there are two species of seagrasses, the eelgrasses *Zostera marina* and *Z. noltii*, which form the biocenosis of *Zostera* (Fig. 24).

Figure 24. On the leaves of the eelgrasses and among them live many species of micro- and macroalgae, invertebrates and fishes; forming the *Zostera* biocenosis

Soft bottoms are inhabited by many representatives of metazoans such as bristle worms (Polychaeta), molluscs, crustaceans and other. Especially characteristic for these bottoms are species of meiofauna, that is small animals able to live in the interstices. Numerous species of nematodes, hapracticoids, cyclopoids, turbellarians, tardigrades and some others belong to the meiofauna of sandy beaches. Almost all phyla of marine invertebrate animals have their representatives in the interstitial meiofauna of sandy and muddy bottoms (Vorobyeva, 1999).

The numbers of nematodes in sandy grounds can achieve 1–3 million individuals per $1m^2$ of bottom. They reach even higher quantities in muddy bottoms and among algae. According to some investigations, nematodes are one the most important functional constituent among metazoans in coastal ecosystems.

3.2. Hard bottom as a habitat

In terms of habitat diversity, rocky (stony) bottoms are much more varied than the soft bottoms. Depending on local geology, they can range from steep, overhanging cliffs to wide, gently-shelving platforms; from smooth, uniform slopes to highly dissected, uneaven masses or even extensive boulder beaches (Lewis, 1977). Considering the hard bottom seascape diversity, it is very important to understand the dynamic relationships between aquatic organisms and their biotic and abiotic environment.

Epilithic species, growing on rocks or other hard inorganic substrata, are much more exposed to the rigours of the habitat than infaunal species living within sediment. Each rock represent a hard stable surface to which aquatic organisms must attach or into which they must bore after having previously drilled the necessary holes in the stone. Therefore, the character of the substrate is considered to be one of the most essential external factors determining the adaptive features of bottom organisms and their distribution.

Surface texture depends on rock type and weathering and for living organisms is important to choose the most appropriate mode of attachment in each specific case. Note that motile organisms inhabiting such habitats need to move over the surface, but must also resist dislodgement by waves and currents.

Many open coasts are permanently subjected to tides (Black Sea is an exception) and storms, while deeply inserted gulfs and bays can be protected from the wave action. Salinity, water temperature and turbidity near the rocky shores also have a wide range of fluctuation.

Inhabitants of rocky bottoms have special adaptive morphological and behavioural features which facilitate the life on hard substrata. First of all, they need strong attachment devices like algal holdfasts which are characteristic, for example, of the Black Sea perennial brown alga *Cystoseira*. Bivalve mollusks such as oysters (*Ostrea edulis*) and bay barnacles (*Balanus improvisus*) resort to cementation of shells to rock, whereas mussels like *Mytilus galloprovincialis* are using byssus; i.e. a bundle of silken anchorage fibers produced by special glands. Another form of attachment to hard substrate is the adhesive foot of gastropods such as the limpet *Patella tarentina*, common along the Black Sea rocky coasts. Among fish inhabiting rocky shores, there are species of gobies (Gobiidae family) represented in the Black Sea by Pontian relics and species of Mediterranean origin. All of them have ventral fins forming a sucking disc which ensures a strong attachment to hard substrata when it is necessary.

Another way of attachment to hard substrata is the drilling into the rock. This is the case of bivalve molluscs such as species of *Litophaga* and *Pholas*, which are successfully boring limestone, marl, argil and some other hard natural underwater substrates. Other stone inhabitants, like the crabs and shrimps, use natural crevices and cavities in hard bottom substrates as refuges.

Species inhabiting the upper parts of rocky coasts (mediolittoral and supralittoral ecological zones) are often exposed to air for a long period. Special adaptations are needed to withstand it and to prevent the organisms' soft tissues from drying. These, for example, are the presence of tight shell plates, as in the case of the barnacles *Balanus* and *Chthamalus.* Unlike the shell of molluscs, these calcareous plates do not have pores. Gastropods are able to survive short time in air due to the lime cover (operculum) covering the external opening (orifice) of their shells. These molluscs inhabiting the mediolittoral and supralittoral zones are able not only to survive a more or less long desiccation, but also «overheating» to which underwater inhabitants are not exposed to. The heat coma of such typical inhabitants of the supralittoral zone as the periwinkle *Littorina neritoides* comes at the temperature of 40°C, while the temperature threshold of other molluscs is only 28°C.

Other inhabitants of hard bottoms are also specifically reacting to intense sunlight. For example, the green algae *Ulva* and *Codium* can «draw off» the chloroplasts from the cells membrane in case of strong sun light. Other algae contain granules of polyphenol, which protect the molecules of chlorophyll from disintegration (photolysis) under the impact of strong solar radiation.

Many organisms inhabiting the surface of rocks and stones are attached to them for their whole life; i.e. they are sedentary species. The main advantage of this mode of life is the stability towards the wave action. However, immobility (sedentary life) strongly limits the possibilities of feeding. Therefore, sedentary organisms widely use gills (bivalves), bristles (barnacles), crown of tentacles (bryozoans) and other adaptations for catching the particles suspended in water. Some of them are also able to obtain dissolved organic matter by filtering large volumes of water through their digestive system.

Chitons and many gastropod species are using special organs (radula) for scraping the stone surface. The main food of these organisms are unicellular algae, protozoans and meiofaunal invertebrates that cover underwater hard surfaces.

The sea anemones with numerous tentacles, e.g., *Actinia equine*, are resembling to «flowers» or plants and, because of this, attract different crustaceans (isopods, amphipods, shrimps), larvae and young fish and grab their trustful victims with stinging cells on tentacles.

3.3. Ecology of individuals (autoecology)

Strictly speaking, separate individuals of aquatic plants or animals do not exist in nature in a, so to speak, «pure form». Each individual coexists with the individuals of other species, which are inside of the host organism, as for example parasites, or are attached to his external covers. The number of this biological «fellow travellers» varies in the various habitat conditions, but they are always present. Science knows little about the role of fellow travellers on the life of host organisms (with exception of the better studied parasites); however there is no doubt that they and their excretions influence the host organism. They can act as factors accelerating (stimulators) or slowing (inhibitors) some processes taking place in the host organism (stimulators) and also as attractants or repellents for other organisms. The role of chemicals as mediators and regulators in the ecological interrelations of organisms is studied by biochemical ecology (Telitchenko and Ostroumov, 1990).

Therefore, when talking about ecology of marine organisms, it is necessary to understand that, actually, researchers do not deal only with the studied organism but also with the other living creatures being in connection with this organism. To somehow «clean» the studied organism from the fellow-travellers is impossible, and it is not needed since, as already said, there are no «clean» organisms in nature.

Figure 25. In eutrophicated marine waters, unicellular algae densely cover the surfaces of other organisms. This is a view of the thalli of green alga *Cladofora*, covered by the cells of the diatom *Cocconeis* under microscope magnification (from Sieburth, 1975)

The special photos in figure 25 give an idea about biological fellow-travellers of hydrobionts. These «microbial seascapes», as professor J. Sieburth has called them, show that, when talking about the attitude of organism (species) towards the sunlight, salinity, temperature and other factors of the aquatic environment, it is necessary to understand that one actually deals with a group of species associated with the object of interest.

3.3.1. Relationships of aquatic organisms with their nonliving environment (abiotic environmental factors)

Let us examine some examples of the reaction of marine organisms (assuming that they exist in a «pure» form) to some possible changes in physical and chemical factors of the marine environment (abiotic factors).

For indicating the attitude of organisms toward environmental factors, the prefixes eury- (meaning wide, various) or steno- (meaning narrow, limited) are normally used. For example, species of plants and animals which are able to live under different temperature conditions and to withstand wide water temperature fluctuations are called eurythermal species. On the contrary, the stenothermal species are adapted to a relatively constant temperature and cannot survive its fluctuations. The attitude towards the other environmental factors is termed in the same way: eury- and stenohaline (attitude towards the salinity), eury- and stenobathic (attitude towards the depth), eury- and stenooxibiontic (attitude towards the dissolved oxygen), etc. (Konstantinov, 1986, Romanenko, 2001).

As a rule, species are more stenobiontic (stenoecious) in the early stages of their individual development (eggs, larvae) than as adults. For example, such fish as sturgeons and salmons are euryhaline at the adult stage, but spawn only in rivers as their eggs and larvae would not bear the seawater salinity.

Most inhabitants of the Black Sea belong to eurybiont species and are able to withstand considerable changes in aquatic environmental factors; otherwise they would not have settled in the Black Sea with its specific conditions.

The mass species of plankton, the copepod *Acartia clausi*, is an example of eurybiontic species which inhabits the Mediterranean, the Atlantic, the Indian and the Pacific Oceans. It withstands high fluctuations of water temperature and, in the Azov Sea, it was registered in winter under the ice cover. Another mass copepod, *Calanus euxinus* – previously named *Calanus helgolandicus*, is also widespread but only in cold waters. In the Black Sea, it inhabits the deep water layers and comes up to the surface only during night time in spring, autumn and winter. *Calanus* is not only a stenothermal coldwater, but also photophobic species.

In the Black Sea, the indigenous comb jelly *Pleurobrachia rhodopis* and, among the fish, the sprat (*Sprattus sprattusphalericus*) and the whiting (*Merlangius merlangus euxinus*) also belong to the cold-water species. These fishes spawn only in cold water. The flounder *Platichthys flesus luscus* also spawns at low water temperature, but its adult individuals are able to withstand the summer high water temperatures and wide fluctuations of salinity: from freshwater (flounder is also called the river flatfish) up to 40‰.

Coastal limans, which are also called the « natural laboratories », are often used for the study of the ecology of the Black Sea species. Limans could be salt, brackish and freshwater; shallow and deep water; and more warmed up in summer and less cold in winter due to the underground fresh water springs. The studies on marine organisms' survival in limans answers many questions about the species ecology.

In 1950s, the water salinity in the Khadzhibeysky liman near Odessa was 35–37‰. In summer, water was warmed up to 28°C, and in winter, the liman froze. In those years, the liman was inhabited by flounder, grass goby (*Gobius ophiocephalus*), black goby (*G. niger*), common green crab (*Carcinus aestuarii*), mussels and some other species, all of them reaching high quantities. As a cold-water species of northern origin, the flounder spawned during the winter and spring and successfully survived the summer high water temperatures so that it was a trade object. The other species originating from the Mediterranean (the so-called Mediterranean immigrants) were not able to survive the cold winter temperatures which sometimes dropped to the negative value of – 1.4°C.

Notably, none of the relict species of gobies have adapted in this liman, although attempts to introduce them were repeatedly undertaken. About ten thousands fries of the golden grey mullet (*Liza aurata*) from the Odessa Gulf and about 20 million of fertilized eggs of turbot (*Psetta maeotica*) from the Zmeiny Island area were also introduced. Both species have adapted and successfully developed until the beginning of November, whereupon they perished from the critically low water temperature. By this time the grey mullet was achieving its commercial size and weight of 140–150 g and fries of turbot raised the length of 66–70 mm.

The results of these large-scale experiments in real environmental conditions clearly illustrate the features of the ecology of these two species. The fish has positively reacted towards the different environmental conditions of the sea (high salinity, different ionic composition of the water, other set of forage organisms, lack of deep depths, high summer water temperature, etc.), but the factor limiting their further adaptation was the low water temperature in winter. In those limans where wintering ponds are constructed, the temperature barrier is overcome.

Comparing with the open sea, the blue mussel was growing better in the Khadzhibeyskiy liman and it was successfully cultivated. At the market, the buyers always asked for the «liman» mussel because not only it was larger than the marine one, but also its shells were not fouled by barnacles and the polychaete *Pomatoceros triqueter*, which had to be scraped off prior to cooking. For barnacles and the polychaete *Pomatoceros*, the water salinity in the liman was intolerably high.

The anchovy (*Engraulis encrasicholus ponticus*), the mass pelagial fish of the opened waters of the Black Sea, belongs to the thermophilic species. It starts spawning after the water has warmed up to at least to 17°C and, in autumn, it migrates for wintering to the Caucasian and Asia Minor coastal waters. One of the most thermophilic fish of the Black Sea is the damselfish (*Chromis chromis*), which is perennially met only off the coasts of Southern Crimea, Caucasus and Asia Minor.

Many bottom-dwelling organisms behave selectively towards the type of sediment. Gobies and scorpionfish (*Scorpaena porcus*) prefer rocky substrates; while *Gymnammodytes cicerellus* and *Ophidion rochei* inhabit sandy bottoms in which it is easy to bury. The lancelet (*Amphioxus lanceolatum*) is especially demanding as to the type of sand. It prefers coarse-grained sand without fine-grained sand or silt admixture. It is buried almost wholly into this sand which got the name of «amphioxus sand».

3.3.2. Relationships of aquatic organisms with their living environment (Biotic environmental factors)

The interrelationships among organisms (biotic interrelationships) constitute a special branch of ecology and include both autecology (interrelationships of individual organisms (species) with the environment) and synecology (ecology of populations and communities). The main part of the adaptations in relation to other living creatures belongs to the category of «predator-prey» relationships. A vast literature is devoted to the problem of predation, which is one of the basic forms of interpopulational communication in biocoenoses. In the present chapter, the features and behavior of predators to overtake and seize their «victims» and of preys to avoid their predators will be discussed.

Like on land, marine organisms are widely using different kinds of protective coloration. Cryptic coloration is a coloring similar to the main environmental background, so that an animal «merge» with its habitat. Many benthic species (e.g., swimming crab, round goby, flounder, turbot, and other) have a body pigmentation which confounds itself with the sand or silt in which they usually bury. The inhabitants of rocky substrates (many species of crabs, scorpionfish, Brauner's goby and Lepadogasters) are also colored accordingly.

Most inhabitants of the water column have a transparent body which makes them almost invisible and only their dark eyes betray the presence of such otherwise «invisible» creatures. The larvae of anchovy and species of the Blenniidae family remain transparent up to a body length of 30–35 mm. The pelagic fish eggs and larvae of shrimps and crabs are also quite transparent. The body of the transparent goby (*Aphia minuta*) remains colorless during all its life cycle as, unlike all other types of gobies, this species inhabits the water column.

Adult fish inhabiting the water column use a so-called «antishade principle»; that is the body side which is directed upwards (dorsal) is colored in greenish and bluish tones, while the ventral side is light-colored. As a result, an animal looses its voluminosity and masks more easily.

The methods of masking among the organisms of neuston are especially interesting as, unlike individuals of other marine communities, they live under the double «pressure» of predators from both water and air.

The body of some neuston species, as for example the copepods *Pontella mediterranea* and *Anomalocera patersoni*, are colored in greenish and bluish tones which make them unnoticeable for their pursuers from the air. However, such pigmentation unmasks them on the background of the «silver-and-white ceiling» of the water column when observed from below. This disadvantage, from the point of camouflage, is compensated by an ability to jump out of the water at the appearance of a danger from underneath. These jumps can achieve 10–15 cm in height and 15–20 cm in length, and can be both single and repeated. Basically, this protective reaction is similar to the flights of the flying fish and has the only aim to escape from the aquatic pursuers.

Other organisms of neuston bring the «antishade principle» to the highest degree of contrast and their dorsal side of the body is dark blue, while the ventral is bright-silver. These masking is typical of all the species of the grey mullet, red mullet (*Mullus barbatus ponticus*) and shore rocking (*Gaidropsarus mediterraneus*). The adult individuals of these fishes live at the bottom, or near it, and have a proper patronized coloring; while their fries have colors adequate to life in the neustal habitat. The fries of the shore rocking and of the red mullet inhabit the neustal until they achieve a body length of 50–55 mm and up to 60 mm respectively.

Another type of cryptic coloration is the so-called disruptive coloration, which delays recognition of the whole animal by attracting the attention of the observer to certain elements of the color pattern. This coloration is characteristic for the neustonic larvae of the sole (*Solea nasuta*) which, being well noticeable on the sea surface, appear like lifeless objects. The same type of masking is used by man when putting on a camouflage. Besides the disruptive coloration, the larvae of sole also use protective forms of behavior. When touched, they immediately stiffen and submerge into the water column. Pelagic fish do not usually touch such «objects».

Although cryptic coloring does not fully exclude a danger from the side of predators, it undoubtedly diminishes the intensity of consumption; otherwise this type of masking would not have spread in nature. However, the sight and other sense-organs of predators are also going through adaptations to ensure the possibility to find and grasp their victims. Once, in the Black Sea central waters, were caught 24 neuston fries of the red mullet. Along with other food, their stomachs contained about 16–249 fish eggs of anchovy, showing that the fish eggs were found and consumed by the fries in spite of their complete transparency.

Mimicry is an even more advanced method of masking than the cryptic coloration. Potential victims look similar to biotope objects that are indifferent to a predator. Thus, the pipefish resemble to the leaves of the eelgrass *Zostera* and sea-horses look like algae pieces.

The fries of the grey mullet carry, on their backs, air bubbles which not only help them to stay in the neuston layer during their adlitoral migrations to the shore, but also serve as a perfect camouflage. From above, the young fish looks like air bubbles and its sparkling back reflects the light like a lamp distracting predators from the prey associations.

Other organisms of neuston imitate small floating objects, such as pieces of bark, pumice, slag and other objects that are indifferent for predators. All these land-derived objects, after a sufficiently long stay in water, are covered by bacterial and algal films and turn brown or greenish in color. Many organisms of neuston imitate these floating objects by their typical appearance and are sometimes named «flotsam fauna» (Besednov, 1960). These organisms are met especially often in the marine convergent zones.

In the Black Sea, the neustonic isopod *Idotea ostroumovi* imitates flotsam. The dorsal side of its body is of umber color, often with a bluish metallic glitter, and reminds flotsam covered by the fouling or oil film. Quite often *Idotea* attaches to a piece of flotsam and, due to its flattered body, completely merges with the imitated object. However, in spite of its excellent masking, this isopod is successfully consumed by the dolphins. Professor S.E. Kleinenberg has observed the stomachs of caught individuals of the common dolphin (*Delphinus delphis ponticus*) and harbor porpoise (*Phocoena phocoena relicta*) that were exceptionally filled with this isopod.

The organisms of neuston also imitate the flotsam of marine origin such as the fragments of bottom algae and *Zostera* leaves, which are quite common on the sea surface not only in the shelf area, but also in its central waters. The body of larvae and fries of the dragonet *Callionymus belenus* (5–6 mm length) is colored in brown shades and resembles the fragments of the brown alga *Cystoseira.* The larvae of the garfish (*Belone belone euxini*) imitate the same fragments but are 12–15 mm long. When growing up, the fries of the garfish lose their brown pigmentation and develop the green-back and silvery-belly coloring. The latter successfully masks them as the floating leaves of *Zostera*. In the central waters of the Black Sea, juveniles of the garfish with lengths of 10–15 cm were observed staying close to the leaves of *Zostera* and even repeating their swaying on the surface. In the stomachs of these fries were found 100–200 individuals of the *Pontella*, lots of neuston fish larvae, crab larvae and terrestrial insects from the sea surface.

In nature, including the marine environment, the trophic (food) interrelationships could be sketchily presented as trophic webs and trophic chains. A trophic chain (food chain) is an interrelationship between the organisms and consists in the transfer of the food energy from its source, the green plants (i.e., the primary producers), through the chain of organisms. This transfer occurs via the consumption of one organism by another one from a higher trophic level. It should be noted that up to 80–90 % of the food energy is lost in the form of heat during the transfer from one trophic level to another. These losses should be taken into account when calculating biological production. A trophic web is an interlacement of food chains in a diversified natural community. The structure of the local food chain of marine organisms could be observed, for example, in the Odessa Gulf.

After the winter cooling, the water in the coastal zone of the Gulf (at the depths less than 3–4 m) warms up more quickly than offshore. Benthic algae grow on the stony bottom, while rich and diverse phyto- and zooplankton develop in water column. The small-sized schooling fish silverside returns from its wintering zones in the deep waters and, starting from April, lay its eggs on algae. Its planktonic larvae are then provided with good forage and grow up quickly. Spawning of the silverside takes place during the period April–August and fish schools of various body sizes can be observed simultaneously. Thus, on July 19, 1998, through a submarine mask were observed three generations of larvae and fries of the silverside. Each generation was staying in separate flocks: 15–20 mm, 25–30 mm and 40–45 mm (Zaitsev, 2001). Young fish grows quickly and joins the silverside population in the sea coastal zone. Once, on August 14, 1993, the author succeeded to count up that, in a dense fish flock having dimensions of about 100x20x20cm, there were nearly 40 thousand youngs of silverside. Such abundance is typical for the end of summer – beginning of autumn. Therefore it is not surprising that, in September and October, this high number of silversides attracts to the shore large predatory fish such as garfish, bluefish and even the Black Sea salmon. During this time of the year, the amateur-fishermen catch the garfish and bluefishes. As a bait they use the live silverside and fish with lengths of 40–45 cm can get on hooks. Silverside is also preyed upon by benthic predators (i.e. gobies and turbot) which seize the small fish that swim near the bottom. The trophic chain of the events described above is presented in fig. 26.

Figure 26. Example of a trophic chain in the coastal waters of the of the Odessa Gulf area.
In spring silverside spawns on algae (1). Abundant phytoplankton develops here (2). The organisms of zooplankton (3) feeding on phytoplankton are a food source for adult and young silversides (4). In September–October the population of silverside, which has strongly increased due to the young fish, attracts to the shore predatory fish: garfish (5), bluefish (6) and the Black Sea salmon.
This food chain starts to function in April and achieves its complete development in autumn.

More complicated trophic relationships are observed in the open waters.

The small organisms (unicellular algae and bacteria) serve as the initial link, being the source of food for representatives of zooneuston and zooplankton (infusoria, copepods and other crustaceans) and also for larger organisms like the neustonic isopod *Idotea ostroumovi* which has a length of 3–4 cm. In turn, these organisms constitute the forage base of small pelagic fish like silverside (near to the coast), or anchovy and sprat in the open sea. To this trophic level also belong the fries of the grey mullet, red mullet, and rockling that inhabit the neustonic biotope.

The small fish are consumed by the large pelagic fish such as garfish, bluefish, herring, and in the recent past, mackerel and bonito. (Note that there are reasons to consider that bonito's population in the Black Sea has started to recover.) Some large fish, such as herring, also feed on plankton along with the small-sized fish.

Finally, dolphins occupy the highest trophic level among the inhabitants of the Black Sea. They eat up the large pelagic fish as well as anchovy and sprat and, sometimes, the neuston isopod *Idotea ostroumov*. Cases when common dolphins and porpoises having stomachs exceptionally full of *Idotea ostroumovi* have already been mentioned.

A trophic net in pelagic zone of the open Black Sea can be represented as in fig. 27. As every chart, this trophic net represents the actual events in a very simplified way. In reality the food interrelationships of the marine organisms are much more complicated. Many large-sized fish of pelagial eat up plankton and sometimes benthos , along with the small-sized fish. Dolphins often feed not only on pelagian fish and *Idotea*, but also on benthic fish, mollusks, crabs and other bottom inhabitants. Nonetheless, the present chart shows how complicated are the interrelationships among the sea inhabitants and from how many factors depend the life and well-being of organisms' populations. Yet, on a chart, only food chains and not their quantitative expressions (who eats who and how much) are shown. How much organic matter is produced due to the growth and reproduction of plants and animals? Obtaining these data and expressing them in units of biomass or energy would make it possible to find out how functions the ecosystem of pelagial according to the history of its formation and not merely as if it were an accidental set of species. Such attempts were repeatedly undertaken but, taking into account the difficulty to obtain reliable primary data, the final results vary and so the scientific research still goes on.

Various attempts to define the mass of organisms inhabiting the Black Sea have been undertaken. This task is very complicated since, to accomplish it, the amount of organisms of one species or population should be defined along with the average biomass of one organism, the total mass of its Black Sea population, the biomass of all the species inhabiting the Sea, the increase of living mass per time unit, etc. Therefore, the results of such works are approximate; even in those cases when authors express them in decimal fractions. However, these calculations are useful for estimating the state of the ecosystem and comparing it with that of other seas, determining the tendencies of changes taking place in the ecosystem, knowing the values of biological production, and grounding the possibilities and ways for the rational use and conservation of natural resources while ensuring their stable development. An example of such calculations for the period «end 1970s – beginning of 1980s» was presented in the work of Yu. Zaitsev and G. Polykarpov (1987).

Figure 27. Example of a trophic net in the pelagial of the Black Sea open waters.

The first link is formed by phytoplankton (1) producing the organic matter from mineral substances and sunlight. The phytophagous organisms of zooplankton (infusorians and other protozoa, crustaceans, larvae of the benthic invertebrates – 2) feed on phytoplankton. They represent the trophic level of primary consumers. Planktivorous fish (anchovy, sprat, and young fish of other species – 3) feed on zooplankton.. They are the secondary consumers in the marine pelagic zone. Small planktophagous pelagic fish are consumed by predatory fish (4), such as the garfish, bluefish, horse-mackerel and mackerel which form the trophic level of tertiary consumers. Dolphins (5) feed on the tertiary and secondary consumers.

The annual production of the plants of the Black Sea oxygenated layer amounts to about 2 billion t.; i.e. 48 ton per 1 hectare of the sea surface (Sorokin, 1982). For comparison, the annual production of a young oak-pine forest (taking into account the aerial part of the trees, bushes, herbs as well as their root system) is equal to 12 tons of dry mass per 1 hectare or 20–50 tons of raw mass per 1 hectare. Apparently, the production of the Black Sea plants is rather high and what some researchers were referring to as a «dark blue desert» is actually as productive as a forest.

Phytophagous animals, inhabiting the water column and the sea bottom, are feeding on plants. In the Black Sea, the annual production of this category of organisms, which are generally small-sized, reaches 600–700 million t. The planktonic crustaceans, according to an estimation of V.N. Greze (1979), produce 90 million t. of biomass and arrow worms (*Sagitta*) 32 million t. In late 70s half of all the animal production in the Black Sea belonged to the jelly-fish *Aurelia* which feeds mainly on the phytoplankton, but can also consume the zooplankton including fish eggs and fish larvae.

The annual production of the Black Sea fish feeding on zooplankton, zoobenthos and other fish varies, according to different estimations, from 0.6 up to 2.5 million tons.

Dolphins are at the top of the ecological pyramid. Their annual production does not exceed 40 thousand tons. The general rule is the following: the higher is the taxonomical position of an organism, the lower is its annual production and vice versa. Bacteria, plants and protozoa are reproducing repeatedly during a year and their indexes of annual production are high. The ecological pyramid of the annual production of organisms of the main trophic levels (represented in figure 22 of the mentioned publication of Greze) shows the situation in the ecosystem of the Black Sea during the 1970–1980s. Later on the situation has changed following the accidental introduction of a single exotic species: the combjelly *Mnemiopsis*. This species, which had formed a total biomass of 1 billion t. at the end of 1980s and twice as much annual production, has changed the correlation of numerical values among trophic levels toward the increase in the number of consumers of the phytophagous animals. After the introduction of its biological antagonist, the combjelly *Beroe*, further changes in the structure of the ecological pyramid took place. However, the graphic image of the production of organisms of different trophic levels resembled a pyramid in all cases.

Conformity to this law is encountered also at the scale of the entire biosphere. Thus, the annual production of all plants on Earth (primary production) is about 470 billion tons (dry matter); of which 117 billion tons belong to the dry land and 353 billion tons to the World Ocean. The production of all animals of the Earth (secondary production) makes about 3.934 billion tons; including the World Ocean 3.025 billion tons (acc. to P. Whittaker from Dediu, 1989).

Questions from chapter 3 for seminar (training) in the Black Sea ecology

1. Describe the soft bottom as a habitat.
2. Name some mass inhabitants of the soft bottom among the plants, invertebrates and fish.
3. Describe the hard bottom as a habitat.
4. Name the mass inhabitants of the hard bottom among the plants, invertebrates and fish.
5. How are called the plants and animals that are able to inhabit across a wide range of salinity, temperature, depth and light conditions?
6. Give some examples of aquatic organisms which are able to withstand considerable fluctuations in ecological factors.
7. How are called the marine plants and animals which are able to withstand only minor fluctuations of the water salinity, temperature, depth and illumination?
8. Make some examples of aquatic organisms incapable to withstand considerable fluctuations of ecological factors.
9. How do marine animals diminish the danger of being noticed by predators? What are crypsis (concealment) and mimicry?
10. How are called the aquatic organisms whose presence or state could serve as indicators of environmental conditions, including the presence of pollutants?
11. What testifies the presence, degradation and disappearance of *Cystoseira* meadows?
12. Explain the term mass mortality of aquatic organisms. What causes it?
13. When and where in the Black Sea was registered the first case of mass mortality of benthic organisms?
14. When does microbial pollution of the sea occur and what causes it?

15. What sources of chemical pollution of the sea are known?
16. What causes the radioactive pollution of the sea?
17. Give some examples of concentration factors of radioactionuclides in the bodies of marine organisms.
18. Give some examples of the sea pollution by the synthetic polymers.
19. What importance for marine organisms have noise and bright light in the coastal zone?
20. What is the biological pollution of the sea?
21. Give examples of species accidentally introduced into the Black Sea which have caused the most serious ecological consequences.
22. What is the danger of the unmanaged catches of marine organisms?
23. Could tourism and shore recreation be factors of negative influence on marine organisms?

4. Ecology of populations and communities of aquatic organisms

In ecology, a population is defined as a group of organisms of one species inhabiting an area with relatively uniform living conditions within the limits of which the unified rhythm of living phenomena and other functional peculiarities are observed; thus distinguishing this population from the other populations of the same species living under different conditions. Many species, which are widespread in seas and oceans, have specific Black Sea populations whose mode of life reflects the local marine environment. Sometimes the peculiarities of the Black Sea populations concerning the ecology, behavior and morphology of their individuals are so significant that they can be considered as distinct Black Sea subspecies.

All species of Mediterranean and Atlantic origin living in the Black Sea are represented by the corresponding Black Sea populations and, sometimes, even Black Sea subspecies because to populate the Black Sea, they had to adapt to its conditions which are different from those characteristic of the Mediterranean Sea and the Atlantic Ocean. These adaptations consist in the acquisition of special morphological and physiological features, properties and behavioral reactions.

A biocenosis, in ecology, is defined as a community or natural assemblage of organisms, or, more in detail, as a biological system represented by the totality of the populations of different species of plants, animals and microorganisms inhabiting a certain biotope. The biocenosis and the biotope form an ecosystem. Each biocenosis usually has a more or less certain set of species populations that could be quantitatively determined with the help of the Shannon equation (Dediu, 1989).

The members of a biocenosis are in certain food interrelationships between each other. Thus, the green plants (autotrophs or producers) create, from inorganic compounds, the organic matter which is necessary not only for their growth and development, but also for all the other living creatures named heterotrophs or consumers.

Consumers which feed on already available organic matter are divided into primary consumers (these are phytophagous organisms), secondary consumers (feeding on the phytophagous animals), third order consumers (feeding on the secondary consumers), etc. Another category of members of biocenosis is made by organisms transforming the dead organic matter into mineral compounds which are again used by the green plants. These organisms are called reducers or destructors. They decompose the dead organic matter and ensure the continuation of life in a given habitat.

The life in a sea depends, to a great extent, on the ability of photosynthetic organisms to use the solar energy for the synthesis of complex and energetically rich organic molecules from simple inorganic molecules. This process is the primary production.

Although macrophitic algae and higher aquatic plants have a substantial significance in providing the productivity of marine coastal waters, the main role in primary production belongs to phytoplankton which inhabits the upper layers of the water column or the pelagial. In the dark zone, below the compensation depth (the depth at which primary production and respiratory utilization are equal, so that there is no net production), chemosynthetic bacteria become the main responsible for primary production.

Primary production is usually measured by indirect indexes, namely the amount of oxygen evolved during the process of photosynthesis. It can also be determined by direct indexes with the use of the radioactive carbon ^{14}C.

In general, the primary production in the open sea is lower than in coastal waters. This is the reason for the corresponding distribution of invertebrates, fish as well as waterfowls and marine mammals.

As a rule, indexes of secondary production (for example the production of zooplankton) repeat the seasonal cycle and spatial distribution of indexes of primary production. However, extremely high rates of primary production (for example because of anthropogenic eutrophication of the sea) can lead, in the end, to the appearance of the benthic hypoxia and mortality of bottom organisms because of the lack of dissolved oxygen. In such cases, a sharp decline of the levels of secondary production takes place along with the strengthening of the activity of reducers; first of all of bacteria and fungi.

4.1. Ecology of the Black Sea population of mackerel

The widespread pelagic fish mackerel (*Scomber scombrus*) inhabits the shelf zone and adjacent waters of the Atlantic Ocean from Labrador, Iceland, Murmansk and Novaya Zemlya in the north, to Florida and the Canary Islands in the south. It also inhabits the North Sea, the Baltic Sea, the Mediterranean Sea and the Black Sea. From this last, it enters the Sea of Azov, the Dneprovsko-Bugsky and Dniester limans.

In the Black Sea, this species is represented by a population which spawns in the north-western part of the Sea of Marmara (Fig. 28). Spawning takes place in February – March and its floating eggs develop in the water with salinity not less than 30‰. Since the surface of the Sea of Marmara is «filled» by the Black Sea waters coming via the permanent current through the Bosporus, mackerel eggs sink to the depth of 30–40 m where the bottom layer of saltier water provides them with buoyancy and allows their normal development. After spawning, at the end of March – beginning of April, the mackerel enters the Black Sea through the Bosporus. Leaving the strait, the main mass of fish migrates to the north along the western coast and already in the middle of April appears in the Tendra Island and Odessa Gulf areas and near capes Tarkhankut and Yevpatoria in Crimea. A smaller part of the mackerel population leaving the Bosporus turns eastwards, moves along the Anatolian coast and reach the Caucasian shore where it is observed from the beginning of May. The average speed of mackerel’s migrations is 0.5–2 km per hour and only when escaping from predators its speed can be up to 10–12 km per hour, but only for a short time.

