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Afterword
Foreword

This small book was planned, and partially written, by a remarkable man: Borys Aleksandrov, who I was privileged to call a friend and colleague for the previous 32 years. Borys Aleksandrov was a unique person, a true scientist, and a wonderful and multifaceted researcher, with interests spanning all of the various subfields of the marine sciences. Borys knew every aspect of marine biology, down to the minutest detail. He dreamt of becoming a scientist since his childhood, and realised his dream according to the canons of classical marine biology, with alacrity and his unique charm.

All of his scientific works – books, articles, and speeches – stand out for their thoroughness, grounded in deep knowledge and on the analyses of great amounts of data. It was both his vocation and his avocation, and he fully devoted himself to the field with endless enthusiasm.

Borys Aleksandrov regrettably passed away earlier last year. Along with his teacher Yuvenaly Zaitsev, who passed away one month after Borys’s death, both scientists were active popularisers of science and lucidly explained the complicated natural processes and phenomena which take place in the Black Sea, in a way understandable to everyone. Thanks to these two concerned people, a significant number of high-quality television programmes, visual materials, and publications about the Black Sea appeared throughout the countries of the Black Sea basin. The merits of Borys Aleksandrov and Yuvenaly Zaitsev in the education of the general public cannot be overemphasised.

This book is another proof of Borys Aleksandrov’s talent. Many people explored the Black Sea, many of them described interesting facts and unexpected phenomena, but Borys managed to do it in such an engrossing way that it becomes impossible to tear oneself away from his stories. His friends and colleagues supplemented and finished the work he left behind, but his absence is keenly felt.

It is painful to acknowledge that the Black Sea has lost two of its greatest defenders and researchers in Y. Zaitsev and B. Aleksandrov. They were both titans in their field, devoted to their work and translating their ideas into real-world changes. Let this book be in honour of these two; let it help reveal some of the secrets of the amazing Black Sea and let it encourage new generations to explore and protect it.

Vladimir Mamaev,
United Nations Development Program

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This book was the last planned publication of Borys Georgievich Aleksandrov. It was finalised by the efforts of his colleagues and companions with the institutional and financial support of the European Union and UNDP project ‘Improving Environmental Monitoring in the Black Sea: selected measures’ (EMBLAS-Plus). Borys Aleksandrov had been acting as the leader and principal partner of this project in the field of marine community monitoring for many years.

This book is intended for a wide range of readers who may be interested in how the Black Sea functions and how it is possible, often just by observing underneath the waves, to find out about the intriguing world the Black Sea hides under its eponymous opacity.
Short stories, which are superficially unconnected to each other, reveal interesting facts about Black Sea life; like pieces of a mosaic which cohere into a single united picture, telling us the secrets of our blue planet.

Galina Minicheva,
The Institute of Marine Biology of the National Academy of Science of Ukraine


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1. Is the Black Sea the youngest sea in the world?

It is sometimes said that the Black Sea is one of the youngest seas on our planet. Only an estimated 5,000-7,000 years separates us from the era when the Bosphorus Strait opened, allowing the Black Sea to merge with the Mediterranean and acquire its current coastline. But if we analyse the structure of its flora and fauna, it will become obvious that the Black Sea is much older, as it is inhabited by numerous ancient species, many of which cannot be found anywhere else. Geologists agree with biologists on the following: while the maximum depth of the Black Sea is 2212 m, the thickness of soft sediment deposits up to basaltic rocks is 16 km. It would take over one million years for such thick sedimentations to be formed. How can these seemingly contradictory facts be reconciled?

For a very long time, from 250 to 40 million years ago (i.e., from the Jurassic period of the Mesozoic era to the Neogene), the Atlantic and the Pacific Oceans were connected by the Tethys Ocean, a part of which was comprised of the modern Black Sea. As the result of the continents’ movement and the formation of mountain systems at the time of the Alpine orogeny, the Tethys Ocean was divided into several sea basins which intermittently joined and separated from the Atlantic Ocean. Prior to acquiring its modern form, the Black Sea was a highly desalinated water body four separate times, and was a part of salinated seawaters three separate times. The second-to-last time the future Black Sea was connected to the Atlantic Ocean through the Mediterranean Sea was during the Riss-Würm Interglacial, 150,000-100,000 years ago, when the Strait of the Dardanelles appeared. Subsequently, there was another freshwater period: the Neoeuxinian lake-sea; 5,000-7,000 years ago this lake-sea connected to the Mediterranean Sea through the Bosphorus Strait, probably as the result of an earthquake. The isthmus between the Bosphorus’ banks functioned as a natural dam, because the water level in the Neoeuxinian Sea was lower than that of the Mediterranean Sea. After the breakage of that natural dam, giant waves gushed into the Black Sea, whose coast was densely populated at the time. Some historians believe that the failure of the Bosphorus natural dam and rapid rise of the Black Sea waters served as the prototype for the Genesis flood narrative described in the Bible.

As a result of its complicated geological history, Black Sea inhabitants are divided into several groups of different origin:

- **Boreal-Atlantic or Celtic relics:** <1% - cold-water species e.g. red alga phyllophora, sprat, whiting, the European flounder, Black Sea salmon, harbour porpoise, calanus etc.; all of them got into the future Black Sea (at that time – the Karangatian sea) during the Riss-Würm Interglacial period.
- **Ponto-Caspian relics:** approximately 9.6% of species are endemic to the Black, Azov and Caspian Seas, and originated at the time of maximal desalination of the Sarmat and Pontian lake-seas; along with a number of mollusks (zebra mussel), polychaetes (hypania) and crustaceans (pontogammarus) preserved in the majority of the Black Sea estuaries. This group also includes sturgeons, round goby, and their relatives. After the breakage of the Bosphorus dam, these relics retreated to the deltas, estuaries, and freshwater parts of the sea;
- **Freshwater species withstanding** the Black Sea’s 3% salinity: about 10% of the total species composition – these are blue-green and some green algae (cladophora, ulothrix), almost all species of rotifers, oligochaetes, leeches etc.; the fish belonging
to this group are perch and pike that often go far into the sea from the Danube and the Dnieper-Bug estuary.

**Species of Mediterranean origin:** about 80% of flora and fauna, most of which penetrated after the last connection of the Black Sea to the Mediterranean; brown algae (*Cystoseira barbata*), mussels, oysters, all species of crabs, seahorse, mullets, horse mackerel, garfish, anchovy, the Black Sea turbot, dogfish, rays: common stingray and thornback ray, common and bottlenose dolphins and many others.

Ergo, the Black Sea is not in actuality our youngest sea; it is an ancient sea which traces its history back to the Mesozoic era and to the great Tethys Ocean that vanished.
2. Why is the Black Sea called ‘black’?

Roman geographer Pomponius Mela was the author of the first geography to offer written evidence of the Black Sea’s name, with an origin in the 1st century ACE. He wrote that at first Greek travellers called the Black Sea ‘Scythian’, but after numerous clashes with local populations they began to call it ‘In hospitable’ or in Greek Pontos Axeinos (Pont means ‘sea’ in Greek). Along with storms and overpowering fogs, the Greeks faced a belligerent local population along the Black Sea’s coasts. It is not by chance that the temple for Achilles Pontarch (‘Pontarch’- the patron of the sea) was built on Snake Island, along the routes plied by early Greek sailors. This became the place where early voyagers made sacrifices to their gods, asking for safe passage in their journeys and protection from hostile local residents such as the Scythians and Taurians. This ominous nomenclature was eventually euphemised to Euxine, which means ‘hospitable sea’, after the Milesians colonised the southern shoreline of the Black Sea, and folded it into Greek civilisation.

Thus, the earliest credible etymology is connected with the assumption that the word ‘black’ in the name of the sea relates to something negative and sinister. Alternate etymologies are a product of guesswork and surmise. For example, there is a suggestion that the sea was called ‘black’ because of oxidation of metals with hydrogen sulphide, which was only discovered in 1865—much later than the Sea’s name originated. There has also been conjecture that the sea was called ‘Black’ due to its depth, which made the waters look dark. However, it should be noted that the Greeks, the Bulgarians, and the Turks all called the Aegean Sea and the wider Mediterranean Sea ‘white’, even though those seas were no less deep than the Black Sea. In Kerch, on the Crimean peninsula, fish of Mediterranean origins (e.g. mackerel or horse mackerel), were known as ‘white fish’, insofar as they are fish from the White Sea. As such, it is likeliest that the Black Sea received its name from ancient Greeks.

The ability for emotions to colour our perceptions is borne out in the famous Neapolitan hit ‘O Sole Mio’, glorifying the sunrise, which was written by Eduardo di Capua when he was visiting Odesa on the Black Sea coast. Here, unlike in his native Gulf of Naples, the sun rises over the sea, and whilst admiring the sun’s rays playing on the water surface, the author wrote his Black Sea-inspired paean to the sun.
3. Why does the temperature vary so much at different depths of the Black Sea?

The Black Sea can be compared to a layer cake, every layer of which is made of different batter. The temperature of deep layers of the sea is +8-9 °C year round, but from the water surface to the depth of 50 m temperatures can change rapidly and significantly. Contiguous with the deepest layer, the cold intermediate layer is located between two different water masses. Here, the water is cooler than on the surface, with a temperature always between +5-8 °C. Cold intermediate layers are also found in other parts of the world’s oceans, but generally only in certain seasons, whereas the Black Sea’s cold intermediate layer is perennial. At a depth of 500 m, the temperature is +8.9 °C, and is nearly uniform (changing by only 0.2 °C all the way to the bottom (more than 2200 m). But in contrast with the rest of the world’s oceans, temperatures rise at the very lowest layer, to +9.1 °C. It is assumed that the reason for this phenomenon is heat flowing through the earth’s crust, coupled with low water exchange in the Black Sea basin.

So, what is the secret of the Black Sea ‘layer cake’? Water comes to the Black Sea from two sources: from the Sea of Marmara through the Bosphorus, and from rivers. The water of the Bosphorus is much saltier – and accordingly denser – compared to Black Sea water and especially in comparison with fresh water. Heavy water masses from the Bosphorus Strait run down the continental slope to the bottom, whilst fresh water spreads over the surface. The density of fresh water further depends on temperature: the warmer it is, the less dense are the waters. In winter as the water cools, it becomes heavier and descends, whilst in summer the surface water heats up and – being warm and light – ‘rests’ on cooler and denser layers. Mixing occurs only within the desalinated surface layer; below this lie the saltier and denser Bosphorus waters, which form an insuperable barrier - a sort of ‘liquid bottom’. But the change of water properties according to depth is uneven: from the surface up to the depth of 50-100 m the salinity changes rapidly – from 17% to 21%. Underneath these uppermost layers, salinity rises evenly to a maximum of 30 % (matching the salinity of the Sea of Marmara). This is how two different types of waters appear: the desalinated surface layer mainly of river origin and the saline ‘Bosphorus’ bottom layer.

