Black Sea Study Pack: A Resource for Teachers

Edited by
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Global Environment Facility
Black Sea Ecosystem Recovery Project
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Teachers cleaning the beach as part of their workshop, Bulgaria, 2000

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Preface – Development and purpose of the Study Pack

(1) Introduction

Environmental education is not the same as teaching biology or ecology; it is about helping to form values regarding the key issues of sustainability and the environment. In some countries, the wider term *Education for Sustainability* is employed and reflects the need to form new attitudes and skills to live sustainably. The crisis in the Black Sea is ultimately a consequence of unsustainable living and our ability to protect this sea will be evidence of a profound change in the way we manage our society. This crisis was demonstrated on a global and regional scale in the recent Millennium Assessment (2005) which signalled that unless we change our current pattern of development, the ability of the ecosystem to produce the goods and services we depend on will be in serious jeopardy. Change, whether on a large or very local scale, will only occur when there is a greater understanding of the problems and their solutions and the role of every citizen in making the change.

We feel that the long-term success of the policy and legal reforms instituted through the work of the Black Sea Commission, BSEP and projects such as BSERP, will ultimately depend on the involvement of all stakeholders in the region. But it is insufficient to convince current leaders; there is already a need to work with younger people who will be replacing them (or at least voting for them) in a relatively near future. This is why we need an environmental education programme.

(2) Development of the Study Pack

The first Black Sea Teacher's workshop was held in 1997 in conjunction with the Black Sea University in Mangalia, Romania, using funds from GEF-BSEP. This workshop, involving a mixture of teachers and journalists, discovered that environmental education was virtually absent from school curricula throughout the region. It also examined the various alternatives for correcting this deficit. Here, it was seen that it was not simply possible to import ideas from the West; the social and economic circumstances in the Black Sea region were quite different. There is little possibility of relying on voluntarism for example; teachers were heavily occupied and very poorly paid and out of class activities were minimal. Also, why should an activity so fundamental as forming new values about the environment be relegated to clubs for the better-off children? The answer was clearly to work alongside the formal education sector in a manner that was creative and helpful, did not try to impose new workloads or try to bring about an unlikely revolution in the way education is delivered. But, on the other hand, all teachers complained that there were no easily accessible materials to support them in their work; the products of BSEP were informative but not very useful for the purposes of teaching new generations of citizens. Clearly there was an important gap that the BSEP had yet to fill.

The opportunity for developing this work was greatly enhanced in 1998 by the award of a fellowship grant from the Pew Fellows Programme in Marine Conservation. This provided three years of financial support for the development of environmental education in the Black Sea region through two two-week workshops (in Arkutino, Bulgaria and Alushta, Crimea, Ukraine), pedagogical research activities and school

projects throughout the region. The idea was to bring together a core group of inspired teachers and help them to work together to develop and test facultative teaching material tailored to their own needs. The project provided a means of translating all of the scientific, social and political requirements for sustainably managing the Black Sea into educational material that was relevant and interesting. The product was the first version of the Black Sea Study Pack.

A huge amount of effort went into developing the Study Pack. It involved some of the best scientists in the region, authors, experienced managers and the core group of teachers themselves. The activities were tested in many schools in the region and feed back was used to improve the material, or tailor it to the needs of particular countries.

Following the completion of the Pew-funded phase of the programme, work continued in Phase One of BSERP. Further inputs from specialists within the region were incorporated, providing material such as species identification keys and 'Black Sea Fact Sheets' that are of use to a much wider audience than upper high-school children. Furthermore, the study pack material itself was sent to educationalists from the formal government sectors in each country for comments and eventual approval. The response has been positive in every case.

(3) Who is the material designed for?

We have endeavoured to provide material to satisfy the needs of high school teachers though some of it has been tested on a much wider age range. The Study Pack is targeted at teachers but also includes material that can be photocopied and distributed to the students. We feel that the study pack has a much wider use however, particularly for members of NGOs who may benefit from its integrated approach and factual detail.

(4) Feedback

We always appreciate feedback from teachers regarding the study pack. We learn by 'doing' and the cycle of developing new approaches, learning from them and using the lessons to refine the approaches will never end. Please email us your comments to olga.maiboroda@plymouth.ac.uk.

Contents

Please note that the following additional resources accompany this Study Pack:

(1) The booklet *How to Save the Black Sea: Your guide to the Black Sea Action Plan*

(2) The colour guide to Black Sea Flora and Fauna (developed by Acad. Yuvenaly Zaitsev)

(3) The board game *Black Sea Survival* to help understand the decisions that have to be made in wildlife conservation

What is environmental education?

The term "environmental education" has been applied to so many different forms of education that we feel it is necessary to clarify what the authors of this Study Pack mean under environmental education.

Very often environmental education is confused with ecology. Indeed, some of the Black Sea languages, Russian, for example, uses the term "ecological education" instead. Environmental education is not ecology, or nature studies. Learning about living organisms, their habitats and the ways in which these organisms interact with each other and their environment is an important part of environmental education, but not the whole of it.