The Black Sea attracts mackerel because of its rich food resources; in particular zooplankton (especially *Acartia clausi* and mysids) and anchovy. The fish sticks to the upper water layers and rarely dives to the depth of 10–15 m. It is a fast-growing fish and, in a year, it reaches lengths of 22–24 cm. Its maximal length in the Black Sea attains 32 cm with a mass of 265 g. In August–September, the growing up young mackerels (local name cirus, possibly from the Italian cirosi – mackerel) appear in the north-western Black Sea (NWBS). At the age of 6 months, cirus has a length of 17–18 cm.

In autumn (September–October), mackerel concentrates near the Kerch Strait, where it is attracted by the mass autumn migration of the anchovy from the Sea of Azov into the Black Sea.

The major enemies of mackerel in the Black Sea are bonito (*Sarda sarda*) and dolphins. Sometimes spiny dogfish also feeds on mackerel.

Figure 28. Ecological pictogram of the life cycle of the Black and Marmara Seas

population of mackerel (from Krotov, 1940 with additions)

When the water temperature in the Black Sea drops to 8°C, the mackerel leaves it through the Bosporus for the warmer Sea of Marmara. Part of its population can sometimes remain wintering in the southeastern part of the Black Sea, but here it has no possibilities for spawning. After spending the winter and spawning season in the Sea of Marmara, mackerel again migrates into the Black Sea feeding grounds. Its life-span in the Black Sea makes 4 or, more rarely, 5–6 years. Its maximal length does not exceed 32 cm. In the Mediterranean Sea and the Atlantic Ocean its length can reach 50 cm and more. The general rule is that many fish originating from the Mediterranean Sea and the Atlantic Ocean become smaller but can reach a higher fatness when growing in the Black Sea,. It explains why, since the ancient times, the Black Sea fish was valued on the Mediterranean market in spite of the fact that the same species, apart from sturgeons, were caught locally.

In 1930–1950s, the catches of mackerel in the Black Sea have reached 10 thousand tons and mackarel was considered one of the most valuable commercial fish.

The Black Sea population of mackerel was formed several thousand years ago when, as a result of the opening of the Bosporus, the Black Sea became accessible for the Mediterranean species. To form its Black Sea populations, the mackerel had to adapt to the reduced water salinity and other specific local conditions. Mackerel has not only adapted to spend the winter, but also to reproduce in the Black Sea. It was rewarded by the nearness of the spawning areas in the northwest of the Sea of Marmara near the Princes' Islands. To achieve the feeding grounds in the adjoining Black Sea, it was not necessary to overpass long distances either.

The Black Sea population of mackerel was a commercial species until the beginning of 1970s. In the Ukrainian part of the NWBS, mackerel was caught for the last time in 1969 and, in the Romanian and Bulgarian waters, in 1970. At the beginning, its sudden disappearance in the Black Sea was explained as a temporal phenomenon; that is as a manifestation of fluctuations in its population number that were already observed in the past. However, years and decades have passed, but its population has not regenerated yet. At present, mackerel inhabits and is fished in the Mediterranean Sea and the Atlantic Ocean, but the Black Sea has been crossed out of the list of the natural habitats of this species.

According to Kokatas *et al*. (1993), an increasing pollution of the Sea of Marmara by local industrial and domestic sewage has started in the 1960s. The pollution has caused deep negative changes in this ecosystem, including a sharp reduction (up to complete disappearance) in the quantity of some fish including mackerel. Presently, on Istanbul markets, it is still possible to purchase a fresh mackerel *Scomber scombrus*; but it is from the Aegean Sea instead of the Black Sea population. The mackerel population from the Aegean Sea does not enter the waters of the Black Sea either because the salinity of the Aegean Sea is 3 times higher than in the Black Sea or because a peculiar «chemical barrier» of harmful matters, which not all the fish are able to cross, has formed in the north of the Sea of Marmara and in the Bosporus. Specialists record that, in the last two-three decades, migrations of bonito and tuna through the Bosporus into the Black Sea were also sharply reduced. The ecological consequences of the «acoustic barrier» in the Bosporus, which has increased because the intensification of navigation in the channel, are not yet studied enough. It is quite possible that this factor is also connected with the inhibition of exchange of marine fish between the Black Sea and the Sea of Marmara.

4.2. Ecology of the Black Sea population of stripped mullet

One of the representatives of the family of grey mullets, the stripped mullet (*Mugil cephalus*), is widespread in the seas and oceans. It lives in the warm and temperate waters of the Atlantic, Pacific and Indian Oceans and in the adjacent seas. The stripped mullet is common along the Atlantic coasts of America from Cape Code in the north as far as the Brazilian shores in the south and, along the western shores of the Atlantic Ocean, from Brest to Cape of Good Hope; in the Pacific Ocean from San Francisco to Chile and from Sakhalin Island to the New Zealand; in the Indian Ocean from Australia and south of Africa up to the Red Sea; and in the Mediterranean, Black and Azov Seas. In the Black Sea, a local population of this cosmopolitan species, which reproduces, grows fat and winters within the limits of the sea, has formed. Stripped mullet belongs to the euryhaline species which prefer to enter in limans and lagoons for feeding in the warm period of the year. It can be also observed in the rivers' lower stretches and, for wintering, it moves to the southern coastal waters of the Black Sea. There are data that part of the Black Sea populations of the stripped mullet enters the Sea of Marmara during winter.

Its main food is composed by the organisms of micro- and meiobenthos, which it collects by the scoop-like lower jaw from the surface of sandy and muddy bottoms as well as from the stone surfaces. Like other species of the Black Sea grey mullets, except for the haarder *Liza haematochiela* (syn. *Mugil soiuy*), the stripped mullet spawns in the Black Sea open waters. The grey mullets, including the striped mullet, belong to the small ecological group of fish which migrates for spawning into the open sea and not vice versa. This characteristic behavior is linked with the fact that the eggs of the grey mullet, containing large oil globules, have the highest buoyancy among the other fish and develop in the neuston microlayer (Zaitsev, 1960). Spawned in coastal waters, these eggs could be thrown out by waves onto the beach; which would lead to inevitable death. In the open sea, the fish eggs have enough time to develop into larvae, which, growing into fries, gradually approach to the coasts searching for straits and channels conducting into limans and lagoons.

The ecology of the Black Sea populations of stripped mullet is shown on the ecological pictogram (Fig. 29). A similar life cycle is characteristic for the other Black Sea species of grey mullets: the golden mullet (*Liza aurata*) and the little mullet (*L. saliens*).

In June–July, adult individuals feed in coastal shallow waters. They scoop up the upper layer of sand, filtrate it through the gills and swallow the edible fraction of the bottom deposits. Fish then starts the courtship ritual; a genetically determined characteristical behavior. One large female and several smaller and more active males move in a «courtship dance». The mullets become less attentive; which makes them a perfect target for submarine hunters. Courtship may culminate solely during fertilization of new-laid eggs; after which the behavioral bond between males and female is broken. However, this occurs in the open sea.

On their way to the open sea, mullets are pursued by the bottle-nosed dolphin and, more rarely, by the spiny dogfish. The bottle-nosed dolphin attacks the stripped mullet from below, the fish jumps out from the water (it is characteristic for this species) and the dolphin catches it in the air, first seizing it across the body and then throwing it up and swallowing it from the head.

The migration of the striped mullet from the Sea of Azov into the Black Sea for spawning was traditionally used for the commercial extraction of its eggs up to 1960s. Salted and covered by a layer of molten beeswax, eggs of the stripped mullet were one renowed marine delicacy.

However, not all fish get into the fisherman nets and the major part spawns at the distance of 30–50 km from the shore.

Figure 29. Ecological pictogram of the life cycle of the Black Sea population of stripped mullet, *Mugil cephalus* (from Yu. Zaitsev, 1974)

Figure 30. The largest fish of the grey mullets family (Mugilidae) in the Black Sea:
On the top – the local species the stripped mullet (*Mugil cephalus*); on the bottom – the acclimatized Far-Eastern species haarder (*Liza haematocheila* syn. *Mugil soiuy*)

The neustonic eggs of the stripped mullet develop during 30–35 hours (Dekhnik, 1973). Such a short period of embryonic development diminishes the eggs' chances to get under the wave action and passing vessels. Pre-larvae and larvae are also developing quickly and at the length of 5–6 mm the formation of fins ends and the silver pigmentation of ventral part and dark blue pigmentation of the dorsal part of the body appear. Fries begin their migration towards the coast without leaving the neuston biotope.

The adult individuals leave the breeding areas after spawning. The fries reach the shores at the age of 2–3 weeks. On their migration to the shores fries are pursued by gulls, terns and other marine birds; while the bubbles of air on their back serve them not only as «floats» but also as a camouflage.

At the beginning of August, but sometimes already at the end of July, it is possible to observe how the flocks of fries move along the water line, directed towards the feeding areas (Savchuk, 1967). Nowadays, their migrations are restrained by different hydrotechnical constructions, boats, scooters and people swimming at the beaches. The fries of stripped mullet are awaited by the ichthyophagous birds (e.g., by the small white heron) along the manless beaches and by the voracious young blue fishes hidden under the stones algae and other shelters. These predatory fish, with the lightning speed, attack the fries and disperse their school so that a couple of fries immediately gets into the sharp teeth of the bluefish (Fig. 29).

Fries eventually find channels and entrances into the limans and lagoons, where they successfully grow until the end of October – beginning of November and achieve a mass of 18–20 grams. By this time, the water temperature in estuaries falls down to 4–5°C, while in the sea it still stays within the limits of 8–10°C. The fries are therefore stimulated to go out into the sea. If they succeed, they make for the south for wintering in the Bulgarian and Turkish coastal waters; where the adult specimens of grey mullets also winter. Another part of the stripped mullet population is wintering along the southern Crimean coast. Sometimes, during winter, fries remain in ports, attracted by their considerable depths (such situation was observed in the Port of Skadovsk), but such harbors usually turn into traps for fries since they cannot resist the low winter temperatures in the northern ports of the Black Sea.

In spring, the adult individuals and growing young fish appear at the northern shores of the Sea. However, they do no reveal a tendency to enter the limans and lagoons.

Special ponds for hibernation are build in some limans near the output of underground fresh water springs (whose temperature is at the level of 8–10°C during the whole year). Fries of the stripped mullet (and other grey mullets which belong to the eurihaline species) successfully survive the winter and, in spring, start to subsist in limans. By the next autumn these mullets reach the commercial size and a mass of about 0.5 kg.

4.3. Ecology of the Black Sea population of the red alga *Phyllophora* and its biocoenosis

Four species of *Phyllophora*, belonging to the red algae (Rhodophyta), are growing in the Black Sea. These are *Phyllophora crispa* (syn *P. nervosa*), *P. truncata* (syn. *P. brodiaei*), *P. membranifolia* and *P. pseudoceranoides.* The most widespread species *Phyllophora crispa* originates from the Mediterranean Sea, while the other three species originate from the North Atlantic and are absent in the Mediterranean Sea as they belong to the coldwater species. In the Black Sea they inhabit mainly the depth of 20–55 m.

On the contrary, *P. crispa* is registered on coastal underwater rocks at depths of 2–35 m and its maximal density occurs at 10–20 m with biomass up to 2–3 kg m^2 (Kalugina-Gutnik, 1979). Its thalli have the form of small bushes with a height of 50 cm. They are fragile and therefore easily torn away by currents and can be transported far away from their places of vegetation. Due to rather stable cyclonic current in the NWBS, the torn thalli of *Phyllophora* are gathered near the bottom of the central part of the north-western shelf at depths from 25 to 55 m where the three coldwater species of *Phyllophora* are growing. They form a huge accumulation of red algae in which the share of *Phyllophora crispa* can reach 80%. This algal accumulation was discovered in 1908 by the well-known hydrobiologist S.A. Zernov and later got the name of the Zernov's *Phyllophora* Field (ZPF). Fundamentally, the oceanographical mechanism of the ZPF formation is similar to that of the Sargasso Sea in the Atlantic Ocean with the only difference that *Sargassum* seaweeds, due to the presence of air bubbles in their thalli, remain on the water surface, while *P. crispa* sinks to the bottom.

Small accumulations of *P. crispa* are also noted in the eastern part of the Karkinitsky Bay at the depths of 8–10 m where acts a local anticyclonic current. Other two small accumulations of the unfastened *Phyllophora* are in the Tendra and Egorlitsky Bays at the depths of 7–10 and 4–5 m respectively.

The ZPF covers an area of about 11 thousand km^2 and its total algal biomass, according to estimation of different authors, reaches 6–10 million tons. Before the beginning of 1990s, 15–20 thousand tons of algae were collected annually on the ZPF for further extraction of iodine and, after 1932, of the gelatinizing agaroid agent.

Population of *P. crispa* of ZPF grows in conditions which are notably different from those of the fastened algae of the same species growing on the coastal stones and rocks. Considerably less sunlight reaches the bottom layer, the water temperature during the year does not exceed 10°C and water salinity stays within 18±0.5‰. Under these conditions, *P. crispa* continues to vegetate, propagate and to carry out photosynthesis. It is calculated that, during the day, the *Phyllophora* field, at the time of it maximal development, evolves into the water about 6 million m^3 of oxygen; which is highly important for bottom marine organisms.

Unlike the fastened algae of the same species, the benthic unfastened *Phyllophora* serves as a key (edificatory or dominant) species playing the primary role in the formation of the specific *Phyllophora* biocoenosis. More than 100 species of invertebrates and about 40 fish species were found in this community. The members of the *Phyllophora* biocoenosis are finding here food, substratum for spawning, material for construction of their nests or shelter from predators and so on. Many species have developed the masking color including the rose, red and purple sponges, worms, amphipods, shrimps, crabs and other invertebrates, gobies, blennies, clingfishes, rockling and other fish jointly designated under the name of «*Phyllophora's* fauna».

Practically all red algae are able to develop at a weak water illumination. The unfastened *Phyllophora* ability to vegetate up to the depth of 55 m seems to be one of macrophytes' depth record for vegetation in the Black Sea.

In the ecology of aquatic plants, the term of «compensation depth» is used to indicate the depth at which the value of photosynthesis is equal to the value of respiration; i.e. the production of oxygen is equal to its consumption and there is no net increase in the biomass of the organism.

Since the end of 1960s, the water transparency in the northwestern part of the Black Sea has decreased sharply and, when compared with the values registered for the 1950s, it has diminished by 2–3 folds. As a result, ZPF found itself below the former level of compensative depth. Under the sunlight deficit, *Phyllophora* began to perish and its field has grown smaller (Fig. 13). The ZPF area and total biomass have shrunk to 3 thousand km^2 and 1.7 million tons respectively at the beginning of the 1980s, and to 500 km^2 and 300 thousand tons at the beginning of the 1990s (Zaitsev, 1992).

In 1984, an author has observed the state of ZPF *in situ* from the scientific submersible «Argus», based on the research ship «Vityaz» of the Institute of Oceanology of the National Academy of USSR. Small algae accumulations were registered only in the northern part of ZPF at the depth of 25–30 m. Algae with a height of 0.5–0.7 m were covered by a friable layer of so-called «sea snow» (flakes of dead plankton and organic detritus which sediment to the bottom in areas of mass development of phytoplankton in the superficial layers). The porous lumps of organic detritus, whose diameter was increasing with depth to 5–10 mm, with their microbial population, indeed resembled an abundant snow-fall. The sedimentation of these «snowflakes» was covering algae and worsening the already difficult conditions of illumination thus further restraining the photosynthesis.

Attempts to find representatives of the previously abundant *Phyllophora* fauna either by visual observations or in the samples collected by «Argus» manipulator were not successful. By sight, only two specimens of wrasses resembling *Crenilabrus quinquemaculatus* were observed at the northern edge of ZPF. The length of these fishes did not exceed 8–10 cm and their external pigmentation were without the protective red color.

Deeper, at the depth of 35–40 m, only single specimens of *Phyllophora truncata* attached to the mollusks shells were noted and, below the depth of 40 m, *Phyllophora* was not observed anymore. Till present there are no published data about the fate of ZPF in the middle of 1990s when water transparency has started to increase again.

So, in the relatively homogeneous environmental conditions far from the coastal sources of pollution, has once existed the largest full deep-water biocoenosis of the Black Sea, consisting of autotrophic algae and heterotrophic animals. This biocoenosis has attracted many invertebrates and fish which have adapted to its conditions and developed the protective coloration. The biocoenosis of *Phyllophora* has successfully developed on the border of the euphotic zone of the sea with sufficient light penetration for photosynthesis of red algae. When the water transparency in the northwestern part of the Black Sea has diminished as a result of anthropogenic eutrophication and other reasons, *Phyllophora* has fallen into degradation and with it the whole biocoenosis. Since the late 1990s, a gradual rehabilitation of the Black Sea ecosystem has been noted. In this situation, a special research of the present state of the *Phyllophora* biocoenosis could be of scientific and practical interest.

4.4. Ecology of the Black Sea population of the brown alga *Cystoseira* and its biocoenosis

The representatives of the brown algae from the Sargassum family *Cystoseira* (two species *Cystoseira barbata* and *C. crinita* are known in the Black Sea) inhabit rocky coasts at depths between 0.5 and 32 m; although the bulk of their biomass is noted at the depths from 0.5 to 8–10 m (Fig. 31). *Cystoseira* grows unevenly during the whole year. In December–January, its vegetation slows down while in February–March, in connection with the strengthening of the sun radiation, the rate of its vegetation increases achieving its maximal values in May. In July and August, it slows down again and there is the mass fall of its lateral branches that have grown during the spring months (Kalugina-Gutnik, 1979). The dead branches of *Cystoseira* bushes float for a long time on the water surface as they contain many air bubbles. In September–October, the rates of growing increase once again, but they never achieve the spring values. The age of the lateral branches of *Cystoseira* bush can reach 5–7 months; while its thalli are perennial.

Cystoseira is the largest alga of the Black Sea. The length of adult plants could achieve 170 cm, but is frequently only 60–70 cm. Due to the air bubbles, the whole *Cystoseira* «bush» is able to maintain a vertical position in water.

Figure 31. The thick bushes of brown alga *Cystoseira* are reflected by the sea surface and resemble a fairy-tale forest. Biologists have discovered that this «forest» is inhabited by dozens of species of other algae, invertebrates and fish that together are forming the *Cystoseira* biocoenosis.

The lower limit of the *Cystoseira* population in the Black Sea depends on the bottom type and is located at the depth of 6–32 m. Average algal biomass (total for both species) is equal to 3.4 kg/m^2; while maximal biomass could reach 21 kg/m^2. The highest values of biomass of *Cystoseira* are found at the depths of 1–10 m.

In the areas of its mass development *Cystoseira* becomes a key species of *Cystoseira* biocoenosis which includes epiphytic algae such as diatoms and brown algae *Stilophora* and *Cladostephus*; red algae *Polysiphonia*, *Ceramium*, *Porphyra* (Makkaveeva, 1959); about 25–60 species of macrozoobenthos and dozens of species of meiobenthos. These are polychaetes, e.g. *Spirorbis,* barnacles (*Balanus eburneus*, *Chthamalus stellatus*), amphipods (*Ericthonius difformi*s, *Amphithoe vaillanti*) and others. To *Cystoseira* branches are attached the eggs of the small shallow water fish silverside (*Atherina mochon pontica*) and of the large carnivore garfish (*Belone belone euxini*).

Cystoseira is very sensitive to eutrophication factors; for example to detergents. In coastal waters, where the concentration of detergents exceeds 0.1 mg/l, *Cystoseira* disappears; as it happened in the Gulf of Marseille in the Mediterranean Sea in the 1960s (Bellan, 1976; Bellan et Peres, 1974). This alga also disappeared in the north of the Adriatic Sea and in some fiords of the Norwegian Sea where large cities are located (Gerlah, 1985).

Probably, the same reason was responsible for its disappearance in the north-western Black Sea and on the Romanian coasts at the end of 1970s (Petranu, 1997) and in the Odessa Gulf area at the beginning of the 1980s. According to special research of man-made macrophytes' succession (Minicheva, 1993), *Cystoseira* is substituted by filamentous algae. It is a general rule: as the trophic status of marine water increases, the algae whose thallus has the low index of specific surface (ration of surface of the thallus towards its volume, S/V) are replaced by the filamentous algae with higher S/V values and which are more tolerant towards the high concentrations of fertilizers

(Minicheva, 2006).

Together with the key species, the *Cystoseira* biocoenosis disappeared along the north-western coast of the Black Sea and the Zmiyni Island. On the rocky coasts of Southern Crimea, for example in the Yalta Gulf, a gradual replacement of *Cystoseira* by filamentous green algae *Cladophora*, *Enteromorpha* and others is also noted.

Another community of marine organisms, the nucleus of which is formed by plants, is the biocoenosis of *Zostera* (Fig. 24). Two species of this flowering plant, the common eelgrass (*Zostera marina*) and the dwarf eelgrass (*Z. noltii*), are common in the shallow water zones of the Black Sea and in coastal wetlands. Their main habitats are sandy and muddy bottoms at depths from 0.2 to 5 m and mainly in shallow bays protected from the wave action. Animals which inhabit the meadows of *Zostera* form a temporal (seasonal) biocoenosis, because in winter *Zostera* shed its leaves. In different areas of the Black Sea coast, the composition of *Zostera* biocoenosis includes a couple of species of epiphytic algae. The mass animals of this biocoenosis are mollusks (*Mytilaster lineatus*, *Rissoa euxinica*, *Bittium reticulatum*), polychaetes, amphipods, shrimps (*Palaemon adspersus*, *P. elegans*) and grass crab (*Carcinus aestuarii*). Among the typical fish of this community, there are pipefish, sea-horse, grass goby (*Gobius ophiocephalus*) and several species of wrasses (Labridae).

4.5. Ecology of other bottom biocoenoses of the Black Sea

Other bottom biocoenoses of the Black Sea could include some algal species, but the macrobenthic invertebrates represent the leading part of their biomass. Biocoenoses get their name from the key species of invertebrates; e.g. the mussel's (*Mytilus galloprovincialis*) biocoenosis which is wide-spread in the Black Sea at the depths from 1 to 55 m; the biocenosis of the clam *Chamelea gallina* at the depth of 7–30 m; the biocoenosis of *Lentidium mediterraneum* at the depth of 0.5–20 m; the biocoenosis of the soft-shelled clam *Mya arenaria* at the depth of 3–16 m; the biocenosis of the polychaete *Melinna palmata* at the depth of 12–28 m; and some others. In all these biocoenoses, along with the animals, are also present producers such as the unicellular algae of the microphytobenthos and macrophytic algae. Unicellular algae are registered on the bottom of the Black Sea down to the depth of 55–60 m (Bodeanu, 1979).

The biocoenosis of the horse-mussel *Modiolus phaseolinus*, at the depths from 60 to 125 m, is the deepest in the Black Sea. Although algae, which are not growing deeper than 60 m in the Black Sea, are not members of this community, this biocenosis is composed by up to 85 species of macrozoobenthos belonging to sponges, polychaetes, molluscs, crustaceans and some other groups.

In addition, high numbers of organisms of meiobenthos, on average about 40 thousand individuals per 1 m^2 (Kiseleva, 1979), are noted in this biocoenosis. Based on their feeding habits, the macrobenthic organisms of this biocoenosis can belong to detritivorous, planktivorous, fitrators and predators. This deep-bottom biocoenosis exists mainly due to sedimentation of organic particles (the so-called «marine snow» formed by dead plankton and detritus) from the upper layers of the pelagial zone.

Through the deadlights of the scientific submersible «Argus», on the north-western shelf at the depths of 100–120 m, the author has noted the even bottom of dark-olive colors, which was pitted by the creeps, covered by silt, shells and live individuals of the bivalve *Modiolus phaseolinus*. On this background, like tangerines that have been spread by somebody, the orange-red sponges *Suberites carnosus* with a diameter up to 50 mm were observed. At some places, their number reached 10 per 1m^2 of the bottom. Above the bottom, were passing schools of whiting (*Merlangius merlangus euxinus*) counting 5–10 large individuals with body lengths up to 40 cm. Fish were slowly swimming, picking up something, possibly polychaets, from the bottom. No water motion was observed around and particles of fine silt roiled by «Argus» were slowly sedimenting back to the bottom. The vast spaces, occupied by the biocoenosis of horse-mussel, appeared to be the kingdom of peace and stability in the marine ecosystem. Certainly, the peace here is relative and the life develops with all its displays, but, indeed, the wave action does not reach the 100-meter isobath, and, if it does, it is very weak. The visible part of the sun spectrum reaches these depths only at midday in the form of a late dusk. The water temperature and salinity are practically constant during the year and pollutants from the land-based sources almost do not reach this zone. The quantity of food particles falling from above depends on the water currents at the surface of the pelagial zone and varies from abundant to barely noticeable.

The apparent peace of this deep-water biocoenosis is violated by the brightly colored polychaetes *Platynereis dumerilii*, *Nereis zonata* and, a rarity for the Black Sea, *Nereis longissima* (Zakutsky, 1963, 1968) which, in summer, rises up every night through the 100-meter water layer and makes a real «swarming» in the neustal zone. At dawn, they return back to their habitat. The reason for the voyage of these bottom polychaetes has not yet been found. It is assumed that they are attracted in the neustal microlayer by the abundance of food. Here, both adult individuals and larvae find more available food than in the water column and in the deep bottom biotope.

Compared with the biocoenosis of horse-mussel, the biocoenosis of *Donacilla*+*Ophelia* (*Donacilla cornea*, *Ophelia bicornis*) stands at the ecological antipodes. The bivalve *Donacilla* and the polychaete *Ophelia* inhabit the coarse-grained and medium-grained sands in the splash zone of the mediolittoral where, under the influence of wave action and water currents, the water masses and bottom sediments are very dynamic and the seasonal and diurnal fluctuations of temperature achieve their largest amplitude. This biocoenosis is registered in limited areas of sandy beaches and ceases to exist if the coarse grained sand is replaced by fine-grained particles (which clog the interstitial spaces between the sand grains) or if toxic matters are present. Only well aerated sand is suitable for the life of *Donacilla* and *Ophelia*. In this sand, one-celled algae (up to 230 thousand cells under 1 cm^2 of sand surface) and meiobenthic organisms develop successfully. Algae enrich sand with oxygen and, along with the organisms of meiofauna, serve as food for macrobenthos. In the composition of this biocoenosis, only 13 species of macrobenthos were registered; which is not surprising taking into account the specific terms of habitat. This biocoenosis serves as a biological indicator of a healthy biotope of the psammocontour (splash zone). In this sand can be registered up to 22 thousand individuals of *Donacilla* and up to 4.5 thousand individuals of *Ophelia* per 1 m^2.

For more detailed descriptions of biocoenoses and their comparison, specialists are using different formulas and equations. In particular, the ratio of the number of common species towards the total number of all species in compared biotopes is expressed by the coefficient of specific community (K), or coefficient of specific likeness of biocoenoses (the Jaccuard's coefficient), which is determined by the equation:

$$K = \frac{C}{(a+b)-c},$$

where **C** – the total number of the species registered for the two explored areas of the biotope;

a and **b** – the number of the species registered for each of the compared biocoenoses;

c – the number of their common species.

Quantitative estimation of biocoenoses structure characterizing their diversity, or the Shannon's diversity index (H), is calculated as:

$$H = -\sum_{i-1}^{m} \frac{Ni}{N} \log_2 \frac{Ni}{N}$$

where *Ni* – is the number of each i-species;

N – the total number of all species in the community;

m – the number of groups.

The Shannon's index summarizes the numerous information about the number and specific composition of organisms in biocoenoses.

There are a lot of other methods of mathematical treatment of the data which are used for ecological observations but, in the end, their exactness depends on the adequacy of basic data obtained *in situ* or during experiments. It is possible to create a mathematically perfect formula of calculation, but it will not prove to be correct if the basic data was inaccurate. However, without the application of mathematics, it is impossible to study the quantitative relations in ecology, to make a correct summary of the large volumes of obtained materials, and to estimate the data adequacy as well as to make a prognosis of how the ecological processes can develop in various possible scenarios.

4.6. Birds in the Black Sea ecology

All birds feeding in the water are more or less adapted to the aquatic environment. The well-diving birds have the heavier bodies; thus the specific gravity of cormorant and grebes bodies approaches 1.0. For this reason, the grebe needs a minor effort of its feet to submerge under the water, while gulls, whose specific body gravity barely exceeds 0.5, are unable to dive. The gull can submerge only on the wing and only superficially for a few seconds; that is why it feeds at the water surface.

Species that spend a long time in the sea, as for example the shearwaters, have well developed nasal glands. These organs function on the same principle as the kidneys of higher vertebrates and excret the excessive amounts of salts which get into the birds' organism.

In spite of the fact that the life of aquatic organisms inhabiting the Black Sea and the birds inhabiting its coastal zone is studied well enough, comprehensive investigations of the birds' role in the Black Sea ecology and the role of the Black Sea in the birds' ecology are practically absent. It is especially noticeable in comparison with the other World seas, where the co-operation between hydrobiologists and ornithologists is more effective. In the meantime, in this aspect, the Black Sea is distinguished not only by its diverse and abundant ornitofauna, but also by the fact that it is a key area of biosphere communications («biological corridor») for migrating birds (Nazarenko and Amonskyy, 1986). During the seasonal migrations, with prolonged stops at the Black Sea shores, the pressure of the «ornithological factor» on the sea and coastal reservoirs increases repeatedly, but it is not known how high this pressure is. Also it is not known how the Black Sea «rescues» these aerial travelers during their stops and feeding at the sea coasts. The aim of this chapter is to attract the biologists' and ecologists' attention to the important scientific and practical problem «Birds and the Black Sea Ecology» and to encourage its profound and complex study.

In nature no birds are known which spend their whole life cycle in seas and oceans. Even the penguins, which are unable to fly but are able to dive to depths up to 250 m, are nesting on land. However, there are a lot of birds' species which are closely connected with the marine environment. Some authors suggest to distinguish the primary and secondary marine birds (Boaden and Seed, 1985). To the first group are ascribed the birds for which the sea, or coastal waters, represent the ordinary environment for habitat and source of food and the costal zone is used only during their nesting season. The second group is composed by the birds which mainly inhabit the fresh and brackish water coastal wetlands and which are using the sea-shores mainly as feeding grounds.

It should be noted that, essentially, the primary marine birds cannot exist because birds, as a class of chordates, originate from land and only later on some of them were adapted to life in the sea to a greater or smaller extent. The same happens with mammals. However, the various bird species have different degrees of attachment and dependence on the marine environment

Species such as the Manx shearwater (*Puffinus puffinus*), the white and Dalmatian pelicans (*Pelecanus onocrotalus*, *P. crispus*), some species of cormorants (*Phalacrocorax*), and a few species of gulls (*Larus*) and terns of the genera *Sterna* and *Hydroprogne* are the most connected with the Black Sea. Birds mainly inhabiting the coastal wetlands and feeding at the seashores are connected with the Black Sea to a lesser extent. These are the species of waders, ducks, geese and swans. Some terrestrial birds also can feed at the seashores; for example crows, rooks, wagtails and other.

The birds connected with the sea have some morphological and physiological adaptations to the marine environment. Species that stay for a long time in the salt water have well developed nasal glands which excrete the salts from the bird's organism. Among the Black Sea birds, this adaptation is characteristic for the gulls, shearwaters and ducks.

A number of adaptations of birds related to the sea assure their swimming, diving, pursuing and catching of the prey and its further transportation ashore to the place of their nestlings. For the underwater movement, some birds use not only their feet, but also the wings. To them belongs the Manx shearwater which pursues its prey to depths up to 40 m. Some birds are able to change the focal distance of their eyes' lens for the best underwater orientation, pursuit and prey catching. The moistened contour feathers of the cormorants serve for reducing body buoyancy. These birds could be seen drying out there wings sitting on some eminences.

The plumage color is also one of ecological adaptations. White feathers covering the ventral part of body and wings of marine birds make them unnoticeable for their prey from below.

However, fish also use same kind of adaptation: their dorsal part of body is colored in dark blue in order not to be noticed against the sea surface from air; while their ventral part is silver-white to mask the fish from the water column.

Marine birds use different strategies to prey their food. With regard to the Black Sea species, it is possible to identify the following types:

Pursuing and catching of the prey under the water using wings and legs (shearwater),

Pursuing and catching of the prey under water using legs (cormorants and grebes),

Catch of food from the sea surface; i.e. in the neustal layer (gulls, terns),

Stealing the prey from the other birds (skuas),

Hunting on birds which are flying above the sea by dropping them into the water (Lesser black-backed gull).

While on the shore or in shallow water areas, birds also use various ways of food hunting. The mallard and other species of ducks, which are unable to dive, filter water using a special structure of their tongue and beak. The diving birds such as the cormorants, pochards and grebes are seizing fish, mollusks and other invertebrates at the bottom and therefore they quite often get into fish nets and die (Fig. 32).

Figure 32. Ichthyophagous birds quite often get stuck in the fish nets and die. This cormorant which got trapped into a net in the Danube delta has been be rescued in time (photo A. Birkun Jr.)

The waders are probing the soft soil in the mediolittoral zone and, depending on beak's length, feed on amphipods, bivalves, and worms that live at different depths. The Kentish plower (*Charadrius alexandrinus*) and the ringed plover (*Charadrius hiaticula*) which have short-length beaks feed on gastropods living on the bottom surface, like *Hydrobia*; while worms which are borrowing quite deep into the substrate could be grasped only when they appear in the upper layers. The waders with the middle-length beaks, as well as the redshank (*Tringa totanus*), can feed on worms, crustaceans and bivalves borrowed into the sediment. Only the long-beaked waders, as the large curlew (*Numenius arquata*) and the bar-tailed godwit (*Limosa lapponica*) can test the ground up to the depth of 10 cm (Fig.33).