A reader may have an erroneous impression that there is no exchange between the deep and the surface water masses. This would be a misapprehension. In the case of the Black Sea, the layers are indeed involved in water exchange, albeit not via its rapid variety
(which is implemented by means of mixing) but via the slower exchange which arises due to diffusion and to gradual displacement of upper waters by the lower ones. Concurrently, the replaced waters partially evaporate and partially run into the Marmara Sea – across the Bosphorus Strait surface over the heavy and saline current, which carries deep waters to the Black Sea. Thus, the two currents are divided like floors in a building and, opposed like counter escalators in the subway. As such, waters of the Black Sea gradually renew; the journey of a hypothetical water molecule en route from the Bosphorus to the sea bottom, and then onwards to the surface, would take approximately 400 years.

This illusion of an absolute separation between layers was almost responsible for an ecological disaster. In the 1960s, a plan to gather radioactive wastes from all the Soviet Union’s nuclear power plants – and for their disposal in the Black Sea – was developed. It was considered that radioactive materials would never surface, and would therefore be securely buried under the sea. Fortunately, scientists realised beforehand that all the waters of the Black Sea were inseparably connected, and therefore stopped the project, which would have killed the sea and transformed it into a giant, liquid Chornobyl’.
4. Is the Black Sea really more dead than alive?

The diversity of lifeforms in the Black Sea is concentrated in the oxygenated upper layer of water. Concurrently, almost 87% of the Black Sea water is anoxic. For the last 20 years, the hydrosulphuric layer has risen by 20-25 m, and now the anoxic zone starts at the depth of 90-160 m. The thickness of the upper oxygenated layer is unevenly distributed. There are a number of currents that flow along the continental slope and form western and eastern cyclonic circulations. In the course of EMBLAS project activities in 2016-2017, it was discovered that the lower limit of the oxygenated layer in the centres of these circulations rises by 54 m, forming so-called hydrosulphuric domes.

Hydrogen sulphide is formed through the process of the decomposition of plant and animal remains by sulphate-reducing microorganisms. The concentration of hydrogen sulphide in the sea water increases in proportion to pressure increases. The difference in salinity and density prevents the hydrosulphuric layer from extra mixing with oxygen – there is a transition zone between them, but it is quite thin (only 10-20 m) relative to the sea's total depth.

The anoxic zone is often called lifeless. Indeed, it is not very hospitable for fish, dolphins, and even invertebrates. But still the life found here is very diverse! Only two of the oldest branches of living creatures are able to survive there – bacteria and archaea. On the plus side, this zone became a kind of nature reserve for these organisms - nowhere on our planet can we found such quantities of anoxic water, which precisely replicate the living conditions that held sway during the earth's earliest eras, before plants began to photosynthesise and create our oxygen-based atmosphere. During the EMBLAS project, this 'natural reserve' was examined using metagenomic analysis (DNA reading of all microbes in a sample). It turned out that the Black Sea was inhabited by various bacteria and archaea species belonging to dozens of different genera, which were found in other places of the world's oceans only in very specific settlements, e.g. geothermal abruptions (i.e. geysers located in the zones of ocean ridges), Norway's closed fiords, and others. So, the Black Sea gives us a unique opportunity to look back into the distant past of the Earth, or to train before we explore other planets, most of which do not have oxygen-based atmospheres. Thus, although it is devoid of oxygen and permeated by hydrogen sulphide, the anoxic layer is more alive than dead, and absolutely unique.

However, this large anoxic 'natural reserve' is in contradistinction to dead zones in the worlds waters, which are also frequently anoxic, albeit due to processes like eutrophication or acidification. This phenomenon of localised fish die-offs is a real problem throughout the North-Western shelf. These die-offs take place as a result of algal blooms and eutrophication of water, i.e. excessive nitrogen and phosphorus run-off into water bodies. In the 1970s–1980s, fish kills covered an area of 70,000 square kilometres of sea surface. Nowadays, the scope of fish kills has decreased somewhat, but they are still far from rare. They can be detected from the seashore by the smell of hydrogen sulphide, a whitish colour in the water, and a concentration of dormant fish near the coast. As such, despite its anoxia, the Black Sea's life (or death) depends on us, and what we dump into it.
Oxygen Layer
- min = 54 m; max = 160 m

Hydrogen Sulphide
- \( \text{O}_2 \)
- \( \text{H}_2\text{S} \)

THE TRANSITION ZONE
- DETRITUS (Soil Organic Matter)
- ANAEROBIC BACTERIA SAPROTROPHES
- MINERAL SUBSTANCES

2210 m
5. Is it possible to set fire to the Black Sea?

The famous children’s writer Korney Chukovsky anticipated the answer to this question a year before the events connected to the ‘burning sea’. He wrote in his well-known poem ‘Confusion’ (1926): «...And the foxes took matches, went to the blue sea and set it on fire...». On September 11th, 1927 at 22:15 there was an 8-9 magnitude earthquake in Crimea. Many cities of the Southern coast were badly damaged. The frightened citizens dealing with the consequences of the disaster did not notice an extraordinary event, which happened in the sea. A huge fire line was observed from three lighthouses located on the western coast of the Black Sea 5.5 km away from the seashore between Sevastopol and Cape Lucull. This phenomenon was described at the time by a famous professor and geologist named Sergey Popov. It was assumed that the fire was a result of an inflammation of methane gas coming out of the cracks on the continental slope bottom at a depth of about 200 m. Unfortunately, the vessel sent to explore the phenomenon was immediately caught in a storm and stranded not far from Khersoness lighthouse.

The first report of the discovery of ‘cold seep’-type methane jet gas emissions (which differ from hot hydrothermal sources, or ‘smokers’) was published in 1976 as a result of studies across the Gulf of Mexico shelf near the USA. In the Black Sea, these cold seep emissions were detected in 1989. The discovery had great significance as a new chemooecological factor, involved in the origination of unusual varieties of life at the bottom of the sea, and also as an important indicator of gas deposits.

Methane gas emission areas are specific formations on the seafloor resembling volcanoes, not higher than half a metre and comprised of calcium carbonate. In the Black Sea, methane discharge takes place at depth, within the anoxic zone. Bacteria able to dispose methane for the creation of organic matter are discovered here. But nobody had yet succeeded in getting axenic (i.e. single species) cultures of these bacteria.

As it turned out, jet methane gas emissions in the Black Sea are widespread at different depths. In 2007, a new marine reserve ‘Methanogenic structures from Sfântu Gheorghe branch’ was established on the Romanian shelf in front of the Danube Delta. This reserve placed under protection the new biotype of methane emissions, including all the resulting unique organisms, composed of mostly unexplored species.

So, the answer to the question posed in the beginning may be affirmative. Sometimes even the sea can burn if it has methane deposits below the seafloor.
6. How does climate change threaten the Black Sea?

In Antiquity, from the VII -VI centuries BCE, average temperatures in the Northern Black Sea region were 1.5-2 °C lower than the present, and the climate was much damper. Concurrently, the Black Sea level was significantly lower compared to the present day; according to various estimates, by as many as 2-10 metres, which is why the coastline was more indented at that time. There are numerous examples of antique settlements that are now underwater, including the city of Olbia, the population of which was about 15,000.

Sea level rise has become a primary danger of global warming: firstly, glaciers are melted and thus add water to the world’s oceans, and secondly, water expands when heated. So, Odesa and other cities of the Black Sea basin could share the fate of drowned Olbia, though it may take a few thousand years.

However, against the background of the Black Sea level rise tendency, which is consistent with water level rise in the rest of the world’s oceans (0.1-0.2 cm/year), the Black Sea has its own water level fluctuation cycles. For example, from the end of the 1990s until 2015, the Black Sea level decreased by 1 cm on average. These changes are connected with global climate change, because the warmer the sea is, the more water evaporates from its surface. Moreover, the warmer and the more arid the year is, the less water comes to the sea from the rivers flowing into it. Nowadays, the rivers’ flow to the Black Sea is less than it was 100 years ago, because the majority of the volume of the Dnieper, Bug, Dniester, Danube rivers is used to irrigate the fields. With temperature rises, water consumption on land increases and its flow from upper rivers decreases. Thus, every year the Black Sea’s deficit of water to compensate for evaporation increases, and the waters become more saline. Such a salination (compounded by warming) makes the Black Sea more attractive and available for occupation by flora and fauna of the Mediterranean Sea. Every year, more and more Mediterranean species, such as eyelight fish, barracuda, and sea turtles push further into the Black Sea. This process is called ‘mediterranisation’, which means that the Black Sea becomes similar to the Mediterranean.

The heating of water in the shallow coastal regions can cause lower solubility of oxygen in water, which can give rise to areas of ‘dead water’, wherein the concentration of oxygen is too low for fish, crabs, and clams to breathe, they perish en masse, literally suffocating.

Further, climate change influences the hydrosulphuric layer of the Black Sea and is considered to be one of the main reasons for the progressive rise of anoxic layers towards the surface. For now, the mechanism of this influence has been scarcely investigated and scientists still cannot say for sure how exactly the warming determines the rise of the hydrogen sulphide level, and find it difficult to foretell the behaviour of this layer in future. Studies of this issue are one of the most urgent tasks in the field of Black Sea exploration.
7. How does the chemical composition of water affect sea life?

Different groups of chemicals can influence the lives and lifestyles of sea dwellers in markedly different ways. If industrial chemicals, petrochemicals, heavy metals, surfactants, pesticides, etc. get into the marine environment at concentrations over a certain limit, they can destroy marine flora and fauna, breaking the development and reproductive cycles of sea dwellers and putting them on the path to extinction. Within the framework of the EMBLAS project, water, bottom deposits, and living organisms were screened for more than 40,000 pollutants. More than 124 such pollutants were detected, including pesticides, fire retardants, sunscreen components, etc. The concentration of polybrominated ethers, chlorinated hydrocarbons (e.g. DDT), and chemical compounds like dioxins and mercury found in the tissues of dead dolphins was significantly high. Toxicity thresholds have been established for these compounds, and if thresholds are exceeded it may signal that the chemicals involved should be banned for industrial use, and/or that mitigation and prevention efforts (e.g. the sewage treatment system) should be improved.