Perhaps, an analogy will help. Think of environmental education as a tree. The roots of this tree are chemistry, physics, biology and geography. Environmental education is science based. The trunk of this tree is ecology. The understanding of interconnectedness and interdependence of all life is central to environmental education. Beliefs and attitudes are the branches of this tree. Environmental education challenges beliefs of human superiority to other life forms and promotes attitudes of respect and care towards nature. The leaves of the tree are feelings. The leaves turn sunlight into energy for the entire tree. Without them, the tree would be lifeless and would eventually decay. It is the leaves that give the tree vitality, and meaning as a whole tree and not merely a collection of roots and branches. Equally, without the involvement of feelings, environmental education loses its purpose and effectiveness. Environmental education puts students in direct contact with nature to help them develop love and empathy for all living beings. Finally, the blossoms on the tree are signs of changing consciousness, and the fruit are actions towards a sustainable living.

The reality of present environmental situation in the world is often negative and depressing, but environmental education is careful not to promote apathy and fatalism among the young. Any presentation of an environmental problem must begin with the root causes and end with positive alternatives and possible ways of solving it. Most environmental issues are also complex. Their understanding requires an interdisciplinary synthesis. In other words, "environment" as a subject of environmental education, includes not only nature, but also society, culture, economy and politics.

To summarize, environmental education:

- Awakens and develops feelings of love and empathy for all Life.
- Gives knowledge about the environment in the environment.
- Practices, through school policies and family involvement, minimal impact behaviour – conservation of water and electricity, recycling and reuse of paper and other materials, buying locally grown food, whenever possible, and growing some of your own.
- Encourages active civic position through personal involvement in environmental protection.

All teachers who contributed to this Study Pack practice environmental education because they want to see their students choosing a sustainable lifestyle, not damaging to the environment and respectful of other present and future generations of humans and other life forms. We invite you to join us in bringing environmental education to more schools in the Black Sea region!

How to use this Study Pack

This Study Pack consists of two types of material, Fact Sheets and Study Sheets.

Fact sheets provide concise information on the Black Sea from the standpoint of a number of disciplines. They are designed to help specialist teachers incorporate information on the Black Sea in their regular classes. Several of the sheets were prepared by leading regional specialists in the Black Sea. In some cases, the material is rather technical in style and we have provided a glossary of important terms (or more general background information) that runs in parallel to the main text in the right-hand margin. The texts are illustrated with diagrams that may be useful when delivering the material and can also be found on the web site of the BSERP (www.blacksea-environment.org) or the University of Plymouth (www.research.plymouth.ac.uk/marine-policy).

Study sheets are intended to provide cross disciplinary classroom material on a number of key issues in the Black Sea. We consider this to be the most innovative part of the Study Pack and we have prepared it in close association with teachers from the region in order to ensure that each sheet is realistic in its goals and approach. The first part of each sheet provides a series of short pieces of factual information interspersed with group exercises, most of which can be undertaken in the classroom. The exercises are designed to be participatory and provocative. In addition, each student sheet includes a section denominated *The Moral Maze* which poses some of the ethical dilemmas encountered in the pursuit of sustainable development. In order to help teachers with delivery of the material and with the exercises, we have provided pedagogical notes that explain the purpose of each exercise and provide additional material in some cases. We have kept the number of study sheets quite small in recognition of the difficulty many teachers find in accommodating new materials in busy curricula. Some teachers may find it helpful to deliver some of the exercises over a number of shorter sessions.

The **additional materials** presented in parallel with the study pack (see contents page) provides information (1) on the practical actions that Black Sea governments are taking to protect the Black Sea ecosystem, (2) a handy reference guide to Black Sea species for student fieldwork, and (3) a participatory game to help students to understand the difficulties faced when trying to protect key species in the Black Sea.

In addition to the material provided through this programme, some schools may wish to participate in the work of Globe (www.globe.gov) which helps schools to establish observatories and to learn from making and interpreting their own observations.

Part One

Black Sea Fact Sheets

Peoples of the Black Sea

Neal Ascherson[1]

1. The Black Sea: The Place Where Strangers Meet.

For perhaps four thousand years, perhaps even longer, the Black Sea has been a meeting place. Around its shores, many different peoples with completely different styles of living made contact for the first time. Sometimes the meeting was violent, as new waves of immigrants drove Black Sea inhabitants out of their homes. Often, though, these peoples settled down to live with each other, especially in the ancient cities all round the Black Sea coast. The rivers and the sea swarmed with fish, and the land around the shore was rich and fertile. Craftsmen, merchants, fishermen and farmers with many different religions and customs cooperated to take benefit from the region's wealth in fish, timber, wheat and precious metals.