Figure 33. Depending on the beak's length, different species of waders in search of food could probe the soft bottom up to different depths: 1 – curlew, 2 – black-tailed godwit, 3 – redshank, 4 – knot, 5 – sanderling, 6 – ringed plover (from J. Green, 1968)

The oyster catcher (*Haematopus ostralegus*) inserts its sharp bill between the valves of mussels and twists them open (Fig. 34). Rations and periods of food search of the oyster catcher can vary on different coasts depending on food availability, strength of its junction with substratum and other conditions.

The herons use to track down their prey. For this purpose they stiffen motionlessly at a shallow depth and with a swift peck seize up the passing by fries. In the stomach of one little egret (*Egretta garzetta*), which was hunted at a shore at the depth of 10–15 cm (it happened in August in the Karkinitsky Gulf), were found about 120 fries of the grey mullets (*Liza saliens* and *Mugil cephalus*). The schools of these fries, with the body length of 15–20 mm, are migrating just along the water line in search of an entrance into the limans and lagoons.

Figure 34. With its strong beak the oyster catcher is able to open easily the shells of freshwater and marine bivalve mollusks (from Yu. Zaitsev and V. Prokopenko, 1989)

Unlike the waders whose beaks are adapted for grasping single organisms, the beaks of many ducks, as for example the shelduck and mallard, are able to filter water and to catch crustaceans and other small sized preys. This method of hunting is only effective in areas with high numbers of small aquatic organisms. In the Black Sea and its coastal wetlands, the shelduck (*Tadorna tadorna*) successfully uses this method in zones of mass development of the gastropod *Hydrobia ulvae* and amphipod *Pontogammarus maeoticus*. The mallard is also attracted by floating corn. Thus, in summer, in the grain harbor of Odessa port, a great number of mallards can quite often be observed arriving from the neighboring wetlands for feeding on the grains falling into the water during the loading and unloading operations.

Published data on the ecological role of the birds in the coastal zone of the Black Sea are quite rare and sparse. This interesting and important research field still awaits the attention of scientists. The fact that, in nature, important ecological processes indeed take place with the participation of birds and marine organisms is confirmed by publications related to other European seas, although the authors regret that the quantitative information about the birds' influence on coastal zone ecology is surprisingly scanty (Green, 1968; Milne and Dunnet, 1972; Furness, 1982, Boaden and Seed, 1985, *et al*).

The birds inhabiting the coastal waters, the waders and ducks in particular, consume plenty of invertebrates. One individual of the redshank consumes about 40 thousand individuals of amphipods, mainly *Corophium*, during one day. One oystercatcher eats up to 300 bivalve mollusks *Cardium* per day and one knot (*Calidris canutus*) more than 70 individuals of the bivalve *Macoma*. The flocks of these birds often count a couple of thousands of individuals. In the Dutch Waddenzee area, the population of eider (*Somateria*) consumes more than one billion of small sized bivalves, 220 million of mussels and 30 million of crabs during a year. The population of oyster catchers eats up to 3 billion of *Cardium* during a year and the population of snipe more than 1 billion of worms. A middle-size flock of shelducks can consume 15 billion of *Hydrobia* during the summer–autumn period. The stilt eats up 214–315 individuals of *Cardium* during one day. In one of the coastal areas of the Irish Sea, these birds eat about 22% of *Cardium* population during the winter. The oyster catcher eats up to 40% of the total production of *Cardium* population. It was calculated that in Scotland the waterfowl eats up about 37% of the annual production of these bivalves (Milne and Dunnet, 1972).

It was noticed that the waterfowls prefer not only certain species of aquatic organisms, but also certain sizes of their prey; meaning that predators are influencing the population structure of the prey species.

All the above mentioned species are registered in the Black Sea area as nesting or migrating birds (Fesenko and Bokotey, 2002; Radu, 1979). However, it is unknown at what time of the year and to what degree these birds, consuming marine organisms, are influencing the Black Sea ecology; especially in the coastal zone. The publication of B.G. Alexandrov (1999) represents, in this context, a promising start.

The data reported by Yu.V. Kostin in the book «The Birds of Crimea» (1983) are also of a cartain interest.

In 34 stomachs of the Manx sherwaters obtained in July–August 1957–1958 near the Cape Tarkhankut (western Crimea) were found the following food items: anchovy (50% of individuals), sand lance (12%), horse-mackerel (9%), sea-horse and sprat (3%), unidentified fish species (17%), isopods (9%), amphipods (3%), and unidentified invertebrates (15%). Based on this list of food species, it is possible to judge about the manner of hunting and about the feeding areas of different birds. Usually, in autumn, the shearwaters fly southwards to the islands of the Sea of Marmara and Aegean Sea (where are located the main nesting-places of this species) and, only at the end of spring, it returns back to the Black Sea which is the main feeding ground for this species. However, in winter 2003–2004 these birds were seen on the southern Crimea coasts. Thus, in February 29, 2004, during the dolphin monitoring, A.A. Birkun and S.V. Krivokhizhin (personal communication) observed numerous flocks of the shearwaters, accounting dozens individuals each, that were feeding in the coastal waters between the Aya and Fiolent Capes. Probably, their basic food was the horse-mackerel wintering here and whose population has increased considerably during the last 2–3 years. Obviously dolphins were feeding on the same fish.

In the stomachs of two red-necked grebes were found 12 shrimps, 10 pipefish and 2 gobies. In 22 pellets of the nestlings of cormorant on 18–21 July, 1978 were found 43 gobies and other fish. Sixteen stomachs from 20 of the birds which were wintering at the Southern coast of Crimea, and were caught on 16–21 January, 1978, did not contain any food and the remnants of grey mullets were found in the other 4. The largest grey mullet caught by the cormorant had a length up to 40 cm and a mass of 950 g. The average daily ration of an adult cormorant makes about 350 g of fish; therefore, the prolonged stay of this bird in a given area testifies to the presence of its corresponding food.

In the stomachs of 62 individuals of the shag (*Phalacrocorax aristotelis*), from the area Tarkhankut-Chernomorskoe (NW Crimea), were found the following food items: gobies (72%), pickerel (12.6%), sprat (4.9%), horse-mackerel (6.4%), anchovy (3.2%), shrimps (8%), crabs (6.4%) and isopods (1.6%). The shags sampled at the southern Crimean coast in January 1978, were having in their stomachs only sand lance, silverside and some fish from Labridae family.

The shelduck, caught in the area of Swan Islands (NW Crimea) on 24th of December, contained 20 mussels and remains of unidentified crustaceans. The gadwall (*Anas strepera*) caught at the same area contained about 400 mollusks. In 200 pellets of terns from July 1971, were found remains of round gobies (54.2% of cases), rotan goby (32.8%), ginger goby (13%), toad goby *Mesogobius batrachocephalus* (13%) and annular gilthead *Diplodus annularis* (13%).

In the stomachs of coot (*Fulica atra*) were found only plants in form of a green mass and in those of two specimens of the exceptionally ichthyophagous bird osprey, caught at the Bakal spit area (NW Crimea) in April 25, 1966, one large goby and a garfish about 30 cm length.

Questions from chapter 4 for seminar (training) in the Black Sea ecology

1. Give the definition of species population and species community?
2. What environmental conditions attract the Mediterranean fish into the Black Sea?
3. Describe the life cycle of the Black Sea population of mackerel.
4. When and why the Black Sea population of mackerel has stopped to be an object of commercial fishing?
5. Describe the life cycle of the Black Sea population of the striped mullet.

6. What factors either natural or anthropogenic have the most influence on the Black Sea population of the striped mullet?
7. What species are called the species-edificators or key species of the biocoenoses?
8. Name the main species that form the Black Sea *Phyllophora* biocoenosis.
9. Where is located the Zernov's *Phyllophora* Field? What is its area and total biomass of algae? Describe its modern ecological state.
10. Which species are forming the Black Sea *Cystoseira* biocoenosis?
11. Where and why *Cystoseira* and it biocoenosis are getting oppressed and disappearing?
12. Where is located the biocoenosis of the eelgrass *Zostera* and what organisms are its members?
13. Which birds are feeding on marine organisms?
14. How birds are hunting on the marine animals?
15. Name the seabird which can be considered the «champion» in depth diving in the Black Sea? Name birds that are incapable to dive.
16. What benefit and harm can cause to man the birds' species which are feeding on marine organisms?

5. Ecological reasons of migrations of marine organisms

Ecological bases of fisheries and protection of marine organisms

The term «migrations» indicates the movements of organisms in space caused by the changes in the environmental conditions of their habitats or related to the peculiarities of their life cycle. The former can be regular (e.g., seasonal or diurnal) or irregular (e.g., leaving a habitat because of unfavorable life conditions). The latter provides dispersal and can take place during the larval stages, the maturation period of adult individuals or the spawning period.

Regular migrations are accomplished via more or less defined routes, while irregular migrations do not have a clear orientation and are quite often chaotic. According to their direction in the water column, migrations are divided into horizontal and vertical.

Among marine organisms, fish migrations are the most studied due to the necessity of a detailed knowledge of the fish life cycles for fishing purposes. Spawning, feeding and wintering fish migrations can be distinguished.

The fish movements related to the reproduction are aimed to provide the best conditions for the normal development of eggs, larvae and fries. Some fish species, which are called diadromous, migrate from the sea into the rivers for spawning. In the Black Sea, these are herrings, sturgeons and salmon and their migrations are termed anadromous. These species are going into the rivers because their eggs can only develop in freshwater, while adult individuals inhabit the sea.

The Black Sea herring (*Alosa kessleri pontica*) enters rivers from March to June, goes upstream, surmounting 180–400 km in the Danube river, and spawn there. After spawning, adult fish returns back into the sea. The floating herrings' eggs develop in the river and hatched larvae drift downstream to the river mouth. Larvae stay in deltas and in predeltaic areas of the sea for fattening and go out into the sea in autumn.

This and other species of the Black Sea herrings are catched by nets during their spawning migration and are valuable commercial species. The rules of fishing regulate place, time of catch and scientific-grounded quotas (amounts) of herring's catch in order not to undermine the supplies of every separate population. When strictly observing the rules of fishing, the use of sea living resources ensures a steady development of the fish industry. In the conditions of the Black Sea, the acceptance and observance of fishing rules depends not only on scientists and fishermen, but also, because of transboundary migrations of the herring, on the coordinated actions of the governments of all the Black Sea countries.

Spawning, anadromous migrations are also typical of the Black Sea sturgeons – the white sturgeon, the star sturgeon, the Russian sturgeon and some other species. In former times, when the rivers were not dammed up, the white sturgeon, for example, was going upstream the Danube up to Austria. Starting from the middle of the XXth century, following the construction of river dams, the long-range migrations of sturgeons became impossible and this fact, along with other reasons, has reflected on the effectiveness of spawning. A considerable decline of the sturgeon's populations has taken place. At present in Ukraine, the white sturgeon (*Huso huso ponticus*), the Atlantic sturgeon (*Acipenser sturio*) and the fringebarb sturgeon (*A. nudiventris*) are included in the Red Data Book and their fishing is forbidden. In rivers, the sturgeon spawns on pebbles and larvae move downstream and fatten in deltas until the beginning of the autumn season. The grown up fries and adult individuals inhabit the open sea.

Salmons are represented in the Black Sea by a single species, the Black Sea salmon (*Salmo trutta labrax*), which spawns on pebbles in the rivers of Caucasus. Its adult individuals inhabit the coastal waters of the sea. The Black Sea population of this species is not numerous and is included in the Red Data Book of Ukraine.

Migrations of fish from rivers into the sea are termed catadromous migrations. Thus, the larvae of anadromous fish (Clupeidae, Acipenseridae and Salmonidae), after hatching in rivers, accomplish passive catadromous migrations into the sea. Among the Black Sea fish, the only species actively migrating from rivers into the sea for spawning is the European eel (*Anguilla anguilla*). The knowledge about spawning migrations of this genus is based on data obtained at the beginning of the XXth century by the Danish ichthyologist I. Schmidt. According to his research, the mature individuals of eel leave, on spawning, from the rivers of Europe and North America into the Atlantic Ocean in region of the Sargasso Sea where, at the depth of 500–1000m, they lay pelagic eggs at a water temperature not less than 7°C and salinity not less than 35‰. After spawning, the adult individuals perish and the larvae are caught by the North-Atlantic branch of the Gulf Stream current and are carried away to the European shores. Another part of the larvae is carried to the shores of North America. The larvae's «voyage» from the places of their hatching to the European coast lasts about 3 years. During this time, larvae develop into fries and then into young fish which enter rivers that are flowing into the North, Baltic, Mediterranean and Black seas. Here they grow up during the next 10–15 years and quite often they come into the sea. After reaching the maturity, the fish start their first and last catadromous spawning migration.

Following the version of I. Schmidt, it is necessary to assume that, for example, eels from the Dnieper pass from the north to the south of the Black Sea and then (across the Bosporus, Sea of Marmara, Dardanelles, Mediterranean, and Gibraltar strait) go out into the Atlantic Ocean and direct to the Sargasso Sea where they spawn at depth and then perish. Although fish species which accomplish such long spawning migrations and perish after spawning are known (for example many species of the Far Eastern salmons), this description is probably not entirely plausible.

In particular, according to a hypothesis stated by English ichthyologist Tucker (1959), the European eels perish in the Atlantic Ocean before spawning and new generations of this species originate from the North-American eel *Anguilla rostrata* which also spawns in the Sargasso Sea. The larvae of this eel are taken away by the North-Atlantic branch of the Gulf Stream and are forced to prolong their larval life for up to 3 years. That is the reason why they have more vertebrae than the American species of the same genera. However, this hypothesis has not received further confirmation and I. Schmidt's version remains at present in force.

Fish also accomplish regular spawning migrations within the limits of the Black Sea. For the period of spawning, most species move from the deep-waters towards the coastal zone. These movements are called adlittoral migrations. They are characteristic for turbot, gobies, wrasses and many other fish. The fishing of the commercially valuable species turbot (*Psetta maeotica*) is based on its spawning migrations to the shore.

The grey mullets, on the contrary, move for spawning from the coastal zone into the open sea. Till recently this migration was used for the trade of eggs of the striped mullet (Fig. 30). The fries of the grey mullet hatch in the open sea and migrate to the coasts; i.e. they made a feeding adlittoral migration.

Practically all feeding fish migrations are oriented towards the coastal zone which is richer in food for young fish and adult specimens than the deep-water shelf zone and the open sea. Such behaviour is characteristic not only for benthic, but also for pelagic species such as anchovy and horse-mackerel. In spring and sometimes in summer, the feeding sprat approaches to the shores at low water temperature. The schools of this fish migrate along the coast and are caught by large fixed fishing nets.

When compared to the Sea of Marmara and the Mediterranean Sea, the Black Sea is much more suitable as a feeding area. Therefore, in summer, some species from the Mediterranean and the Sea of Marmara migrate into the Black Sea for feeding and go back in autumn for wintering. Such species are the mackerel (*Scomber scombrus*), tuna (*Thunnus thynnus*), swordfish (*Xiphias gladius*) and bonito (*Sarda sarda*). The first three species do not spawn in the Black Sea, while bonito has formed a Black Sea population. Until the beginning of the 1970s, mackerel was a valuable commercial species, but only single specimen of tuna and swordfish were registered.

The wintering migrations of fish which does not leave the Black Sea are oriented towards the areas with the higher water temperatures during the cold season. These are the coastal waters in front of Southern Crimea and, especially, along the coasts of Caucasus and Asia Minor. In winter, the populations of the Black and Azov Seas subspecieses of anchovy (*Engraulis encrasicholus ponticus* and *E. encrasicholus maeoticus*), horse-mackerel (*Trachurus mediterraneus ponticus*), bonito (*Sarda sarda*), grey mullet (Mugilidae) and other species concentrate here in a very limited area. Dolphins also head here for wintering. It is not surprising that such winter accumulations of fish attract fishermen who catch them by trawls and other fishing gear. Because the main part of the fish resources of the whole Black Sea are concentrated along the southern and south-eastern coasts, the winter fishing also requires international regulations.

Many species of zooplankton accomplish long (taking into consideration their body sizes), vertical, diurnal (circadian) migrations. During the day-time they stay in the deep layers of the water column and, in the evening, start to rise approaching the upper layers of the pelagial or concentrating in the neustal. At dawn they return back.

In the Black Sea, the most marked migrations of this kind are the daily vertical movements accomplished by the copepods *Calanus euxinus* and *Pseudocalanus elongatus* (Greze, 1979). They rise up from the depth of 100–150 m into surface waters. The typical picture of these migrations has been studied by A.P. Kusmorskaya (1954) in the eastern part of the Black Sea using sampling by planktonic nets at different depths. This method helped to obtain the data on the gradual rising up of *C. euxinus* from the depth of 100–150 m to the surface. The migration of *P. elongatus* has smaller vertical amplitude. As shown by N.I. Chokhuri (1939), the copepods *Oithona similes* and *Centropages kroyeri* and the arrow worm (chaetognath) *Sagitta setosa* also accomplish diurnal vertical migrations. In the Sevastopol Bay, during the sun eclipse on June 30, 1954, when the sun's disk was obscured for 92%, T.S. Petipa (1955) has discovered a rapid raise up of more than 70% of the organisms of plankton from the layer of 14–5 m into the layer 5–0 m. This phenomenon was recorded for all zooplankton species. That fact, as supposed by V.N. Greze (1979), indicates light intensity as the main factor causing vertical migrations of plankton.

Concerning the reasons of vertical migrations, there is no universal agreement in the scientific literature. Indeed, many facts point to sunlight as the principal factor controlling migrations. But migrations often envelop a vast range of depths and some deep-water species accomplish vertical migrations in pelagial layers which are distant from the surface. Some scientists explain the biological expedience of vertical migrations by the fact that, at night time, the migrants are not so noticeable for predators from the superficial water layer. However, many migrants luminesce in water thus giving themselves away completely. In addition, many predators also accomplish diurnal vertical migrations.

Another hypothesis is that vertical migrations, in condition of different current's speed at different depths, serve for dispersion of migrant's populations. Without such dispersion the dense accumulations of zooplankton would result in the total consumption of phytoplankton. Migrations therefore help the phytophagous species to change their «pastures».

Finally, it is suggested that the vertical migrations are related to the energy metabolism. For the organisms of zooplankton, it is more energy-favorable to spend part of the day-time in the cold waters of the deep layers of pelagial where their metabolic rate is slower.

It is obvious that all the above stated considerations have various relations with the vertical migrations of the plankton; which involve enormous masses of marine organisms rhythmically rising up to the surface at night-time and returning back to depth during day-time.

The author got a chance to observe the night vertical migrations of the plankton in the north-western part of the Black Sea through the deadlights of the scientific submersible craft «Argus» on May 31, 1984 above the depth of 100–120 m. During night-time, «Argus» performed repeated immersions at depths and returned back to the surface with intermediate stops to observe the process of vertical migrations. These surveys not only confirmed the occurrence of migrations, but also allowed to find a number of details about the behavior of the organisms which cannot be obtained during their studies in aquariums or in the laboratory during tests on plankton organisms collected by nets.

In the light of the outboard searchlights of «Argus», it was clearly visible how the organisms of zooplankton were activated after 6 p.m. The large copepods *Calanus euxinus* and *Pseudocalanus elongatus* and the chaetognath marine arrows *Sagitta setosa* were identified visually. Copepods moved upwards with the help of energetic blows of their first antennas, therefore their movement was saltatory with short stops after each jump. *Sagitta*, in spite of the arrow-shaped external form that earned its Latin name to the genus, was also moving by jerks accompanied by eel-like, bogy movements. Many other organisms were also moving upwards, but it was not possible to identify them by sight because of their small body size.

The transparent, crystal-like comb jelly, the sea gooseberry *Pleurobrachia rhodopis*, were also distinctly visible on the black background of pelagial layer in the light of searchlights. On its spherical body (diameter 5–10 mm), 8 meridional rows of rowing plates, each of them comb like (that resemblance gave it its common name) were visible. On each side of the «ball» two long tentacles are attached. Their length multiply the body length and long fine filaments go out from the tentacles. Tentacles are able to hide into special pockets. The surface of the tentacles and their filaments is covered with numerous sticky cells. When touching the tentacles, the small-sized marine organisms are firmly glued and become tangled in the tentacles. The caught victim is pulled up to the edges of the mouth of the comb jelly fish and consumed. This rather detailed description of the external view of the sea gooseberry was needed to understand the method of its hunting which was observed by the author from the board of «Argus» and is not yet described elsewhere in scientific literature.

It was assumed that, behind the comb jelly fish slowly moving due to the beating of its rowing plates, the tentacles with filaments were stretching like the tail of a kite and that the small-sized organisms that were stuck on them became the food of this not mobile animal. In reality, it appeared that the comb jelly fish is able to make flash-light rotatory motions around its axis. Thus, submitted to centrifugal forces, the tentacles stretch out at maximal length and, because of the rotation, their thin threadlike outgrowths form a continuous hunting net that, by sight, reminds the circle which becomes noticeable during the work of an helicopter propeller. The diameter of this «propeller» varies from 10 to 20 cm, according to author's observations. The swift rotation of the comb jelly lasts no more than 3–5 seconds whereupon, in place of a silvery disk in eyeshot, appears the comb jelly fish itself pulling up to its mouth the tentacles with the catch. Placing on the path of migrating plankton a hunting net whose area exceeds by hundred times its body size, the comb jelly fish multiplies the probability of catching prey. Certainly, not all preys are caught by the predator, as it was also observed by the author. Sometimes, by energetic movements, the copepod calanus and the large arrow-worms *Sagitta* succeeded in tearing the thin sticky filaments and escaping; although their majority was getting caught.

Thus, the comb jelly *Pleurobrachia*, which appeared as a languid medusoid creature, is able to conduct active hunting and inflict a serious damage to the populations of its victims. In this context, it is necessary to note that, unlike *Pleurobrachia*, the other comb jelly *Mnemiopsis*, which was accidentally introduced into the Black Sea, has a different anatomy and uses another hunting behaviour.

Special studies have shown that, in the Black Sea (and also in the Azov and Caspian Seas), benthic organisms make regular mass migrations to the sea surface concentrating in the neustal (Zakutsky, 1968). It turned out that many benthic species have two ways of life. During the day, they stay in the composition of the benthos and at darkness in the neuston composition, namely in its lower layer, the hyponeuston. Both benthic and neuston states appear important to an equal degree for the life of these species which are called benthohyponeustonic (Zaitsev, 1964).

According to data of V.P. Zakutskiy, 47 species were recorded in the composition of the benthohyponeuston of the Black Sea in the summer period; including 7 species of polichaetaes, 8 species of cumaceans, 8 of mysydacea, 5 of isopods, 1 of tanaids, 15 of amphipods and 3 of decapods.

The maximal accumulation of organisms of the benthohyponeuston was observed in the layer of 0–5 cm from 9 p.m. to 4 a.m., whereupon the return flow of migrants started and they were not registered anymore at 7 a.m. at the pelagial surface. Sometimes, among the benthohyponeustonic migrants, some species that are rarely known for the benthos samples were noted. Thus, in July–August 1965, on the Caucasian shelf of the Black Sea, marine hairworms were repeatedly registered. They were accumulated in neustal for no more than one hour, whereupon they started migrating downwards. According to E.S. Kiryanova, they were a new subspecies *Nectonema agile euxina* ssp. nov. (Zakutsky, 1968).

It is noted that, in rainy days and misty weather, the vertical migrations of organisms of the benthohyponeuston start earlier and finish later than on clear days. In winter months they seem to slacken, but do not halt.

The highest numbers of organisms of benthohyponeuston were registered within the shelf zone, at depths above 50–60 m. With the increase of the depth, over the *Phaseolina* biocoenosis, the number of migrants from the benthos reduced, however on the surface it was possible to observe the «swarming» of polychaetae *Platynereis dumerilii* and *Nereis zonata* (Zakutsky, 1963).

Of special interest are the repeated findings of adult organisms of benthohyponeuston in the near-surface layer of the central areas of the Black Sea. There, V.P. Zakutskiy (1968) registered cumaceans *Cumella limicola* and *Cumella pygmaea*, which were considered typical benthic organisms. Individuals of *C. pygmaea* were registered in the night catches with a neuston nets even above the depth of 2000 m.

Half-way between the Sarych (Crimea) and Inebolu (Turkey) capes, above the depth of 2100 m, were registered opossum shrimp *Gastrosaccus sanctus* and, above the depth of 2026 m in the western part of the sea, the amphipod *Dexamine spinosa*.

It is possible to suppose that these organisms were transported by currents from the shelf area, however, being above the hydrogen sulphide zone, they continued to accomplish daily vertical migrations as on the shelf. Nothing is known about the duration of the forced pelagian way of life of these organisms. It is possible to assume that they become the prey of pelagian fish or perish as a result of hittin into the deep-sea layers of pelagial, infected by hydrogen sulphide.

The diurnal vertical migrations of the bottom organisms serve for transferring into a biotope which is richer in food and where adult specimens and larvae are better provided with food comparing to the benthal habitats. The fact that the reproduction of the bottom organisms takes place in neustal could be supposed from the discovery of the epitokous forms of polychaetes. Epitokous is a sharp change of external form and internal body structure of polychaete worms during the maturation of gametes. At this time, polychaete are raising up to the surface for reproduction. Among the crustaceans of the benthohyponeuston a lot of oviparous females are noted.

Vertical migrations of the benthic organisms in the Black Sea are not yet studied enough. However, it is obvious that the differentiation of marine organisms into benthos, plankton and neuston is not absolute since they pass from one group to another not only during the period of individual development (for example, planktonic larvae developing in benthic adult individuals) which usually has seasonal character, but even during the day like the organisms of benthohyponeuston. It brings to the conclusion that the equipment traditionally used for the sampling of benthic organisms (for example as bottom-grab, drag, and trawls during the night hours) gives an awry picture of the numbers and biomasses of those species which accomplish the diurnal vertical migrations. For their calculation, along with the classic equipment for benthos sampling should be used the planktonic and especially the neustonic nets.

Fish migrations are taken into account when grounding measures on their protection. Thus, during the spawning migrations, the catch of sturgeons, herring, turbot and other fish is forbidden for a certain period of time. The fish catch in the places of their wintering accumulations also need to be regulated by law. Fishes accomplishing transboundary migrations need to be protected by corresponding international agreements and regulations. The internal and international legislation need to be constantly improved, considering new data on fish biology, ecology and migrations.

Questions from chapter 5 for seminar (training) in the Black Sea ecology

1. Describe the phenomenon of migration of aquatic animals.
2. Name different kinds of migration of invertebrates and fish which are taking place in the Black Sea.
3. Explain the ecological expediency of vertical migrations of zooplanktonic organisms.
4. What distances are covering daily the organisms of zooplankton when performing the vertical migrations?
5. Give examples of commercial fishing of migrating fish in the Black Sea.
6. What fish species are catched in large volumes in your coastal area?
7. What fishing gears are used in your coastal area: floating nets, fixed nets, trawls, etc.?
8. What is the danger of the migrating fish catching for the process of natural reproduction of such species?
9. Which species of the Black Sea fish are caught in their wintering areas? Where are located these wintering areas?
10. Are there any other marine species catched in your area besides the fish?
11. How can the knowledge about fish migrations help to elaborate the most reasonable and effective methods for their protection?

6. Human impact on the state of the Black Sea ecosystem

The problems of human impact on the environment and its consequences for the nature and society are among the most current topics which are discussed today not only in scientific papers and meetings, but also in mass media. Analysts consider that nothing excites the interest of the general public as much as news about happened or expected ecological cataclysms. Thus, unchecked or wrong information quite often comes along with established facts and conclusions; especially in those cases when some economical or political aims are pursued.

As any other marine basin, the Black Sea has its ecological problems related to human activities. In such cases one speaks about anthropogenic, or man-made, factors of influence on the marine environment. Since the Black Sea is a quite isolated water body, its ecological problems are more acute than those in open marginal seas having a freer water exchange with the Ocean.

The types of direct and indirect human impact on a sea are quite different, but their majority fall under the definition of «pollution».

The Intergovernmental Oceanographic Commission (IOC) of UNESCO gives the following definition to marine pollution: Marine pollution is a direct or indirect human input of different substances or energy into the marine environment (including estuaries), resulting in unfavorable consequences such as damage to biological resources, hazard to human health, impact on economic activities of marine industries (including fishing), decrease of seawater quality for further use and worsening of aesthetic values of marine landscapes. Thus, the publicly deep-rooted conviction that sea pollution is solely a consequence of the input of harmful substances is not quite complete. Indeed, the chemical, toxic, radioactive substances cause the sea pollution, but there are many other factors having a negative influence on the sea such as thermal, light, noise and biological pollution.

It is considered that the Black Sea pollution has already started in ancient times. Though there are no reliable proofs, according to some authors, ancient navigators have introduced into the Black Sea the shipworm (*Teredo navalis*) with the ships' wooden hulls. In the Mediterranean this wood drilling mollusk is absent, but it could be transported from the Atlantic Ocean. In the Black Sea, this shipworm has found favorable conditions, reproduced and started to cause damage to ships and harbor constructions. It inhabited the Black Sea as a mass species until the 1950s harming, in particular, the fishing industry since it was able to put out of order the wooden bearings of the fixed fishing nets for a couple of months. As wood was replaced by concrete, metal and synthetic materials, the number of this species has reduced and nowadays it is insignificant.

Other examples of the Black Sea pollution are known from the past and not all of them are of biological nature. However, pollution has become especially notable in the second half of the XXth century, linked to agriculture intensification, industrial development, transport, population growth of the seaside cities and other manifestations of human activities. Large numbers of people visiting coastal areas can directly harm marine plants and frighten away organisms that use the area for feeding or breeding.

The ecological problems caused by human activity showed up with particular sharpness in small, shallow-water coastal wetlands-limans and lagoons or in their separate areas. This is especially evident in cases when these water bodies turn into reservoirs of polluted sewage waters, as it happened, for example, in the Budaksky, Sasyk and Khadzhibeisky limans, and also in the Karagolsky Bay of the Dniester River Liman. Taking into account that marine ecosystem suffers the deepest changes in, and in extreme situations starts to disappear exactly from, coastal wetlands, the fate of these water bodies deserves special scientific and practical interest. The present chapter of the book is devoted to the ecological problems of the modern Black Sea.

6.1. Anthropogenic eutrophication

Many important changes in the Black Sea ecosystem were caused by the anthropogenic (man-made or cultural) eutrophication. Excessive nutrients contamination, or overnourishment, is now characteristic for many world's coastal areas (especially for gulfs, bays, lagoons and estuaries), but the Black Sea is one of the most impacted seas. The overfertilization of natural waters by mineral and organic substances containing nitrogen and phosphorus causes first of all an intensive development of aquatic plants. These substances enter the sea via river runoff, discharges of untreated wastes of cities and industrial centers, and atmospheric precipitation. The most heavily eutrophicated area of the Black Sea is in its north-western part where the large rivers Danube, Dniester and Dnieper discharge after flowing through huge agricultural areas, industrial centers and large settlements. Anthropogenic eutrophication is noted also in other marine areas, especially in bays and gulfs, but in the NWBS it has attained the highest levels and caused the most grave consequences in pelagic and benthic ecosystems.

According to the long-term data (Garkavaya *et al*., 1991), in the 1950s, the three major rivers inflowing into the NWBS discharged an annual average of $14*10^3$ tons of phosphates, $150*10^3$ tons of nitrates and $2350*10^3$ tons of organic matter. In the 1980s, the annual input of nutrients increased to $55*10^3$ tons of phosphates, $340*10^3$ tons of nitrates and $10,488*10^3$ tons of organic matter. The reasons of this phenomenon (which is more or less characteristic also for other inland seas) reside first of all in the intensification of agriculture; the so-called «Green revolution» that took place all around the world characterized by the sharp increase of production and intensive application of various fertilizers. It has also affected the Black Sea, which has a large drainage basin with vast areas of intensive agriculture and animal husbandry (Zaitsev, 1998).

6.1.1. Increasing in phytoplankton number and biomass

Powerful inflow of phosphates and nitrates into the sea has caused the corresponding retaliatory reactions of marine ecosystem, first of all, in the form of phytoplankton mass development in the north-western part of the Black Sea. The average biomass of phytoplankton in the NWBS has changed over the decades as follows (in milligrams of biomass per one cubic meter of seawater):

1950s	670	(Ivanov, 1967)
1960s	1030	(Mashtakova, 1971)
1970s	18690	(Nesterova, 1987)
1980s	30000	(Nesterova, 1987)

One can see that, in the 1970s, the average biomass of phytoplankton has increased 18-fold compared with the 1960s and has doubled in the 1980s.

With regard to phytoplankton species, the changes are even more drastic than the quantitative ones. For example, the number of the dinophlagellate *Prorocentrum cordatum* in the 1950s did not exceed 3 million cells in one liter of water. In the 1970s, it had raised to 140 million cells in the same volume. In the 1950s, the seawater was transparent but when the number of cells exceeded the level of 100 million in one liter, marine water became green, brown or red colored and its transparency was greatly decreased. The mass development of phytoplankton is often called «blooming» or «red tides». The first scientifically proved case of «red tide» in the Black Sea was observed in the 1970s (Nesterova, 1979). Many Black Sea phytoplankton species have reacted to eutrophication by an outburst in numbers and therefore the areas of «blooming» waters in the sea have substantially widened since the 1970s. In the NWBS, these areas have increased by about tenfold compared with the 1950s. The increase in number and biomass of phytoplankton since the 1970s creates favorable conditions for phytophagous and detritophagous species of zooplankton such as the protozoan *Noctiluca scintillans* and the moon jelly *Aurelia aurita* which have reacted especially noticeably. The biomass of *Noctiluca* in the NWBS has increased by a dozen times and the total average biomass of the jellyfish *Aurelia* has changed from 670 thousand tons in the 1950s to 222 million tons in 1981–1982 and 25% of the Black Sea population of this jellyfish was detected in the NWBS. Unfortunately, both these species, with more than 97% of their body mass composed by water, are not eaten by fish or invertebrates. Other marine organisms, which are used as food (crustaceans, larvae of mollusks, polychaetes and other animals), have not showed any tendency towards increasing in their numbers. On the contrary, their amount has reduced compared with the period before the start of man-made eutrophication; partly because they are eaten by increased population of jellyfishes.