The other group of chemicals detected includes various inorganic compounds of nitrogen (NO$_2$, NO$_3$, NH$_2$) and phosphorus (PO$_4$), which are termed ‘biogenic’ or ‘nutritive’, along with other organic matter. These groups are closely connected with natural phenomena and can affect sea dwellers either positively or negatively. The chemicals, as a rule, get into the sea via river flow and are able to stimulate high productivity in some cases. But if you make tea with twenty-two sugars instead of two, there will be consequences. That is why the problem of eutrophication (nutrient over-enrichment) is especially urgent for those Black Sea areas connected to river estuaries, e.g. within the north-western sector, where three large European rivers: the Danube, the Dniester and the Dnieper, flow into it. Agricultural runoff comprised of highly concentrated nitrogen and phosphorus cause algal blooms, which lead to fish kills when all the oxygen dissolved in water is spent on the oxidation of organic matter. For this reason, most hydrobionts, especially those that are unable to physically flee, will perish under these conditions. If the excessively concentrated biogenic substances get into the sea frequently, the sea’s entire ecosystem changes. Large perennial plants and animals – indicators of Good Environmental Status (GES), disappear. They are replaced by small, rapidly reproducing species, which form large homogeneous accumulations, but rendering the sea itself less attractive to other sea dwellers and the humans who depend on them. The highest level of eutrophication in the north-western portion of the Black Sea was observed from the end of the 1960s through to the beginning of the current century. Underwater kelp forests represented by perennial brown algae (*Cystoseira barbata*) were replaced by cotton-like accumulations of finely branched green algae. Valuable fish species such as mackerel (*Scomber scombrus*), horse mackerel (*Trachurus mediterraneus*), and bluefish (*Pomatomus saltatrix*) almost completely disappeared and were replaced by smaller and less valuable species: the European anchovy (*Engraulis encrasicolus*), sprat (*Sprattus sprattus*), and sand smelt (*Atherina spp*). According to EMBLAS project data, the recovery of plant and animal species – indicators of Good Environmental Status - has now begun. One example is the red agar-containing algae phyllophora (*Phyllophora crispa*), which form famous ‘fields’ throughout the north-western shelf. Crabs, shrimps, and seahorses can be observed again along the coasts, to the delight of coastal inhabitants.
8. Can it be too noisy in the sea?

The sound of the sea is familiar to all of us - the tender whisper of waves, sometimes followed by a crashing storm. Because sea depths are associated with silence, many presume that marine dwellers are themselves soundless. But with the use of a hydrophone – a device for listening to underwater sounds – it becomes clear that the catchphrase ‘silent as a fish’ is mistaken. It turned out that in fact, (some) fish are more talkative and clamorous than birds! After years of study, there is now a sizable knowledge base of the vocal stylings of marine dwellers, and they are very diverse – clicks, whistles, squeaks, and creaks, which can be of different pitches, volumes, and rhythms.

Of course, the most complicated systems of marine sound communication belong not to fish but to cetaceans – whales and dolphins. Cetaceans make noises in a range much wider than human ears are able to perceive. These noises fluctuate from ultrasound to infrasound and contain a lot of information. As scientists study the communication of cetaceans, the term ‘dialects’ is frequently used, because it was discovered that sound signals differ not only among species, but also among populations within a single species. Thus, the vocabulary and diction are not only inherited genetically, but also are transmitted from adults to juveniles, just as with human languages and dialects. In addition, toothed whales (the category that includes dolphins, porpoises, sperm whales, and beaked whales) use ultrasound for echolocation – i.e. high-pitched signals for spatial orientation and food searches. The toothed whales’ perception of the world is based on images created thanks to echolocation. As such, an auditory picture of the world is instinctive to them.

Because of the centrality of sound in marine life, marine dwellers suffer from artificial, human-made sounds (e.g. the underwater background noise of ships’ engines) even more than humans suffer from street and industrial noise. Take, say, a container ship, which is 300 m long: it can produce a noise of about 190 dB. Large tankers, 177 dB; fishing trawlers, 156 dB (by way of comparison, a jet engine is only about 150 dB). As such, areas of heavy sea traffic are characterised by constant underwater noise – similar to city streets and highways. The worst thing from the perspective of marine life is that this noise is strongest within a frequency range of 20-300 Hz, which is used by large baleen whales for communication. Though some marine dwellers adjust to constant noise, in the same way that people living in cities get used to ambient sounds, the effect is overall deleterious. The most dangerous sounds are so-called impulse sounds, when short signals of great power are created, which can frighten, deafen, and lead to contusions. For example, the air guns used for underwater seismic mineral exploration can create impulses louder than space rocket launch sounds. Signals of acoustic sonar - mid-range radar, exceeds the safe perception limits of cetaceans reaching 230 dB. That is why the acoustic trauma to the middle ear suffered by cetaceans during military manoeuvres or seismic surveys may be one of the reasons for seemingly suicidal strandings. In addition to their pain and fear, the mechanism of auditory perception in cetaceans is damaged, decreasing their ability to orient by means of echolocation or to differentiate between shore and open water.

Active development of the shelf by humanity and coastal building also contributes to the noise pollution of the sea. During construction, the loudest impulse noises occur when pile-driving or dredging. Peak noise levels during these works significantly exceed
the limits of safe perception for many fish species. Though some fish have adjusted to low-level background noise, powerful impulse discharge is something we should protect all marine animals from.

We came to appreciate the danger of anthropogenic underwater noises relatively recently. That is why the newest environmental documents of the EU, in particular the EU Marine Strategy Framework Directive, refer to anthropogenic noise as pollution along with ‘traditional’ chemical pollution of sea waters. European countries have begun to monitor sea noise constantly, and have developed measures for its decrease. In the Black Sea, water noise monitoring was carried out for the first time by EU-members Bulgaria and Romania, where since 2017-2018, the estimation of underwater noise level is included within the National Marine Environment Monitoring Program. Other Black Sea countries are now developing similar programmes; in the case of Ukraine and Georgia, these programmes were developed within the framework of the EMBLAS Project.
9. How does marine litter threaten the Black Sea?

In the 21st century, the Black Sea faces a new type of pollution: marine litter. Of course, this litter is not all new: the remains of fishing tackle, buoys, automobile tires, sunk ships etc. are widespread in the ocean. But during the last 20 years, the usage of plastic has become ubiquitous, with the amount of litter in the world’s oceans increasing hundreds of times. At present, about 8 million tonnes of plastic are thrown in the ocean annually. Circular currents concentrate it in particular areas creating ‘garbage islands’ which are more like a plastic broth than actual islands. The Black Sea has twice the amount of marine litter than the Mediterranean, both because of the plastic input from large rivers and the relatively closed character of the sea.

In the Black Sea, 85% of all marine debris consists of fragments of different types of plastic. Light PET bottles and plastic bags float on the water surface and – under the influence of ultraviolet rays and temperature – gradually fragment into smaller pieces, which sink under the weight of organisms settling on them.

Why is marine litter such a problem for ecosystems? First of all, marine dwellers often confuse it with food and swallow it, clogging their digestive tracts. In the Black Sea, the main victims are seagulls. Secondly, plastic adsorbs organic pollutants which further poison sea dwellers as they are consumed. Last but not least, animals can simply get stuck or lost and even perish among litter. Sad marine reality shows us dolphins with plastic bags on their tails, or anchovies stuck in rubber gloves.

It is important to know that along with large marine debris there is also microscopic litter, called microplastic. Its size is comparable to unicellular algae. It gets into the sea both as a result of the fragmentation of large pieces, as well as already-formed microplastic (e.g. plastic microbeads). Almost two thirds of microplastic appear as tires rub against the highways and get washed; another fourth enters sewage waters during the washing of synthetic clothing, from which microfibres flake away. Also small plastic granules are often added into household chemical goods, as well as creams, scrubs, and tooth paste, which ultimately wind up in sewage waters. Scientists with the EMBLAS Project have already discovered significant deposits of microplastic at the bottom of the Black Sea.

Along with the fact that plastic litter is a huge problem for seas and oceans, marine biologists consider it to be a new type of habitat for marine life, as everything that is put into the sea sooner or later becomes home for hydrobionts. At first, a thin membrane consisting of bacteria and microalgae forms on these surfaces, transforming a lifeless desert into a nice habitat for small animals (e.g. infusoria) providing them with food. Subsequently, algae and mollusc larvae settle on the prepared surface, and small crustaceans and other animals appear. However, the harm caused by plastic is not offset by its use as a marginal habitat for small sea creatures; rather, it should be understood as a desperate coping strategy by nature to make anthropogenic litter less dangerous. Therefore, an urgent task for every human is to reduce the amount of litter entering the sea, through reducing single-use plastic items such as bags, straws, packaging, and disposable cups.
Circular Currents
Concentrations of Marine Litter
10. How many species live in the Black Sea?

There are far fewer inhabitants in the Black Sea than in neighbouring seas. While there are 10,000 known species in the Mediterranean Sea, about half as many (5600) species can be found in the Black Sea. But this does not make it scarcely inhabited or lifeless. On the contrary, the Black Sea is nearly equal to the Mediterranean in terms of its quantity, productivity, and biomass volume of living organisms. The reason for the relatively low diversity of species in the Black Sea is primarily a function of low salinity (half as much as the ocean) and also temperature conditions (cold winters), which are not suitable for many cephalopods, starfish, sea urchins, lobsters, and other animals that are accustomed to the ocean's salinity and subtropical climate.

Of course, the majority of the Black Sea's inhabitants are small organisms, some of which cannot be seen with the naked eye: unicellular algae (almost 2800 species!), minute crustaceans (390 species), marine fungi (175 species are described, but every year new species are discovered in this group; they are hard to study). The group of relatively large algae and seed plants includes 453 species. Among macroscopic invertebrates, there are molluscs (bivalves and gastropods), shrimps, crabs, and the Diogenidae hermit crab, the latter of which used to live in the cast-off shells of small Black Sea molluscs, and therefore did not grow particularly large, but after the invasion of a huge, predatory rapana snail, the hermit crab quickly grew into its more spacious living quarters; it turned out that the crab was limited only by its dwelling. Another interesting case is the union of Diogenidae and sea anemone – the only representative of corals in the Black Sea. The hermit crab chooses the anemone it likes and settles it on the ‘roof’ of its ‘house’; the tentacles of the anemone protect the crab from enemies, and the soft-bodied coral gets food remnants and free transport.

The Black Sea is inhabited by over 200 species of fish, of which more than 150 are endemic; the others are invaders and ‘guests’ from other bodies of water. For example, the so-iuy mullet (Planiliza haematocheilu), native to the Japan Sea, successfully took root throughout the Azov-Black Sea basin. The most widespread and valuable species are anchovy, sprat, and herring. There is a variety of fancy blennies (10 species), bright wrasses (10 species) and gobies (more than 30 species); the lattermost category includes the smallest Black Sea fish – aphia minuta or transparent goby. There are also Chondrichthyes in the Black Sea – dogfish – the only shark permanently living in the Black Sea, and rays – both the common stingray and the thornback ray. The largest Black Sea fish is the beluga, one of the seven species of sturgeon in the sea.

The highest position in the food chain of the Black Sea ecosystem is occupied by 3 main Black Sea predators: bottlenose dolphin, common dolphin, and harbour porpoise. Middle-sized common dolphin with their bright contrasting colours can be found mainly in the open sea, where these high-speed predators chase large schools of small fish. The bottlenose dolphin is the largest Black Sea mammal; it is often observed near coasts. These dolphins are playful and curious, and can come close to beaches, jump out of the water, and put on a real show. Small and secretive harbour porpoises live in the Black Sea all year round. In spring, a pack of these sea animals migrates to the Sea of Azov through the Kerch Strait, following the stocks of anchovy to spend summer there and to come back in autumn for wintering in warmer waters.