Most of the immigrants who arrived on the Black Sea coast came from the East – from different regions of central Asia. They were nomadic peoples, who moved across the open grasslands in wagons with great herds of horses and cattle. When they reached the Sea, they could go no further and settled down. The Scythians and the Sarmatians who followed them stayed in the region for almost a thousand years, until new invasions in the 4th century AD drove them westwards. These people spoke a language related to modern Iranian. Later waves of incomers, such as the Huns and Tartars, had a more Turkic culture and speech. The Goths, who arrived from the Baltic in the 3rd century AD, spoke an early form of German.

But other settlers reached the Black Sea from the West and South. They came not as conquerors but as merchants. The first were the Greeks, who began to found colonies around the coast 2,700 years ago. The Greeks were town-dwellers and traders, many of whom could read and write. So they were amazed to meet Black Sea nomads such as the Scythians, who seemed to have no settled home and no cities, and who lived on the move with their herds and wagons. This meeting was very important for the future of human thinking. It made the Greeks claim that there were two kinds of human being on earth – the "civilised" who lived in towns and villages and spoke Greek, and the "barbarians". Soon the Greeks began to use the world "barbarian" to mean everything that was primitive and cruel, and the word "civilised" to exalt their own way of life. This one-eyed way of seeing other peoples still dominates most of the world.

Greek traders bought goods from the Scythians and paid their kings with gold and silver jewellery. Without dried fish and wheat from the Black Sea, the Greek and Roman empires would not have been able to feed themselves. Most of the cities around the Black Sea today were founded as ancient Greek colonies. Later, in the Middle Ages, came colonists from the Italian city-states, Genoa and Venice. They bought luxury goods imported from China down the Silk Road, but also slaves from Russia and the Caucasus to make good the labour shortage in Western Europe. Many other trading peoples, such as Armenians and Jews, also settled in these coastal cities. But Greek merchants and farmers continued to live around the Black Sea for another 2000 years, until in the 20th century Turkish and Soviet rulers found reasons to expel them.

[1] Neal Ascherson is a well known author and journalist. He is also editor of the Journal of Public Archaeology. His book, 'Black Sea' received worldwide acclaim as a masterpiece and has been translated into Turkish.

These were cities with many languages and many religions. In the 6th century BC, the Greek colony of Dioscurios used nine different languages in its market-place. When that city became Sukhumi, in modern Abkhazia, much the same was true until a few years ago. That rich mix has been the special nature of Black Sea culture. But while life in these multiethnic towns did not change much over the centuries, the big picture of conquest and invasion around the Black Sea changed dramatically.

After the Greek period, the region became part of the Roman Empire, until the Goths and then the Huns conquered the northern shore of the Sea. In the 7th century AD, Islam arrived on the Black Sea as the Arabs invaded the Caucasus. Eight hundred years later, a section of the Mongol-Tatar "Golden Horde" established its own Moslem "Khanate" in Crimea. Soon afterwards the Byzantine Empire, which had once ruled all the Black Sea shores, was overthrown by the Ottoman Turks who captured Constantinople in 1453. This isolated the Black Sea peoples from their old links with Europe, until – in the 17th century - a new Power arrived from the North. Russia began to expand southwards until it reached the Black Sea, finally conquering Crimea in 1783. There followed almost two centuries of Black Sea wars between Russia and the Ottoman Empire, which gave Russia (later the Soviet Union) control of the Caucasus and led to the emergence of independent Bulgaria and Romania.

It is many centuries since a single Power ruled the whole Black Sea shore. Today, after the fall of the Soviet Union, six independent nation-states live around the Sea. Each has a rich culture of its own. But in the 20th century, a new ethnic nationalism arose. Tolerance for minority cultures in the Black Sea port-cities began to weaken. Greek communities left Trabzon in Turkey and Anapa in Russia, to take two examples, after nearly three thousand years. The Jews, Poles and Italians have almost all left Odessa in Ukraine, the city whose wealth they created in the 19th century.

2. Peoples on the Black Sea coast today.

The inhabitants of the modern Black Sea region fall into four main groups. These are not "races" in a biological sense. They are defined mostly by their languages, and by their culture. The Black Sea has no "original inhabitants" or natives. Everyone here is a descendent of immigrants – even if they first reached the Sea four thousand years ago.

a) Slav Peoples.

Bulgarians, Russians and Ukrainians all speak closely related Slav languages. The origins of the Slavs seem to lie in the Bronze Age somewhere north of the Black Sea. It is very possible that they all spoke one "proto-Slav" language before they spread out in different directions. But their languages now unite cultures which are often made up of very different elements.

The Russians, as a nation, include not only Slavs but millions of people whose ancestors were Mongol-Tatars, Balts, or Finno-Ugrians related to modern Finns and Estonians. Many city-dwelling Russians have family roots which are Polish, German, Jewish or Caucasian.

The Bulgarians probably originated as a Turkic-speaking people, who entered Europe with Hunnish invaders in the 3rd century AD. They finally settled in the lands south of the lower Danube in the 7th century, where they mingled and intermarried with other immigrant peoples, including Slavs whose language they eventually adopted. The Bulgarians were ruled by the Ottoman Empire from 1396 to 1878, but most of them retained their Orthodox Christian religion. The largest minority in Bulgaria is Turkish.