A detailed overview of eutrophication in different marine water bodies was done by the well-known Romanian marine biologist M.-T. Gomoiu (1985).

6.1.2. Degradation of bottom algal communities

Another consequence of the excessive increase in phytoplankton number and biomass is the decline of the water transparency. Algal blooms cloud the water, reducing the amount of sunlight that reaches the bottom. This is a negative consequence for the bottom algae, which cease to receive the solar radiation in amounts sufficient for photosynthesis. Algae growing at a depth of 20 m and deeper have been so shaded that they were unable to develop and started to perish. This phenomenon was well illustrated by the example of the Zernov's *Phyllophora* Field (ZPF), which occupied the depths of 25–60 m in the central part of the north-western shelf of the Black Sea (Fig. 13). In the 1950s, this unique *Phyllophora* field occupied an area of about 11 thousand km^2 and the total biomass of algae, according to different estimations, was 7–10 million t. Starting from the 1970s the *Phyllophora* field began to reduce and, by the middle of 1980, had diminished to an area of 500 km^2 with a biomass of 200 thousand t. (Zaitsev, 1992). It is quite possible that the fate of *Phyllophora* was also aggravated by the progressing eutrophication of the north-western part of the Black Sea, although this process has affected mainly the upper layers of the pelagic zone.

This decline of a huge algal agglomeration is a serious loss for the marine ecosystem, as *Phyllophora* serves as a refuge (in which prey may escape from or avoid a predator), spawning area and source of food for more than a hundred species of invertebrates and fish that form the *Phyllophora* biocoenosis; one of the largest associations of organisms in the Black Sea. During the period of its mass development, the ZPF produced daily up to 2 million m^3 of oxygen, which enriched the near-bottom layers of water.

Another example of negative reaction to eutrophication is the large brown alga *Cystoseira barbata*; a photophilic, perennial plant which cannot withstand the overfertilization of water (Minicheva, 1993). *Cystoseira* grows on stones and rocks at depths up to 10–20 m, but its mass development occurs at 0.5–5 m. Along the north-western coast of the Black Sea, *Cystoseira* disappeared in the late 1970s – early 1980s. The main reason were the increased concentrations of nutrients in water because of the anthropogenic eutrophication of the sea. This alga is the key species of the *Cystoseira* biocenosis composed by several tens of epiphytic algae (growing on

Cystoseira thallus), different invertebrates and fish. It is also used as a sensitive biological indicator of the water quality in a coastal zone.

6.1.3. Oxygen deficiency in near-bottom water layers

One of the gravest ecological consequences of man-made eutrophication of the sea is the appearance of hypoxic and anoxic zones in the near-bottom layer of water. Oxygen levels in the water are depleted because of algal blooms when increasing number of dead cells are decomposed by bacteria.

After the end of their vegetative period, the cells of phytoplankton dye and fall onto the bottom. Such process always happens with dead plankton. But, since the 1970s, as a result of eutrophication, the amount of sedimentated phytoplankton has greatly increased compared with previous years. For example, in the 1950s, 2–3 grams of lifeless phytoplankton per one square meter of bottom were sedimenting each day in the NWBS at a depth of 10 m during a «blooming» period. In the 1960s, this amount had raised to 5–6 g, in the 1970s to 90 g, and in the 1980s up to 150 g of phytoplankton (Zaitsev, 1998).

Although there are many detritophagous benthic animals feeding on these «organic falls» they are not able to consume such sharply increased amounts of dead plankton. The organic remains are therefore decomposed by bacteria, which use the oxygen dissolved in water until its complete disappearance. After this, due to the activity of anaerobic bacteria, hydrogen sulphide is produced and the bottom fauna dies out. Such conditions of hypoxia (low oxygen content) and anoxia (absence of oxygen) arise in the bottom layer of the north-western shelf at depths from 8–10 to 30–40 m during summer and autumn seasons.

In August 1973, for the first time in the recent history of the Black Sea, a vast area of anoxia and a mass mortality of bottom organisms has been recorded by an expedition on the research vessel «Milukho-Maklay» (fig. 35). It happened in the NWBS between the Danube river delta and the mouth of the Dniestr river liman. There, on an area of about 3500 km^2 at the depths from 10 to 22 m, were discovered about 500 thousand tons of dead bottom animals: mussels, shrimps, crabs, other invertebrates, gobies, flounder, sole, turbot and other fish. In the subsequent years, the areas of anoxia and hypoxia on the NWBS increased up to 40 thousand km^2. According to estimations (Zaitsev, 1992), the loss of biomass of the bottom animals in this area has reached 60 million tons in the period between 1973 and 1990; including 5 million tons of fish, both adult and juvenile, belonging to commercial and noncommercial species.

Along with the economical loss, mass mortality of bottom organisms from anoxia and hypoxia has inflicted important ecological losses to the marine ecosystem; in particular related to mass mortality of filter feeders such as the mussel. There are data that the mussel biocenosis on one square kilometer of the shelf filters 15–20 million m^3 of seawater daily (Kiseleva, 1979). In the 1960s only in the NWBS the mussel biocenosis occupied an area up to 10 thousand km^2. In the 1980s the area of this community has reduced several times and the total biomass of mussels has decreased by one order of magnitude. It is difficult to compute, but impossible to over-estimate, the ecological significance of the mortality of active filtrators at the moment when the amount of phytoplankton, bacterioplankton and different kinds of organic particles has sharply increased in the water column.

6.1.4. Decline in biological diversity

As a result of anthropogenic eutrophication, a sharp decline in biological diversity of fauna and flora occurs (Zaitsev and Mamaev, 1997). Besides the already mentioned biocenoses of *Phyllophora* and *Cystoseira*, each comprising many dozens of species which either disappeared or strongly reduced their abundances, some previously mass species of neuston, plankton, benthos and fish became extremely rare.

Figure 35. The areas devoid of molecular oxygen (hypoxia and anoxia) and mass mortality of bottom animals on the north-western shelf, recorded for the first time for the Black Sea in 1973, continued to increase until the beginning of 1990s (from Yu. Zaitsev, 1998, 2006)

The number of some typical neustonic organisms declined by two orders of magnitude. These include the copepods *Pontella mediterranea*, *Anomalocera patersoni*, *Labidocera brunescens*, the isopod *Idotea ostroumovi*, and fries of grey mullet, red mullet and garfish. The copepod *Centropages kroyeri* has practically disappeared from the plankton. In the north-western part of the Sea, the abundance of previously mass benthic species has reduced by 2–3 orders of magnitude compared with the 1960s. These are the white hermit crab *Diogenes pugilator*, the ghost shrimps *Callianassa pestai* and *Upogebia pusilla*, the grass crab *Carcinus aestuarii*, the crab *Pilumnus hirtellus* and other crabs and, among the bottom fishes, the sole *Solea nasuta*, the dragonet *Callionymus risso* and the sea-horse *Hippocampus ramulosus*.

The disappearance from the Black Sea biota of mass species of predatory fish such as the mackerel (*Scomber scombrus*) was already discussed, although this grand event was related mainly to the pollution of the adjacent Sea of Marmara.

On the other hand, in 1970s–1990s, the number of the exotic species that were accidentally introduced into the Black Sea with the ship's ballast waters has increased substantially. Numerically, this could be considered as an increase of biological diversity, but many of introduced species were actually the reason of a sharp reduction in populations of local species. The increasing influx of exotic species is related to the anthropogenic eutrophication of the sea, because the trophic base of planktophagous organisms has improved significantly. However, there are some other reasons, and the acute problem of exotic species will be discussed in the section dedicated to biological pollution.

In other areas of the Black Sea shelf, the anthropogenic eutrophication and its consequences did not show up so distinctly as in the NWBS. Nevertheless, similar processes took place in other regions (Zaika *et al*., 1990; Konsoulova, 1993). Not long ago, the eutrophication of the southern part of the Black Sea has increased notably and in summer 1995, in the area of the Kizilirmak river delta, were first registered a zone of anoxia and mass fish mortality (B. Öztürk, personal communication).

6.2. Microbial pollution

In the Strategic Plan for the Rehabilitation and Protection of the Black Sea, signed in Istanbul (Turkey) on 31st October, 1996 by the ministers on the problems of ecology of all the Black Sea countries, the microbial pollution was named as the second important kind of human impact on the Black Sea ecosystem. Its scale is not comparable with the anthropogenic eutrophication, but by its social and economic consequences are not less harmful. It is enough to name the cases of epidemics of cholera and other gastrointestinal infections, closing of beaches for bathing due to microbiological reasons, closing of all balneological and recreational infrastructure (i.e. sanatorium, rest-houses, hotels, restaurants etc) and losses of touristic industry, to understand the importance of this kind of marine pollution.

Already in the middle of the XXth century, the microbiologists considered the seawater as an unfavorable environment for the development of pathogenic microorganisms, and some were even ascribing bactericidal properties to it. With time, it was found that not the marine water itself, but the absence in it of high amounts of organic matter inhibit the mass development of bacteria, which need enriched nourishing media for successful development. When later on, due to man-made eutrophication, the favorable conditions were created in the Black Sea, the marine water was no more a limiting factor for the growth and reproduction of pathogenic microorganisms. Naturally, the «bactericidal» properties of marine water were forgotten and the problems concerning the bacteriological state of coastal waters became actual.

At present, microbial pollution of water, bottom sediments and marine organisms is observed worldwide. Mass media continuously inform about deseases cases resulting from direct human contact with contaminated seawater or seafood. According to regulations in force in most European countries, the threshold quantity of coliform bacteria in balneary areas should not exceed 2 thousand cells per 100 ml of water, or 20 thousand cells in one liter of seawater (Boaden and Seed, 1985).

In the late 1940s–early 1950s, the microbiological situation on the Black Sea was quite favorable, as confirmed by the corresponding published data. Careful sampling was carried out by S. Khait and I. Shpilberg (1950) in the shoreline zone of Odessa Gulf beaches in the summer months of 1946–1947. They found 10–200 cells of *Escherichia coli* per one liter of marine water.

Later on, in the 1960s, D. Babov (1970) has registered in the same area up to 90 thousand cells of this species in one liter of water. At the beginning of 1980s, L. Nizhegorodova (personal communication) defined the average quantity of *Esherichia* as 140 thousand cells, and the maximal as 620 thousand cells in one liter of water. In the late 1980s, the average number rose up to 250 thousand cells and maximal values at one of the most popular beaches of Odessa (Arcadia) reached up to 2 million 400 thousand cells in one liter of seawater.

The increase in the number of *Esherichia* cells from 200 to 2.5 million cells in one liter of water during four decades is the result of pollution of the marine coastal zone by untreated sewage waters of the large city. However, *Esherichia* is not the only pathogenic microorganism entering the sea via this route. In the seawater, are also found *Salmonella*, cholera's vibrios, helmint's eggs, viruses and other pathogenic organisms which are usually common in insufficiently treated sewage waters. In addition, the man itself is a source of microbial pollution of coastal waters. During the bathing seasons, dozens of millions microorganisms (including pathogenic) are washed off from the bodies' surface into the sea. At large concentrations of bathing people in limited water areas, the probability of infection is high; especially on windless days when the currents are very slow and the water exchange near the coast is practically stopped.

The first cases of cholera epidemic in Odessa and in some other coastal cities of the Black and Azov Sea were registered in summer 1970. In summer 1995, an epidemiological situation was registered in the city of Nikolaev located on the Bug river liman. During the same summer, Odessa beaches were generally closed for bathing because of high microbiological indexes. Only in rare days, during land winds when a wind upwelling occurs, microbiologically clean waters appeared at the shore. However, in those days the water temperature was usually 10–12°C, sometimes even 8°C, which was not suitable for bathing.

A considerable increase in the number of pathogenic microorganisms was registered in the 1980s at the coasts of Adjaria, Georgia (Komakhidze and Mazmanidi, 1998). In coastal waters, high numbers of *Esherichia coli*, *Proteus vulgaris*, *Staphylococcus aureus*, *Salmonella typhi murium*, *Pseudomonas aeruginosa*, *Klebsiella* and other pathogenic microorganisms were recorded.

6.3. Chemical pollution

This process is the consequence of the input into the sea of a large group of substances, hazardous for living organisms, from river waters, precipitations, ships, oil and gas production facilities on the shelf, and other technological objects located on land. About it, mass media inform the population more frequently than about eutrophication and microbial pollution and, therefore, the attention towards it is much more focused than towards the other kinds of pollution. Ironically, the real damage to the Black Sea and man from chemical pollutants is less than the harm caused by the anthropogenic eutrophication and microbial pollution; although chemical pollution also belongs to the sea-threatening factors.

According to some estimations, about 80 tons of mercury enter annually into the Black Sea with the river waters and from the atmosphere (Zaitsev, 1993). What happens with it later on and in what food chains it is involved in the Black Sea ecosystem is not yet clear enough. It is known that some organisms, such as the amphipod *Corophium*, the polychaete *Nereis* and the gastropod *Hydrobia*, accumulate this heavy metal in their tissues. It is also known that the knot (*Calidris canutus*), who feeds on them, accumulates, especially in the liver, up to 14.4 mg of mercury per one kilogram of its mass (Gerlakh, 1985). All the above-mentioned invertebrates inhabit the Black Sea and high numbers of *Calidris canutus* are registered during its seasonal migrations. However, the «mercury» relations between these species in the Black Sea are not well studied.

High concentration factors of mercury (from 309 to 2714) are known for many organisms inhabiting the Danube delta and the Black Sea, such as the bivalves (*Unio pictorum* and the zebra mussel *Dreissena polymorpha*), crayfish (*Astacus leptodactylus*), the Black Sea shad (*Alosa kessleri pontica*), pike (*Esox lucius*), cat-fish (*Silurus glanis*), weever (*Trachinus draco*), horse mackerel (*Trachurus mediterraneus ponticus*), Kesler’s goby (*Neogobius kessleri*) and other (Polikarpov and Risik, 1977).

Besides mercury, the Black Sea annually receives about 4500 t of lead and 12 thousand t of zinc and other heavy metals. Obviously, these metals can also harm the marine organisms; especially in those coastal areas where they enter into the sea from the land-based sources. However, there are no direct confirmations to this fact.

Pesticides also have a harmful influence on marine organisms. This influence is noticeable as growth inhibition of algae in the areas of discharge into the sea of the waters from rice fields. These waters contain herbicides (chemicals used for suppression of plants), fungicides (chemicals used against fungi) and insecticides (chemicals against insects). Discharges of these waters are located in the Tendrovsky and Dzharylgatch Bays, and on the Crimean coast of the Karkinitsky Bay. Many pesticides are accumulated in the bodies of aquatic invertebrates and fish and are transmitted to the ichthyophagous birds. Thus, in agreement with the rule of the biomagnificaton, the concentration of pesticides is considerably increased, sometimes by orders of magnitude, during the transfer from one trophic level to the next (for example from algae to invertebrates, from invertebrates to fish, from fish to birds) until it reaches levels critical for the life of the various organisms. This rule concerns not only pesticides, but also any other chemical substance and radionuclides.

A well-studied example of pesticides impact on waterfowls is the population of the Sandwich tern (*Sterna sandwicensis*) on the Grind Island in the North Sea near the Netherlands coast (Gerlach, 1985). Fish on which terns feed was contaminated, via trophic transfer, by wastewater of the pesticides factory located nearby. As a result, in 1965, only 650 pairs of nesting terns, from 20 thousand pairs, have survived on the island. In 1967, the discharge of toxic flows was halted and, by 1974, the number of nesting birds had raised to 5 thousand pairs. All the characters of this ecological tragedy (pesticides, algae, invertebrates, fish and Sandwich tern) are present also in the Black Sea.. Special study of the toxicological aspects of their interrelationships could be not only of theoretical interest.

In this regard, attention must be paid to the fact that in the eggs of the white pelican (*Pelecanus onocrotalus*) from the populations nesting in the Danube delta was discovered the DDE (derivative of DDT) pesticide in an amount of 13.3 mg per one kilogram of bird's weight (Fossi, 1985). This concentration is similar to that which was registered in the eggs of brown pelican (*Pelecanus occidentalis*) nesting on Florida shores where it has caused the sharp decline of reproductive capabilities of its population. White pelican, which mainly nests in the Romanian part of the Danube delta and mainly feeds in its Ukrainian part, is included into the Red Book of Ukraine (1994) and, according to its ecological status, is ascribed to the species being under the threat of disappearance. The amounts of DDT exceeding the maximum permissible concentrations (MPC), namely 0.5 mg/kg, have been registered during research works on aquatic organisms from the Danube delta and adjacent marine waters (Polikarpov and Risik, 1977). The DDT concentrations exceeding the MPC were registered in tissues of crayfish, sprat, red mullet, bream and cat-fish.

To the chemical pollutants of the sea also belong detergents, or synthetic surface-active matter (SPAM). During the last decades, they have been widely used in the industry and everyday life, mainly as cleansers.

About 50 thousand tons of detergents enter annually into the Black Sea with the river water and urban and industrial flows (Zaitsev, 1993). It is considered that the detergents become toxic for aquatic organisms at concentrations higher that 0.1 mg per 1 kg of water (Bellan, 1976). G. Bellan notes that, in coastal waters where detergents concentrations exceed this threshold value, the brown alga *Cystoseira* disappears. Indeed, in the 1970s and 1980s, *Cystoseira* has disappeared from zones of its growing on the north-western coast of the Black Sea between the Kaliakra Cape, on the south, and the Adzhiask Cape, on the north. This is the area most influenced by river runoff and, possibly, detergents from the rivers waters' were involved in this process. Anyhow, in the Ukrainian coastal waters of the Black Sea, the detergents concentration exceeds by 2–3 times the maximum permissible concentrations (Bilyavsky *et al*., 1998).

According to public consciousness, mineral oil or petroleum is of most concern among the marine pollutants. There are both objective and subjective grounds for that. To the former belongs the fact that oil, as a rule, is toxic at amounts exceeding certain threshold levels and it results in oppression or even death of animals and plants. The subjective ground is that, in a sea, petroleum is visible and notable since it forms films on the water surface, spots on the beach, and, certainly, black streams directed towards the shore from a tanker victim of the shipwreck. Furthermore, it gives «kerosene» smell to fish.

Besides all the above mentioned reasons, the oil as a sea pollutant has some «extenuating circumstances». Unlike many other chemical pollutants, oil is a natural product. It got into the seas and oceans before human origin and without human participation as a result of seepage from the sea-bottom, earthquakes and shearing of the earth crust. Therefore, many marine organisms have elaborated adaptations to petroleum. Where mineral oil leaks constantly, as for example on the coasts of California, marine fauna develops as well as in areas where oils eruptions have not been observed (Straughan, 1976).

Large groups of organisms feed on oil, for example oil-destructive bacteria. Other organisms successfully grow on the hard lumps of fuel floating on the sea surface; these include one-celled algae, fungi, crustaceans and mollusks. Oil fields formed by the lumps of fuel could be considered as specific ecological niches at the pelagial surface (Polikarpov *et al*., 1971).

The consequences of accidental oil spills are thoroughly studied. They depend on the quality and volumes of oil and its products and on the duration of their influence on living organisms. Data of in-situ measurements and experiments showed that oil overflows are fatal for most species of plants and animals. Both oil and its water extracts could be toxic. Only few mollusks that have tightly closed shells are able to resist to oil spills for 2–3 days. The ecological consequences of oil spills are felt for periods spanning from a couple of months to years; especially in cold waters where microbial destruction of petroleum proceeds slowly.

In the Black Sea, until present, the oil pollution has not achieved the scales of ecological catastrophes. Into the sea, oil enters mainly with the river runoff and rain waters in the amount of about 111 thousand tons per year (Black Sea Transboundary Diagnostic Analysis, 1997).

6.4. Radioactive pollution

Radioactive wastes containing radionuclides are produced in laboratories, hospitals and other places employing radioactive materials, but principally occur as a by-product of nuclear power generation. Radioactivity is the property exhibited by unstable isotopes of elements which decay emitting alpha, beta and gamma radiation which can be biologically harmful.

The study of the radioactive pollution of the Black Sea belongs to the discipline of marine radioecology; an area of knowledge founded by G.G. Polikarpov (1961, 1964, 1966). Marine radioecology deals with the appearance of anthropogenic radioactive nuclides, which were absent during the pre-nuclear epoch, in the abiotic and biotic components of ecosystem or an increase in the values of naturally occurring radionuclides compared with their pre-industrial levels. The entrance and transportation of high concentrations of ^{90}Sr via the Dnieper cascade into the Black Sea and further into the Aegean Sea after the catastrophe on Chernobil APP on April 26th 1986 (Polikarpov *et al*., 1988, 1991; Egorov *et al*., 1999) could serve as a characteristic example.

The radionuclides are accumulating in contour biotopes of the sea in the same way as the chemical substances (Zaitsev and Polikarpov, 1964, 2002; Polikarpov, 1971). The sea foam, as a cell-membranous concentrate of organic and other surfactants emerging from the water layers and entering with the atmospheric precipitation, can contain higher values of toxic substances than the water surface layer.

It is known that the chemical and radioactive pollutants, after being injected into the atmosphere by industrial plants or released during nuclear trials and accidents, are accumulated on the land and especially in the water for different time spans depending on their half-lives (Polikarpov, 1964; Zaitsev and Polikarpov, 2002). Muddy biotopes of the pelocontour also serve as concentrating surfaces, in particular for chemical and radioactive substances precipitated from the water column in the form of colloids and particles.

Marine plants and animals are able to accumulate in their bodies, organs and tissues not only chemical but also radioactive substances. Concentration of radioactive substances can be dozen, hundred, and sometimes thousand times higher than in the water. The ratio of radionuclide concentration in aquatic organism to the concentration of this radionuclide in the external aquatic environment is called the concentration factor (Cf).

The Cf of radionuclides for many inhabitants of the Black Sea and coastal wetlands were estimated by G.G. Polikarpov and his students (tab. 6).

Radionuclides accumulated by aquatic plants and animals are transmitted along the food chains, according to the rule of biomagnification, and can induce chromosomal mutations in organisms. The available data (Polikarpov and Tsitsugina, 1999; Tsitsugina and Polikarpov, 2000) serve as a fundamental base for the studies of induced chromosomal mutagenesis of hydrobionts in the areas of radioactive and chemical pollution.

Table 6

Concentration factors of radionuclides in different species of the Black Sea flora and fauna (Polikarpov 1964, 1966)

Species	^{90}Se	^{137}Cs	^{65}Zn	^{144}Ce	^{95}Zr	^{95}Nb	^{131}I	^{54}Fe	^{106}Ru	^{60}Co
Plants										
Nitzschia closterium	17	-*	5,000	2,000	-	-	-	-	-	-
Prorocentrum micans	6	-	-	-	-	-	-	-	-	-
Ulva rigida	2	-	127	350	-	335	200	730	95	335
Enteromorpha compressa	-	-	-	340	-	-	-	-	-	-
Bryopsis plumosa	-	-	-	640	-	-	-	-	-	-
Cystoseira barbata	43	-	186	350	-	2,038	300	1,060	197	45
Phyllophora nervosa	8	-	-	1,100	2,960	1,020	-	1,650	593	-
Ceramium rubrum	-	-	-	430	-	500	-	100	-	-
Zostera marina	3	-	336	210	1,120	1,094	30	435	181	-
Invertebrates										
Mytilus galloprovincialis, body	-	-	629	35	20	140	20	99	16	125
Byssus	-	12	-	1,000	600	3,000	2,000	-	500	186
Calanus euxinus	-	13	-	-	-	-	-	-	-	-
Palaemon elegans	-	-	37	-	-	-	-	-	-	-

Palaemon adspersus	-	-	-	-	-	-	-	-	-	11
Pachygrapsus marmoratus	-	-	-	220	-	-	-	-	-	-
Sagitta setosa	-	-	-	-	-	-	-	1,800	-	-
Fishes										
Anchovy, *Engraulis encrasicholus ponticus*	-	9	-	-	14.5	-	-	-	12	-
praelarva	-	9.4	-	-	34.1	-	-	-	3.6	-
larva, 42-96 hours	-	26.1	-	-	152	-	-	-	26.2	-
Garfish, *Belone belone*										
Ovarial eggs	-	-	-	22	24	106	-	-	-	
Eggs membrane	-	-	-	156	56.7	256	-	-	-	-
Youk	-	-	-	12	18.7	126	-	-	-	-
Whiting, *Merlangius merlangus euxinus*										
Ovarial eggs	-	-	-	152	-	-	-	-	-	-
Larvae 24 hours	-	-	-	20.4	-	-	-	-	-	-
Horse mackerel, *Trachurus mediterraneus ponticus*										
Ovarial eggs	-	-	-	495	-	-	-	-	-	-
Larvae 24 hours	-	-	-	538	-	-	-	-	-	-
Turbot, *Psetta maeotica*										
Ovarial eggs	1.6	8.8	-	308	-	-	-	-	-	-
Praelarvae	1.8	10.3	-	4.4	-	-	-	-	-	-
Larvae	1.3	14,1	-	611	-	-	-	-	-	-

* - no available data

6.5. Pollution by synthetic polymers

Different items made of synthetic polymers are presently one of the most typical marine and freshwater pollutants. The modern society has increased the use of various plastic materials that got the common name «plastics». Their major properties (durability, longevity, lightness, simplicity of production and, finally, cheapness) have resulted in their more frequent preference compared to other materials.

The polyester fibers have substituted cotton, wool and linen; fiberglass and other similar materials have changed for wood and steel; plexiglass and polystyrene replaced glass and cardboard, while polyethylene turned to be the best packing and isolating material.

The utility of objects made of synthetic polymers becomes more obvious with each day, but at the same time, raises the problem of their disposal after use. Plastics are taken out to dumps, buried, or thrown out from the ships' boards into the sea without a thought that lots of them are very slowly decomposing. There is a lot of information about the «longevity» of different «hard wastes» in the seawater. Thus, cotton fabric fully decomposes within 4–5 months and the woollen cloth during one year. The hemp rope can survive up to 1.5 years in water; painted wooden plank up to 10 years. The capron rope could be preserved in the sea for about 100–200 years, beer or coca-cola tins around 200–400 years and plastic bottles from a drinking-water or other beverages up to 500 years. Apparently, synthetic materials in seawater could be from ten to a hundred times more durable than the natural ones.

Previously, when nets from the cotton fiber where used in fishing, the fishermen had their new nets impregnated with tanning agents and drying oil and then had them washed carefully in fresh water and dried in a shadow after the each use in order to extend their life time. When carefully used, these nets would have served for a couple of months. With the invention of capron nets this treatment was not needed anymore. The wet nets were recovered from the seawater and folded without washing and drying and were used again the next day. These nets can last for a couple of years, until the breaks of the net's linen (but not its destruction!) will force to replace it with a new one.

There are a lot of sources of the synthetic polymers that are supplying sea with these pollutants. On a land these are the various enterprises, settlements, tourists camping on a shore. Their wastes, sooner or later, get into the rivers and sea. Fishing, trade, passenger and other ships could also be the source of plastics to the sea.

The consequences of the synthetic materials' impact on the marine environment are also different. The nets or trawls lost by fishermen continue to catch benthic and pelagic animals such as crabs and other invertebrates, fish, dolphins and seals. These animals die tangled in the nets. The capron nets and fishing-lines are often found around the necks of seals and on the dolphins' tails.

Plastic granules floating at the sea surface are swallowed by the shearwaters and other marine birds, that mistaken them for some neustonic organisms. It could be that the birds are misled by the microscopic thin algal film that covers the plastics surfaces. Such «food», especially when brought to the nestlings, can cause a lot of harm.

Synthetic polymers in the sea can also cause harm to man. Fine nets, lines and fishing-line tie around the swimmers and divers; nets and ropes are turned around the propeller screws and propeller shafts of the vessels, bringing them out of order. In cases when in the plastic containers are preserved some pharmacological substances (so-called medical wastes) they can harm the human health.

Various polymer films, plastic bags, packing and bottles buried into the sand on a beach or in the coastal zone hamper ventilation and water exchange in sand, create stagnant areas causing death of many sand inhabitants that are being responsible for the processes of biological cleaning of the beaches and marine shallow waters from the organic matter. If to lift up the plastic objects lying during a few days on a beach, beneath it, the sand will be black with the smell of hydrogen sulphide produced by the dead organisms. If to estimate the amount of plastic wastes that get into the sea and the duration of their stay there, it is possible to imagine the harm from this kind of pollution to the sea.

Besides, the wastes of synthetic polymers greatly damnify the aesthetic state of the seashores and reduce their recreational value.

According to a good tradition, on the Black Sea Day, on the 31st of October (this day in 1996 in Istanbul was signed the Strategic Action Plan for the Rehabilitation and Protection of the Black Sea) NGOs and citizens carry a lot of useful actions including collection of plastics on the beaches. How could be good if in the next year the amount of these wastes would be diminished!

6.6. Noise and light pollution

The noise pollution (or sound pollution) is rarely mentioned as a risk to marine organisms, yet it is pervasive throughout the seas (Norse,1993). The negative consequences of both these types of marine pollution are obvious; however, their research in the Black Sea has not been conducted yet. It is known that the increase of a sound level over the natural one, and artificial sources of powerful light, violate the normal life of organisms, affect their circadian rhythms and alter their behavior. Everybody knows that a good fishing is possible only in quiet conditions and where there are no excessive light irritating fish. During collection of the living material in the sea, biologists often use the light of a lamp to attract such marine organisms like polychaetes, shrimps, crabs, other invertebrates and fish which positively react to an even light and accumulate in the lighted up area. Fishermen also practice fish catch on light.

These facts are well known. But the influence on marine life of the night mass entertainments on a shore, with their inevitable accompaniment of loud sounds and bright uneven light, is still unknown. They disturb, for example, the migrations of fries of the grey mullets along the shoreline to the feeding grounds or the spawning coastal migrations of fish. This factor should be considered during estimation of the ecological state of a concrete area of the seashore. At least it is senseless to organize protected areas in the regions of mass coastal recreation.

Approximately 50 km northeast from the Bulgarian port Varna is located the largest cape of the western part of the Black Sea, Cape Kaliakra. It projects into the sea more than 2 km and has a height of 70 m above the sea level. It has steep shores and stone blocks, that were broken under the waves' action, form the submarine reefs at a distance of a dozen meters from the shore, well known to the navigators from old times. During centuries, the cape Kaliakra was the key habitat of the Black Sea populations of the Mediterranean monk seal (*Monachus monachus*). This area attracts the seals with its deserted shores, submarine caves (grottos) and plenty of fish which migrating through this cape to spawning, feeding and wintering grounds.

So it was until the 60s of the XXth century. In the 1930s here were counted 140 seals, in 1941–1945 their number had reduced to 25–30 individuals. In 1966 the author saw from the cape Kaliakra two seals playing in the water. Seals were also registered in 1979 but after 1981, according to the Red Book of Bulgaria (1985), there have been no new records. The Mediterranean monk seal also became a very rare animal in other regions of the Black Sea and after 1997, according to author's information, there were no new records about its presence in the Black Sea. The cape Kaliakra has lost its faunal feature, but has not lost its attractiveness for the tourists. On its terraces were build restaurants, bars, discos and other pleasure resorts which become sources of noise and light pollution of the adjoining marine waters. Therefore, even if the separate individuals of seal, when following the schools of fish, will enter from the Aegean Sea into the Black Sea hardly will they approach the anxious cape Kaliakra. According to information, which needs to be confirmed, two monk seals were observed in 2006 nearly the cape Opuk in the south-eastern Crimea.

However, the loud sounds and bright light on the sea shore are limited point sources of the pollution of marine environment by these physical factors. Much more seriously they affect the channels with intensive navigation. Shipping is a great source of noise. In this respect the Kerch Strait and especially the Bosporus are of a great ecological significance. Some researchers assume that a specific «acoustic barrier», which appeared in the Bosporus as a result of strengthening of navigation of big ships during the last years, was one of the reasons of the sharp reduction of fish and dolphins migration through this channel into the Black Sea for feeding and back for wintering. This problem deserves a special comprehensive study.

6.7. Biological pollution

Biological pollution of the sea is a result of an accidental introduction into the marine environment of exotic (alien, foreign, not native) species of plants and animals caused by direct or indirect human activities. During naturalization (final stage of acclimatization) in a new area, the exotic species can have inhibitory or destructive influence, especially noticeable when mass reproduction of settlers occurs.

Appearance of a new species in an area which it has not populated earlier means intrusion into the historically formed community of plants, animals and microorganisms (biota), in the equilibrium between species and biological diversity of ecosystem. Functionally it means a break of the historically formed biological and ecological structures and relationships, therefore such event is named biological pollution (Dediu, 1989).

There is a rather large number of scientific literature on the Black Sea biological pollution by the alien species and in this book it will be enough to make a brief exposition of this problem.

The Black Sea happened to be a good receiver for many exotic species because of a number of factors promoting their successful acclimatization here. Among them there are a high diversity of habitats (biotopes), both in the sea and in the coastal wetlands – limans, lagoons, river deltas and good feeding conditions for planktiphagous, benthophagous and ichthyophagous species. Another favourable factor for exotics in the Black Sea is the low «ecological immunity» of its marine ecosystem. Under immunity of ecosystem is implied its stability in front of intrusion of new species.