The biodiversity of the Black Sea is not unchangeable. Some species become rare and extinct, but at the same time other organisms may become more plentiful. Global climate change also influences the colonisation of the Black Sea. As the earth warms, the sea becomes a little warmer and saltier, which makes it more hospitable for life of some species, and less so for others. In their research, scientists have discovered numerous previously-unknown species in the Black Sea.
Three Species of Cetaceans

2,780 Species of Unicellular Algae

- *Tripos muelleri*
- *Chaetoceros sp*

201 Species of Fish

390 Species of the Smallest Crustaceans

1,677 Species of Zoobenthos (Molluscs, Crabs, Worms)

453 Species of Macrophytes

175 Species of Marine Fungi

- *Chaetomium globosum*
11. Why are there so many invasive species in the Black Sea?

As noted above, in earlier times, the Black Sea, or Pontos Axeinos was known as the hospitable sea. This statement holds true for both sailors and exotic sea dwellers. For many of them, the Black Sea became a better place for living than their homeland (or as biologists say, natural habitat), no matter whether they got there accidently or on purpose. Many transplanted species integrate into local ecosystems without significantly changing anything. For example, molluscs such as the sand gaper (Mya arenaria) from the North Atlantic and anadara (Anadara kagoshimensis) from Indonesia have settled in the Black Sea and are now a naturalised part of its fauna. But sometimes non-indigenous species reproduce so actively that they can compete with local species until the last are completely forced out. These invasive species destroy those local flora and fauna who are simply not prepared for the pressure of a new neighbour. The Black Sea’s history contains more than one example of bio invasions – e.g. the so-iuy mullet (Planiliza haematocheila) brought from the Pacific Ocean was a very serious competitor to local mullet species, so much so that local mullet species had to be classified as protected in some Black Sea countries. The predatory gastropod mollusc rapana (Rapana venosa) completely destroyed the oyster population and influenced the mussels’ stocks quite badly. But the most significant damage was caused by the accidental invasion of the warty comb jelly (Mnemiopsis leidyi), which was detected for the first time in the Black Sea at the end of the 1980s. This typical species of the jelly-bodied (more that 99% of its body consists of water like that of jellyfish) is an active predator eating plankton, fish eggs, and larvae. The natural habitat of this species is comprised of desalinated gulfs along the North America Atlantic coast. Due to its extremely high fertility and growth rate, the total mnemiopsis mass in the Black Sea by the end of the 1980s was close to 1 billion tonnes. Considering such a population size, the comb jelly became a serious competitor to pelagic fish, and a menace to their survival as the mnemiopsis consumed fish eggs and larvae. In 1989-1990, this led to a catastrophic decrease in European anchovy (Engraulis encrasicolus) catches. Only at the end of the 1990s, when another species of comb jelly from the North American waters – beroe (Beroe ovata) invaded the Black Sea, did the mnemiopsis population diminish and anchovy populations began to recover. This phenomenon is explained by the fact that beroe in its natural habitat consumes mnemiopsis, and each year eats away up to 25% of its population.

New species enter the Black Sea in several ways. Firstly, via natural migration from the Mediterranean Sea through the Bosphorus. That is how the majority (80%) of modern fauna that are considered ‘aboriginal’ to the Black Sea were introduced. Moreover, this process of migration continues to this day. Before the Black Sea was connected to the Mediterranean (about 5,000-7,000 years ago, which is not much on a geological time scale), it was inhabited with semi-freshwater fish now preserved in the Caspian Sea as well as the least salinated parts of the Black Sea; these semi-freshwater fish are called Ponto-Caspian relics, an exemplar of which is the sturgeon.

Another means of invasion is via transportation within ship’s ballast tanks. That is how rapana, mnemiopsis, beroe and others got into the Black Sea. The species to settle especially well in the Black Sea are those inhabiting deltas and river estuaries, where fresh water mixes with saline. The salinity of the Black Sea is half as high as the ocean, and thus, species coming to the sea discover something like a giant estuary; these introduced
species therefore get an opportunity for profusion unavailable in their natural habitat.

However, the Black Sea not only suffers from introduced species, it is itself the source of biological invasions of other bodies of water, as shipping is carried out in all the cardinal directions, and ballast waters help to exchange flora and fauna between seas, spreading invaders across thousands of kilometres. Thus, Black Sea species (in particular, Ponto-Caspian relics) such as bivalves of the zebra mussel genus (*Dreissena polymorpha, Dreissena bugensis*) and round goby (*Neogobius melanostomus*) invaded the Great Lakes and became a real disaster in Northern America. Round goby several years ago was also brought to the Baltic Sea, where it acted as a noxious invader, affecting the fishing industries of all Baltic countries.
12. What jellyfish species inhabit the Black Sea and how many of them are venomous?

There are 30 jellyfish species in the Black Sea, the majority of which (26 species) are small – not more than 1-20 mm in diameter. The large ones are common jellyfish or moon jellyfish (Aurelia aurita) – up to 20 cm in diameter, barrel jellyfish (Rhizostoma pulmo) – up to 60 cm in diameter, and the very rare lucernaria (Calvadosia campanulata). In 2009, compass jellyfish (Chrysaora hysoscella) from the Mediterranean were found for the first time in the Black Sea, not far from the Turkish coast. This nettle-fish if touched leaves red marks on human skin resembling chemical burns. Moon jellyfish sometimes leave light burns, which pass in an hour or so, and bigger barrel jellyfish can very painfully damage skin, though the burns generally disappear in a few days.

Jellyfish are predators eating small planktonic animals. They grasp food with their mouths, which also serve to discharge food remains. The manubrium also has gonads attached to it. They produce reproductive cells, which are directly involved in the breeding process. The majority of jellyfish species are characterised by alternating sexual and asexual reproduction. The full-grown jellyfish are diclinous animals (i.e. they reproduce sexually). Their fertilisation is represented by a merging of cells moving actively in water, forming planula larvae. These larvae swim in water columns and then attach to solid surfaces on the seafloor. There they transform into polyps (part of asexual reproduction) following a sedentary lifestyle and increasing in number via gemmation. Polyps grow, divide, and form strobils – piles of ‘plates’ (young jellyfish arranged such that the concave sides of their pilei point upwards) connected by central trunk. The interesting thing is that the less frequent sexual reproduction is, the more frequent asexual reproduction becomes. Polyps of moon and barrel jellyfish are only about 2 cm high, whilst polyp thickets of more wide-spread Black Sea nettle-fish, e.g. obelia (Obelia longissima) reach 30 cm in height and more closely resemble discoloured algae than animals. For example, the diameter of obelia jellyfish’s umbrella-shaped bell is only 4 mm, rendering them almost invisible in water columns. The reproduction alternation cycle repeats annually. It is likely that jellyfish reproduction follows similar patterns as outbreaks, as their quantity depends on living conditions either at the seafloor or within water columns. The most significant surges in barrel jellyfish populations were observed in the 1970s; moon jellyfish populations similarly surged in the 1980s. The phenomenon was explained by so-called anthropogenic eutrophication – the increase of organic matter concentrations in water. At the end of the 1980s, moon jellyfish stocks in the Black Sea reached a mass of 300-500 million tonnes. Casting about for a solution included various ideas for decreasing jellyfish numbers. Among them, using nettle-fish in heavy-duty concrete production and practicing reinforced metal welding with the help of dried jellyfish powder. However, the Black Sea ecosystem soon stabilised and jellies ‘retreated’. People living around the Black Sea didn’t previously consider nettle-fish to be a foodstuff, although moon and barrel jellyfish are traditional in Asian cuisines, where they are semi-romantically referred to as ‘crystal meat’. They are usually pickled, fried, dried, and conserved. Nowadays the annual harvest of jellyfish is estimated to be around 250,000 tonnes.
13. What is the fate of seahorse?

The long-snouted seahorse (*Hippocampus guttulatus*) inhabiting the Black Sea is an absolutely amazing creature. The body of this small fish is covered with horn-like plates and various outgrowths, which serve as natural camouflage and protect it from predators. The fish’s exoskeleton is quite sturdy, and does not lose its shape even if dried. Its unusual body shape and long-snouted head, indeed, make it look like a chess knight. In the 1960s it was easy to find this fish in shallow waters across almost all the Black Sea coasts and in the Kerch Strait, but eventually its exotic look became the reason for the almost total extinction of the population. The seahorse leads a nearshore life and is not very mobile; for that reason, it was defenceless against predatory harvesting in the 1980-90s. Tens of thousands of specimens were dried annually to become souvenirs for tourists, and seahorses almost completely disappeared from sea areas located near resorts. That is why in 1994 it was listed in the Red Book of Ukraine and seahorse harvesting was prohibited. After these measures were taken, its population increased enough not to be listed into the next edition of the Red Book in 2009.

Seahorses belong to the syngnathidae family; their closest relatives are pipefish. But the difference is that seahorses swim upright nearly all the time. This ability is provided by the unique structure of its swim bladder, which is located along the seahorse’s body and is divided by a septum which separates its body from its head. The head swimming bladder is bigger than the abdominal one, and this helps seahorse to stay in a vertical orientation. Additionally, the seahorse can move its head up and down, which is a unique skill among fish. The reproduction process of seahorses is also rather peculiar. During spawning, they cling together using their flexible, finless prehensile tails. Then, the male seahorse opens a special brood pouch, which the female fills by laying up to one thousand eggs. A male seahorse broods the eggs, which eventually develop into juvenile fish. The newborn seahorses rise to the surface to take a first gulp of air, filling their swim bladders. Subsequently, they return to deeper waters and spend time with their father, hiding in its brood pouch in case of danger. Additionally, seahorses are real chameleons: like those of the reptile, seahorses’ eyes can move independently, providing it with a 300-degree viewing angle; furthermore, the seahorse can also change its colour, camouflaging itself among seaweed and stones.

Today, the prospects for seahorse populations are becoming more encouraging. Compared to the end of the last century, when this amazing fish almost completely disappeared from the North-Western part of the Black Sea, now it can be found even along the coast of Odesa. But people who are fond of Black Sea souvenirs should remember that the fate of the Black Sea depends not only on the condition of the marine ecosystem condition, but also on our wise conduct.
14. What amazing properties has the Black Sea spiny dogfish?

The Black Sea spiny dogfish (*Squalus acanthias ponticus*) is the only species of shark constantly populating the Black Sea basin. It is universal in occurrence in the Black Sea and the Southern part of the Azov. Because of its pointed snout, its head resembles a dog’s face, hence the dogfish appellation. The fish’s massive spines in front of each of their two dorsal fins is why it is termed ‘spiny’. As there are no known cases of dogfish attacking humans, the main danger is hidden in its spines, because the punctures and scratches they can leave on exposed skin may be painful and take a long time to heal, due to venomous glands at the base of the spines.