The Ukrainians are a recent nation formed out of several elements, most of them Slav. One element is Cossack, the communities of escaped serfs from Russia, Turkic nomads and other marginalised people who lived in the steppe between the Dnieper and the Don. A second element is ethnically Russian, settled mainly in eastern Ukraine but also forming the main Slav population of port cities like Odessa and Sevastopol. The third component, are non-Russian Slavs speaking the Ukrainian language, have their original homeland is inland in western Ukraine near the Polish borders.

After the Russians, the Crimean Tatars are the most important minority. They were deported to central Asia by Stalin but have now returned to Crimea, and have reoccupied some of their ancestral lands. Until the Second World War, the larger landowners of western Ukraine were almost all Poles, while the small towns and villages were often strongly Jewish. Stalin and Hitler between them destroyed both groups, although a Polish minority still exists in this part of Ukraine. . .

b) "Dacian" People: Romania.

The Romanian language is the only "Latin" language in the Black Sea region. It is much closer to Italian, Spanish or French than to Turkish, Greek or to any Slav language. But how it came to be spoken by people on the lower Danube is not entirely clear. One traditional and popular explanation claims that Romanians are the descendants of Latin-speaking Roman soldiers settled in the region as colonists after completing military service. Another version suggests that the ancestors of modern Romanians are Thracian and Dacian peoples who inhabited the country 2000 years ago and set up powerful military kingdoms.

Romania's main national minority is the large Hungarian community living in Transylvania. The ancient German minorities in the same region, the Banat Swabians and the Transylvanian Saxons, have almost all emigrated to Germany in the last decade. There are small Slav communities living in the reeds of the Danube Delta, including a community of Russian "old believers" who took refuge from persecution there. Romania also contains a large Roma population, distributed across the country.

c) Turkic Peoples: Turks and Tatars.

The Turks, another originally nomad group from central Asia, arrived on the south shore of the Black Sea in the 12th century. A hundred years later, they conquered Anatolia and established what was to be the Moslem "Ottoman Empire" which eventually - after the fall of Constantinople in 1453 - completely encircled the Black Sea. When the Empire collapsed after the First World War, the new Turkish state expelled a number of non-Moslem minorities, above all the large and ancient Greek communities along the north coast of Anatolia.

The Tatars, or Mongol-Tatars, arrived in the Volga river basin from Central Asia in the Middle Ages. The so-called "Golden Horde", the name of the western part of the Mongol-Tatar empire, converted to Islam in the 14th century. One branch of the Horde moved down to the Black Sea and entered Crimea, where they established the Crimean-Tatar Khanate in 1423. The Crimean Tatars later became part of the Ottoman Empire, until Russia seized Crimea from the Turks in 1783. At the end of the Second World War, Stalin deported the Crimean Tatars to central Asia, but they have now returned to Crimea and number about 270,000.

c) **Caucasian Peoples : Georgians and Abkhazians**.

The Georgians rightly consider themselves one of the oldest nations in Eurasia. Their language, belonging to the Kartvelian family, is pre-Indo-European and the Georgian people have probably been settled on the Black Sea for some 4000 years. The population along the Black Sea coast is largely Mingrelian, a people often counted as Georgian but who speak a slightly different Kartvelian language. Most Georgians are Orthodox Christians, but there are many Moslems in the province of Ajaria, on the south-eastern corner of the Black Sea next to the Turkish frontier. Georgia regained its independence in 1991.

The Abkhazians are a tiny people belonging to the north-west Caucasian language family. They inhabit the foothills of the western Caucasus and the coastal strip, between the Russian border near Sochi and the current demarcation line with Georgia on the Inguri river in the south. Many of them emigrated to Turkey when Russia conquered the Caucasus 140 years ago, but the remaining Abkhazians were eventually given a form of autonomy within the Soviet Union. After Georgia became independent in 1991, Abkhazia was claimed as an integral part of Georgian territory. War broke out in 1992, ending with the flight of the Georgian and Mingrelian population. Abkhazia declared independence, but remains unrecognised by Georgia or other states. Most of the Greek and Jewish communities left at the time of the war. Large Russian and Armenian minorities remain, and many Mingrelians have returned to the southern province of Gali.

3. Minority Groups around the Black Sea.

Until now, the special quality of the Black Sea region has been its mixture of many peoples living together as neighbours. This mixture used to exist not only in the big cosmopolitan ports, like Odessa, Constanta, Trabzon or Batumi, but often in small farming villages as well.

These mixtures have been ethnic, religious and social - in the sense that different ethnic groups often specialised in different trades. They have given Black Sea region its variety of different life-styles, cooking and language.

But over the last hundred years, this diversity has been badly reduced. This is partly because of the coming of new nationalist ideologies ("one race, one language, one state"). It is also because liberation from oppressive regimes seems, for reasons we don't really understand, to melt the cement which holds old multi-ethnic communities together.