In general, the kingdom of living creatures is characterized by a high functional stability (reliability). This is the result of a long-term evolution process of natural selection of more resistant forms, populations, species and communities. The terms «good surviving» and «high stability» are considered almost as synonyms and definition of population and community stability almost fully coincides with the definition of stability in the technical systems (Grodzinskiy, 1983).

One of the conditions of stability provision of the biological systems is related to the phenomenon of antagonism. Thus in ecology are named opposing organisms, when one species restrains or represses the development of other species, an inhibition of one species by the action of another. As a result of such competition (for food, feeding, breeding, wintering gounds, etc.) the number of one species is never high enough to suppress the number of another. In a stable environment all species have their species-antagonists, which, finally, maintain a biological equilibrium in all the system of living organisms.

Because of its low water salinity, significant seasonal fluctuations of temperature and other factors, the Black Sea has a low biological diversity comparing to other, so-called «true» seas. Because of it, an exotic species introduced into the Black Sea not always meets its antagonists among the local species and gets a possibility for an intensive multiplication in a new habitat. This is the reason of the initial «outbutst» of numbers of many exotic species in the Black Sea shortly after their introduction.

A similar pattern is observed in terrestrial habitats. For example, the outburst of the European wild rabbit acclimatized in Australia, the gypsy moth, *Lymantria dispar*, a Palaeoarctic insect which has spread to the Northern America, whose caterpillar stripes leaves from ornamental and forest trees.

The exotic species are entering the Black Sea mainly by water way. Aquatic organisms are «traveling» either as a part of the fouling on the submarine part of the ship's hull or, more frequently, in the ship's ballast tanks, in which they get together with the outboard water. Ballast water is used by a vessel to improve her stability.

Ballast water is usually taken near the shore area and therefore contains a great number of organisms, including plankton and pelagic larvae of bottom organisms. Some of them, for example algal spores and resting eggs of invertebrates, find favorable conditions in sediment on the bottom of the ballast tanks. The number of ballast-mediated invasions appear to have grown dramatically since the 1970s. Ships become larger, so more ballast water is moved, and also faster, allowing more organisms to survive in the ballast water. On arrival into the port of call, the ballast waters are pumped out and organisms find themselves in new environmental conditions. If they find them acceptable, they begin to adapt to the life in the new water body. The opening of the sea level Suez Canal in 1869 initiated the invasion of Erythrean biota into the Mediterranean (Galil *et al*., 2002). This specific group of exotic species (so-called, Lessepsian migrants) are mainly confined to the littoral zone of the Levantine Sea and the southeastern Aegean Sea, but single specimens were found in the Black Sea.

However the introduction of other exotic species does not fall under the term of biological pollution. These are the species that were intentionally introduced on the basis of preliminary research and for special practical purposes.

In the 1920s, the small mosquitofish (*Gambusia affinis holbrooki*) was introduced into the coastal wetlands of the Kolkhida lowland (Georgia) to combat the malaria mosquitoes. It was brought from Italy, after being introduced to Europe from the North America. Due to the special jaw structure (elongated lower jaw, top position of a mouth), mosquitofish successfully eats up larvae and pupae of mosquitoes which develop in the freshwaters neuston. This mode of feeding won fame to *Gambusia* as an object of biological fight against mosquitoes. Introduction of this fish has helped to overcome malaria in the Caucasian wetland zone of the Black Sea. As euryhaline species, tolerant to a wide range of salinity, *Gambusia* is rather common in many coastal areas of the Black Sea with low water salinity.

The haarder (*Liza haematocheila*, syn. *Mugil soiuy*) was also intentionally introduced into the Black Sea after preliminary researches, as a valuable commercial species of fish (Zaitsev and Öztürk, 2001). In 1972–1982 the fries of haarder were delivered by air from the lower part of the Amur River and adjoining waters of the Sea of Japan and released into the Molochniy Liman of the Sea of Azov and some limans of the NWBS. This species got adapted and has reproduced so well that at the end of 1980s it became a commercial fish in all the Black Sea countries and entered the Mediterranean Sea, being observed even in the Algerian coastal waters.

Competitive relationships of the haarder with the local species of grey mullet and other fishes have not been observed. The main part of haarder's food in the Sea of Azov and the Black Seas consist of bottom foraminifera, harpacticoids, larvae of mollusks, polychaets and some other representatives of meiobenthos (Chechun, 2003). Thus, a priori accusations in the address of this settler, as a competitor and even predator against the local species, should be dismissed. There is evidence that the internal parasites of the haarder have migrated into the bodies of local grey mullets and vice versa, but no changes in stock of local grey mullets were registered.

Different is the situation with some other species which accidentally were introduced into the Black Sea and got adapted to its environment. The majority of them, in all likelihood, were in the ships' ballast waters and via them got into the Black Sea. It is considered that during the XXth century more than fifty species of plants and animals got into the Black Sea in the same way. They are originating from different regions of the World Ocean, but their majority originates from the coastal waters of the boreal zone of the Atlantic Ocean.

The influence of the main part of exotic species on a local fauna and flora does not cause serious impact and some of these species even happened to be useful. For example, the small white-fingered mud crab *Rhithropanopeus harrisi tridentata*, that in the Black Sea got the name of the Dutch crab as it was conceivably introduced from the Zuiderzee Bay of the North Sea, serves as a food for local commercial species of fish – gobies, flounder, turbot, sturgeon (Zaitsev and Öztürk, 2001). On the contrary, in the Caspian Sea, this crab is considered to be a harmful exotic species as it consumes the food of benthophagous fish and damages the catches in nets. Actually it is not so easy to subdivide the species into useful and harmful, good and bad, if only such subdivision is possible in general. Therefore a formula «the species is more useful, than harmful» or vice versa is frequently used.

However some alien species are certainly harmful ones from which the ecosystem of the Black Sea and stocks of commercial species bear obvious losses. Such species, fortunately, are not numerous, but they «cost» a lot, both in terms of «ecological currency», (acc. to Yu.Odum) and money.

For the first time the large carnivore gastropod rapana *Rapana thomasiana* (Fig. 15), originating from the Sea of Japan, was discovered in the Black Sea in 1946. Probably it was introduced at the beginning of the 1940s by ships. Its eggs can be attached to the bottom of the hull. However its pelagic larvae could be also transported with the ballast waters. *Rapana* has successfully reproduced first along the Caucasian coast and in the 1950s had annihilated almost all oysters on the large Gudauta oyster bank, and then came the turn of mussels and scallops inhabiting the same bank. Later *Rapana* has spread to the mussel settlements at the Southern coast of Crimea, and then at the shores of Bulgaria and Turkey. In the 1980s, as the Asiatic market provided the request of *Rapana* meat from the Black Sea, an intensive catch of this mollusk started. At the beginning the catch was conducted by scuba divers by hand, but later on by bottom trawls. The commercial catch has sharply reduced the number of rapana population and its pressure on local mollusks, but it is the only example of reduction by man of a harmful accidentally introduced species.

Due to the scientific literature and to the mass media, the Atlantic comb jelly, or Leidy's comb jelly (*Mnemiopsis leidyi*) got a wide notoriety. It is assumed that it was introduced into the Black Sea with the ballast waters from the Atlantic coastal zone of the North America, possibly, from the Chesapeake Bay (Fig. 14). The first specimens of this large (up to 10–11 cm in length), jelly-fish like creatures in the Black Sea were registered in 1982. Afterwards many biologists have studied it, finding hat the 99% of its body consists of water, that it quickly grows and has a high fecundity, and that its basic food is composed of zooplankton, fish eggs and larvae.

By the end of 1980s, the total biomass of *Mnemiopsis* in the Black Sea, by estimation of academician M.E. Vinogradov, has reached its record level of one billion tons. For comparison, the biomass of the «heavy» moon jelly *Aurelia aurita*, at the peak of its development in the Black Sea in 1980–1981, did not exceed 225 million t. At such a high quantity and large sizes, *Mnemiopsis* became a serious food competitor of planktivorous fish and its direct enemy as a consumer of its eggs and larvae.

Anchovy, the major target of the Black Sea fisheries, turned to be the main victim in this ecological conflict as its food, its eggs and larvae are consumed by *Mnemiopsis.* As a result, in

1989–1990 a collapse of anchovy fishery in the Black Sea has occured. By estimation of J. Keidy and R. Grifits from the Food and Agricultural Organization (FAO), this sharp decline of catches brought to the Black Sea countries losses in amount of $200 million per year. More considerable losses are related to the downtime of the fishing fleet, fishing ports, fish-factories and the whole infrastructure of the fishery industry.

The problem of *Mnemiopsis* in the Black Sea attained an international significance and in March 1995 in Geneva (Switzerland) the meeting of the working group GESAMP (UN Group of Experts on Scientific Aspects of Marine Protection) was called. This was the first case when an ecological problem of the Black Sea was examined on the UN experts level. Among the recommendations proposed by the experts there was a proposal to introduce into the Black Sea the natural enemies of *Mnemiopsis*, such as the predatory comb-jelly fish *Beroe*, an antagonistic species of *Mnemiopsis*. While the GESAMP recommendation was discussed in the corresponding departments of the Black Sea countries, in 1997 hydrobiologists of several local institutions simultaneously found a new species of comb-jelly, *Beroe ovata* (Nastenko and Polischuk, 1999). Exactly with the recommendation of GESAMP Commission, but independently of them. It was obviously introduced with the ballast waters and, finding a suitable feeding ground, it has adapted in the Black Sea and started to reproduce. Population of *Mnemiopsis* started to reduce sharply and anchovy catches were notably increased (Fig. 36).

Figure 36. Long-term dynamics of fish catches, mainly anchovy, in the Black Sea. It is noteworthy that the sharp falling of anchovy catches happened after the outburst of *Mnemiopsis* at the end of the 1980s and the early 1990s and the increase of its catches after the outburst of antagonistic species – *Beroe* at the end of 1990s. The images of mackerel, bonito and bluefish mark the end of their commercial catches in the Black Sea (from Zaitsev, 1993 with additions).

With the time *Beroe* will reduce *Mnemiopsis* population to the minimum level and then will be reduced as well. *Mnemiopsis* will take advantage of it and will again spread around, causing the decline of anchovy population. The time of *Beroe* (availability of food) will come once again and the story will repeat endlessly. The only new fact is that both *Mnemiopsis* and *Beroe* will never disappear from the Black Sea biota and competitive fight of these antagonistic species will determine the years of «poor» and «rich» catch of anchovy and other fish. On this example it is especially clear how important, both ecologically and economically, is the problem of accidental introduction of exotic species in a new areas.

Other accidentally introduced species of the Black Sea have not got yet the ill fame of *Mnemiopsis* or *Rapana*. However we do not exclude the possibility especially taking into consideration that the new settlers often behave differently than in their native habitats. The behavioral (etological) changes of exotic species will be discussed later.

There are some introduced species, which are not yet mass organisms. In case of their sucessful reproduction in the Black Sea, they can touch human interests and it is necessary to note it in the context of biological pollution of the sea.

Figure 37. Two exotic species of crabs found in the Black Sea: on the left – the Blue crab (*Callinectes sapidus*), on the right – the Chinese mitten crab (*Eriocheir sinensis*). In case of successful acclimatization in the Black Sea these species can substantially influence the local species of invertebrates and fish.

The large swimming blue crab (*Callinectes sapidus*) in the Black Sea meets sporadically. However the environmental conditions, including the low water salinity, are quite suitable for it and it can become a mass species. In this case its appearance will be variously estimated. Fishermen will ascribe it to the malicious enemies: the swimming blue crab easily finds nets and damages catched fish, preferring the insides. It is enough to imagine a net with the valuable Danube herring where all fish has a torn abdominal parts of the body. Gourmets, on the contrary, will be only glad to the appearance of a local delicate decapode instead of the expensive foreign lobster. In the USA, for example, the blue crab is even specially cultivated for gastronomic aims.

Concerning another possible alien species, the Chinese mitten crab (*Eriocheir sinensis*), there are more fears than in the case with the blue crab (Fig. 37). This crab was accidentally introduced to Europe in 1912 with the ships, probably from the Yellow Sea. First it got into the lower areas of the Elbe River and from there began to spread quickly along the coast of Western Europe and presently is found in many rivers and their deltas reaching high numbers in Germany, Belgium, Holland, Denmark, France, Sweden and Finland. About the quantity of this crab it is possible to judge according to published data (Gollash *et al*., 1999). In spring 1998 in the Elbe River, 850 kg (75 thousand of individuals) of this crab were caught by hand during 2 hours. Daily catches can reach 2 thousand kilograms of young crabs (180 thousand individuals). The Chinese mitten crab, like no other crab, can go upstream for hundred and thousand kilometers from a river mouth, it burrows holes in the river banks, accelerating their destruction, and it leads to rapid river and delta silting creating serious impediments for navigation. This crab feeds on plants, different invertebrates, fish (including caught in the nets) and fish eggs, but however gives the preference to mollusks. With the aim to reduce its quantity in the Western Europe, it was recommend to use it as bait for the ell catch, in the production of forage flour, as pharmaceutical and partly food raw material.

Several specimens of the Chinese mitten crab were recorded in the Black Sea during the last years in the Grigorievsky Liman (aquatorium of the port Yuzhniy), in the Odessa Gulf, nearly the mouth of Dniester Liman, in the Danube delta and in other coastal areas (Gomoiu and Skolka, 1998; Zaitsev and Öztürk, 2001). Among the found exemplars there were oviparous females, which mean that naturalization of this species in the Black Sea in the nearest future is fully possible. In the Danube Biosphere Reserve (Ukraine), in November 2003, were found specimens of the Chinese mitten crab with carapace width of 7.5 and 10.5 cm (E. Voloshkevich, personal communication), that considerably exceeds the maximal dimensions of this species quoted in literature (Gollash *et al*., 1999, Galil *et al*., 2002).

Introduction of new species in the Black Sea continue. Last time two Indo-Pacific origin fish species, *Sphyraena obtusata* and *Heniochus acuminatus* in coastal waters of the Sourhern Crimea were recorded (Boltachov and Astakhov, 2004). In 2005 the same origin prawn *Penaeus semisulcatus* was noted near Caucasian coast (Khvorov *et al*., 2006). All of them are Erythrean (Lessepsian) migrants via the Suez Canal and the Levantine Sea. If the winter temperature of the Black Sea water will be acceptable, these organisms will enlarge their species diversity.

6.8. Unmanaged fisheries

Among the different kinds of negative human impact on the Black Sea ecosystem the inadequate resources management and, in particular, inadequate policies with respect to fisheries and coastal zone management continue to impede the sustainable development of this area (Strategic Action Plan, 1996).

Thus, the stocks of dolphins, sturgeons and turbot, already stressed as a consequence of pollution, have been over exploited or are threatened by over exploitation.

Except intensive catch, these animals are suffering from the other threats. The turbot is subjected to high mortality because of the seasonal bottom hypoxia on the shelf. Sturgeons stocks are declined because of ineffective spawning as a result of the dams constructed on the rivers on the fish spawning migratory ways. Dolphins' high mortality is a result of accumulation of toxic substances in their organisms. This is a general fate of terminal links in the food chains in the sea. To such terminal links belong the dolphins, the monk seal, already extinct in the sea, pelicans, cormorants and other ichthyophagous birds inhabiting the Black Sea.

However at all the cases, the fishing management in the Black Sea is one of the crucial conditions to provide their sustainable reproduction and catch. This is especially important since most of the commercial species of fish of the Black Sea have a transboundary distribution i.e. during their spawning, feeding and wintering migrations they repeatedly cross the frontiers of the Black Sea riparian countries. In this condition only scientifically justificated and internationally agreed and coordinated terms, methods, and quotas would help to protect the biological resources of the Black Sea from their exhaustion because of unmanaged fishing.

As to the dolphins, moratorium on their catch in the Black Sea proceeds hitherto and it allows to maintain the number of these animals at a level, according to estimates of different experts, from 10 thousand up to 50 thousand of individuals. It is at least 20 times less than that registered in the 1950s, during the time of their free catch, and 6 times less than in the 1960s, when their catch was mainly stopped. However the accepted prohibition on the dolphins catch, to all appearances, did not increase their total number in the Black Sea. More exact information could be obtained by means of special monitoring in the whole Black Sea from the board of a couple of vessels and airplanes, as it was done for the last time in the middle of the 1980s. However the fact of dolphins being affected by toxic substances is without doubts. During the period of mass toxicological deaths of dolphins in 1989–1990, research works on their fat samples were conducted (Birkun and Krivokhizhin, 1996). As a result, it was found that harbor porpoise has a DDT and hexachlorocyclohexane content five times higher than that of bottlenose and ten times higher than common dolphin. Obviously, is not accidental that harbor porpoise accounted for about 80% of the number of beached dolphins.

Along with pesticides, other chemical and radioactive substances also enter the tissues and organs of dolphins. As showed by researches carried out under the supervision of G.G. Polikarpov (1992), with the discharging waters from the rice fields and flows of the chemical factories particularly high amounts of mercury enter into the Karkinitskiy Bay. In muscles and liver of harbor porpoise from this area, the mercury concentrations were considerably exceeding its maximum permissible level (Birkun and Krivokhizhin, 1996). Besides the above mentioned reasons, serious influence on the dolphins' population number has their trapping into the fish nets with the following death from asphyxia. Most vulnerable to it is harbor porpoise which feeds on benthic organisms (Birkun, 2002). According to data of various authors (Tonay and Öztürk, 2003; Radu *et al*., 2003), the wide-meshed bottom nets used for the turbot catching are the most hazardous traps for dolphins.

6.9. Negative ecological consequences of mass tourism and recreation

Recreation (from the Latin word «recreation» – rest, renewal, recovery) indicates the renewal of health and strength by means of rest in the nature's lap, a tourist's journey, or hiking while visiting interesting sightseeing natural places. As a health-improving measure, recreation at the seashore is called thalassotherapy and constitutes one of the climatotherapy types, i.e., use of environmental conditions and climate features in medicine for health-improving purposes.

Reasoning ecologically, recreation at the seashore is one of the potentially dangerous kinds of negative human impact on marine environment. In general, a great risk factor for coastal marine ecosystems is heaving high concentrations of humans as neighbors. To consider this situation, the terms «landscape's recreational capacity» and «recreational loading» have been introduced (Dediu, 1989). The landscape's recreational capacity is the ability of a territory to provide the holiday-makers with psycho-physiological comfort and possibilities for a sport activity without degradation of the natural environment. It is evaluated as the number of people (or man-days) per area unit (or per recreational object) during the certain time. Estimation of the recreational loading examines only the endurance of natural complexes and recreational objects, while estimation of the landscape's recreational capacity pays attention to the comfort's degree (Dediu, 1989). When the norms of recreational loading are not considered and the landscape's recreational capacity is exceeded, the recreational digression manifests in negative changes in the natural habitats under the influence of intensive use for recreation purposes.

The main forms of recreational impact on the seashore in the supralittoral, mediolittoral and upper sublittoral (Fig. 38) zones are the following:

a) mechanical impact – trampling down of the beaches and sea-bottom resulting in their compression and worsening of sand aeration, damage and annihilation of living organisms;

b) chemical and bacteriological impact – input of chemicals and organic matters (remainings of food, cigarette butts, excretes, etc.) to the beaches, sea-bottom and water which results in worsening of their conditions, and quality as well as in worsening of the life conditions of marine organisms;

c) unmanaged collecting of marine organisms and underwater hunting – collection and annihilation of plants and animals are especially dangerous for marine ecosystems since these organisms are the biological cleaners of the coastal zone. Algae and higher aquatic plants are sources of oxygen; mussels and sponges are feeding by filtering of the suspended particulate organic matter from water; shrimps, crabs and other feeders on carrion or organic refuse are scavengers;

d) disturbance caused to fish and other vertebrates – because of the presence in water of large number of active recreants, animals abandon the coastal zone in a search of a shelter, stop their activity and halt migrations;

e) during the mass entertaining actions at a seashore, for example night discos, the coastal zone is exposed to strong noise and light pollution.

Figure 38. Main ecological zones of the marine psammocontour (chart): 1 – dunes, not moistened by seawater, inhabited by xerophyte plants and terrestrial fauna; 2 – supralittoral zone, at times moistened by the waves sprays, inhabited by terrestrial and marine species of flora and fauna; 3 – mediolittoral zone, regularly moistened by waves, inhabited mainly by marine organisms; 4 – upper sublittoral zone, constantly covered by marine water and inhabited by marine organisms.

Questions from chapter 6 for seminar (training) in the Black Sea ecology

1. Give the definition of marine pollution according to the IOC UNESCO?
2. Name the main types of pollution of the marine environment.
3. Describe the process of anthropogenic eutrophication of the sea.
4. What areas of the Black Sea are the most subjected to anthropogenic eutrophication?
5. Why the ecological problems are most acute in limans and lagoons than in the open coastal waters?
6. Describe the water «blooming» phenomenon; name factors which are causing it. How water «blooming» affect the transparency of the Black Sea waters column?
7. What marine organisms are most of all suffering from the sunlight insufficiency?
8. Explain the hypoxia and anoxia phenomena on the shelf, what causes it?
9. When and where the first case of a mass mortality of benthic organisms in the Black Sea was registered?
10. What species of bottom organisms perish during the hypoxia? What harm was inflicted by hypoxia on the north-western shelf in the 1970s–1980s?
11. What causes the microbial pollution of the sea?
12. What sources of chemical pollution of the sea are known?
13. What causes the radioactive pollution of the sea?
14. Give examples of concentration factors of radionuclides in marine organisms.
15. Give examples of the sea pollution by the synthetic polymers.
16. Could noise and bright light have any importance for marine organisms in the coastal zone?
17. Describe the phenomenon of the biological pollution of the sea.
18. Give examples of when accidentally introduced exotic species have caused the most serious ecological consequences in the Black Sea.

19. What is the danger of the unmanaged catch of marine organisms?
20. Is the haarder considered as a commercial fish in the area of your observations?
21. Is there submarine fishing conducted by scuba divers and how it is regulated in your area?
22. Can tourism and recreation at the shore be the factors of negative impact on marine life?
23. What species of marine flora and fauna were in the past numerous in your area and have presently become rare or disappeared?
24. Have you ever observed living oysters in your coastal area?

7. Possibilities and ways of rehabilitation of the Black Sea ecosystem

Because of some objective circumstances caused by the physiographic peculiarities of the Black Sea and its drainage area, the development of ecologically aggressive technologies on the land and the excessive exploitation of the natural resources during the last decades, a serious harm was inflicted to marine ecosystem of the Sea. One of the severest impacted zones is the north-western shelf which in the XXth century was considered as the main «nursery» of the Black Sea. Recovery of this area from the present damaged state will demand huge efforts during the forthcoming future. It will then be necessary to put the bases of steady nature protection measures over the long period. Both short- and long-term measures require a thoughtful planning and co-ordination of actions among many partners, including national and local authorities of all the six Black Sea countries.

To this end, the six Black Sea countries have accepted the Strategic Plan of Action in 1996. This plan is not yet another document with a scientifically-based chart for environmental sanitation, but a clear and accurately formulated pragmatic statement of the main aims and tasks for the Black Sea countries and the ways of their implementation.

At present, the Black Sea countries experience a time of economic difficulties and are not ready for carrying out the urgent and expensive measures for nature protection. Therefore, the Black Sea Ecological Program (BSEP), which ran from 1994 to 1998, has suggested to the governments of the Black Sea countries to develop an innovative mechanisms for rising funds. In particular, the BSEP suggested the creation of the Black Sea Ecological Fund which will be financed with deductions from the incomes of economic activities such as transport, tourism, inspection and guard of the Black Sea. According to its promoters, the BSEP will also serve as an instrument for accelerating economic growth and will avoid leaving the solution of ecological problems to the next generations; which will be more expensive and more difficult on both economic and ethics criteria.

Because of the present macroecological problems, the nature protection actions on the Black Sea should be coordinated with similar programs on the Danube, Dnieper and other large rivers flowing into the Black Sea. Integration of these works into the Management Strategy of the Black Sea ecosystem belongs to the number of priority tasks for the nearest years. Unification of efforts of the entire Black Sea countries and countries of the drainage basin is needed. The Black Sea conservation can not be carried out on a one way basis. Even specific and local ecological influences (such as discharge of the non purified waters into the coastal zone or extermination of the young fish which afterwards could have migrated into the waters of other country) can affect the economic interests of several countries.

However, many ecological problems on the Black Sea have a local character and are generated by local reasons. Their solving mostly depends on the local administrations and on understanding and help from the side of public organizations which possess the necessary information. These problems are very frequent in the coastal zones and in the coastal wetlands.

The coastal zones are typically the most densely populated and, at the same time, the most ecologically vulnerable thus needing special protection and a rational use of the available resources. In this context it is possible to highlight four basic tasks which should be carried out: 1) prevention of the exploitation of some types of resources in the coastal zone; 2) clear determination of the resources priority of use; 3) to avoide insufficiency of information (ignorance) and 4) correction of decisions which were previously adopted by mistake. Apparently, the most difficult of these tasks is related to the lack of information. Without sufficient knowledge, it is impossible to define the priorities and, in such cases, the decisions are taken arbitrarily or on the basis of some subjective criteria. In the latter case, a short-term gain is often privileged instead of a long-term benefit.

In urban districts, the difficulties of the coastal zone conservation increase considerably because of the different kind of influences of mass human presence on the marine environment. Complex research works of the ecologists and economists on the complicate system of mutual relations between man and urbanized coast are only at the beginning. Besides, quite often, it seems that the decision makers do not pay sufficient attention to the necessity of complex ecosystem approach when addressing such issues. As a result, ecological and economic problems appear and could bring about social conflicts since their delayed solution consumes time, forces and finances.

Observance by each country of the accepted international obligations is the main condition for the improvement of the ecological system of the Black Sea. The most important international treaties are the Ramsar Convention on Wetlands of International Importance (1975), the Convention on Biological Diversity (1993), the Bucharest Convention on Protection of the Black Sea Against Pollution (1992), the Odessa Declaration on the Black Sea Protection (1993), and the Strategic Plan of Actions for the Rehabilitation and Protection of the Black Sea (1996).

In any case, when a decision-making responsibility lies in the hand of a single individual, a great deal depends on his personal knowledge of the Black Sea ecology, his ecological beliefs and ecological ethics.

Therefore the sea conservation and, particularly, the conservation of coastal areas is deeply entangled with the process of ecological education. The latter must be a part of the vast World Conservation Strategy main objectives: 1) to maintain essential ecological process and life support systems; 2) to preserve genetic diversity, which is being dangerously impoverished; and 3) to ensure the sustainable use by present and future generations of the species and ecosystems (Boaden and Seed, 1985).

These aims are clear and scientifically grounded. However, their achievement mainly depends on the personal knowledge and ecological persuasions of people rather than on the perfection of technologies, qualification of producers of material welfares and strict endorsement of current legislation. In a great measure it depends also on personal knowledge of each of us, from trained lectures on ecology. Knowledge must lead to action, but intellectual understanding is useless unless linked to moral commitment.

When man remains alone with nature, only his personal knowledge, persuasions and ethical principles determine his decisions and attitude towards nature itself. The famous ecologist and philosopher Professor Otto Kinne underlines that man, as a species, is not the center of the universe (Kinne, 1997). He is only one among millions of other species and part of the life process, just as dolphins, mice or viruses. For billions years, life on Earth has evolved closely tying and integrating the biological species into balanced ecological systems. A single species, even *Homo sapiens*, cannot exist separately from the ecosystem to which it belongs and to which it has adapted during the thousands preceding generations. O. Kinne considers that we will be severely punished, if we will not be able to set up new and balanced relations between our modern life and nature.

In order to assist the dissemination of the ethical principles and persuasions towards nature among the specialists and managers (and especially among the young generations), Professor Otto Kinne (Germany) and Academician Gennady Polikarpov (Ukraine) have founded in 1998 the Eco-

Ethics International Union (EEIU) with the motto «The Humanity will be able to survive only with the new ethic conception: ecoethics». EEIU presently counts several hundreds members in a dozen countries around the world and is open for all people that are sharing its visions and principles. The application for membership can be addressed to:

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Questions to the chapter 7 for a seminar (training) in the Black Sea ecology

1. What ecological problems in your area of the Black Sea coast have local causes and should be resolved on a local level?
2. What is the transboundary transfer of the pollutants?
3. What ecological problems of the modern Black Sea are caused not only by local, but also by outside factors and should be resolved on an international level?
4. Name some international conventions and other legal documents related to the ecology of the Black Sea and its coastal wetlands.
5. How are formed and on what depends the peoples' ecological persuasions?
6. Give the definition to the conception «ecological ethics (ecoethics)».
7. Are there any nature-conservative actions conducted or that will be conducted in your area of the Black Sea coast? If yes, answer the following questions.
8. Are there any natural reserves, national parks and other protected territories and aquatic areas functioning in your region? What species, communities, habitats and landscapes they protect?
9. Are there temporal or permanent rules of fishing that forbid or limit the catch of fish and other biological resources of the sea?
10. Is regular monitoring conducted on microbial pollution of coastal waters and their fitness for peoples' recreation?
11. Are the sewage waters cleaned before their discharge into the sea?

12. Are there any actions taken for collection of synthetic polymers and other objects polluting the beach area?
13. Are there any local nongovernmental organizations (NGO) that take care of the nature protection including the Black Sea?
14. What public actions on protection of the Black Sea coastal zone proposed by NGO were successfully implemented?
15. What additional nature conservation actions should, in your opinion, be taken in the area of your monitoring of the Black Sea coast? Ground your proposal.

8. How to assess the ecological state of a marine coastal zone by accessible means?

In order to obtain preliminary data about the state of the coastal ecosystem, it is possible to organize individual observations on biology and ecology of the marine coastal zone. Certainly, research expeditions involving highly skilled specialists equipped with modern techniques will give a much more complete and detailed estimation. However, large field trips often take place infrequently and not in every region of the coast and their organization and realization require significant scientific, financial and time expenses.

Young naturalists and students during their practical studies are visiting different coastal areas and when possessing basic knowledge (at least within the framework of this book) can observe and note a lot of phenomena and events, which were sometimes overlooked by scientific expeditions that had previously worked in the same areas. The results of these autonomous supervisions can substantially supplement the knowledge about the environmental state of respective area.

The author is convinced that groups of naturalists using a unified system of observations on the shores could contribute substantially to the study of the Black Sea and to the estimation of its ongoing changes. The results of these supervisions, when being analyzed and summarized by the specialists, could be a significant contribution into the studies of biology and ecology of the most «blue sea in the world». All these considerations equally apply to the adjacent Sea of Azov whose coasts are also inhabited by people that are not indifferent to the surrounding environment.

Rather interesting observations in the marine coastal areas could be carried by simple means, alone or in small groups. However, a few fixed rules should be observed for this purpose. First of all, it is necessary to desire this intercourse with the nature in order to learn about it, to be ready to give up other employments and to take a rest from other everyday occupations. When this aim is reached it is necessary to keep in mind that some of our habits (whose existence we do not realize) could interfere with the naturalistic supervisions.

All talks on other topics should be stopped as they could distract from nature observation. The sunglasses do not allow to distinguish the natural colors of the seawater, sand, stones and their inhabitants. Music distracts from the sounds of nature while tobacco smoke distracts from its odors. In other words, it is needed to stay focused and to talk only when necessary; quietly and only on the theme of supervisions.

It is necessary to carry a field notebook to be able to write down all results of supervisions. It is also desirable to have a thermometer for measuring of the water temperature, pocket magnifying glass, ruler (with a scale of division of 1 mm), camera and binoculars.

Some skeptic people may ask what’s the use of these things, why not to let the children and young people to run, play, bathe and strengthen their health on the shore? But one thing does not eliminate the other and everybody is free to use the nature according to his interests. Naturalists, both amateurs and professionals, receive a pleasure from the process of intercourse with the natural values. In addition, this kind of activity requires a lot of patience, ability and purposefulness and is a good school of natural science, especially for young people, as well as an unobtrusive method of education of correct ecological views and persuasions.

Furthermore, another substantial circumstance must be mentioned. Nowadays, as a result of the direct or indirect influence of human activity, nature experiences more and more often what in ecology has the name of anthropogenic stress. The consequences of such stress vary, but almost invariable reduce the value of nature for a man.

Different human traces could be found everywhere: on the tops of the mountains, on plains, in rivers, seas and oceans. However, the number of these tracks in mountains is less than on plains and in the depths of oceans because everything slides down and flows down from the top to the bottom. As far as the greatest depths of the oceans they can’t reach so far, but are revealed in excess in rivers’ deltas and in marine coastal zone.

Some people consider the Black Sea to be one of the most polluted seas of the world, but it is not true. Not all the Black Sea is polluted, but some coastal shallow areas such as its north-western part surely are. Its central waters and the coastal waters of the Southern Crimea, Caucasus and Asia Minor have a satisfactory ecological state. However, the mass media pay much attention to the extraordinary situations, catastrophes and rarely draw attention to the beautiful nature images. Some leaders of the NGOs which are oriented on the ecological problems quite often exaggerate the situation either because of the lack of scientifically substantiated information or because of some personal convenience. Certainly, everybody needs to know what takes place in nature in order to learn the lesson and to elaborate the norm of behavior. However, as a result of the surplus of negative information, the most impressionable and added to suggestion people (mainly from the ranks of those not enough formed in natural science and ecology) get persuaded that nature is already annihilated and polluted, that the more frightful catastrophes are forthcoming and that the end of the world is not far.

The possibility to receive reliable information about the ecological state of the coastal zone gives an advantage to the naturalist, including a weapon against the uninformed prophets. To obtain this information the following is needed.

8.1. Choice of site for regular observations (monitoring)

As a site (testing area, polygon) for regular ecological observations (monitoring) could serve a prominent point, for example a cape or a rock which is salient into the sea, or any other coastal area which, as a rule, should not be much populated and convenient for the regular visits. It would be of help if, in the area of monitoring, a pier for boats and yachts mooring, which could be used for observations, is present.