Compared to other sharks, dogfish have a small-sized body, rarely reaching more than 1.5 m in length or more than 10 kg of weight. These fish live for 25 years and they reach reproductive age at not less than 13-14 years, which is comparatively late. It is interesting that these fish mate at great depths. As part of its reproductive process, embryos develop inside the female’s body and after a very long period of time (18 months!) the already-formed 30 cm-long tiny sharks are born resembling their parents. The process is called ovoviviparity.

The name of the genus and family of spiny sharks, to which the Black Sea dogfish belongs, derives from the Latin word squalidus – ‘covered with calloused skin’. The point is that the dogfish body is covered with scales, which can be represented by plates with spines, and which resemble teeth in both their strength and structure. So, it could be said that the dogfish body is literally dotted with sharp teeth, nestled snugly against each other. Due to this arrangement, the skin may seem relatively smooth if you run your hand from head towards tail, but rough as sandpaper if you do so contrariwise.

Dogfish, like other sharks, do not have a swim bladder. As such, they depend on their giant livers for buoyancy; these sometimes reach 25% of the shark’s total weight. The liver of the spiny dogfish contains many low density fats, which make the shark lighter than water. For this reason, the fats from dogfish livers are rich in vitamins A and D, and are used in pharmacology and medicine as a valuable raw material.

Unfortunately, their late maturity and slow reproduction cycle, along with very long period of pregnancy, make dogfish particularly vulnerable to overfishing. These sharks are caught on a massive scale by Japan, China, England, Norway and other countries. In recent years, dogfish in the Black Sea are more often found in bycatches while conducting fishing operations seeking other species, and their population numbers have been decreasing for decades. According to the International Union for the Conservation of Nature, dogfish are classified as a vulnerable species, which means they must be protected.
15. Are there any whales in the Black Sea?

If someone says ‘whale’, we usually imagine an ocean giant slowly travelling from the Arctic or the Antarctic to the tropics and back. Indeed, the modern baleen whale is the largest known living creature to have ever inhabited our planet. Blue whales can reach more than 30 metres in length, with a weight of approximately 150 tonnes! Besides baleen whales, there are large and small toothed whales throughout the world’s oceans. Sperm whales, beaked whales, narwhals, dolphins (the largest of which is the orca), as well as the smallest example – harbour porpoises – belong to this parvorder. Baleen and toothed whales are cetaceans and have a common ancestor. Cetaceans are mammals: they need atmospheric air to breathe (that is why we can observe them rising to the surface to take a breath), feed their calves with milk, and sometimes have hairs on their body – the remains of fur.

In the Black Sea, three species of cetaceans are regularly found – bottlenose dolphins (Tursiops truncatus), common dolphins (Delphinus delphis) and harbour porpoises (Phocoena phocoena), all of which have several local names. The harbour porpoise is the smallest living cetacean not only in the Black Sea, but in the whole world: mature animals sometimes can be only 110 cm long and only 25 kg in weight. All the Black Sea cetaceans eat fish; harbour porpoises prefer gobies, while bottlenose dolphins prefer turbots and mullets; all of them eagerly consume anchovy, sprat, horse mackerel and whiting. Common dolphins gather into large pods consisting of hundreds of individuals, whilst bottlenose dolphins prefer to live in smaller groups, and harbour porpoises gather only rarely, e.g. when they need to migrate. Research in recent years, including the EMBLAS Project, shows that in summer, the largest accumulations of cetaceans were concentrated in Turkish and Bulgarian waters, with additional significant populations near the Danube Delta and around Dzharylhach Island. But during colder times of year, dolphins preferentially inhabit the seas near Georgia and the Sochi-Tuapse district, likely due to the large numbers of prey fish overwintering there.

And what about baleen whales? These creatures first inhabited local waters millions of years ago, when it was the Paratethys Sea, rather than the Black. Paleontologists have found thousands of fossilised bones in Ukraine and Moldova, formerly belonging to pygmy whales (cetotheres) with a body length of only three metres. Like modern dolphins, they also ate small fish, swallowing them in a fashion resembling large ducks. The closest modern relative of cetotheres is the pygmy right whale, which now lives in the southern hemisphere, although in the past it inhabited our neighbouring Mediterranean...
Sea. Baleen whales were also present in the Black Sea historically. Bones of common or northern minke whale (*Balaenoptera acutorostrata*) were found by archeologists during excavations of ancient Bulgarian settlements, which were 5,000–6,000 years old. In 1880, a minke whale came to the Black Sea from the Mediterranean and was stranded near Batumi, Georgia: its skeleton is still preserved at Georgian National Museum.

Is it possible for such an event to repeat? Who knows! We should note that in 2009, a gray whale from the Arctic confused the Pacific Ocean with the Atlantic and swam into the Mediterranean Sea, where these species of whales had not been observed for thousands of years. So, perhaps baleen whales will emerge near our coasts in future.
What crab species live in the Black Sea?

It is impossible to imagine a sea coast without crabs. These hard-working members of the ocean's clean-up crew play a significant role in the utilisation of dead fish, molluscs, and other decaying organic material. Crabs move across the seafloor predominantly sideways; they go ashore mainly at night, and breathe air. The species that can not only walk but swim are portunid crabs. This became possible when their back pair of legs broadened and transformed into fins. In the Black Sea until recently, such 'swimming' crabs were represented by a single main species: the small flying crab (*Liocarcinus holsatus*).

Until the middle of the last century, 18 species of crabs were known in the Black Sea. The largest of them was the warty crab (*Eriphia verrucosa*) with an 88 mm-wide carapace. Due to its size, the warty crab not only clears the sea of carrion, but also ambushes small fish, worms, and snails. The littoral crab (*Carcinus aestuarii*) reaches almost the same size. Both of the most numerous Black Sea crabs have ecological and behavioural peculiarities – the warty crab prefers rocky bottoms, and its colour helps it to stay camouflaged among pebbles and boulders; the littoral crab hides among algae and seaweed thanks to its greenish carapace. *Carcinus aestuarii*, as we can surmise from its name, prefers the most desalinated sea areas including river deltas and estuaries.

Alas, the larger the crab, the more chances it has to be caught and eaten by human. The largest 6 out of 18 species of crabs – the aforementioned warty and littoral crabs (*Carcinus aestuarii*), as well as the marbled crab (*Pachygrapsus marmoratus*), jaguar round crab (*Xantho poressa*), hairy crab (*Pilumnus hirtellus*), and - living not right in the sea, but in rapid rocky rivers flowing into it - freshwater crab (*Potamon potamios*), are all listed in the Red Books of the majority of the Black Sea countries. Marbled crabs living on the rocky coast and feeding on stone accretions spends almost half of its life ashore or in a surf zone, sometimes diving to moisten its gills. This crab is on the list developed during the EMBLAS Project – the list of 'environmental sentinels', who serve as indicators of the Good Environmental Status of the sea coastal zone. Unfortunately, because of its pretty, shining, eponymous marble-esque carapace, this species often becomes the victim of the souvenir industry.

Small species of Black Sea crabs are also interesting in their own way: e.g. the invisible crab (*Macropodia longirostris*) grows bushes of various algae species on its shell for camouflage. One of the smallest species is *Brachinotus sexdentatus*, living in the coastal zone at silty-sandy and silty grounds. The length of its almost squire shell is not more than 20 mm.

During the last 50 years, the Black Sea crab roster was increased via the addition of three more species of transplants: the blue crab (*Callinectes sapidus*) - a very large representative of the aforementioned family of portunid crabs (first detected in 1967), the sirpus crab (*Sirpus zariquieyi*) (detected in 1982), and the Chinese mitten crab (*Eriocheir sinensis*). The blue crab is now the largest Black Sea crab – its carapace can reach 20 cm! Though it has become naturalised in the Black Sea, the
species did not become widespread, and its presence has had little influence on the local ecosystem. The mitten crab, however, massively populates desalinated areas (and even goes upstream into freshwaters), and digs holes in clay shores, becoming a significant factor in coastal erosion. It is interesting that the *Carcinus aestuarii* crab, when accidentally brought to Japan became an invasive species there, whilst in the Black Sea it is rather rare and is in danger of local extinction.
17. Why does the sea glow in the dark?

From ancient times, people observed a mysterious night-time glow from the sea. In some cases, it looked like milky light flowing through the water, in other cases it left a trail behind a ship's stern, and sometimes it appeared as flashes and sparks in a water column. Scientists at first were stymied by the phenomenon. They offered various hypotheses, until finally in the XVIIth century ACE, its biological basis was discovered: it turned out that the reason for the sea's enigmatic glow was bioluminescence, i.e. the ability of living organisms to give off light. The biological glow can be caused by plankton organisms of various sizes, as well as by microscopic bacteria. The best-studied – and the most common representative of bioluminescent organisms in the Black Sea – is the sea sparkle (Noctiluca scintillans). It is usually referred to as a phytoplankton, along with other species of dinoflagellates (Dynophyta). But these large spherical algae, sized between 0.5-2 mm (occasionally reaching 3 mm), have lost the ability to photosynthesise, and became predators. At the same time, the inclusions of fat in their cytoplasm helps sea sparkles to stay afloat in water columns. Thus, the now-useless chlorophyll produced an interesting derivative, which released a ray of light when oxidised, and this causes the glowing of the sea sparkle when physically or chemically disturbed. As the sea glow was originally associated with the infernal, the chlorophyll derivative responsible for it was wittily called ‘luciferine’, and its particular oxidative fermentation product – ‘luciferase’.

At the end of summer, the glowing of the Black Sea surf, or from wake trails left by passing motor boats, can often be observed. Sparkling lines, left by swimming fish, are seen throughout the water column. There is an old Crimean legend about the glowing waves foamed with ships’ oars, which prevented the Greek fleet from coming unnoticed to the shores of Taurida. If this legend has a historical basis, then, most likely, it was the sea sparkle that saved Tauri from an unexpected assault. It is not the only case of bioluminescence helping humans. Before sonar was invented, bioluminescence could save ships by showing navigators the proximity of coastlines, shallows, or reefs. Fishermen often discovered schools of fish at night, thanks to the glow from the depth.

Sea sparkle can also be found far from the Black Sea, and continues to spread further afield. Scientists believe this distribution is a function global warming, which affects ocean currents, and in turn influences the spread of plankton.
18. Why does plankton “travel” from the depths to the surface and back?

The term ‘plankton’ refers to all organisms who are unable to resist a current. As a rule, they are small (except for jellyfish and ctenophores). Plankton can be divided into phytoplankton (micro algae), and zooplankton (small animals, mainly crustaceans). Within the space of a day, many species of zooplankton carry out long-distance (relative to their body size) vertical migrations. In the daytime, they rest in the deepest layers of the water column, and in twilight they return upwards, coming close to or reaching the surface, and concentrating in a thin upper layer. With the sunrise, these species once more return to deep water.