The main minority losses are:

1. The Pontic Greeks, who are descended from 7th century BC Greek colonists. After the new Turkish Republic was established, the Greek population of Turkey was expelled in 1923. Some went to Greece; others moved to the Caucasus and south Russia. But in 1949 Stalin deported all Greeks in the southern USSR to Asia. Most survivors have now moved to Greece.
2. The Jews, who formed large and often wealthy communities in coastal cities around the Black Sea, especially in Odessa and other Ukrainian ports. Most of them were murdered by the Nazis. The majority of the survivors left for Israel or the United States as soon as emigration from the Soviet Union became possible in the 1980s.
3. The German and Swiss communities. As mentioned above, the old German settlements in Romania have been almost abandoned in the last 20 years. The big German and Swiss colonies planted in Ukraine, south Russia and Crimea by several Russian Tsars were mostly abolished after the Bolshevik Revolution.

4. The Italians. In the 19th century, Italians and Greeks dominated the Black Sea shipping trade, and Italian was the main commercial language of Odessa. Much earlier, Italian trading colonies existed around the Crimean coast and the Sea of Azov up to the Don delta. None of this remains.
5. The Turks. Outside Turkey itself, Turkish minorities lived in towns and villages alongside Christian neighbours in almost every Black Sea country. Most have now left. Stalin deported Turkish populations from the Caucasus in the 1950s, while much of Bulgaria's large Turkish community left in the 1980s.

In spite of these great changes, many ethnic minorities can still be found around the Black Sea. A few Pontic Greeks still live around the northern and eastern coasts. Some Jewish people, missing the city they loved, are beginning to return to Odessa, mostly from America and Israel. The Crimean Tatars are back in their own homeland. There are large, flourishing Armenian communities throughout the eastern Black Sea region, especially in Georgia, Abkhazia and southern Russia (the exception is Turkey, where much of the Armenian nation was massacred in 1915-18). North Caucasian peoples, still speaking their own languages, live around the Russian resort of Sochi.

In northern Turkey, a large number of non-Turkish groups still exist along the Black Sea shore. Among these are the Lazi, a Kartvelian-speaking people who fled into Turkey to escape the Russians in the 19th century, the Hemsinli, probably descended from Armenians who converted to Islam, and an Abkhaz population numbering several thousands. On the Asian shore of the Bosporus, a few miles from the Black Sea, there is a Polish village established by political exiles in 1842.

And Russians are to be found in almost every Black Sea country outside their own. They are the majority population in Crimea; they exist as "Old Believer" religious exiles in the Danube Delta, or as retired pensioners along the Abkhazian or Georgian coast, or as the descendants of many waves of political refugees who found shelter in Bulgaria. Once Greek was the world-language used around the Black Sea. Today, in spite of all the upheavals of the last few years, the most-used language along all but the Sea's southern shore is still Russian.

Black Sea Geography

Text prepared by Stela Nedkova Petrova[2]

Introduction

People wonder why our sea is called "black". On sunny days, the seawater is blue-green and when the sky is heavy clouded, it is silver-grey or azure. Ancient Greeks first called it Pontus Axeinus meaning an "inhospitable sea". In comparison to the Mediterranean, they found it cold and stormy, and even dangerous because of the wild tribes inhabiting its shores. It took a few centuries for the Ancient Greeks to get to know the Black Sea and its human inhabitants, before they changed their mind and started calling it Pontus Euxinus ("Hospitable Sea"), often referring to it in a friendly way, simply as the Pontus. Its treasures were reflected in the myth of the Golden Fleece, and Herodotus describes it as the most remarkable of all seas. There are several hypotheses for the origin of its present name. Historians say that it is an old name given by the Persians. Hydrologists explain it by the Black sea's ability to tint metal objects black, due to high content of dissolved hydrogen sulphide. Biologists tend to explain it with the fact that there is no oxygen and virtually no life in its depths. Whatever the origin of it present name, the Black Sea is unlike any other sea in the world, and it is greatly important for all people living around it, for it sustains them and supports their economy by attracting millions of tourists.

1. Physical geography: Facts and figures

The Black Sea is a small intercontinental sea situated East-West between Europe and Asia. Six countries border the sea: Bulgaria and Romania to the West, Ukraine to the North, the Russian Federation to the North-East, Georgia to the East and Turkey to the South.

Table 1. Geographical Coordinates of the Black Sea

		Distances
W (Burgas Bay, Bulgaria)	$27^0 27'$	Max 1149 km
E (between Batumi and Poti, Georgia)	$41^0 42'$	Min
S (Giresun, Turkey)	$40^0 56'$	Max 611 km
N (Berezan – Ochakov, Ukraine)	$46^0 33'$	Min 263 km

The Black Sea is one of the most landlocked seas in the world. Its isolation from the world ocean is due to the restricted link with other seas. It communicates to the Southwest with the Sea of Marmara through the Bosphorus Strait and with the Aegean Sea and the Mediterranean through the Dardanelles, and further with the Pacific through the Gibraltar. In the Northeast the Black Sea connects with the shallow Sea of Azov through the Kerch Strait.