The length of the selected coastal area could be various, depending on observers' possibilities to travel on foot. Frequency of observations also depends on possibilities, but must be regular and over a long period of time (i.e. be conducted all-the-year-round and at any weather). Good results could be obtained when conducting the observations once per week or at least once in ten days. Some important details could be missed with rarer visits.

8.2. Determination of hydrometeorological conditions*

* Here and below are listed the basic recommendations on observations. In each case they could be supplemented or adjusted according to the specific conditions of the region

1. To register in a diary the place, date and time of your observations.
2. To define the wind direction (according to compass): north (N.), north-eastern (N.-E.), south (S.), etc. With the winds' activity are connected different phenomena in the sea. The land winds (blowing off the land) drive away the superficial water layer into the open sea and pull up the deep waters towards the shore (wind upwelling). At such winds the sea surface near the shore is smooth and water (during the summer period) is cold and transparent. Winds that are blowing from the sea side bring to the shore the superficial waters and cause waves. The water during these winds in summer is warm and turbid.

3. To determine the wind speed. From a research vessel it is done with the help of the special devices and is expressed in Beaufort wind scale. For an observer it is enough to note the approximate values of the wind speed: calm, moderate or strong wind.

4. To determine nebulosity. In this case the number of clouds on the firmament are considered. It is determined by eye. For example, the 50% nebulosity means that the half of the firmament is overcast.

5. To determine the waves' height. In the absence of special devices it is determined by eye.

6. To define direction of currents. At the shore the water masses are usually moving this or that way. Winds, nearness of a river, shore configuration and other factors influence the currents' direction. The current direction can be determined on motion of different floating objects: algae, foam, terrestrial insects, etc. In their absence, a piece of wood should be thrown into the water and the direction of its motion should be traced. At a very weak current an object can stay for a long time at the same place. The current's direction is expressed in the points of horizon: N, N.-W., S., W., etc., according to the direction where the water flows and not its wherefrom direction. For example, the water masses which move from the north to the south are called the southern currents and the wind which blows from the north to the south is called the northern wind.

7. To define the water transparency. To define on eye, the maximal depth (in meters) until which the sea-bottom and separate large objects on it could be seen. This parameter could be better determined from a pier.

8. To register the presence or absence on the water surface of stable foam that is not vanishing over a long period of time. This foam appears as a result of decomposition of algae or marine organisms, or as a result of discharges containing different detergents into the sea. Under the action of waves this foam can be thrown onto the beach.

9. To measure the water temperature with a thermometer. During the warm season, measurements could be taken entering in the sea with a thermometer. In cold time, measurements could be taken in a bucket filled with the sea water. The observation accuracy depends on accuracy of the thermometer. It is desirable to compare your thermometer's data with that of an exact thermometer and to introduce corresponding amendments. It is necessary to note that air temperature, wind and other factors influence the accuracy of the thermometer's data. Therefore it is necessary to read the measurements of thermometer as quick as possible after its extraction from the water while keeping it in a shelter from a direct sunlight and wind.

10. To mark the time of ice appearance and its melting on a sea surface if such phenomena takes place in the area of observations. To determine the density of floating ice (in % from the sea

surface).

11. To note the distance from observation area of the nearest river and to indicate its name.

12. To note the time of appearance in the coastal zone of the wintering aquatic birds as well as the time of their departure.

13. To note the cases of mass throw outs ashore by waves, of algae, mollusks, fish and other organisms. The studies of the stormy throws provide with information about the flora and fauna of the sea coastal waters.

The data on hydrometeorological conditions are important for explanations of various biological features of the marine organisms as well as of the ecological processes that occurr in this marine coastal area.

8.3. Observations of flora and fauna of sandy beaches

The sandy beaches as well as the rocky coasts could be subdivided into the three basic ecological zones of vertical distribution of the living organisms and their communities (fig. 38). The upper zone, which is called supralittoral, is only sometimes moistened by the wave sprays and is formed by the dry sand of the beaches and the dry surface of the coastal rocks and stones. It is called the spray zone. The sand of the supralittoral zone is dry only at the surface, but, starting from the depths of 10–15cm, it is moist and the interstitial spaces are filled with the salt, brackish or fresh water, depending on the conditions of the specific coastal area.

The subjacent zone is called mediolittoral or pseudolittoral, and is regularly moistened by the waves and has an inclination towards the sea. It is the splash zone. The third zone, which is usually studied by naturalists, is the upper sublittoral. It starts beneath the mediolittoral zone and extends (only in the examined case!) up to that depth until which it is possible to make observations without the special equipment and skills. In practice, it is the depth of 1–1.5 m, where a supervision could be conducted both from the shore or pier and while being in water. A submarine mask and respiratory tube could ease up the task.

Figure 39. Shores of the Budaksky liman (Odessa region, Ukraine) covered by the marsh samphire meadows. Behind the sandy bar, the Black Sea could be seen. It is the feeding area of the waders and other birds (photo Yu. Zaitsev)

On the surface of sandy supralittoral zone, various species of plants are growing using the capillary water of the deeper sand layers. These are the sedges (species of the genus *Carex*), couch-grass (*Elytrigia*), statice (*Limonium*), fever-weed (*Eryngium campestre*), thistle (species of the genus *Cirsium*), rib-grass (*Plantago maritima*) and some other. On the salt soils abundantly grows the marsh samphire (*Salsola pestifera*). By the end of summer this plant turns red and vinous colors, creating a remarkable coloring of the supralittoral of limans and lagoons (Fig. 39). In areas of the output of the fresh waters grows the reed (*Phragmites*) and on the old sand bars and sandy dunes are growing the bushes of oleaster (*Eleagnus*) and tamarisk.

With regard to invertebrates, various insects could be met on the dry sand, for example the shore earwig (*Labidura riparia*) which feeds on remains of plants and animals, or the tiger beetle (*Cicindela hybrida*) which is a small beetle, 12–15 mm in length, brown-green colored with the metallic lustre (Fig. 40). It inhabits the coasts and deltas' islands, preferring mainly the border between water and dry land. It runs very quickly and jumps on a sand instantly fling up and then again landing down, alternating its run with short stops. It is quite difficult to catch it, but it hunts easily on other insects and amphipods that are left on the shore by the waves, seizing them with the sharp jaws that gave it the name «tiger beetle». Its larvae live here, in holes on the shore, and hunt on amphipods and other small aquatic and terrestrial invertebrates. The beetle tiger is a mass insect of the supralittoral zone of islands of the Danube delta and other rivers.

Figure 40. The tiger beetle is a very active insect, armed by powerful jaws by which it grabs its victim. Because of them it gained its name the «tiger-beetle». On the seashore its usual prey are amphipods (from Yu. Zaitsev and V. Prokopenko, 1989)

The sandy beaches are inhabited by many insect species, especially if the beach is covered by algae and various marine inhabitants that were thrown ashore by the waves. Algae are drying quickly under the sun rays, but still remain a tasty food for insects and other inhabitants of the coastal line. If to lift up such layer of dried up algae and seagrasses, under them could be found a lot of amphipods, so-called sand hoppers of the genus *Orchestia*. Other amphipods are not risking to appear on the supralittoral zone while the species of the genus *Orchestia* find here a rich food. Consuming organic remainders they perform the very important ecologically role of «marine sanitary staff».

The sandy mediolittoral zone is inhabited by many species of invertebrates. Among them especially numerous are amphipods and the species *Pontogammarus maeoticus* sometimes reaches such numbers that its biomass rises up to 1–3 kg per one square meter of the splash zone. It is herein possible to make sure, sifting (washing) sand through a sieve with 1–1.5 mm mesh. The high quantity of amphipods testifies to plenty remainders of plants and animals which serve as a food for these crustaceans.

The sandy mediolittoral zone is populated by some species which are very sensitive towards the worsening of the life conditions of this habitat. Such are the bivalve mollusc *Donacilla* and the polychaete *Ophelia*. As a rule, they inhabit the coarse and middle grained sand in the areas where the amount of organic matter does not exceed the acceptable levels for these species. In favorable conditions the number of *Donacilla* and *Ophelia* can raise up to dozens or hundreds of individuals per 1 m^2 of the splash zone.

The life in the upper sublittoral zone in front of the sandy shores is very rich and diverse (Fig. 41). By looking attentively, even without submerging into the water, it is possible to see a great number of organisms. Here, as a rule, algae are not growing because they need submerged stones and other hard substrata for attachment, but there are two species of the seagrasses *Zostera marina* and *Zostera noltii*. Their long leaves form thick submarine «meadows» starting from the depth of 0.5m, but only if this coastal area is protected from the big waves. On *Zostera* leaves settle small algae and some invertebrates and its meadows are inhabited by shrimps and other crustaceans and fish such as the pipefish and sea horse.

Figure 41. Under the action of gentle waves on the sand of shallow bottom areas forms a characteristic ripple. In the sand depressions are accumulated detritus particles, small organisms of micro- and meiobenthos and their consumers like the hermit-crabs, shrimps, fries of fish, etc. (photo Yu. Zaitsev)

On the sandy bottom in the areas free from the seagrasses could be observed two species of hermit crabs: the white hermit crab *Diogenes pugilator* and the red hermit crab *Clibanarius erythropus*. They hide their unprotected abdomen into empty shells of gastropod mollusks. The number of hermit crabs within a certain area of the bottom could serve as an index of its ecological state. For example, as a result of worsening of life conditions in the north-western part of the sea in the 1970s and 1980s, the white hermit crab was practically disappeared.

Into the sandy bottom is skillfully burying the swimming crab (species of the *Macropipus* genus) which is also able to emerge and to swim in the water column. These species have been also disappeared on the north-western shelf same like the white hermit crab.

The sandy bottoms of the upper sublittoral zone are important feeding grounds for young fish including such commercial species as gobies, turbot, flounder, sole, grey mullets and other.

Up to the depth of 20–25 cm into the sandy bottom burrows the soft-shelled clam *Mya arenaria.* This mollusc, accidentally introduced into the Black Sea in the 1960s, became one of the most common bivalves in the upper sublittoral of the sea and in limans. Boring into the sand, *Mya* expose out the tubes-siphons, through which the mollusk receives the food particles and dissolved oxygen. When hided into the sand, *Mya* is protected from fish, but it could be extracted from its shelter by big waves. After each storm on sandy beaches can be seen piles of grey-and-white shells of this mollusk. On a shore *Mya* is eaten up by birds and terrestrial animals and its fragile shells become crashed and participate in the formation of the beach sediments.

The ecological state of a sandy bottom coastal area can be determined analyzing the sizes of *M*y*a* shells. For example, 8–10 cm long shells testify that, during a couple of years, the living conditions were acceptable for this species. Otherwise, mollusks would have died at a younger age. The largest *Mya* shells, observed by the author, were 11.5 cm long. It was on the beaches of the Odessa Gulf in 1970–1971. Later on the sizes of shells have noticeably diminished. It would be of interest to know what size achieve *Mya* shells in other areas of the Black Sea coastal zone.

The high diversity of marine organisms could be met on the shores after the storms. Besides the eelgrass and algae, there are sponges, mollusks, amphipods, ghost crabs, hermit crabs, shrimps, crabs, sea squirts, fish and other organisms which will significantly supplement with the knowledge on flora and fauna of the upper sublittoral during the visual and submarine observations.

8.4. Observations on flora and fauna of rocky shores

The rocky and stone shores in some areas of the Black Sea are more extended than the sandy beaches. In some cases the cliffs drop vertically into the sea, in other they receed from the water line leaving at their feet the pebble and gravel beaches. But in all cases, under the water near the shore, could be found stones of different mineralogic composition, sizes and forms (Fig. 42).

Figure 42. The cliffs and submerged stones at their foot create exceptional conditions for the development of the lithocontour communities, such as in the Golubaya Bay (Blue Bay) at the southern Crimean coast (photo A. Birkun Jr.).

The supralittoral zone at the rocky shores is represented mainly by the pebble beaches (Fig. 43) and by the aerial parts of rocks which are moistened by the sprays from the sea waves. Living creatures are thrown out on the stony surface; their majority is breached, but more firm small forms, such as algal cysts and eggs of some invertebrates, not only survive, but manage to fasten on the stone surface and to develop on it. Later they develop into algae and invertebrates larvae, which in course of time, are also washed off back into the sea. During the windless weather these organisms dry out in the air without losing their viability and could survive for days, weeks and months until the moment when they will be again washed away by the waves back into the sea.

Figure 43. The pebble beach near the rocky shore. Under the wave action the pebbles are constantly moving, but in the cavities of this beach inhabit many marine organisms (photo Yu. Zaitsev)

Calm weather can last for a long time and the living fouling of the aerial part of the rocks dry out until the state of a thin, dark, almost black film. This dry film marks the level that could be reached by the waves' sprays and, consequently, the upper limit of the supralittoral zone on a rocky shore. It has the common name of the «black belt». This black stripe of dried-up algae indeed reminds a giant ribbon that belt the sea along its rocky coast.

It is easy to make sure that the «black belt» is an aggregation of living organisms. For this purpose a piece of the belt should be taken off carefully and placed into the sea water that should be filtered through a filtration paper in order not to add foreign organisms from the water. After the couple of hours it is possible to see, under a microscope, how the tape comes to life: algae are starting to grow and the microscopic invertebrates appear.

In the supralittoral zone marine organisms are protected from their aquatic enemies, therefore the possibility to spend part of the life cycle out of water is a specific protective adaptation. However it does not guarantee an absolute safety. In misty and rainy days the supralittoral black film gets moistened and turns green, becoming a prey for such marine animals like the marble crab (*Pachygrapsus marmoratus*) and the gastropod limpet (*Patella tarentina*). The crab grabs separate particles with its pincers and *Patella* use for this purpose its special organ, the lingual ribbon or radula (Fig. 44). Radula is characteristic for all gastropod molluscs and consists of odontophore which is a flexible ribbon-like tongue. This structure has, on its surface, transversal rows of sharp chitinous dents of different shapes. With the help of the radula, the mollusks scrape off the surfaces of hard objects, including the fouling of submerged stones. The limpet, unlike other gastropod species, is able to feed by scraping off the supralittoral surfaces above the water, mainly during night-time. Looking at the track left, it is possible to determine how far above the water level could climb up this mollusk in the search of food (sometimes up to 1 m) and how it was changing its movement direction. The Black Sea limpet's shell has a form of a low cone up to the 35–40 mm at its base it is tightly fitting to the stone surface even when it is rough. This mollusk is widely collected and used as an edible species.

As for the marble crab, it could be observed on the rocks even 4–5 m higher than the sea level. At a signal of danger from above, for example, a low flying seagull or a man climbing a rock this crab immediately falls down into the water.

Commonly, both the marble crab and the limpet inhabit the rocky mediolittoral and upper sublittoral zones. These species are used by the biologists as sensible indicators (bioindicators) of the coastal waters quality. At worsening of the environmental conditions, the number of these animals noticeably decline and, in extreme cases, they disappear. Thus, for example, up to the end of 1970s and the beginning of 1980s, *Patella* was a common species not only at the southern Crimean shore, but also in the Sevastopol Bay. Presently, this species is not recorded anymore in the Sevastopol Bay and single individuals can be seen in other areas.

Figure 44. Inhabitants of the rocky supralittoral zone of the Black Sea:
1 – gastropod mollusk, limpet (*Patella tarentina*); 2 – general view of radula, on the gastropod's tongue with which it scratch off the food from stone surfaces; 3 – marble crab (*Pachygrapsus marmoratus*).

The rocky medioolittoral zone of the Black Sea is inhabited by the same species and also by the common periwinkle or littorina (*Melaraphe neritoides*), several species of crabs, other invertebrates and some algal species.

The highest species diversity can be observed in the upper sublittoral zone of the rocky shoes. Here dominate the green, brown and red macroalgae. They cover all the hard submerged substrata and create the basic background of the aquatic landscapes. Among algae, the most notable are *Cystoseira* meadows. Large thalli of these perennial brown algae are growing at the shallow depths. In sun days, in clear water, reflected from the marine surface they give the impression of some fairy-tale forest (Fig. 31). Previously it was already noted, that this widely distributed alga is a key species of a biocoenosis, which include dozens of species of other algae, invertebrates and fish. But *Cystoseira* can't withstand the anthropogenic eutrophication of marine coastal waters. If such process occurs, the meadows of *Cystoseira* first thin out, then its thalli becomes fouled by a number of filamentous epiphyte algae and finally this species disappear, as it happened at the end of 1970s – beginning of 1980s in the north-western coast of the Black Sea.

That is why the monitoring of the state of *Cystoseira* meadows is a reliable instrument of the ecological assessment of the coastal waters along the rocky shores.

Among the algae and stones the rocky sublittoral zone is inhabited by many species. For ecological monitoring, mussels, oysters and crabs are the more frequently used as indicatory organisms. Mussels are one of the mass inhabitants of this zone. They withstand rather well eutrophication and other types of pollution, provided that there is normal water saturation by oxygen. However, mussels are able to accumulate in their body different toxic substances, including heavy metals, pesticides and radionuclides. This affects the physiological state of the mollusc and leads to growth inhibition and degeneration of populations. The findings of large-size mussels prove that, during many years, they have not met with the harmful substances in water. The size reduction of mussel population can be also caused by the intensive catch of this mollusc. The largest specimens of mussel can achieve the length of 8–11 cm.

The Black Sea oyster (*Ostrea edulis*) is even more sensitive towards the water pollution than the mussel. Its shells are firmly fixing (cementing) to the stones surfaces and are able to withstand the wave action. After the strong wind blowing from the seaside, it is possible to observe quite a lot of mussels on the beach, but not a single oyster. However, their number in the sea is obviously not high. A.O. Vershin in his interesting and colorful book «Life of the Black Sea» (2003), intended for the young naturalists, affirms that *Ostrea edulis* does not anymore inhabit the Black Sea as it was wholly consumed by the carnivore gastropod *Rapana.* However, there is no exact information about oyster populations along the rocky perimeter of the Black Sea and the observations of naturalists could be of help. There are recent data that, in the area of the cape Tarkhankut (western Crimea), live oysters were presently recorded. They were also found in some areas on the Southern Crimean coast.

Among the mussels and oysters their main consumer, exotic gastropod mollusc *Rapana*, is commonly present. This large mollusc and its eggs could be found in the stormy troop landings. Information about the numbers of *Rapana* in different coastal areas is of scientific and practical interest.

Various crab species inhabit the rocky sublittoral. These are the already mentioned marble crab, littoral crab, *Pilumnus* crab and some other species. The largest among them, the stone crab (*Eriphia verrucosa*), has the width of its carapace achieving 8–9 cm. Last years such large specimens became very rare because of their active catch by the scuba hunters. The crabs are very sensitive to the pollution and the data about their species diversity and numbers are used in the ecological monitoring of the sea coastal zones.

It is quite possible that, in the Bosporus area, lobsters or spiny lobsters could be observed in the upper sublittoral. There are some data about their findings in the Black Sea, but they need to be confirmed. These Mediterranean species can't withstand the low salinity and low winter temperatures of the Black Sea waters which explains why they have not received a wide distribution to the north of the Bosporus Strait.

8.5. Observations in the water column and on its surface

In the second half of July, in August and September, at the water surface near the water line could be observed the schools of small fries with a body length of about 10–20 mm moving in one or other direction. From above, they seem to be bright-silver, but this not exactly so. Actually, the dorsal part of their body is colored in dark blue tones, but, due to the air bubbles which are fastened to the dorsal fins and are reflecting the sunrays, it gives the impression of the mirror lustre. That is the way the fries of the little gray mullet (*Liza saliens*) and the striped mullet (*Mugil cephalus*) look like from the air. They have hatched from the eggs which were spawned in the open sea and after two or three weeks or a bit more have approached to the coast. The air bubbles help them to stay at the water surface, where they are provided with abundant food. At the same time, the fish is masked by the air bubbles and protected from the sharp-sighted marine birds. Coming to the shore, these fries start to search for the nearest feeding grounds in limans and lagoons.

The data of naturalists' observations on the number of fries of grey mullets and direction of their migration could provide useful information for estimation of the effectivness of reproduction of these fish which are traditionally cultured in the Black Sea coastal wetlands.

Also, from the air, it is possible to see the large jelly-fishes like the moon jelly, *Aurelia aurita* and root-mouthed jelly-fish, *Rhizostoma pulmo* (Fig. 45), to register their numbers, dimensions, coloring and behavior.

When having experience of naturalistic observations, it is possible to make interesting supervisions in the water column up to the depth of 1–1.5 m using a submarine face mask,

Figure 45. The largest jellyfish of the Black Sea:

1 – Moon jelly, *Aurelia aurita,*

2 – Root-mouthed jelly, *Rhizostoma pulmo*

Quite often near the root-mouthed jellies it is possible to see the fries of fish which, in danger, find a rescue under its umbrella and among the cavities of its body. These are the fries of horse mackerel, the only from the Black Sea fish that does not fear the poisonous tentacles of the root-mouthed jelly-fish. The fries get food by harvesting it on the surface of jelly-fish (which is covered with the adhered plankton) and, in the case of danger, find a reliable protection. Near one jellyfish it is possible to meet up to several tens of fries of horse mackerel. It is a good example of symbiosis in the marine coastal zone.

Under the water rather large schools of silverside (*Atherina*) and its larvae could be seen. The silverside deposits its eggs on algae (it also could be observed) and both larvae and adult individuals could be seen among algae. Adult fish are easily recognized by a silver stripe along the lateral side of the body. The silverside schools are attracting predatory fish to the shores, such as the garfish, bluefish, Black Sea salmon and some other. It is quite hard to directly observe these quick fish, but they can be seen in the catches of fishermen.

In the June and July, before going into the open sea for spawning, the adult grey mullets are feeding near the coast. Sometimes it is possible to see after how they scoop up by their lower jaw the bottom surface with its small inhabitants or scrape them off from the stones' fouling.

The gobies, blennies and other fishes, could be also easily observed under the water surface by an experienced diver.

The gulls, terns, cormorants, shearwaters and other birds could be observed at the sea surface. In the journal it is necessary to note the birds species that were observed (in winter they could be even more than in the summer season), what they were doing (resting, feeding) and, if they were diving, the duration of their stay under the water. The results of these observations are interesting in various aspects. They show the seasonal changes of birds' specific composition, numbers, and feeding strategies. In addition, the presence of ichthyophagous birds in this area over a long period of time and their hunting indicates an abundance of fish. Otherwise birds would have fly away to other feeding areas.

8.6. Other observations related to the ecological monitoring of the coastal zone

The data about the catches of rare or regionally unusual species of fish or other animals could be of scientific interest, as for example in the case of mackerel, bonito, tuna, swordfish or sea turtle. They were registered in the Black Sea in former times, but there are no new observations since a long time.

Data about the main commercial fish, such as what species make the base of the industrial and amateur catch or how are changing catches according to the season and other information, are of scientific and practical interest.

The cases of findings of dead dolphins on the shore should be fixed in the survey journal If it is possible, the dolphin's species should be determined and its length should be taken.

Of particular interest is the information about the appearance of new species of algae, invertebrates and fish. Mainly such information can be gathered only with the help of the specialists, but some new species could be recognized quite easily as, for example, the Chinese mitten crab and the blue crab (Fig. 37). These species are already noted in the Black Sea, but only the long-term surveys along the Black Sea coasts can tell how far they have spread around.

All information about the species composition and abundance (even at the qualitative level: «one», «few», «many») of marine organisms, about their behavior and other observations registered in the field journals can serve as a good initial material for more detailed scientific analysis of ecological situation in the region, provided that this work is carried regularly and is uniform during a long period.

The book of A.O. Vershin «The Life of the Black Sea», published in Moscow in 2003 under the support of the John D. and Catherine T. MacArthur Foundation and the ARTY Company could serve as a guidance for conducting independent surveys of life in the coastal waters of the Black Sea. The author is a marine biologist and experienced scuba diver and photographer. In a popular form, he animatedly describes to the young naturalists the possible objects of observations at the north-eastern coast of the Black Sea near Anapa, where the stone and sandy coasts and limans are adjoined.

Dr. A.O. Vershin kindly granted permission to the author to use some of his images in the present book.

Questions to the chapter 8 for seminar (training) in the Black Sea ecology

1. What characteristics should have an area at the seashore which is selected for regular independent observations?
2. What meteorological (weather) observations could be carried out by the observer?
3. What hydrological (aquatic) observations and measuring near the shore could be conducted by the observer?
4. To what should be paid attention during observations of life at a sea sandy beach?
5. To what should be paid attention when observing life at a stony (rocky) shore?
6. What birds species and when (indicate the season) could be observed in your area of the

coastal zone of the Black Sea?

7. What marine organisms could be seen when observing the water surface in a coastal zone?
8. What it is possible to see near the sea-shore in the water column using a submarine mask? What plankton and fish species could be found?
9. What could be seen on a sea-bottom in the coastal zone with the help of a submarine mask? What algae, invertebrates and fish could be registered in your area?
10. What unusual phenomena or rare marine organisms could be noted when conducting the regular observations in the sea coastal zone?
11. Are there any freshwater crabs in the mountain rivers of your area?

AFTERWORD

Here comes to the end this short introduction into the ecology of the Black Sea. The author has tried to consider and examine the ecological processes occurring in the Black Sea, using as a background both the similar phenomena which are taking place in other seas and oceans (in order to show their common origin and development according to similar scenarios) and specific features which are determined by the specific conditions of this marine basin. So far, not so many attempts of integrated exposition of ecological questions of a single sea have been undertaken in the literature. This task becomes especially difficult when the matter concerns a marine environment being under strong human impact.

Stating the concepts of ecology and the associated ecological problems is not a simple task and it could be compared with the study of the structure and physiology of one species, for example man, and its different illnesses, causes, manifestations and medical treatments. However, in a natural system, in our case in the sea, are living thousands of different species and each of them has its special relationships with the neighboring species and with the environment itself. In addition, a human organism is studied from the deep antiquity, whereas people have started to pay attention to the nature's «organism» and ecosystems quite recently when various signs of ecological «illness» began to show up.

In fact, the comprehensive research of ecological problems by ecologists and economists is only starting. Therefore sometimes we are surprised by those cases when, during the economic interference with the nature, the decision-making people does not consider the principles of ecosystem approach.

We would like to draw the young reader's attention to the fact that to interpret, to comment the problems of ecology as well as to offer concrete ways of solving them is only possible after a detailed and comprehensive study. When this condition is neglected it is possible to come to erroneous conclusions, which do not solve the problem and do not favor to the authority of the one of the most actual and wanted human sciences – ecology.

The author hopes that the present book will help to the ecological formation of young people that are faced with the three primary aims in this sphere (Boaden, Seed, 1985):

a) maintenance of main ecological processes and ecological systems;

b) safeguard of biological diversity which continues to reduce with anxious acceleration;

c) use of species' populations and ecosystems, remembering about the present and forthcoming generations;

Therefore, practical actions should be reasonable, deliberated and supported by ethical obligations of the man towards nature.

Glossary of special terms

Aerobic organism – an organism which is growing or occurr only in the presence of molecular oxygen.

Anadromous migrations – fish migrations from a sea into a river for spawning (e.g. sturgeon, herring, salmon).

Anaerobic organism (anaerobe) – an organism which is growing or occurr in the absence of molecular oxygen.

Anthropogenic factors – the factors caused by the human activity (man-made factors).

Anticyclonic circulation – the circular clockwise current in the northern hemisphere and anti-clockwise in the southern hemisphere.

Association of organisms – a large assemblage of organisms in a particular area, with one or more dominant species (see **Biocenosis**).

Autotrophic organisms (autotroph) **–** organisms capable to synthesize complex organic substances from simple inorganic substrates; including both chemoautotrophic and photoautotrophic organisms.

Ballast water – an outboard water used to ensure the vessel's stability when the cargo weight is not enough. B.w. is a way of transportation of exotic species.

Benthal – the bottom of natural waters. The benthos habitat.

Benthos – organisms attached to, living on, in or near the sea bed, river bed or lake floor. It is divided into plant B. (phytobenthos), animal B. (zoobenthos) and bacterial B. (bacteriobenthos).

Biocoenosis – community or natural assemblage of organisms; often used as an alternative to ecosystem, but strictly is the animal and plant species association, excluding physical aspects of the environment. Biocoenosis together with the habitat forms an ecosystem.

Biological diversity (Biodiversity) – according to the Convention on Biological Diversity, adopted by UN Conference in Rio de Janeiro in 1992, is defined as: «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 and ecosystems». In ecological research and in monitoring are distinguished: the species diversity, genic diversity, diversity of other taxonomic levels (families, orders, classes and phyla), diversity of communities (biocoenosis), habitats diversity (ecotopes), etc.

Biological indicator – an organism or association of organisms on whose presence and state it is possible to judge about the characteristics of the environment of their habitat.

Biological pollution (of the sea) – accidental introduction into a sea of alien species of plants and animals (e.g. introduction of alien species via ballast water).

Biological production – rate of formation of the organic matter by a population or community (biocoenosis) per certain time period and per unit of space in an ecosystem. The primary, secondary, net and gross productions are distinguished.

Biological productivity – the ability of an ecosystem to produce a certain amount of organic matter in the form of living organisms.

Biomass – mass of living organisms of the benthos or plankton expressed in units of mass (mg, g and kg) per unit of area or volume.

Biome – a major regional ecological community characterized by distinctive life forms and principal plant and animal species (e.g. sandy bottom biome, stony bottom biome).

Biotope – the smallest geographical unit of the biosphere or of a habitat that can be delimited by conventional boundaries and inhabited by its biocoenosis or community. Relatively homogeneous living space of a certain biocoenosis.

Bloom – an explosive increase in the density of phytoplankton within an area. Algal bloom. B. is a consequence of eutrophication.

Concentration factor – the ratio of the concentration of a chemical element in the organism and in the water (for aquatic organisms).

Catadromous migrations – fish spawning migrations from the rivers into the sea (e.g. river eel).

Contourobionts – organisms inhabiting the contour (marginal) marine habitats, such as aerocontour, lithocontour, psammocontour, pelocontour and potamocontour.

Crypsis – protective adaptation of marine organisms, expressed by merging of their bodies with the general background of their environment. Concealment.

Currents' convergence – an area in which the surface waters of different origin come together and where the denser water sinks beneath the lighter water. In C.c. zones occurs concentration of neustonic organisms.

Currents divergence – an area of upwelling where deep water rises and spreads over the surface. C.d. zones are rich in nutrients and phytoplankton.

Cyclonic current (cyclonic circulation) – water motion with the closed superficial current that has an anticlockwise rotation in the northern hemisphere and an clockwise motion in the southern hemisphere. The main Black Sea current is cyclonic.

Detritus – fragmented particulate organic matter derived from the decomposition of plants and animals remains suspended in the water and later on sedimentated on the bottom. Detritus is a basic food for detritivorous organisms.

Drainage basin – an area from which the superficial and underground waters drain into a river, lake or sea.

Dumping – disposal of sediments, after the dredging works, in the specially authorized marine areas.

Ecological hot points – 1) areas with high biological diversity; 2) areas with severe man-made impact.

Ecological factors – abiotic and biotic factors influencing the organisms, populations and biocoenosis (e.g. temperature, salinity, type of bottom, light, predators, etc.).

Ecological pictogram (ecopictogram) – representation of life-cycles, events in species, populations or communities ecology by means of conventional signs.

Ecology – science about the interrelations between the living organisms, communities and their environment. Study of ecological systems.

Ecosystem (ecological system) – a community of organisms and their physical environment functioning as an ecological unit. Unity of living and nonliving components of a biotope**.**

Ecotone – the boundary or transitional zone between the adjacent communities or biomes; tension zone.

Edge effect – the effect exerted by adjoining communities on the structure of population within the marginal zone (ecotone), which often contains a greater number of species and higher population densities than any adjoining community.

Endemic species – species native and restricted to a particular geographical region.

Eury…– prefix meaning wide; cf. Steno-

Eutrophication – enrichment of water body with nutrients (especially nitrogen and phosphorus compounds) resulting in excessive algae growth (see bloom) and reduction of oxygen concentration.

Exotic species (alien species) – species of plants and animals untypical for a given area that were accidentally or intentionally introduced from other areas**.**

Fattening – the period of intensive feeding and growth of fish or other aquatic organisms.

Fouling – 1) an assemblage of organisms growing on the hard submerged substrata of natural and man-made origin. 2) benthic organisms attached to submerged objects of economic importance, such as pilings or boat-bottom.

Hard bottom – rocky, stony, pebble, etc. bottom surfaces of natural or man-made origin.

Heterotrophic organisms (heterotrophs) – organisms unable to synthesize organic compounds from inorganic substrates, that use the organic matters produced by autotrophic organisms as a food source. To heterotrophs belong man, all animals, some plants, fungi and most bacteria.

Hypoxia (anoxia) in a water body – a state of low concentration of dissolved molecular oxygen insufficient for a normal development of aerobic organisms.

Interstitial organisms – pertaining to, or occurring within the pore spaces (interstices) between the sediment particles (e.g. bacteria, unicellular algae and small invertebrates).

Life cycle – sequence of all the stages of development of an organism starting from the zygote till the death of an individual.

Life form – organisms (including different systematic levels) characterized by general features of adaptation to a given set of environmental conditions. Ecomorph.

Liman – former river mouths flooded by seawater as a result of lowering of the Earth's crust.

Macrobenthos – benthic organisms with a body size of more than 1 mm.

Mass mortality – the massive death of aquatic animals caused by reduction of the dissolved oxygen concentrations in the near-bottom water layer. First case of mass mortality of the bottom invertebrates and fish on the Black Sea shelf was registered in 1973 as a result of man-made eutrophication.