The most noteworthy vertical migrations in the Black Sea are performed by copepods – calanus (Calanus euxinus) and pseudocalanus (Pseudocalanus elongates). They rise from a depth of 100-150 m to surface waters rich in phytoplankton. Other copepods also migrate during the day, e.g. oithona (Oithona similis), centropages (Centropages kroyeri), and even a few organisms not related to copepods, such as the predatory arrow worm (Sagitta setosa).

Scientists say that the biological rationale for vertical migration lies in the fact that at night, plankton become less visible to predators, although many migrants glow in the dark and reveal themselves even at night. Moreover, there are a multiplicity of predators, who themselves perform daily vertical migrations. There is also a hypothesis that vertical migrations under conditions of different speeds of current, and at different depths, cause the dispersal of migrating crustaceans’ populations. This dispersal is necessary to prevent the complete predation of phytoplankton by dense accumulations of zooplankton. In this connection, the following analogy can be drawn: herds of hoofed animals moving constantly across the area save their pastures from being completely eaten away. At the least, it is believed that vertical migrations are connected of energy exchange. It is more profitable for zooplankton to spend the majority of the day in the cold waters of the deep pelagic zone, where their metabolic rate is lower.

So, how does plankton know when it is time to go up or down? During the eclipse on the 30th of June 1954, when the solar disc was covered and the luminosity of the sea surface became 17 times lower, more than 70% of plankton organisms rapidly rose from the 14-5 m layer to the 5-0 m layer. Later, such a rise was noted among all plankton species, which proved that luminosity was the main factor regulating their vertical migrations.

This raises the question: what would happen if luminosity didn’t change for a long time, say for three or four weeks? Would zooplankton follow its usual daily migration patterns? Such a case was observed in the Arctic in the midst of the polar summer, when there was no sunset for more than 24 hours. It turned out that during the polar day, plankton stayed at the same depth without migrating, whilst in autumn, when day and night alternated, it began to carry out its daily migrations again.

It should be said that besides plankton, there are several other large ecological groups in the sea. Nekton are active swimmers, who can determine the direction of
their movement and are therefore not at the sole mercy of currents. In the Black Sea, this group is represented first by all by pelagic (i.e. living in open sea waters, not along the seafloor) fish and cetaceans. Marine dwellers, which spend the majority of their life at the seafloor are called benthos. These can be further divided into phyto (algae) and zoobenthos (bottom animals). And what about demersal fish, such as turbots, rays, gobies, blennies, and black scorpionfish? They can swim actively, but almost all the time stay in a thin bottom layer of water or directly at the seafloor, which is why they are known as nektobenthos and benthonekton. Periphyton is a community of fouling organisms which in nature settle first of all on the surfaces of seaweed and macroscopic algae, turtle shells, and on whales’ skin. A separate group is neuston or pleuston, living in the water surface tension area at the air-water boundary. Yes, our Black Sea is very diverse!
19. Does sea foam assist in the development of life?

Sea foam is formed in the coastal area of seas and oceans at the boundary between water and air. It consists of various organic and inorganic compounds being adsorbed by gas bubbles and delivered from the water column to the surface layer. Of course, sea foam also contains dead unicellular planktonic algae. The remains of algal pigments, which have not yet decomposed, can colour the foam from light green to pink depending on the species of algae prevailing in the water column, be they chlorophytes, diatoms, dinoflagellates, or representatives of other taxa. But mostly sea foam is a dirty grey colour and looks the same as the foam that we can observe when doing laundry.

There is a myth about the beautiful ancient Greek goddess Aphrodite, who was born from the sea foam. And the name itself, Aphrodite — Ἀφροδίτη derives from ἀφρός, or foam. According to the hypothesis of English scientist John Bernal, sea foam is the cradle of life on Earth, as it contains concentrated organic matter dissolved in a column of water. Bernal draws an analogy by comparing the beginning of life on Earth with Aphrodite coming out of the sea foam. For a long time, water columns and the sea floor were primarily the objects of hydrobiological research. The surface layers of seas and oceans were considered to be lifeless, because the first several uppermost centimetres of water column and sea foam were vulnerable to the effects of ultraviolet solar radiation and wave mixing. But in 1964, Academician of the National Academy of Sciences of Ukraine Yuvenaly Zaitsev began to systematically study life in the surface portion of the Black Sea. He discovered that the upper layer of the water column, which is 5cm thick, is inhabited by various organisms that are adjusted to environmental conditions of both the water and the atmosphere boundary area. Critically, an essential portion in the lifespan of many fish species, viz. the development of pelagic eggs and larvae, takes place precisely within this thinnest layer. And some vertebrates are able to survive solely on neuston (the group of organisms atop or attached to the underside of a sea's surface film). That is how the hyponeuston — creatures along the water surface — were discovered. Similar communities of organisms were later found in other seas and oceans.

The area of surface tension in seas and oceans constantly increases due to organic matter from the atmosphere and the water column. Thanks to this, foam containing a great amount of organic matter is formed. The organic matter is deposited in the water via marine dwellers’ wastes. A high concentration of nutrients in the surface (hyponeuston) layer leads to active development of bacteria, crustaceans, and juvenile fish. It was found that sea foam stimulates the growth and development of both plants and animals. This phenomenon was also reproduced by numerous experiments with marine organisms (blue-green algae, crustaceans, fish larvae) and land plants (oat, barley, and wheat). Sea foam contains hundred of times more organic and mineral matter than water.

Zaitsev concluded that sea foam had biologically active properties, but can lose them due to surfactant sea pollution. This is why the pollution of the sea with surfactants (including soaps and detergents), if prevented, can help return sea foam its rightful position as the cradle of life.
20. How long do mussels live and how do they populate new territories?

Professor of the Hydrobiology department of the Odesa National University Simeon Grinbart demonstrated to students an especially large mussel with a shell length of 14.3 cm during his lectures. He classified it as a species of ‘herculea’. The mussel was found by the professor in 1939 while examining accretions on the vessel Patagonia, which had sunk in the Black Sea in 1915. As the ship was raised from the bottom of the sea, it was unknown for how long the mollusc had been attached to the ship’s hull. The age of molluscs was formerly measured by examining their length and the radial growth rings on shell valves. But studying shell cross-sections under the microscope proved such an approach to be wrong. According to Valentine Zolotarev, who developed a new method of age estimation based on the study of shell cross-sections, with age molluscs stop growing in length and begin to thicken as if folding their front parts. Unfortunately, Professor Grinbrat’s giant mussel had not been preserved, but measurements based on the new method showed that the age limit of a mussel recorded in the Black Sea was 28 years. The length of a mussel found in 1984 in Dzharylhach Bay was 11.4 cm, which was 3 cm shorter than ‘herculea’. However, not many molluscs survive to this old age. And the average age of mussels in the Black Sea is 5-6 years.

By examining the valves of dead molluscs in order to estimate the age of mussels that lived in different parts of the Black Sea at different times, it is possible to glean information about changes in ecological conditions for that regions. The cooler it is and the less food is available, the longer mussels live, like all poikilothermic molluscs. Thus, mussels, one of the most widespread molluscs in the Black Sea, are not only the trademark of the Black Sea coast, but also a reliable biological tool for an assessment of the state of marine ecosystems.

So, how do mussels occupy new territories while following a sedentary lifestyle? The spawning of mussels occurs in intervals, and in the Black Sea it usually takes place in December – January. During one spawning period, a female mussel is able to spawn several million mature egg cells, but only a small portion become full-fledged mussels. Larvae formed as a result of external fertilisation become a part of plankton – the community of tiny organisms carried passively by sea currents. During this journey, larvae gradually fatten and grow by consuming unicellular algae. Progressively, the tissues for future organs are formed, with the foot serving as a sail of sorts, which helps larvae to manoeuvre through the water column. The next stage of development is as follows: larvae turn upside-down, and the ‘sail’ disappears and is replaced by the formation of locking muscles. Finally, shell valves begin to grow. At the stage of transformation into a shell (as a rule, 1.5-2 months after the beginning of their life) larvae no longer swim, and endeavour to cling to stone substrates, forming entire mussel reefs.
REPRODUCTION AND DEVELOPMENT OF MUSSELS

Mature Dioecious Individuals

Zygote

Development of Swimming Larvae

Juvenile Mussels

Development of Swimming Larvae
21. How did rapana affect marine life and that of coastal-dwellers?

Rapana (Rapana venosa) is the largest mollusc in the Black Sea, reaching 19 cm in length and having a shell weighing up to 300 g. It was first detected right after the end of WWII in 1946, in Novorossiysk Bay. It is assumed that rapana was carried here from the Japanese Sea within the ballast waters of ships. This ravenous predator has practically no natural enemies (in its natural habitat, rapana is consumed by starfish, but the Black Sea water is too cool for these starfish). In just a few years, the rapana destroyed the Gudauta oyster-bank in Abkhazia, where the largest stocks of oysters – which are now on the Red Lists of all Black Sea countries – was concentrated. Luckily, the situation has changed and there are data indicating progress in the recovery of oyster populations near the coasts of Georgia.

Today, rapana is no longer an exotic invader, it is an aggressive member of the seafloor biocenosis, and one of the most wide-spread Black Sea molluscs. If you were to stroll along the seashore anywhere between the Danube estuary to the Dnieper, during a walk of 100 metres, you would likely find accumulations of small, strange-looking uncinate bags of colour, ranging from whitish to light-purple. These are eggs’ capsules (cover of eggs’ laying), in each of which there is from 200 to 1000 eggs (!). Each rapana laying, attached to hard substate (stones or shells), has from few to several dozens of such eggs’ capsules in a form of bunch or brush.

After rapana consumed all the oysters, it in turn became a serious threat for mussels, which form the basis of its new diet. Nowadays, general numbers of rapana stocks continue to increase, and its only natural enemy (and hence the main control on its population) is the human. For example, in Turkey, the annual harvest of is estimated to be about 1,000 tonnes of this delicious mollusc’s meat. Its high food value and the decorative nature of its shell made rapana a popular Black Sea bioresource, and even led to the creation of a new profession: rapana harvester. Today, the muscle foot of this mollusc is a product of high demand on the menu of Black Sea restaurants and diners. The bright-orange inner layer and beautiful spiral shape of the shell made it a popular material among Black Sea souvenir shoppers.

It is interesting that along with the continuing tendency of rapana populations to increase, it is still impossible to find a shell of this mollusc of a size less than 2 cm. It is likely that its larvae, which follow a planktonic lifestyle, have too fragile a shell before they transfer to the demersal way of life. So, in case they die young, the remnant shells are ground by waves before being driven ashore. A large number of small, living rapana-encrusting natural and artificial substrates can prove this hypothesis.