Table 2. The Straits

	Minimum width /km/	*Maximum depth /m/*
Bosphorus	0.7	80
Dardanelles	1.3	106
Gibraltar	14.0	1181
Kerch	3.7	11

Part of the Black Sea uniqueness depends on the fact that its surface area is about five times less than its drainage area, which covers entirely or partly the territory of 20 countries in Central and Eastern Europe and 2 in Asia. These include the six states surrounding it and also Germany, Switzerland, Italy, Austria, Poland, the Czech Republic, Slovakia, Hungary, Slovenia, Albania, Macedonia, Bosnia and Herzegovina, Croatia, Serbia and Montenegro, Belarus and Moldova.

Table 3. Geographical Facts about the Black Sea

Surface area /km²/	423,000 (462,000 with the Sea of Azov)
Depth /m/	1271 (average) 2212 (maximum)
Drainage area /km²/	2,500,000
Volume /km³/	547,000
Tides /cm/	3-10
Length of coastline / km/	4090
Number of islands /km²/	About 10 (with area more than 0.5)

The second and the third biggest rivers of Europe feed the sea with fresh water and influence the salinity of marine waters. The inflow of the Danube, the Dnistro, the Dnipro and the Don play even greater role in the Black Sea water balance than evaporation and the exchange of saline

[2] The author is a senior geography teacher in Varna and has an active involvement in Black Sea protection at a national and international level

Figure 1. The Drainage Basin of the Black Sea

waters with the Mediterranean (which forms only 0.1% of the sea volume annually). The first three rivers together with the South Bug, entering the sea in the northwestern part, contribute more than 70 % of all fresh water flowing into it. The rivers on the eastern, southern and western coasts have much smaller drainage areas and provide about 20 % of fresh water inflow.

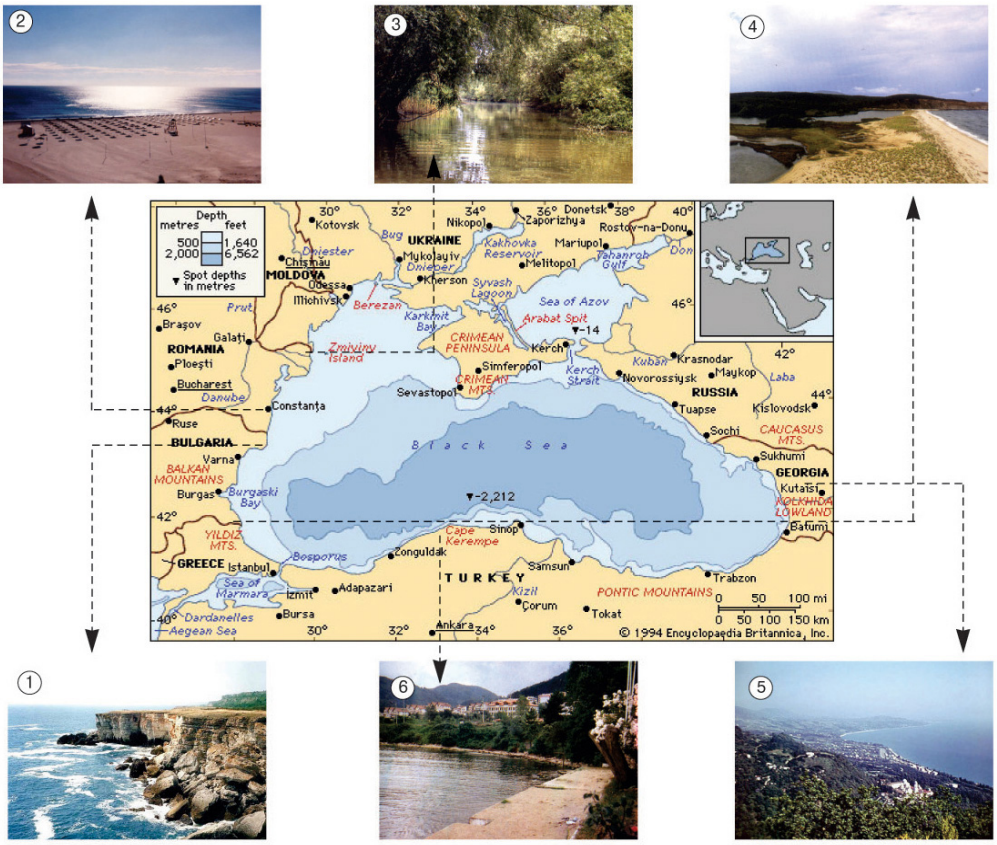
Table 4. The Black Sea Rivers

Main rivers	*Length /km/*	*Drainage area /km^2/*
Danube	2,860	817,000
Dniepr	2,201	504,000
South Bug	806	63,700
Dniestr	1,362	72,100
Don /Azov Sea/	1870	422,000
Kuban /Azov Sea/	870	57,900
Rioni	327	13,400
Chorokhi	438	22,000
Kizilirmak	1151	77,100
Sakarya	790	65,000
Kamchia	244.5	5,358

The kidney-shaped sea depression is surrounded to the West and North by the relatively low lands in the Balkan Peninsula and Eastern Europe, where the Balkans (mount Botev, 2373 m), the Danube Plain with the Danube Delta, the Russian Plain and the Crimean Mountains (mount Roman Kosh, 1545 m) border the sea. The East and Southern coasts rise in the skirts of the Caucasus (mount Elbrus, 5642 m) and the Pontic Mountains (mount Kachkar, 3937 m) in Asia Minor. It is only the Kolkhida lowland that breaks the mountainous relief to the East.