Meiobenthos – small benthic organisms that pass through 1 mm mesh sieve, but retained by 0.1 mm mesh. This is the widespread formal definition. Reasoning ecologically, M., together with the microbenthos is the totality of bottom organisms able to inhabit the pore spaces (interstices) between the sediment particles.

Microbenthos – microscopic benthic organisms less than 0.1 mm in size.

Mictium – mixture of species that occurr in a transition zone between the two distinct habitats.

Migrations of marine organisms – regular, repetitive mass movements in time and space of the marine animals in search of the most favorable and vitally important conditions**.**

Mimesis – protective adaptation of marine organisms, when coloring and form of a potential victim are similar to the objects of the present biotope which are indifferent for a predator (e.g. coloring of neuston organisms imitating fragments of algae, wood pieces, air bubbles, etc.).

Nekton – organisms inhabiting the water column, adapted to active swimming and able to withstand the currents (fish, aquatic mammals, squids).

Neustal – upper water layer, 5 cm thick, of the marine pelagial with specific abiotic and biotic conditions and inhabited by neuston organisms**.**

Neuston – community of small- and middle-sized organisms inhabiting the neustal and adapted to its specific environmental conditions.

Nutrients – salts dissolved in water and necessary for plants for the maintenance of their vital functions.

Pelagic organisms – inhabitants of pelagic zone or pelagial.

Pelagic zone – the water column of the oceans, seas and lakes.

Phytobenthos – the bottom-living flora.

Phytoplankton – pelagic unicellular algae.

Plankton – aggregate of the bacteria (bacterioplankton), unicellular plants (phytoplankton) and animals (zooplankton) which are passively floating and transferred by currents in the water column.

Pontian relicts (Caspian relicts) – the species of plants and animals which were wide-spread in the brackish Pontian Lake-Sea and which are presently inhabiting the brackish areas of the Black, Azov and Caspian Seas.

Population of organisms – aggregate of individuals of a certain species occupying a defined territory (water area) and usually isolated to some degree from other adjacent populations. The important condition of the organisms' population is the ability to maintain the quantity of its individuals at a certain level during a prolonged time.

Radioactivity – property exhibited by unstable isotopes of elements which decay, emitting radiation, principally alpha, beta and gamma particles, which are biologically harmful.

Red tides – a mass development of planktonic algae (phytoplankton) coloring water into green, dark blue-green, brown and red colors, depending on the pigmentation of the species causing «blooms».

Salinity – the total amount of all dissolved solids in grams per 1 kg of the sea water. It is expressed in part per thousand, symbolized ‰.

Sea contour biotopes – external sea biotopes adjoining to the surfaces of the interfaces sea-atmosphere (aircontour); sea-rocky coast and bottom (lithocontour), sandy coast and bottom (psammocontour), silty coast and bottom (pelocontour); and also sea-river waters (potamocontour).

Sea contour communities – communities of the contour biotopes of a sea: neuston and pleuston on the aerocontour, associations of species inhabiting stones and rocks on the lithocontour, associations of species inhabiting sand and interstitial spaces on the psammocontour, associations of species inhabiting muddy bottom on the pelocontour. Potamocontour does not have specific associations, however here takes place accumulation of organisms of neuston and plankton.

Sea luminescence – the emission of light by biochemical processes without production of heat by some marine organisms, for example *Noctiluca*.

Sea pollution – according to definition of the IOC UNESCO, the sea pollution is «a direct or indirect human input of matter or energy into the marine environment (including estuaries), resulting in unfavorable consequences such as a damage to the biological resources, hazard to humans' health, hindrances for economic activity of the marine industries (including fishing), decline of the sea water suitability for its further use and worsening of the aesthetic value of the marine landscapes».

Shelf – coastal zone up to the depth of 150–200 meters which has a common geological structure with the continental land. From the side of the dry land the shelf is limited by the water line and from the sea (ocean) side by the continental slope.

Species-edificators of communities – species playing a determining (key) role in the formation of biocoenoses. Key species.

Soft bottoms – sandy, sandy-muddy and muddy bottom biotopes.

Symbiosis – the close relationships of the organisms of two or more species, which, as a rule, became necessary and useful for both partners (symbionts).

Systematics – the biological science of diversity, organisms' classification and relations among them.

Steno…**–** prefix of compound words meaning: narrow, limited, close.

Transboundary transport of the pollutants into a sea – pollutants transfer by the sea currents outside the state or administrative boundaries.

Trophic chain (food chain) – interrelationships between organisms during the transfer of the food's energy from its source (green plant) through the line of consumers when the organisms of the lower trophic level are consumed by those from the higher ones.

Trophic web (food web) – interlacement of the food chains in a complex natural community.

Taxon – a taxonomic group of any rank, including all the subordinate groups.

Taxonomy – the theory and practice of description, name giving and classification of the organisms. Methods and rules of the hierarchical classification of organisms (kingdom, type, class, order, family, genus, species and subspecies) depending on the degree of their relationship.

Thallus – body of lower plants (algae, fungi, lichens) which has no differentiation into root, stem and leaves.

Upwelling – an upward movement of the water from the sea or ocean depths.

Zoobenthos – the animals of the benthos.

Zooplankton – the animals of the plankton.

SCIENTIFIC AND ENGLISH (in brackets) NAMES OF ORGANISMS

Acartia clausi (Claus acartia)
Acipenser guldenstadti colchicus (Russian sturgeon)
Acipenser nudiventris (Fringebarbel sturgeon)
Acipenser stellatus (Starry sturgeon)
Acipenser sturio (Atlantic sturgeon, Common sturgeon)
Alosa kessleri pontica (Black Sea shad)
Amphioxus lanceolatum (Lancelet)
Amphithoe vaillanti (Vailant's amphitoe)
Anas platyrhynchos (Mallard)
Anas strepera (Gadwall)
Anguilla anguilla (European eel)
Anguilla rostrata (American eel)
Anomalocera patersoni (Paterson's anomalocera)
Aphia minuta (Transparent goby)
Aporrhais pespelecani (Pelican's foot shell)
Astacus leptodactylus (European crayfish)
Asterionella (Asterionella)
Atherina mochon pontica (Black Sea silverside)
Aurelia aurita (Moon jelly, Saucer jelly)
Aythya fuligula (Tufted duck)
Balanus eburneus (Ivory barnacle)
Balanus improvisus (Bay barnacle, Acorn barnacle)
Beggiatoa (Beggiatoa)
Belone belone euxini (Black Sea garfish)
Bentophiloides brauneri (Brauner's bentophiloid)
Beroe ovata (Beroe's comb jelly)
Bittium reticulatum (Needle whelk)
Blennius (Blennies)
Botryllus schlosseri (Golden star ascidian)
Bryopsis plumosa (Green sea fern)
Chironomus salinarius (Tendipes midge)
Calanus euxinus (Black Sea calanus)
Calanus helgolandicus (Northern calanus)
Calidris alba (Sanderling)
Calidris canutus (Lesser knot, Knot)
Callianassa pestai (Short-browed mud shrimp)

Callinectes sapidus (Blue crab)
Callionymus belenus (Small dragonet)
Callionymus risso (Dotted dragonet)
Callithamnion (Callithamnion)
Campanularia (Campanularia)
Carcinus aestuarii (Common green crab)
Carcinus mediterraneus (Mediterranean green crab)
Cardium (Cockle)
Centropages ponticus (Black Sea centropages)
Ceramium (Banded weed)
Ceramium rubrum (Red ceramium)
Cerastoderma lamarcki (Lamark's cockle)
Cerataulina pelagica (Pelagic cerataulina)
Ceratium sp. (Ceratium)
Cerithium (Cerithium snail)
Chaetoceros socialis (Chaetoceros)
Chaetomorpha (Green hair weed)
Chamelea gallina (Clam, Striped venus)
Charadrius alexandrinus (Kentish plover)
Charadrius hiaticula (Ringed plover)
Chelura terebrans (Wood borer)
Chironomus plumosus (Midge tendipes)
Chironomus salinarius (Saline midge)
Chromis chromis (Blue damselfish, damselfish)
Chthamalus stellatus (Star barnacle, Poli's stellate barnacle)
Cicindela hybrida (Tiger beetle)
Ciona intestinalis (Sea vase)
Cirsium (Cirsium)
Cladophora (Cladophora)
Cladostephus (Bottle brush)
Clibanarius erythropus (Red hermit crab)
Clunio marinus (Marine clunio)
Clunio ponticus (Black Sea clunio)
Clupeonella cultriventris cultriventris (Kilka)
Codium (Green fleece)
Corophium (Tubicolous amphipod corophium)
Crangon crangon (Common sand shrimp)
Crenilabrus quinquemaculatus (Long-stripped wrasse)
Cumella limicola (Muddy cumella)
Cumella pigmaea (Pigmy cumella)
Cunearca cornea (Cunearca)
Cygnus cygnus (Whooper swan)
Cygnus olor (Mute swan)
Cystoseira (Cystoseira)
Cystoseira barbata (Bearded cystoseira)
Cystoseira crinita (Shaggy cystoseira)
Delphinus delphis ponticus (Common dolphin)
Dexamine spinosa (Spiny dexamine)
Diogenes pugilator (White hermit crab)

Diplodus annularis (Annular gilthead)
Donacilla cornea (Donacilla)
Donax trunculus (Coquina)
Dreissensia polymorpha (Zebra mussel)
Ectocarpus (Ectocarpus)
Egretta alba (Great white egret)
Egretta garzetta (Little egret)
Eleagnus (Oleaster)
Elytrigia (Couch-grass)
Emiliana huxleyi (Huksley's emiliana)
Engraulis encrasicholus maeoticus (Azov Sea anchovy)
Engraulis encrasicholus ponticus (Black Sea anchovy)
Enteromorpha (Hollow green)
Erichthonius difformis (Erichthonius)
Eriocheir sinensis (Chinese mitten crab)
Eriphia verrucosa (Stone crab)
Erithromonas (Erithromonas)
Eryngium campestre (Field eryngo)
Esherichia coli (Escherichia)
Esox lucius (Pike)
Flexopecten ponticus (Black Sea scallop)
Fulica atra (Coot)
Gaidropsarus mediterraneus (Mediterranean rockling, shore rockling)
Gambusia affinis holbrooki (Mosquitofish)
Gastrosaccus sanctus (Gastrosaccus)
Gavia arctica (Black-throated diver)
Gibbula (Flat)
Gobius niger (Black goby)
Gobius ophiocephalus (Grass goby)
Goniaulax polyedra (Goniaulax)
Gymnammodytes cicerellus (Smooth sand lance)
Haematopus ostralegus (Oystercatcher)
Haliaeetus albicilla (White-tailed eagle)
Heterocapsa triquetra (Heterocapsa)
Himantopus himantopus (Black-winged stilt)
Hippocampus ramulosus (Sea horse)
Homarus gammarus (Common lobster)
Huso huso ponticus (Black sea white sturgeon)
Hydrobia (Hydrobia)
Hydrobia ulvae (Sea lettuce hydrobia)
Hydroprogne caspia (Caspian tern)
Hypophthalmichthys molitrix (Silver carp)
Idotea algirica (Algerian idotea)
Idotea baltica basteri (Baltic idotea)
Idotea ostroumovi (Ostoumov's idotea)
Klebsiella (Klebsiella)
Labidocera brunescens (Labidicera)
Labidura riparia (Shore earwig)
Larus (Gull)

Larus argentatus (Herring gull)
Larus melanocephalus (Mediterranean gull)
Larus ridibundus (Black-headed gull)
Lentidium mediterraneum (Mediterranean lentidium)
Leptocylindrus minimus (Leptocylindrus)
Limnoria tuberculata (Gribbe isopod)
Limonium (Statice)
Limosa lapponica (Bar-tailed godwit)
Litophaga (Litophaga)
Liza aurata (Golden grey mullet)
Liza haematocheila (Haarder)
Liza saliens (Leaping mullet)
Macoma (Baltic telling macoma)
Macropipus arquatus (Red swimming crab)
Macropipus holsatus (Sand swimming crab)
Melaraphe neritoides (Periwincle)
Melinna palmata (Melinna)
Merlangius merlangus euxinus (Black sea whiting)
Mesodinium rubrum (Mesodinium)
Mesogobius batrachocephalus (Toad goby)
Mnemiopsis leidyi (Leidy's comb jelly)
Modiolus phaseolinus (Horse mussel)
Monachus monachus (Mediterranean monk seal)
Mugil cephalus (Stripped grey mullet)
Mugil soiuy (Haarder)
Mullus barbatus ponticus (Black Se red mullet)
Mya arenaria (Soft-shelled clam)
Mytilaster lineatus (Mytilaster)
Mytilus galloprovincialis (Mediterranean mussel)
Natrix tesselata (Water snake)
Neogobius kessleri (Kesler's goby, bighead goby)
Neogobius melanostomus (Round goby, Black-spotted goby)
Neogobius rattan (Ratan goby)
Nereis (Nereis)
Nereis longissima (Longest nereis)
Nereis zonata (Zoned nereis)
Nitzschia closterium (Nitzschia)
Noctiluca scintillans (Seasparkle)
Numenius arquata (Eurasian curlew)
Obelia (Obelia)
Oikopleura dioica (Oikopleura)
Oithona similis (Oithona)
Ophelia bicornis (Ophelia)
Ophidion rochei (Cusk eel)
Orchestia (Sand hopper)

Oscillatoria (Oscillatoria)
Ostrea edulis (Common oyster, European flat oyster)
Pachygrapsus marmoratus (Marbled rock crab)
Padina pavonia (Peacock-tail)
Palaemon adspersus (Common prawn, Common shrimp)
Palaemon elegans (Elegant shrimp)
Pandion haliaetus (Osprey)
Paracalanus parvus (Paracalanus)
Patella tarentina (Limpet)
Pelecanus crispus (Dalmatian pelican)
Pelecanus occidentalis (Brown pelican)
Pelecanus onocrotalus (White pelican)
Periculoides longimanus (Periculoides)
Phalacrocorax aristotelis (Common shag)
Phalacrocorax carbo (Great cormorant)
Phocoena phocoena relicta (Harbour porpoise)
Pholas (Common piddock)
Phragmites (Reed)
Phyllophora (Phyllophora, Leaf weed)
Phyllophora truncata (syn. *P. brodiaei*) (Phyllophora)
Phyllophora membranifolia (Phyllophora)
Phyllophora cripa (syn. *P. nervosa*) (Phyllophora)
Phyllophora pseudoceranoides (Phyllophora)
Physalia (Portuguese man-of-war)
Pilumnus hirtellus (Hairy crab)
Pisidia longimana (Pisidia)
Plantago maritma (Plantain, Rib-grass)
Platichthys flesus luscus (Flounder)
Platynereis dumerilii (Comb-toothed nereid, Dumeril's bristle worm)
Pleurobrachia rhodopis (Sea gooseberry)
Podiceps cristatus (Great crested grebe)
Podiceps grisegena (Red-necked grebe)
Polysiphonia (Polysiphonia)
Pomatoceros triqueter (Pomatoceros)
Pomatomus saltatrix (Bluefish)
Pontella mediterranea (Mediterranean pontella)
Pontogammarus maeoticus (Azov Sea pontogammarus)
Porphyra (Laver)
Potamogeton (Potamogeton)
Potamon potamios (Fresh-water crab)
Prorocentrum cordatum (Prorocentrum)
Prorocentrum micans (Bright prorocentrum)
Psetta maeotica (Black and Azov Seas turbot)
Pseudocalanus elongatus (Elongate pseudocalanus)
Pseudomonas aeruginosa (Rusty pseudomonas)
Pseudo-nitzschia delicatissima (Pseudonitzschia)
Pseudosolenia calcar avis (Pseudosolenia)
Puffinus puffinus (Manx shearwater)
Punctaria (Ribbon weed)

Raja clavata (Thornback ray)
Rapana thomasiana (Rapana, Asian rapana whelk)
Recurvirostra avosetta (Avocet)
Rhithropanopeus harrisi tridentata (White-fingered mud crab)
Rhizostoma pulmo (Root-mouthed jellyfish, Football jellyfish)
Rissoa euxinica (Black Sea rissoa)
Ruppia (Widgeon grass)
Sagitta setosa (Sagitta, Arrow-worm)
Salmo trutta labrax (Black Sea salmon)
Salmonella typhi murium (Salmonella)
Salsola pestifera (Russian thistle)
Sarda sarda (Bonito)
Sceletonema costatum (Sceletonema)
Scomber scombrus (Mackerel)
Scorpaena porcus (Scorpionfish)
Scripsiella trochoidea (Scripsiella)
Silurus glanis (European catfish, Wels Catfish)
Sinanodonta woodiana (Wood’s paper-shell, Swan mussel)
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Somateria molissima (Common eider)
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Sprattus sprattus phalericus (Black Sea sprat)
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Teredo navalis (Pileworm, Ship's worm)
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Thunnus thynnus (Bluefin tuna)
Trachinus draco (Greater weever)
Trachurus mediterraneus ponticus (Black Sea horse mackerel)
Tringa totanus (Common redshank)
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Tursiops truncatus ponticus (Bottlenosed dolphin)
Ulva rigida (Sea lettuce)
Unio pictorum (Painter's mussel)
Upogebia pusilla (Mediterranean mud shrimp)
Velella (By-the-wind sailor)
Xiphias gladius (Swordfish)
Zannichellia (Pondweed)
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CYRILLIC TITLES

Ayzatullin T.A., Lebedev V.L., Khailov C.M. The Ocean. Active Surfaces and the Life. Айзатуллин Т.А., Лебедев В.Л., Хайлов К.М. Океан. Активные поверхности и жизнь. Ленинград: Гидрометеоиздат, 1979.- 192 с.

Aleev Yu.G. Ecomorphology. Алеев Ю.Г. Экоморфология. Киев: Наукова думка, 1986.- 423 с.

Alekin O.A. Chemistry of the Ocean. Алекин О.А. Химия океана. Л.: Гидрометеоиздат, 1966.- 248 с.

Alexandrov B.G. Aquatic ecosystem of delta and trophic relationships of birds. Александров Б.Г. Водна екосистема плавнів і трофічні зв'язки птахів. Біорізноманітність Дунайського біосферного заповідникабз береженя та управлінняю Київ: Наукова думкаб 1999.- С. 254-266.

Birkun A. Jr., Krivochizhin S. The Black Sea mammals. Биркун А. мл., Кривохижин С. Звери Черного моря. Симферополь: "Таврия", 1996.- 94 с.

Bodeanu N. Microphytobenthos.Бодяну Н. Микрофитобентос. В кн.: Основы биологической продуктивности Черного моря. К.: Наук. думка., 1979.- С. 109-122.

Chechun T.Yu. Feeding of the haarder *Mugil soiuy* (Mugilidae) in the Black and Azov Seas.

Чечун Т.Я. Питание пиленгаса *Mugil soiuy* (Mugilidae) в Азово-Черноморском бассейне. Вопросы ихтиологии, 2003, **43**, № 4.- С. 521-527.

Chilikina N.S. Research on biological activity of the sea foam. Чиликина Н.С. Изучение биологического действия морской пены. В книге: Биологические проблемы океанографии южных морей. Киев: Наукова думка, 1969.- С. 128-129.

Chochury N.I. About the diurnal vertical migrations of zooplankton in the Batumi Bay. Чохури Н.И. К вопросу о суточных вертикальных миграциях в Батумской бухте. Труды Научн. Рыб.-хоз. Биол. Станции Грузии, 1939, вып. 2.- С. 153-172.

Dediu I.I. Dictionary of Ecology. Дедю И.И. Экологический энциклопедический словарь. Кишинев: Главная редакция Молдавской Сов. Энциклопедии, 1989.- 408 с.

Dekhnik T.V. The Black Sea Ichthyoplankton. Дехник Т.В. Ихтиопланктон Черного моря. Киев: Наук. думка, 1973.- 235 с.

Fesenko G.V., Bokotey A.A. Birds of Ukraine (a field guide). Фесенко Г.В., Бокотей А.А. Птахи фауни України (польовий визначник). Київ: Українське товариство охорони птахів, 2002.- 411 с.

Gaevskaya A.V., Korniychuk Yu.M. Parasitic organisms as components of Crimean coastal waters ecosystem. Гаевская А.В., Корнийчук Ю.М. Паразитичекие организмы как составляющая экосистем черноморского побережья Крыма. Современное состояние биоразнообразия прибрежных вод Крыма (Черноморский сектор). Севастопольб 2003.- 425-490.

Gelmboldt M.V. Marine mites of the north-western part of the Back Sea: biology and ecology. Гельмболдт М.В. Морские клещи. Северо-западная часть Черного моря: Биология и экология. Киев: Наукова думка, 2006.- С. 260-267.

Gerlach S.A. Marine Pollution. Diagnosis and therapy. Герлах С.А. Загрязнение морей. Перевод с английского. Ленинград: Гидрометеоиздат, 1985.- 263 с.

Greze V.N. Zooplankton. Vertical distribution and migrations. Грезе В.Н. Зоопланктон. Вертикальное распределение и миграции. В кн.: Основы биологической продуктивности Черного моря. К.: Наук. думка, 1979.- С. 147-149.

Greze V.N. The Sea of Azov. Грезе В.Н. Азовское море. В: Природа Украинской ССР. Моря и внутренние воды. Киев: Наукова думка, 1987.- С. 30-47.

Grodzinsky D.M. The stability of plant systems. Гродзинский Д.М. Надежность растительных систем. Киев: Наук. думка, 1983.- 368 с.

Guslyakov N.E. Benthic diatoms of the Black Sea and adjacent wetlands. Гусляков М.О. Діатомові водорості бентосу Чорного моря та суміжних водойм. Автореферат дисертації на здобуття наук. ступеня докт. біол. наук. Київ, 2002.- 36 с.

Identification Guide of Fauna of the Black and Azov Seas. Определитель фауны Черного и Азовского морей. **2**, Киев: Наукова думка, 1969.- 536 с.

Kalugina-Gutnik A.A. The macrophytobenthos. Калугина-Гутник А.А. Макрофитобентос. В кн: Основы биологической продуктивности Черного моря, Киев: Наукова думка, 1979.- С. 123-142.

Khait S.Z., Shpilberg G.I. Sanitary-bacteriological investigations of coastal marine waters and sandy beaches of the Odessa Gulf. Хаит С.З., Шпильберг Г.И. Санитарно-бактериологическое исследование прибрежной морской воды и песка морских пляжей Одессы. Гигиена и Санитария, 1950. С.- 39-41.

Khailov K.M. Organic external metabolites of marine macrophyte as an internal environmental factor of coastal communities. Хайлов К.М. Органические выделения морских макрофитов, как фактор внутренней среды береговых сообществ. Труды Севастоп. Биол. Ст., **16**,1963.- С. 496-505.

Khristophorova N.K. Fundamentals of Ecology. Христофорова Н.К. Основы экологии. Владивосток: Дальнаука, 1999.- 516 с.

Klebovitch V.V. Critical salinity of biological processes. Хлебович В.В. Критическая соленость

биологических процессов. Л.: Наука, 1974.- 235 с.
Kisseleva M.I. Bottom biocoenoses and their biomass. Киселева М.И. Донные биоценозы и их биомасса. В кн.: Основы биологической продуктивности Черного моря. К.: Наук. думка., 1979.- С. 218-238.
Kleynenberg S.E. Materials on the Black Sea dolphins feeding. Клейненберг С.Е. Материалы к изучению питания дельфинов Черного моря. Бюлл. Моск. Общ-ва испыт. Природы, отд. Биол., 45, 5, 1936.- С. 338-345.
Konstantinov A.S. General Hydrobiology. Константинов А.С. Общая гидробиология. Москва: Высшая школа, 1979. Издание третье.- 480 с. Он же, Издание четвертое, 1986.- 472 с.
Kostin Yu.V. Birds of Crimea. Костин Ю.В. Птицы Крыма. Москва: "Наука", 1983.- 240 с.
Krasnov E. A sea of the Jurasic period. Краснов Е. Море юрского периода. В кн.: Черноморские румбы. Одесса: «Феникс», 2003.- С. 104-118.
Krotov A.V. On the feeding of the Black Sea mackerel (*Scomber scombrus*).Кротов А.В. К познанию биологии черноморской скумбрии (*Scomber scombrus* L.). Труды Укр. Научн.-иссл. станции морского рыбного хозяйства и океанографии, Том , Одесса.- С. 9-74.
Kusmorskaya A.P. The Black Sea zooplankton and its consumption by commercial species of fish. Кусморская А.П. Зоопланктон Черного моря и его выедание промысловыми рыбами. Труды Всес. НИИ мор. рыб. хоз-ва и океанографии, 1954, **28**.- С. 203-216.
Leonov A.K. Regional Oceanography. Леонов А.К. Региональная океанография. Часть I, Берингово, Охотское, Японское, Каспийское и Черное моря. Л.: Гидрометеоиздат, 1960.- 765 с.
Makkaveeva E.B. The *Cystoseira barbata* biocoenosis in the Black Sea coastal zone. Маккавеева Е.Б. Биоценоз *Cystoseira barbata* Ag. (Wor.) Прибрежного участка Черного моря. Труды Севастоп. Биол. Ст., 1959, **XII**.- С. 168-191.
Minicheva G.G. Structural and functional peculiarities of the benthic algal communities. Миничева Г.Г. Структурно-функциональные особенности формирования сообществ морских бентосных водорослей. Альгология, 1993, **3**, № 1.- С. 3-12.
Minicheva G.G. Parameters of the surfaces of macrophytes. Миничева Г.Г. Параметры поверхности макрофитов. Северо-западная часть Черного моря: биология и экология. Киев: Наукова думкаб 2006.- С. 214-223.
Nasarenko L.F., Amonsky L.A. Influence of synoptic processses and weather on bird's migrations in the northern Black Sea area. Назаренко Л.Ф., Амонский Л.А. Влияние синоптических процессов и погоды на миграцию птиц в Причерноморье. Киев: Головное издательство издательского объединения "Вища школа", 1986.- 184 с.
Nesterova D.A. Ratio of living and dead cells in the phytoplankton of low salinity marine areas by means of luminescence analysis. Нестерова Д.А. Определение соотношения живых и мертвых клеток фитопланктона опресненных участков моря иетодом люминесцентного анализа. Материалы XIV конф. По изучению внутренних водоемов Прибалтики, Рига, **3**, 2, 1968.- С. 79-83.
Nesterova D.A. Blooms of phytoplankton in the north-western part of the Black Sea. Нестерова Д.А. "Цветение" воды северо-западной части Черного моря (Обзор) // Альгология, 2001, **11**, № 4, С. 502-513.
Parin N.V. *Liza haematocheila* – a correct specific name of the haarder (Mugilidae). Парин Н.В. *Liza haematocheila* – правильное видовое название кефали-пиленгаса (Mugilidae). Вопросы ихтиологии, 2003, **43**, № 3.- С. 418-419.
Patin S.A. Chemical pollution and its impact on hydrobionts. Патин С.А. Химическое загрязнение и его влияние на гидробионтов. В книге: Океанология. Биология океана, Том 2, Москва: "Наука", 1977.- С. 322-331.

Petipa T.S. Observations on zooplankton behaviour during a solar eclipse. Петипа Т.С. Наблюдения над поведением зоопланктона во время солнечного затмения. Доклады АН СССР, 1955, **104**, №2, С.- 323.
Polikarpov G.G. Radioecology of marine organisms. Поликарпов Г.Г. Радиоэкология морских организмов. Накопление и биологическое действие радиоактивных веществ. (Под ред. В.П. Шведова). Москва: Атомиздат, 1964.- 295 с.
Polikarpov G.G. Radioecology of hydrobionts. Поликарпов Г.Г. Радиоэкология гидробионтов. Природа, 1970.- № 10.- С. 47-56.
Polikarpov G.G. (Ed) Molismology of the Black Sea. Поликарпов Г.Г. (Ред.) Молисмология Черного моря. Киев: Наук. думка, 1992.- 304 с.
Polikarpov G.G. *et al*., Oil fields as an ecological niche. Поликарпов Г.Г., Егоров В.Н., Иванов В.Н., Токарева А.В., Филиппов И.А. Нефтяные поля как экологическая ниша. Природа, 1971, № 11.- С.75-78.
Polikarpov G.G., Risik N.S. (Eds) Radiochemoecology of the Black Sea. Поликарпов Г.Г. и Рисик Н.С. (Ред.) Радиохемоэкология Черного моря. Киев: Наук. думка, 1977.- 232 с.
Polikarpov G.G. *et al*., Concentration of the 90Sr in the water of lower Dnieper River. Поликарпов Г.Г., Тимощук В.И., Кулебакина Л.Г. Концентрация 90Sr в водной среде нижнего Днепра в направлении Черного моря. Докл. АН УССР. Сер. Б.- 1988.- № 3.- С. 77-79.
Polikarpov G.G., Tsytsugyna V.G. A comparison of cytogenetic and ecosystem efficiency of radioactive and chemical mutagens in the hydrobiosohere. Поликарпов Г.Г., Цицугина В.Г. Сравнение цитогенетической и экосистемной эффективности действия радиоактивных и химических мутагенов в гидробиосфере. Доповіді НАН України.- 1999.- № 6.- С. 199-202.
Rass T.S. Modern ideas on the composition of the Black Sea ichthyofauna and its change. Расс Т.С. Современные представления о составе ихтиофауны Черного моря и его изменениях. Вопросы ихтиологии, **7**, вып. 2.- С. 179-187.
Romanenko V.D. Fundamentals of Hydroecology. Романенко В.Д. Основи гідро екології. Київ: Обереги, 2001.- 728 с.
Rouchiyaynen M.I., Senicheva L.G. Luminescence analysis of the Black Sea phytoplankton. Роухияйнен М.И., Сеничева Л.Г. Люминесцентный анализ фитопланктона Черного моря. Гидробиологический журнал, 1985, **20**, № 1,- С. 12-16.
Savchuk M.Ya. On the migrations and distribution of the fries of grey mullets along the north-western Black Sea coasts. Савчук М.Я. О миграциях и размещении молоди кефали у берегов северо-западной части Черного моря. Зоологич. журн., 1967, **XLVI**, вып. 5.- С. 737-740.
Skopintsev B.A. New researches on marine chemistry. Скопинцев Б.А. Новые работы по химии моря. Труды. Морского гидрофизич. Ин-та, 25, 1962.- С. 82-109.
Skopintsev B.A. Formation of the modern chemical composition of Black Sea waters. Скопинцев Б.А Формирование современного химического состава вод Черного моря. Ленинград: Гидрометеоиздат, 1975.- 336 с.
Sorokin Yu.I. The Black Sea: Nature and Resources. Сорокин Ю.И. Черное море: природа и ресурсы. Москва: Наука, 1982.- 217 с.
Telitchenko M.M., Ostroumov S.A. Introduction to the problems of biochemical ecology. Телитченко М.М., Остроумов С.А. Введение в проблемы биохимической экологии. Москва: "Наука", 1990.- 288 с.
Tsyban A.V. Bacterioneuston and bacterioplankton of the Black Sea shelf zone. Цыбань А.В. Бактерионейстон и бактериопланктон шельфовой области Черного моря. Киев: Наук. думка, 1970.- 274 с.
Tsytsugyna V.G., Polikarpov G.G. Cytogenetic and populational effects in Oligochaeta from the

Chernobyl zone. Цыцугина В.Г., Поликарпов Г.Г. Цитогенетические и популяционные эффекты у олигохет из Чернобыльской зоны. Радиационная биология. Радиоэкология.- 2000.- **40**, № 2.- С. 226-230.

Vernadsky V.I. The Biosphere. Вернадский В.И. Биосфера. Москва: Мысль, 1968.- 374 с.

Vershinin A.O. The life of the Black Sea. Вершинин А.О. Жизнь Черного моря. Москва: Изд-во «Макцентр», 2003.- 174 с.

Vinogradov C.A. (Ed.) Ecological biogeography of the Black Sea contact zones. Виноградов К.А. (Ред.) Экологическая биогеография контактных зон моря. Киев: Наукова думка, 1968.- 160 с.

Vorobyova L.V. Meiobenthos of the Ukrainiaan Black and Azov Seas shelf. Воробьева Л.В. Мейобентос украинского шельфа Черного и Азовского морейю Киев: Наукова думка, 1999.- 300 с.

Zaika V.E. *et al*., Mytilidae of the Black Sea. Заика В.Е. и др., Митилиды Черного моря. Киев: Наук. думка, 1990.- 206 с.

Zaitsev Yu.P. Reproduction peculiarities of the Black Sea grey mullets. Зайцев Ю.П. Особенности размножения кефалей (Mugilidae) Черного моря. Зоол. журн., **XL**, № 6, 1961.- С. 1538-1544.

Zaitsev Yu.P. The surface pelagic biocoenosis of the Black sea. Зайцев Ю.П. Приповерхностный пелагический биоценоз Черного моря. Зоол. журн., **XXXIX**, вып. 10, 1960.- С. 818-825.

Zaitsev Yu.P. Problems of the Black Sea Neustonology. Зайцев Ю.П. Проблемы морской нейстонологии. Гидробиол. журн., **3**, 5, 1967.- С. 58-69.

Zaitsev Yu.P. Marine neustonology. Зайцев Ю.П. Морская нейстонология. Киев: Наук. думка, 1970.- 264 с.

Zaitsev Yu.P. The Life of the Sea surface. Зайцев Ю.П. Жизнь морской поверхности. Киев: Наук. думка, 1974.- 112 с.

Zaitsev Yu.P. Contour communities of seas and oceans. Зайцев Ю.П. Контурные сообщества морей и океанов. Фауна и гидробиология шельфовых зон Тихого океана. Материалы XIV Тихоокеанского научного конгресса (Хабаровск, август 1979). Владивосток, 1982.- С. 51-54.

Zaitsev Yu.P. The ecological state of the Black Sea shelf in front of the coasts of Ukraine. Зайцев Ю.П. Экологическое состояние шельфовой зоны Черного моря у побережья Украины (обзор). Гидробиол. журн., **28**, 4, 1992.- С. 3-18.