In addition, shells of mature rapanas became not only desirable souvenirs for tourists but also a new home for the diogenidae hermit crab (Diogenes pugilator). Earlier its largest domicile was the shells of the small gastropod mollusc tritia (Nassarius reticulatus). As a result, the crab itself stayed small, as it was dangerous to grow bigger than its shelter, because in case of a threat it would be impossible to hide itself. With the occupation of newly available rapana-shell shelters, hermit crabs can now grow bigger in proportion to its roomier abode.
22. Where do Black Sea sturgeons come from and what is their status?

Sturgeon fish are one of the key endemic species in the Black Sea, and one of its largest dwellers. The ancestors of this group appeared more than 200 million years ago, when species very similar to modern sturgeon fish, along with ichthyosaurs and plesiosaurs, inhabited the ancient Tethys Sea, from which the Black Sea, the Sea of Azov, and the Caspian Sea were formed. The highest rise of this group took place when the future Black Sea represented a kind of highly desalinated lake, isolated from the ocean and similar to the modern Caspian Sea.

There are seven species of sturgeon in the Black Sea, the largest of which is the beluga (*Huso huso*) which can reach a length of more than 4 metres and weigh about 1.5 tonnes, and can live for more than 100 years. The other six species are in the sturgeon genus (*Acipenser*).

Sturgeons are anadromous fish, meaning that they spend their lives in the sea, but reproduce in rivers. Earlier, their spawning route reached as far as Kyiv and Vienna, but in the 20th century, all the large rivers of the Black Sea basin were blocked by hydroelectric dams and thus, there were no available spawning areas left. Mature sturgeons thrive in saline water, whilst young sturgeons survive only in lightly-salinated water, which is why the sturgeon ‘kindergarten’ is limited to river estuaries and deltas. Not very long ago, the Sea of Azov was an appropriate area for young sturgeon migrations, but for the last several years the Azov has become more saline, and suitable conditions only persist in Tahanrih Bay. As such, the seas and rivers which were the home for the largest Black Sea fish for millions of years, became inhospitable for them because of human impact.

Along with the loss of typical habitats, the sturgeon population was strongly affected by overfishing – mainly poaching, as their meat and, more importantly, its black caviar are considered to be valuable delicacies (in fact, sturgeons were exported from the Black Sea by the ancient Greeks as an especially valuable product). No wonder that all the seven species of sturgeon became endangered and were listed in the Red Books of all Black Sea
countries. The population of the European sturgeon (*Acipenser sturio*) decreased most dramatically. Nowadays, this species is listed in the IUCN Red List of Threatened Species, with its population in a critical state. A few years ago, its entire Black Sea population was believed to have died out. During EMBLAS 2017 Project research, the DNA of the European sturgeon was found in many samples throughout the Black Sea. This situation is similar to that of the beluga sturgeon, which is also under threat of extinction. But DNA analyses of the sea water (and also a case that arose last year, when border guards accidentally caught two poachers with 0.5 tonnes of beluga in their trunk) proves that a number of these unique fish still swim in the Black Sea. At this stage, every Black Sea country must unite in their efforts to prevent the eldest fish of the Black Sea – which has lived through millennia of geological disasters - from sharing the destiny of their contemporaries, the ichthyosaurs.
Aquaculture is the farming of aquatic organisms; mariculture is the cultivation of marine hydrobionts in saltwater reservoirs of natural (enclosed sea areas, estuaries) and man-made (ponds, dammed ponds, and pools) origin. Aquaculture originated a long time ago – 4,000 years ago in China, freshwater fish were bred in special ponds. During the time of the Roman Empire, mullets were farmed in the Mediterranean Sea. Oyster hatcheries for the creation of cultured pearls appeared at the beginning of the XIIIth century. Mussel and oyster farms today are among the best-known examples of mariculture.

Mariculture has great potential for the sustainable production of food, and is a useful solution for many global problems, including overpopulation. The artificial breeding of various hydrobionts, particularly fish, molluscs, and algae can potentially remedy food shortages. Today many living marine resources actively harvested by humans are on the edge of extinction, and in the near future may lose their economic utility due to their low numbers.

The Black Sea is also a ground for mollusc and fish breeding in different bays and estuaries. In the 1960s and 1970s, scientists actively experimented with mussels, oysters, mullets, turbots, and red algae phyllophora cultivation.

Nowadays the most widespread and well-developed product of mariculture in the Black Sea region is the Mediterranean mussel (*Mytilus galloprovincialis*). Mussel farms (collectors) are constructions made of nylon rope, bobbers, and sinkers imitating underwater rocks, on which mussel larvae brought by sea water settle. Such mussel farms are especially effective near the Crimean coasts, because of the absence of ice cover and relatively good water quality. Today, farms specialising in oysters cultivation develop intensively. The breeding of oysters, if compared to mussels, is a harder and more labour-consuming process, which is why the majority of farms buy already-grown molluscs and simply raise them to maturity in special hatcheries.

The fish-breeding experience in the Black Sea also has a long history. For example, when juveniles from species including the golden grey mullet, flathead grey mullet, and leaping mullet came to some Black Sea estuaries, the channels connecting those estuaries to the Black Sea were closed to provide the fish with ample forage. There they fed and actively grew, consuming natural fodder; in autumn they were fished. Similar attempts were made with the Black Sea turbot and European flounder, albeit not on an industrial scale.

Turkey is the leader in marine fish aquaculture among the Black Sea countries. For the last 20 years, hatchery mariculture and fish-breeding in isolated sea bays have been actively developing. The main species raised are gilt-head bream (*Dorado*), European bass, annular bream, common dentex, and others.
24. How are cormorants connected with the sea?

It may seem strange, but the majority of the world’s cormorants are coloured as though they’re en route to a funeral. There are three species of cormorants inhabiting the South of Ukraine: the great cormorant (*Phalacrocorax carbo*), the European shag (*Phalacrocorax aristotelis*) and the pygmy cormorant (*Microcarbo pygmaeus*); their feathers are almost completely black, with a metallic lustre. Only young birds wear a white ‘shirtfront’. Fishermen often confuse cormorants with young Caspian seagulls due to their juvenile brown outfit. These birds constantly hang around fishers on the docks while they load their catches. There is another interesting thing connected with the behaviour of these birds: fishers are observant people and they used to see those gulls impudently snatching goby from a grebe, which came up to the surface, or chasing another gull and making it drop the prey from its beak. Due to its bad manners, in Russian the bird was called ‘baklan’ from the verb ‘baklanit’ which means to behave like a hooligan, or to violently take valuables from others.

The pygmy cormorant differs from the great one not only by being half the size, but also due to the chocolate colour of its neck, head, and nape. Moreover, the pygmy cormorant rarely comes out from large river deltas, which is why observing the pygmy cormorant along seashores is quite an unusual and lucky sight. Another species, the European shag, solely inhabits rocky cliffs on sea coasts. In fact, the European shag is hard to tell apart from the great cormorant, but the possibility of finding this species in the Black Sea areas, not counting the Crimean, Bulgarian, and Turkish coasts, is rather small.

It should be mentioned that the correct name of the black shag is great cormorant. Its life changed dramatically due to human activity, when pond fish farming developed in the region in the 1970s. Suddenly, the great cormorant inherited a very convenient forage base. You should agree that catching fish in deep floodplains or open lakes is much more demanding than hunting in the shallow waters of nursery ponds full of fish. At the end of the last century, the great cormorant population rapidly increased. It turned out that these birds nest not only on high trees, but on flat islands also. At this stage, the cormorants’ only condition is that their colony be located near fish ponds. The chasing of cormorants by fishers ‘reminded’ them to nest in trees. But this time, they occupied not only floodplain forests in river deltas, but all trees anywhere near a body of water.

The result was rather sad. Uric acid contained in the great cormorant’s droppings painted the trees under their nests white, so much so that green leaves disappeared and plants died. It appears that the great cormorant in this situation bites the hand that feeds it, and has to move every year to new places because of its own excrement. Such resettlements slowed the rapid growth of cormorant populations, though they are still rather high. The great cormorant now acts as a nomad species, much like our ancient ancestors practicing slash-and-burn land management: they take over a forest plot, reap a harvest for a couple of years, and when the land stops being fertile, moved to the next forest plot; in much the same way, large flocks of cormorants appear in one or another region, and then altogether disappear for a couple years as the land recovers.
PYGMY CORMORANT

THE EUROPEAN SHAG

GREAT CORMORANT
25. What do the Sargasso and the Black Seas have in common?

The Sargasso and the Black Sea are unique for hosting the world’s biggest accumulations of floating macroalgae. In the Sargasso Sea, these are the brown algae Sargassum (*Sargassum bacciferum*), drifting across the surface thanks to special air bubbles (scafidia), which resemble grape seeds. Columbus discovered an accumulation of these algae in the Atlantic Ocean during his first voyage to the coasts of America (it should be noted that the Sargasso Sea is located in the Atlantic Ocean and has no coasts – instead, it is surrounded by four Atlantic currents: the Gulf Stream, the North Atlantic Current, the Canary Current and the North Equatorial Current). In the Black Sea, the floating macroalgae are a combination of three kinds of red algae from the Phyllophora genus, freely rolling over the seafloor almost like tumbleweed does on the steppe. The accumulation of algae in the North-Western part of the Black Sea, at depths of 20–60 m, is primarily (80%) represented by Phyllophora crispa, which was described for the first time by Sergey Zernov in 1908, and was therefore named ‘Zernov’s Phyllophora Field’. So, there are three things common to the Sargasso Sea and Phyllophora fields: their algae mainly float, the borders of their accumulation areas are determined by circular currents, and the key commonality: algae are the basis of a community, which includes a number of animal and plant organisms.

The community of the phyllophora field in the Black Sea consists of more than 30 species of unicellular and multicellular algae, about 100 species of invertebrates (sponges, worms, crayfish, molluscs, bryozoans, etc.) and about 40 species of fish. The majority of animals living among phyllophora have red protective colouring, e.g. sponges, crustaceans, echinoderms, and fish. Shore rockling, knout goby, and small suckerfish all have red pigmentation, and even ‘red-finned’ varieties of herring and mackerel can be found. Another uncovered secret of Zernov’s Phyllophora Field is that the temperature of the water inside algae accumulations is 4-5 °C higher than the temperature of the overlying layer of water. It is believed that warmth accumulates in
phyllophora masses due to its intense bioenergetic processes.