The coastline is generally mildly curved. The only large peninsula is to the North - the Crimea with the Tarkhankut and the Kerch Peninsula linked to it. The few large bays lay in the northern and northeastern parts - the Odessa Gulf, Yagorlikskiy, Tendrovskiy, Karkinitskiy, Kalamitskiy Bays and the Novorossiysk Bay in the East. The biggest of only few islands (Zmeiniy, Tendrovskiy, Berezan) are also in the northwestern part. The coast is low and flat, and sandy spits often bar the river mouths. Brackish and salty lagoons form large wetlands with great ecological importance. The eastern coastline of Georgia has weak indentation with no sheltered closed bays. Only few smaller peninsulas and bays are located in the South in Turkey – the Capes Ince, Chum, Baba and the Sinop and Samsun Bays. The western coastline is also slightly ragged by the Burgas and the Varna Bays and the small peninsulas of Nessebur and Cape Kaliakra.

2. Landscape diversity



1. *The Steppe Landscape in Dobrudgea*
2. *The Sandy Beaches Landscape in the West*
3. *The Danube Delta Wetlands*
4. *Flooded River Mouths and Spits*
5. *The West Coast Landscape*
6. *The South Coast landscape*

Fig. 2 Black Sea Landscapes

The coastal landscapes represent a remarkable diversity that illustrates the transition of three basic types of environments (biomes):

The steppe landscapes stretch along the Northwest and the Northern coast of the Black and the Azov Seas. These plain or hilly regions have a dry temperate climate. The typical grass vegetation paints the plains with the bright colours of the blooming plants in humid spring, while in summer, the steppe turns dark yellow with the grass drying up under the hot sun. Winters are cold and windy and the snow covers the plains in white for several months. On the Western coast, the steppe gradually turns into the so-called Balkan landscapes, which have milder temperate climate providing for the predominantly oak-forest vegetation. The exclusively fertile soils ("chernozem") and the flat relief led to the development of intensive arable agriculture. In some cases however, intense agriculture and excess use of chemicals led to the depletion of the quality of soils and pollution of watercourses. Low intensity organic farming is often proving to be a more sustainable practice. The wide and flooded river mouths on the Western and Northwestern coasts form valuable wetlands rich in unique wildlife. The Danube Delta (*see illustration 3*) as well as the Bulgarian and Ukrainian coastal wetlands (*see illustration 4*) have great ornithological importance because they are located along the rout of Via Pontica and host a variety of migratory birds. Perfect large fine-sand beaches alternate with picturesque steep and rocky plateau slopes on the shores of Bulgaria and Romania and provide attractions for tourists (*see illustrations 1 and 2*).

The humid subtropical landscapes are typical for the Kolkhida plain on the Eastern Black Sea coast where winters are relatively warm and extremely humid. The annual precipitation here varies from over 2000 mm to almost 4000 mm on the mountain slopes. The high Caucasus to the North protect the shore from continental influence (*see illustration 5*) while the West–East transfer of humid air masses from the Black Sea accounts for the extreme rainfall. Such climate favours the rich tropical-like vegetation of the so-called Pontic type. The narrow and low shores contrast with the mountainous hinterland and add to the exotic views.

The relatively high Pontic Mountains stretching along the East Turkish Black Sea coast confine the coastal plains to a narrow strip (*see illustration 6*) and make summers cool and more humid. Forests cover the mountain slopes where natural landscapes have been preserved. Unfortunately deforestation around human settlements activates erosion and landslides create natural hazards. However, humidity provides excellent conditions for diverse agriculture – much better than in other regions in Turkey.

Typical **Mediterranean landscapes** are found on the South Black Sea coast West of Sinop where the summers are hot and dry while winters are mild and rainy. The climate and the beaches together with other natural resources give options for tourism development that combines well with Mediterranean-type agriculture. Mediterranean landscapes are also found in South Crimea on the opposite coast where the Crimean mountains shelter the narrow coastal strip around Yalta from the cold northern winds. The northwestern Caucasus also shelter the Sochi district of Russia, giving rise to areas with sub-tropical and Mediterranean 'microclimates' with bright and warm summers and rich natural vegetation. Together with warm mineral waters it makes these coasts exclusively attractive for tourism though beaches are often covered with gravel.