Zaitsev Yu.P. The most blue in the world. Зайцев Ю. Самое синее в мире. Нью-Йорк: Издательство ООН, 1998.- XVII + 142 с.

Zaitsev Yu.P. Wild nature in Odessa city. Зайцев Ю. П. Дикая природа в городе. Одесса: парк им. Т.Г. Шевченко – Ланжерон. Одесса: Молодежный экологический центр им. В.И. Вернадского, 2001.- 130 с.

Zaitsev Yu.P., Polikarpov G.G. Problems of the Hyponeuston Radioecology. Зайцев Ю.П., Поликарпов Г.Г. Вопросы радиоэкологии гипонейстона. Океанология.- 1964.- **4**, вып. 3.- С. 423-430.

Zaitsev Yu.P., Polikarpov G.G. The Black Sea. Зайцев Ю.П., Поликарпов Г.Г. Черное море. В кн.: Природа Украинской ССР. Моря и внутренние воды. Киев: Наук. Думка, 1987.- С. 17-29.

Zaitsev Yu.P., Polikarpov G.G. Ecological processes in critical zones of the Black Sea (Results synthesis of two research directions, middle XXth – beginning of the XXIth centuries). Зайцев Ю.П., Поликарпов Г.Г. Экологические процессы в критических зонах Черного моря: синтез результатов двух направлений исследований с середины XX до начала XXI веков. Морской экологический журнал, 2002.- **1**.- № 1.- С. 33-55.

Zaitsev Yu.P., Polikarpov G.G., Egorov V.N., Alexandrov B.G., Garkusha O.P., Kopytina N.I., Kurilov A.V., Nesterova D.A., Nidzvetskaya L.M., Nikonova S.E., Polikarpov I.G., Popovichev V.N., Rusnak E.M., Stokozov N.A., Teplinskaya N.G., Terenko L.M. Accumulation of remains of oxybiotic organisms and a bank of living spores of higher fungi and diatoms in bottom sediments of the hydrogen sulphide bathial of the Black Sea. Зайцев Ю.П., Поликарпов Г.Г., Егоров В.Н., Александров Б.Г., Гаркуша О.П., Копытина Н.И., Курилов А.В., Нестерова Д.А., Нидзвецкая Л.М., Никонова С.Е., Поликарпов И.Г., Поповичев В.Н., Руснак Е.М., Стокозов Н.А., Теплинская Н.Г., Теренько Л.М. Доповіді Національної академії наук України, 2007, 7.

Zakutsky V.P. «Swarming» of polychaets. Закутский В.П. «Роение» полихет. Природа, 1963, 3.- С. 39.

Zakutsky V.P. The benthohyponeuston of the Black and Azov Seas. Закутский В.П. Бентогипонейстон Черного и Азовского морей. В кн.: Экологическая биогеография Контактных зон моря (Ред. К.А. Виноградов). Киев: Наукова думка, 1968.- С.71-90.

Zelezinskaya L.M. The numbers of dead plankton in shallow-water Black Sea areas. Зелезинская Л.М. О количественных показателях смертности компонентов черноморского планктона на мелководье. Зоологический журнал, **45**, вып. 8.- С. 1251-1253.

LATIN TITLES

Băcescu M.C. Fauna Republicii Socialiste România. Bucureşti: Editura Acad. RSR. Crustacea, vol. IV, Fasc. 9, 1967.- 353 pp.

Bellan G. La pollution par les tension-activs. In: La pollution des eaux marines. Paris: Gauthiers-Villars, 1976.- P. 31-50

Bellan G. et Pérès J.-M. La Pollution des mers. Paris: Presses Universitaires de France, 1974.- 127 p.

Bilyavsky G., Tarasova O., Denga Yu. *et al*., Black Sea Environmental Priorities Study. Ukraine. New York: United Nations Publications, 1998.- 105 pp.

Birkun A. Jr. Interaction between cetaceans and fisheries in the Black Sea. In: Notarbartolo di Sciara (Ed.) Certaceans of the Mediterranean and Black Seas: state of knowledge and conservation strategies. A Report to the ACCOBAMS Secretariat, Monaco, Section 10, 11 p.

Black Sea Transboundary Diagnostic Analysis. New York: United Nations Development Programme, 1997.- 142 pp.

Boaden P.J.S., Seed R. An Introduction to Coastal Ecology. Glasgow and London: Blackie, 1985.- 218 pp.

Egorov V.N. *et al*., ^{90}Sr and ^{137}Cs in the Black Sea after Chernobyl NPP accident: inventories, balance and tracer applications. J. Environ Radioactivity.- 1999.- **43**.- P. 137-155.

Furness R.W. Competition between fisheries and seabirds communities. Adv. Mar. Biol., 1982, 20.- P. 225-307.

Galil B., Froglia C. and Noël P. CIESM Atlas of Exotic Species in the Mediterranean. Vol. 2. Crustaceans: decapods and stomatopods. [F. Briand, Ed.]. CIESM Publishers, Monaco, 2002.- 192 pp.

Gollash S., Minchin D., Rosental H., Voigt M. (eds). Case histories on introduced species: their general biology, distribution, range expansion and impact. Publ. by Dept. Of Fishery Biology, Institut for Marine Science, University of Kiel, Germany, 1999.- 73 pp.

Gomoiu M.-T. Problèmes concernant l'eutrophisation marine. Cercetari marine, IRCM Constanta, **18**.- P. 59-95.

Gomoiu M.-T. & Skolka M. Increasing of biodiversity by immigration of new species for the Romanian Fauna. An. Univ. "Ovidius", Constanta, Seria Biologie-Ecologie, 1998, 2.- P.- 181-202.

Gray J.S. Marine biodiversity: patterns, threats and conservation needs. Biodiversity and

Conservation, 1997, **6**.- P. 153-175.
Green J. The Biology of Estuarine Animals. London: Sidgwick and Jackson, 1968.- 401 pp.
Groves D.G. and Hunt L.M. Ocean World Encyclopedia. New York: Mc Graw-Hill Book Comp., 1980.- 443 pp.
Komakhidze A., Mazmanidi N. (Comp.). Black Sea Biological Diversity. Georgia. New York: United Nations Publications, 1998.- 167 pp.
Konsoulova Ts. Marine macrozoobenthic communities structure and ecological status in relation to some environmental factors. Compt. Rendus Acad. Sci. Bulg., 1993, **46**, 5, P. 115-118.
Krey J. Detritus in the ocean and adjacent seas.- Washington D.C.: Estuaries, 1967.- P. 389-394.
Mee L.D. The Black Sea in Crisis: A Need for Concerted International Action. Ambio, 1992, **21**, № 4.- P. 278-286.
Mee L.D. and Topping G. (Eds). Black Sea Pollution Assessment. New York: United Nations Publications, 1998.- 380 pp.
Mee L.D., Friedrich J., Gomoiu M.-T. Restoring the Black Sea in Times of Uncertainty. Oceanography Contents, vol. 18, # 2, 2005.- P. 100-111.
Milne H. and Dunnet G.M. Standing crop, productivity and trophic relations of the fauna of the Ythan Estuary. In: The Estuarine Environment. Barnes R.S.K. and Green J. (eds). Applied Science, London, 1972.- P. 86-106.
Nastenko E.V., Polischuk L.N. The comb jelly *Beroe* (Ctenophora: Beroidea) in the Black Sea. Dopovidy Natoinal. Academy of Sciences of Ukraine, 1999, 11.- P. 159-161.
Neumann G. Die absolute Topographie des Physicalischen Meeresniveaus und die Oberflächenströmungen des Schwarzen Meeres. Ann. Hydr. Marit. Meteorol., 1942, 70, 9.
Norse E.A. (Ed.) Global Marine Biological Diversity. A Strategy for Building Conservation into Decision Making. Washington D.C.: Island Press, 1993.- 383 pp.
Odum E.P. Fundamentals of Ecology. Third edition. Philadelphia.London.Toronto: W.B. Saunders Comp., 1971.- 574 pp.
Petranu A. (Comp.). Black Sea Biological Diversity. Romania. New York: United Nations Publications, 1997.- 314 p.p.
Polikarpov G.G. Ability of some Black Sea organisms to accumulate fission products. Science, 1961, **137**, № 3459. P. 1127-1128.
Polikarpov G.G. Radioecology of aquatic organisms (Ed. V. Schultz & Klement A.R. Jr.) North-Holland Publ. Comp. – Amsterdam, Reinhold Book Division – New York, 1966.- 314 pp.
Polikarpov G.G., Kulebakina L.G., Timoschuk V.I. *et al*. 90Sr and Cs-134 in surface water of the Dniper River, the Black Sea and Aegean Sea in 1987 and 1988. J. Environ. Radioactivity.- 1991.- No 13.- P. 25-38.
Radu D. Păsările din Delta Dunării. Bucureşti: Edit. Acad. Rep. Soc. România, 1979.- 190 pp.
Radu G., Nicolaev S., Anton E., Maximov V., Radu E. Preliminary data about the impact of fishing gears on the dolphins from the Black Sea Romanian Waters. In: Öztürk and Karakulak (Eds.). Workshop on Demersal Resources in the Black Sea and Azov Sea. Publ. by Turkish Marine Research Foundation, Istanbul, 2003, 14, P. 115-129.
Ramsey W.L. Dissolved oxygen in shallow water and its relation to possible bubble formation. Limnol. And Oceanogr., 1962, 7.- P. 453-461.
Sholten S. Role of the Bosporus in Black Sea Chemistry and Sedimentation. The Black Sea – Geology, Chemistry and Biology. Edited by E.T. Degens and D.A. Ross. Publ. by The American Association of Petroleum Geologists. Tulsa, Oklahoma, USA, 1974.- P. 115-132.
Sieburth J.McN. Microbial Seascapes. A Pictorial Essay on Marine Microorganisms and Their Environments. Baltimore, London, Tokyo: University Park Press, 1975.- 248 pp.
Strategic Action Plan for the Rehabilitation and Protection of the Black Sea, Istanbul, Turkey, 31 October 1996.- 29 pp.

Tonay A.M. and Öztürk B. Cetacean bycatch – turbot fisheries interaction in the Western Black Sea. In: Öztürk and Karakulak (Eds.). Workshop on Demersal Resources in the Black Sea and Azov Sea. Publ. by Turkish Marine Research Foundation, Istanbul, 2003, 14, P. 115-129.
Tsyban A.V. Marine Bacterioneuston. Journ. of the Oceanogr. Soc. of Japan, **27**, 1971, № 2.- P. 56-65.
Tucker D.W. A new solution to the Atlantic eel problem. Nature, London, 1959, **183**, № 4660.- P. 495-501.
Wilson A.M. and Moser M.E. Conservation of Black Sea Wetlands: a review and preliminary action plan. International Waterfowl and Wetlands Research Bureau Publication, 1994, 33.- 76 pp.
Zaitsev Yu.P. Contourobionts in Ocean Monitoring. Environmental Monitoring and Assessment. D. Reidel Publishing Company, 1986, 7.- P. 31-38.
Zaitsev Yu. Littoral concentration of life in the black se area and coastal management requirements. Journ. of the Black Sea/Mediterranean Environment, 2006, 12, #2.- P. 113-128.
Zaitsev Yu.P. and Alexandrov B.G. (comp.) Black Sea Biological Diversity. Ukraine. New York: United Nations Publications, 1998.- 351 pp.
Zaitsev and Mamaev, Marine Biological Diversity in the Black Sea. A Study of Change and Decline. New York: United Nations Publications, 1997.- XV+208 pp.
Zaitsev Yu. and Öztürk B. (Eds) Exotic Species in the Aegean, Marmara, Black, Azov and Caspian Seas. Istanbul: Turkish Marine Research Foundation, 2001.- 267 pp.

ANNEX

Chronology of some milestones in the history of the Black Sea ecological research*
* Data on ecology of the Black Sea organisms and their communities could also be found in other publications which are not mentioned below.

1725 – Italian scientist, count Luigi Ferdinando Marsigli, wrote «The Physical History of the Sea» in which he described the current's system in the Bosporus measured by means of special equipment.

1885 – In the work «About the water exchange between the Black and the Mediterranean Seas», the Russian admiral S.O. Makarov states the most complete conception at his time about the two currents studied by him in the Bosporus. His studies and measurements were carried out in 1881–1882 from the vessel «Taman». Knowledge of the currents' system in the channel is important for understanding the natural exchange mechanism of water masses and living organisms between the Black and the Mediterranean Seas.

1890 – Expedition on the gunboat «Chernomorets» (head I.B. Shpindler, geologist N.I. Andrusov) for the first time discovers the hydrogen sulphide in the deep waters of the Black Sea at the depth of 170–200 m.

1891 – Expeditions on the gunboats «Donets» and «Zaporozhets» with participation of A.A. Lebedintsev, A.A. Ostroumov, B.B. Markovnikov, N.D. Zelinsky confirms the results of expedition held in 1890, registering the hydrogen sulphide at the depths of 125 – 200 m.

1909 – S.A. Zernov on the trawler «Fedya» discovers a large accumulation of the red algae *Phyllophora* in the northwestern part of the Black Sea at the depths of 34-60 m. Afterwards this area was named «Zernov's *Phyllophora* Field».

1913 – In his book «To the problem of life study in the Black Sea» S.A. Zernov gives the first description of the bottom biocoenoses in the Black Sea.

1926 – V.I. Vernadsky formulates his views on the biological structure of the ocean and mentions that the borders of its interface with an atmosphere, coast and bottom are of primary importance.

1926 – A. Zagorovsky and D. Rubinshtein publish the first description of the biocoenoses in the Odessa Gulf.

1926 – In the article «About the origin of hydrogen sulphide in the Black Sea» P.T. Danilchenko and N I. Chigirin publish for the first time the results of their research on the theme.

1929 – In the chapter «The Black Sea» of the book «The Crimea», I.I. Puzanov gives characteristics of the major biocenoses of the Black Sea and discusses the conditions of their development.

1934 – First finding of the Chinese mitten crab *Eriocheir sinensis* in the Black Sea (publication of G.D. Vasiliu). Later on, this exotic species was not registered until the 1990s when it was again found not only in the Black Sea, but also in the Sea of Azov.

1934–1939 – Studies of the fouling of the sunken vessels conducted by S.B. Grinbart confirm the ability of the Black Sea mass species of invertebrates to inhabit and to develop successfully on artificial substrata.

1935 – First publication on the ichtyoplankton of the Black Sea (V.A. Vodyanitsky).

1937 – First discovery in the Black Sea of the white-fingered crab *Rhithropanopeus harrisi tridentata*, originating from the North Atlantic coastal waters (A.C. Makarov). Afterwards this exotic crab became the mass species in the bottom fauna of the Black, Azov and Caspian Seas and an additional food source for the benthic fish.

1941 – The analytical article «On the problem of the biological productivity of the Black Sea» V.A. Vodyanitsky opens a long-term discussion on the biological productivity of seas and oceans.

1942 – Publication of the first generalized map of the surface currents in the Black Sea (G. Neumann, Ann. Hydr. Marit. Meteorol.).

1946 – First discovery in the Black Sea of the exotic gastropod *Rapana thomasiana* (E.I. Drapkin). Afterwards *Rapana* has spread widely in the Black Sea, entered the Sea of Marmara and the Mediterranean Sea, caused damage to the banks of oysters, mussels and other bivalves and also turned into a commercial species.

1948 – In his article «Filtration activity and feeding of the Black Sea mussels», G.N. Mironov gives the first quantitative estimation of the mussels as filtering organisms.

1949 – In his book «The Life of the Black Sea», A.V. Krotov reports that one million of dolphins inhabiting the Black Sea consumes annually up to 300 thousand tons of fish, which is almost three times more than that catched by all the Black Sea countries.

1949 – Z.A. Vinogradova launches the studies of chemical (biochemical) composition of the Black Sea organisms and its changes depending on the environmental conditions.

1954 – In his publication «About some changes of marine organisms getting into the salt limans», I.I. Puzanov analyses the morphological changes (plastic and meristic characteristics) of the mass species of the Black Sea invertebrates and fish in a number of coastal limans and lagoons in the north-western part of the Black Sea.

1955–1957 – The specific density (buoyancy) of pelagic eggs of the different species of the Black Sea fish was experimentally estimated (Yu.P. Zaitsev) for the first time. In accordance with this characteristic, the eggs are developing in different water layers. The eggs of the grey mullets have the smallest specific density and correspondingly the highest buoyancy. The studies of the eggs of grey mullets in the sea, with the help of the semisubmerged nets of special construction, resulted in the discovery of the neuston community in the Black Sea.

1960 – First publication on the discovery of the marine neuston in the Black Sea (Yu.P. Zaitsev). Previously the possibility of development of neustonic life in the sea was denied.

1963 – In the monograph «Biology of the Seas of the USSR» by L.A. Zenkevich, for the fist time was given the generalized description of plankton, benthos, fish, mammals and productivity of the Black Sea.

1964 – Detailed data on the biology and ecology of all fish species of the Black Sea are given in the monograph «Fish of the Black Sea» by A.N. Svetovidov.

1964 – Publication of the monograph «Radioecology of marine organisms» by G.G. Polikarpov was the first systematic exposition of the concepts and problems of radioecology of marine organisms with the data on the radioecology of plant and animal species of the Black Sea.

1966 – First discovery in the Black Sea, of the exotic mollusk the soft-shelled clam, *Mya arenaria* (L.E. Beshevli and V.A. Kolyagin). Afterwards this species has spread throughout the Black, Azov and Caspian Seas.

1966 – Developing the ideas of V.I. Vernadsky, K.A. Vinogradov pays attention to the biological importance of the «contact» (marginal) zones of the Black Sea, i.e., the zones of its contact with the atmosphere, coast and rivers.

1967 – In his article «Mediterranization of the Black Sea fauna and future trends of its intensification» I.I. Pusanov noted the fact of strengthening of the influx into the Black Sea of Mediterranean origin species.

1967 – Publication of the collective monograph «Biology of the north-western part of the Black Sea» (edited by K.A. Vinogradov) with description of abiotic conditions of the aquatic environment, plankton, neuston, benthos, fish, marine mammals, and bottom biocoenosis of the main shelf of the Black Sea. It was published shortly before the beginning of the deep changes in ecology of this zone of the sea and this information is widely used for estimation of the changes that took place in the ecosystem later on.

1969 – The key role of neustonic communoty in the marine ecosystem is proved in the work of G.G. Polikarpov and Yu.P. Zaitsev «Horizons and strategy of scientific research in marine biology».

1970 – In the monograph «Marine Neustonology» by Yu.P. Zaitsev for the first time presented full information about the marine neuston and its importance for the marine ecosystem, the methods of its study and the main results are discussed.

1970 – In the monograph «Bacterioneuston and bacterioplankton of the shelf zone of the Black Sea» by A.V. Tsiban the first generalized information on bacterioneuston of the Black Sea is presented.

1970 – The conception of distribution of the brackish water zones and rivers' «hydrofronts» in the Black Sea is given in the book of V.S. Bolshakov «Transformation of river waters in the Black Sea».

1970s – Beginning of the wide application of scientific submersibles for conduction of visual observations in the Black Sea. This method has allowed to specify and to complete information about the distribution and behavioral reactions of marine organisms and their biocoenoses inhabiting the water column and the bottom.

1971 – In the monograph «Ecological metabolism in the sea» by K.M. Khailov for the first time are summarized data on the inter-organisms exchange of the plants and animals external metabolites which are dissolved in the water. In particular, it is shown that the amount of the dissolved organic substances sharply increases at the surfaces.

1971 – The Academy of Sciences of Romania publishes the well-grounded book: «Studies of the Black Sea benthos ecology. Quantitative, qualitative and comparative study of the bottom fauna» (authors: M. C. Băcescu, G.I. Mьller, M.-T. Gomoiu).

1971 – Using the mathematical design methods, the expected changes of the hydrology and hydrochemistry of the Black Sea as a result of the rivers' regulated flow are calculated (K.A. Vinogradov, D.M. Tolmazin).

1973 – Research expedition of the Odessa Branch of the Institute of Biology of Southern Seas on the r/v «Miklukho-Maklay» for the first time in the Black Sea (on the north-western shelf) noted a mass mortality of the bottom animals, caused by the deficiency of oxygen in the near-bottom water layer at the depths of 10–20 m and within the area of 3500 km^2.

1974 – Publication of the monograph of V.V. Khlebovich «Critical salinity of the biological processes» with numerous examples of reaction of the Black Sea organisms and their communities towards the salinity.

1976 – The first report in scientific publications about the negative ecological consequences of the man-made impact on the Black Sea: eutrophication, algal «blooms», bottom hypoxia, mass mortality of bottom organisms and other. (Yu.P. Zaitsev).

1978 – Publication of the collective monograph of the Bulgarian scientists «The Black Sea» (authors A. Valkanov, T. Marinov, V. Petrova *et al.*) with the statement of the problems of the Black Sea ecology.

1979 – Publication of the international collective monograph «Fundamentals of the Black Sea biological productivity » (edited by V. N. Greze).

1979 – D.A. Nesterova noted the sharp increase of the numbers and biomass of planktonic peridineans which causes the «red tides» in the north-western part of the Black Sea.

1979 – In the monograph «Ocean. Active surfaces and life» by T. A. Aizatullin, V.L. Lebedev, K. M. Khailov the physical, chemical and biological processes at the ocean surfaces which are the place of organisms concentration, active transformation of matter and energy are discussed. Developing the ideas of V.I. Vernadskiy, the authors arrive at a conclusion about the «obvious signs of the forthcoming revolution in oceanology».

1982 – Publication of the monograph of Yu.I. Sorokin «The Black Sea: nature and resources». The author gives the detailed characteristic of the Black Sea ecosystem (mainly for the open waters), its structure and functioning.

1982 – Information about revealing of the first single specimens of the exotic comb-jelly *Mnemiopsis leidyi* in the Black Sea (M.V. Pereladov).

1983 – The sharp increasing (in dozen and hundred times) since 1974–1975 of numbers and biomass of phytoplankton, mainly small-celled forms, is noted in the north-western part of the Black Sea (D.A. Nesterova).

1984 – Visual observations on the ecological state of the «Zernov's *Phyllophora* field» and other areas of the north-western shelf are carried out from the scientific submersible «Argus» based on the r/v «Vityaz» (Yu.P. Zaitsev).

1985 – Developing the conceptions of V.I. Vernadsky about the life concentration in the interfaces and the ideas of C.A. Vinogradov about the contact zones, Yu.P. Zaitsev pays attention on the promising line of research activities in the marine contour biotopes. The following terms were proposed: «aerocontour» for the upper layer of water 0–5 cm; «lithocontour» and «psammocontour» for rocky and sandy biotopes of the sea (1–3 m from the water line); «potamocontour» for rivers' hydrofronts (1–5 m). These biotopes are inhabited by the organisms-contourbionts, mainly by the early stages of development and are subjected to a strong impact of external factors, including of man-made origin.

1985 – Results of comprehensive studies of the species diversity of phytoplankton as an indicator of man-made eutrophication in Romanian coastal waters are presented (P.-E. Mihnea).

1985 – The detailed analytical review of publications on anthropogenic eutrophication in the Black Sea and other seas is done by M.-T. Gomoiu, Romania.

1986 – Publication of the monograph «Ecomorphology» by Yu.G. Aleev. For the first time the author formulates the object, aims and tasks of a new field of biology – ecomorphology and summarizes the theory of living forms (ecomorphs) in aquatic and terrestrial environments. Many examples of morphoecological systems of the Black Sea organisms are given.

1989 – The total biomass of the exotic comb jelly *Mnemiopsis leidyi* in the Black Sea reaches up to one billion tons. This alien species actively begins to affect the food resources of fish, most of all of anchovy (M.E. Vinogradov *et al*.).

1989 – In the monograph «Productivity of the Black Sea fish» (G.E. Shulman and S.Yu. Urdenko) are considered the eco-physiological aspects of productivity of the six mass species of Black Sea fishes: anchovy, sprat, horse-mackerel, red mullet, pickerel and whiting. The influence of fisheries on the stocks of these fish in the Black Sea is discussed.

1990 – Review of the modern state of zoobenthos of the Bulgarian sector of the Black Sea is given by T. M. Marinov.

1990 – Review of publications on the physical oceanography of the Bosporus and Dardanelles straits is given by Unluata *et al*.

1990 – The reactions of four mass species of the Black Sea mollusks of the Mytilidae family on anthropogenic changes in the aquatic biotopes are discussed in the monograph «Mytilidae of the Black Sea» (edited by V.E. Zaika).

1991 – Measurements of chlorophyll values at the sea surface from the board of research vessels and from the space showed that, on to this criterion, the Black Sea occupies the first place among all seas of the Mediterranean basin (Yu.P. Zaitsev).

1992 – The monograph «Interstitial meiofauna of the sandy beaches of the Black Sea» (authors:

L.V. Vorobyova, Yu.P. Zaitsev, I.I. Kulakova) summarizes data on the recent state and changes of the psammocontour community.

1992 –In the monograph «Molismology of the Black Sea» (edited by G.G. Polikarpov), data on the Black Sea pollution are detailed analyzed and summarized.

1992 – On the basis of the published data, the conclusion is drawn about the critical state of the Black Sea ecosystem and the necessity of international concerted actions for studying and solving of these problems (L.D. Mee).

1992 – Analytic review of publications on phytoplankton «blooms» in the Romanian part of the Black Sea is given by N. Bodeanu.

1992 – First estimation of the ecological state of the shelf zone of the Black Sea on the Ukrainian coasts is presented (Yu.P. Zaitsev).

1993–1998 – Comprehensive studies on the Black Sea ecology are carried out within the framework of the Black Sea Environmental Programme of the Global Environment Facility (coordinator: L.D. Mee).

1993 – Estimation of the state of the benthic fauna in the Bulgarian sector of the Black Sea is given by Ts. Konsoulova.

1994 – Studies on the changes in composition and stocks of the commercial fish in the Romanian sector of the Black Sea that took place during the last decade are presented (S. Nicolaev *et al*.).

1995 – It is concluded that, as a result of pollution, the Bosporus Strait has turned into a closed corridor for the fish and marine mammals migrations (B. Öztürk).

1995 – First meeting of an UN group of experts (GESAMP) on the problem of exotic species and of the combjelly *Mnemiopsis leidyi* in the Black Sea takes place in Geneva (Switzerland).

1996 – It is concluded that the species of exotic mollusks, accidentally introduced into the Black Sea have caused substantial changes of its ecosystem (V. Zolotarev).

1996–1998 – Research in the north-western part of the Black Sea, zones affected by the runoff of the Danube, Dniester and Dnieper rivers was carried within the framework of the European Union Project EROS (European River-Ocean System Project). Coordinators: J-M. Martin and C. Lancelot.

1996 – The Transboundary Diagnostic Analysis is carried out within the framework of the Black Sea Ecological Program. In this document were summarized the data on the state of the Black Sea ecosystem and have been stated the necessity to protect it by concerted efforts at an international level (Coordinator L.D. Mee).

1996 – The Strategic Action Plan for the Rehabilitation and Protection of the Black Sea was signed in Istanbul, Turkey by the Ministers of the Environment of Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine.

1996–2000 – The reactions of the Black Sea macrophytic algae to the eutrophication are analized in the publications of G.G. Minicheva. The possibility to use the surface characteristics of algal thallomes for estimation of the state of the coastal ecosystem has been grounded.

1997–1998 – The National Reports on biological diversity of the Black Sea national sectors were published by the United Nations Publications (New York, USA). Compilers are: A. Konsulov (Bulgaria), A. Komakhidze and N. Mazmanidi (Georgia), A. Petranu (Romania), B. Öztürk (Turkey), Yu.P. Zaitsev and B.G. Alexandrov (Ukraine). In these documents are marked the changes on the specific and biocoenotic levels caused by man-made factors.

1997 – The book «Marine Biological Diversity in the Black Sea. A Study of Change and Decline» by Yu. Zaitsev and V. Mamaev was published by the United Nations Publications (New York).

1998 – The main ecological problems of the Black Sea, their reasons and paths of their solving are presented in the book «The most blue in the world» by Yu. Zaitsev (United Nations Publications New York).

1998 – The book «Black Sea Pollution Assessment» edited by L.D. Mee and G. Topping (United Nations Publications New York) summarizes the results of the research activities of specialists from 14 countries and international organizations.

1999 – Publication of the first Black Sea Red Data Book, edited by H. Dumont, V. Mamaev, scientific coordinator: Yu.P. Zaitsev (United Nations Office for Project Services, New York). More than 70% of the species of invertebrates registered in the Red Data Book belong to the inhabitants of contour communities.

1999 – In the monograph «Meiobenthos of the Ukrainian Shelf of the Black and Azov Seas», L.V. Vorobyova summarizes for the first time the data on meiobenthos of the Ponto-Azov basin and shows the mechanisms of its anthropogenic successions.

1999–2002 – In the publications of B.G. Alexandrov are summarized data, possibilities and methods of management of the ecological state of the Black Sea coastal ecosystems with the help of artificial reefs.

2000 – In the publications of N.G. Sergeeva are given data about findings of some oxybioyic organisms (but not living forms) in the hydrogen sulphide zone of the Black Sea.

2000 – Publication of the monograph «Combjelly *Mnemiopsis leidyi* (A. Agassiz) in the Azov and the Black Seas: biological consequences of introduction» (edited by S.P. Volovik).

2001 – In the book «Exotic species in the Aegean, Marmara, Black, Azov and Caspian Seas» (Eds. Yu. Zaitsev and B. Öztürk) a comparative estimation is given about the man-made change in the biological diversity of the five interconnected seas by accidental or intentional introduction of exotic species.

2001 – The results of the long-term research of changes of the marginal communities of the Odessa Gulf, one of the most studied areas of the Black Sea, are summarized by the Odessa Branch of the Institute of Biology of Southern Seas.

2002 – Publication of the first issue of the Marine Ecological Journal (Chief editor V.N. Eremeev) of the National Academy of Sciences of Ukraine and the Institute of Biology of Southern Seas. The journal publishes the results of the theoretical and experimental researches in marine ecology.

2002 – Publication of the review article «Ecological processes in the critical zones of the Black Sea: synthesis of results of the two lines of research from the middle of the XXth until the beginning of the XXIst century» (Yu.P. Zaitsev and G.G. Polikarpov).

2003 – Publication of the monograph «Free-living Cyclopoid copepods of the Ponto-Caspian Basin» by V.I. Monchenko with the information on ecology of this vast group inhabiting the Black Sea and its coastal wetlands.

2003 – The collective monograph «Modern state of biodiversity of the Crimean coastal waters (Black Sea sector)» (edited by V.N. Eremeev and A.V. Gaevskaya) presents new data about the specific and biocoenotic diversity as a result of changes in the marine environment and under the influence of the man-made impact.

2003 – In the book «The Black Sea rivers» by Sh. Dzhaoshvily (Georgia) are quantitatively estimated the runoff of the main Black Sea rivers and their sediment loads.

2003 – In the monograph «Parasitic organisms as a component of the ecosystem of the Crimean coast of the Black Sea» by A.V. Gaevskaya and Yu.M. Korniychuk is grounded the necessity to consider the parasitofauna during estimation of the state of the Black Sea ecosystem.

2003 – The book «Sanitary and biological aspects of ecology of the Sevastopol Bays in the XXth century» (authors: O.G. Mironov, L.N. Kirukhina, C.V. Alemov) presents data about the long-term changes in the ecosystem of one of the most investigated coastal areas of the Black Sea.

2003–2004 – Research investigations within the framework of the UNDP-GEF Black Sea Ecosystem Recovery Project (coordinator P. J. Reynolds).

2004 – Publication of the first issue of the International Journal of the Black Sea/Mediterranean Environment. Editor: K.C. Guven (Istanbul University).

2006 – In the collective monograph «The Northwestern part of the Black Sea: Biology and Ecology» (Eds Yu.P. Zaitsev, B.G. Alexandrov, G.G. Minicheva) the main change in the ecosystem of the largest Black Sea shelf occurred during 1967– 2003 are analysed and summarized.

2006 – First Generalized Matrix of expert assessment of ecological conflicts provoked by the man-made impact in the Black Sea coastal zone is published (Yu. Zaitsev).
2007 – For the first time, the living cultures of aerobic species of fungi and diatoms from the spores collected in the bottom sediments in the anaerobic and hydrogen sulphide zone of the Black Sea at the depths of 800–2100 m were obtained (Yu. P. Zaitsev, G. G. Polikarov *et al*.).

ABOUT THE AUTHOR

Yuvenaly P. ZAITSEV, chief scientist of the Odessa Branch of the Institute of Biology of Southern Seas, National Academy of Sciences of Ukraine. He graduated from the I.I Metchnikov Odessa State University (1949) and obtained his PhD (1956) and Doctor of Biological Sciences (1965) from the same University. Professor of Hydrobiology (1968), Full member (Academician) of the National Academy of Sciences of Ukraine (1997). His main research interests are in marine biology and ecology, in particular contour (marginal) habitats and communities. He has discovered the marine neuston, community of organisms, inhabiting the surface microlayer and formulated the fundamentals of a new field of ecology: marine neustonology. He has carried research work in the Black, Azov, Caspian, Baltic, Mediterranean and Caribbean Seas, in some areas of the Atlantic and Pacific Oceans. He has short teaching periods in the universities of Ukraine, Japan, Turkey, and the USA. As an internationally recognized expert in marine biology and ecology he takes part in the work of different commissions, including UN GESAMP Group. He is a member of several societies concerned with the marine environment and published more than 300 scientific papers in 20 countries and several books on environmental education for young people, such as «Through the Glass of Undersea Mask» (1974), «This Amazing Sea» (1978), «Your Friend, the Sea» (1982), «The World of Delta» (1989).