Before the end of the last century, phyllophora stocks had catastrophically reduced because of eutrophication, accompanied by a reduction in water transparency. Sunlight in the majority of algae growth areas could not reach the seafloor. Originally, the area of Zernov’s Phyllophora Field was 11,000 km², and its stocks were enough to harvest 15,000-20,000 tonnes of algae annually for 70 years (through the beginning of the 1990s) for the purposes of iodine extraction and agar-agar production. In 1996, the harvesting of algae ceased, and in 2008 the largest protected water area in the Black Sea – a 402,500 ha botanical reserve of national importance was established to protect Zernov’s Phyllophora Field. An additional reserve, called the Small Phyllophora Field, with an area of 38,500 ha was created in Karkinit Bay in 2012. From the beginning of the 21st century, the process of restoration for biological communities began to be observed on the North-Western shelf of the Black Sea as a result of European countries’ efforts to clean the Danube River basin. Whereas in 1989, only a minimal quantity of multicellular seafloor algae were observed, comprised of only seven species, by 2017 the floral wealth increased again to 30 species and reached volumes last seen in the 1960s. During the last several decades, the Northern boundary of the phyllophora field expanded up to the coastal zone, and to a depth of 12-15 metres.
26. Why did the Greeks go fishing from the Mediterranean Sea to the Black Sea?

Between 600- and 560-years BCE, several ancient Greek colonies were established on the Western coast of the Black Sea. In the Danube (Ister) Delta, the cities of Ister, Tomi, and Odessos, appeared. Tyras (now Belgorod-Dnestrovsky) was built in the downstream reaches of the Dniester, while in the Bug (Hypanis) and Dnieper (Borysthenes) mouths, Olvia (‘the city of plenty’) was built. On the Northern coast of the Black Sea, Greek sailors mainly chose estuaries of big rivers stocked with valuable river fish. These rivers’ firths served as a waystation for vessels. Pliny the Elder wrote in his encyclopaedia: ‘All kinds of fish grow with remarkable rapidity, and more especially those in the Euxine; the reason of which is the vast number of rivers which discharge their fresh water into it. One fish, the growth of which is quite perceptible, day by day, is known as the amia. This fish, and the pelamides, together with the tunnies, enter the Euxine in shoals, for the purpose of obtaining a sweeter nutriment, each under the command of its own leader’. Also, Aristotle in his book ‘History of Animals’ wrote: ‘most fishes migrate to the Euxine for the summer; for owing to the number of the rivers that discharge into this sea its water is exceptionally fresh, and the rivers bring down a large supply of food. Besides, a great number of fishes, such as the bonito and the mullet, swim up the rivers and thrive in the rivers and marshes. The sea-gudgeon also fatten in the rivers and as a rule, countries abounding in lagoons furnish unusually excellent fish’.

Thus, in the VIIth century BCE, ancient Greeks began actively exploring the Black Sea for fishing purposes. The colonies of Byzantium - located where modern Istanbul is found, along with Trebizond (now Trabzon) and Panticapaeum (modern Kerch) became centres of tuna fishing. Then, after the development of Greek colonies in Crimea, settlers started fishing the Black Sea turbot, sarda, mullet, mackerel, rays, and other Black Sea species. They caught common carp, catfish, sander, and certainly sturgeon in the rivers’ estuaries and in the Sea of Azov. The fishery was especially important for Olbia and Panticapaeum. And we cannot fail to mention the anchovy! Stone tanks used to salt and preserve anchovies can be found in ancient Greek settlements. There are especially many of them on the banks of the Kerch Strait. The predilection of ancient Greeks for Black Sea fish can be explained by both their taste and abundance. Desalinated shallow regions in the North-Western part of the Black Sea and the Sea of Azov were valuable feed beds, which attracted a lot of fish. Tuna came to the Sea of Azov from the Mediterranean annually, migrating along the Southern coast of the Black Sea. The unique natural Azov-Black Sea ‘canteen’ contributed to their steady growth and accumulation of fat. This is why the taste of the same fish species that inhabited the Mediterranean and the Black Sea was incomparably better on the northern edges of the antique world.

Ancient Greeks in the Black Sea became the first industrial fishermen. They used different kinds of fishing gear (seines, drift nets, pound nets, and traps) and special vessels for fishing. They were the first to use the pound net (dalyan) and mullet cast net, the construction of which has not changed and remains in use to this day.

Today, people continue to catch a great deal of fish in the Black Sea. In the last few years, about 400,000 tonnes of live marine resources were harvested from the sea. Turkey is the leader in fish harvests among the Black Sea countries; it catches more than a half of all fish caught in the Black Sea. Alas, as a result of overfishing, tuna and mackerel have disappeared from the Black Sea. Sturgeons are considered an endangered species, and their catch is now legally forbidden in all Black Sea countries, although poachers do occasionally violate this rule. Numbers of Black Sea brill and spiny dogfish are rapidly reducing; they have also been included on the Red Book lists of the Black Sea countries. One of the smallest fish in the Black Sea – the European anchovy, as well as two invasive species introduced in the XXth century: the so-iuy mullet and the predator mollusc Rapa, have become key species for Black Sea fisheries.
27. Why are there not so many seagulls in Odesa compared to Istanbul?

Seagulls are amazing birds, if for no other reason than their ability to use people at their own discretion. Sometimes seagulls tolerate a human presence in order to benefit from their harvests; sometimes seagulls expend great efforts to escape humans, for example, during their nesting period, when seagulls seek out isolated islands and rocky cliffs. Near the coasts around Odesa, about 10 species of seagulls can be found across various seasons as they visit the hospitable shores of Luzanivka and Cape Velyky Fontan. The largest among these species is the Caspian gull (*Larus cachinnans*) with a wingspan of slightly more than 1 metre. Its loud ‘laughing’ can be heard on the piers and docks of southern port towns. The image of large, quarrelsome colonies of seagulls is quite common on the quays of Spain, Portugal, Italy, and Croatia, where people feed them for fun. The Caspian gull behaves in a not-at-all aristocratic manner; if people let it, it will trample fishing tackle, snatch bait, or pierce buckets to poach caught fish. Moreover, if a profusion of food appears, a gang of fighting and screaming gulls is quick follow. The most clamorous among seagulls is the black-headed gull (*L. ridibundus*), smaller relative of the Caspian gull. It prefers freshwater lakes in deltas to the coastal islands for reproduction. For this reason, mature seagulls appear near Odesa’s shores only after fulfilling their parental duties, and in the case of a mild winter, they unhurriedly fly along the coast from July to April of the following year. This species, along with the Caspian gulls, escort pleasure boats hoping for a treat from tourists. Their young, which are recognised by their brown feathers on both heads and wings, live as nomads near the Odesa coast all year round.

However, let us return to our earlier question. The number of seagulls on any Odesa coast, especially near ports or oil depots, is indeed smaller than along any part of Istanbul seashore. This happens for several reasons. For one, Istanbul simply hosts more species of gulls during the year. Unlike in Odesa, the Armenian gull (*Larus armenicus*) and Audouin’s gull (*Larus audouinii*) occur here regularly. Beyond the Caspian gull – the main dweller of the Black Sea cities – the yellow-legged gull (*Larus michahellis*) is also widespread in Istanbul. This species usually nests on rocks, and thus easily accommodates house roofs as a rookery. Because of their adaptability, the population of the yellow-legged gull has increased significantly. The Caspian gull, however, prefers Black Sea beaches for nesting, almost completely ignoring roofs. In addition, the Sea of Marmara is full of islands, with a multitude of cliffs suitable for seagull nesting. Another answer to our question is related to human activity. There are many small fishing vessels docked in Istanbul, and birds do not miss an opportunity to scavenge the remains of nearby fish. The sea here is warmer, and schools of small pelagic fish and cuttlefish are easy pickings for gulls that took a fancy to this prosperous place.

It should be noted that only 50 years ago, Caspian seagulls from the Azov-Black Sea region as a rule stayed here to survive winters, moving mainly along the coastline. However, nowadays the majority of local birds prefer to spend winter on the garbage dumps of Northern and Western Europe, which are rich with food and where people are more tolerant than in Southern climes.
28. What are some surprising findings about the Black Sea?

From time to time, mass media reports on the observance of unusual-for-the-Black-Sea species, e.g. the exotic pennant coralfish (*Heniochus acuminatus*) and predatory red barracuda (*Sphyraena pinguis*). The barracuda got to the Mediterranean Sea through the Suez Canal, at which point it became naturalised before pushing into Black Sea waters through the Bosphorus. The tropic pennant coralfish was seen only once in 2003, and most likely was brought into the sea area near the Crimean coast by ballast waters from ships coming originating in the Indian or Pacific Oceans. Also, it could simply have been released from a fish tank, as this fish is a very popular object of aquarium husbandry. In 2013, a dogtooth grouper (*Epinephelus caninus*) was caught near the South-Western coast of Crimea. It was even transported alive to an aquarium, where it lived for more than a year in seawater! The dogtooth grouper is a powerful predator, with a life span up to 75 years inhabiting the Western Atlantic and the Mediterranean Sea waters. It could easily reach the Black Sea by travelling through the straits. Meanwhile, in 2016, a fisher found a specimen of the well-known ocean sunfish (*Mola mola*) not far from the Turkish city of Rize. It was the first sighting of this species in the Black Sea. Most likely, the fish got into the Black Sea from the Aegean through the system of straits.

Another interesting case arose via reports on the appearance of a seal near the Crimean coasts. It carried hopes for the recovery of the Mediterranean monk seal (*Monachus monachus*) population, as the species has not been seen in the Black Sea for more than 50 years. However, there were no firm evidence to prove that the seal really was there. It is also interesting that a female grey seal (*Halichoerus grypus*) was found and photographed in an underwater cave not far from the Western Crimean coast. For a long time, the animal has been confused with the Mediterranean monk seal. The likeliest explanation is that it escaped or was released from captivity. The seal lived in the Black Sea for at least 15 years; what happened to it thereafter is unknown.

The list of exotic species which get into in the Black Sea accidentally and do not take root there, is very long. Nevertheless, some of them assimilate, for instance, rapana and mud crab (*Dyspanopeus sayi*) found in the Black Sea in 2009. Its natural habitat is the North American Atlantic coast, but now the crab actively settles in bodies of water all over the planet.

The increasing incidents of sea turtle catches are of special interest. According to historical data from the XVIIth century, the sea area from Istanbul to the Northern coast of Bulgaria served as their habitat. As further scientific observations took place, the green sea turtle (*Chelonia mydas*) and the loggerhead sea turtle (*Caretta caretta*) were detected a few times in Bulgaria, Romania, and Turkey. The cold spell after the Middle ages led to the diminution of sandy sea coasts, which made the Black Sea shores unusable for turtle egg-laying. However, for the last few years, more turtles have been seen near the coasts of Turkey, and one individual was caught in Georgia. Perhaps, climate change will make the Black Sea attractive for these reptiles again.
Afterword

You have reached the last page of this small book. We have no doubt that, like the team of authors, you always had a penchant for the Black Sea. We tried our best to fulfil your curiosity about this unique ecosystem, this exceptional and singular piece of the world’s oceans. Of course, this book cannot contain everything you need and want to know about the Black Sea, but we hope that these amazing short stories and interesting facts about Black Sea life will arouse your interest in further discovering its secrets. We wish you well on your long and fascinating journey leading to the exploration and protection of this natural treasure.