3. Human Geography

Different landscapes and marine resources determine the **livelihood** of coastal people. Large fertile plains in Bulgaria, Romania, Ukraine and Russia support intensive *agriculture* and the production of wheat, corn, sunflower seeds, sugar beets, fruits and vegetables. The hinterlands of the Black Sea coast are famous as "granaries" that supply a significant part of foodstuff in these countries. Corn and pastures provide fodder for stockbreeding and the production of meat, milk, eggs, etc. Warmer climate and limited arable land in the East and South (Georgia and Turkey) are utilized by growing citrus fruits, tea, rise, nuts and tobacco. Though specialization differs from one country to another the most typical agricultural landscape anywhere around the Black Sea are vineyards. Grapes and excellent wines from the Black Sea region add to the local tourism attractions and special Georgian and Bulgarian wines are famous far beyond it.

Fisheries have long history in the region and it has always provided good income for certain part of the coastal population, except for the last four decades when industrial fisheries suffered a great reduction of fish catches both in quantity and variety. Now Turkey's fish catches leads in the region followed by Ukraine and Russia while Bulgaria, Romania and Georgia have symbolic catches.

Industrial production in the region is not only based on agriculture but on local mineral and energy resources as well as on the qualifications of local people and their traditions. Coal and ore deposits provide row materials for thermal energy and metallurgy especially in Ukraine, Russia and Turkey. In other countries coastal towns have often developed as important industrial centres just because their ports serve as gateways for import or export.

Cut coasts and hospitable bays predetermine the development of *ports* that attract industries and hundred thousands of people in some of the coastal cities like Odessa (the Ukrainian forth biggest city), Mykolayiv, Kherson, Ilichevsk, Mariupol in Ukraine, Sochi and Novorossiysk in the Russian Federation, Constanta in Romania, Varna and Burgas - the third and forth biggest cities in Bulgaria, Batumi in Georgia, Trabzon in Turkey.

The coastal location when favourable for *transport development* has always given best advantages for Black Sea economy, especially in recent decade of great economical changes in the region. Lying on the crossroad between Asia and Europe the region has seen good and bad times: it gives impetus to *trade* but it also challenges the balance between desirable economical profit now and long-term sustainable development for local communities and their environment. Oil transportation in the Black Sea region is part of this challenge especially if social and environmental concerns and long-term economical effects are neglected and only geopolitical arguments dominate important decisions for the future.

It is symptomatic though that the transport system in each country is quite isolated from its neighbours, except for the countries within the former Soviet Union. Actually past political regimes restricted people from moving across borders. Travelling from country to country along the Black Sea coast or across the sea, despite relatively short distances, can be a real challenge even for enthusiasts. If someone from Bulgaria decides to visit the Russian coast, for instance, one should fly to Moscow first or better drive to Istanbul, from where there are regular flights to the Russian coast and the border formalities are minimal. Fortunately, political restrictions on travel within the Black Sea region have been reduced but not eliminated. The poor transport

infrastructure between Black Sea countries renders difficulties to closer economic and cultural relations among them.

Table 5. Direct passenger transport between the coastal zones of Black Sea countries*

	Bulgaria	**Georgia**	**Romania**	**Russian Federation**	**Turkey**
Ukraine	***Plane*** Road Ship (Ferry)[1]	Ship[2]	Road Train	***Road*** ***Train***	***Road*** Plane[2]
Turkey	***Road***	***Road*** Ship[2] Plane[2]	***Road*** Ship (Ferry)[1] Plane[2]	Plane ***Ship***	
Russian Federation	Road	Ship Road[3] Train[3] Plane[2]	Road		
Romania	***Road***	Ship (Ferry)[1]			
Georgia	Ship (Ferry)[1]				

* The transport marked in Italic is recommended as regular and more convenient / safe / less formalities

[1] Summer services only
[2] Occasional services only / Charter services
[3] Blocked for the moment for political / safety reasons

Tourism is a relatively new industry in the region. It offers very good options for combining the conventional sea tourism with balneology and cultural tourism. Impressive tourism complexes were created in the 1960s – 80s along the Western coast, including big resorts for international tourists like Sunny Beach and the Golden Sands in Bulgaria, and Mamaya in Romania. At the same time Ukraine, Russia and Georgia kept to their traditional resort towns like Yalta, Evpatoria, Anapa, Sochi, etc. hosting mainly national tourists. Later Bulgaria set up a new model of tourism development following the present market demands – small quiet and beautiful resorts and tourist villages appear where tourists can rest in closeness with nature. The same tendency exists in Turkey, too, though Black Sea resorts there have to compete with the Turkish Mediterranean and Marmara tourism regions. In all Black Sea countries now there is a growing interest towards rural tourism and ecotourism because the regional natural resources offer exceptional opportunities for unconventional tourism activities like bird watching, rafting, underwater archaeology, photo-tourism, etc.

The Black Sea coasts support millions of people of different cultures, historical and geographical background. Nevertheless, the common land and sea as well as interactions between them for ages have resulted in the formation of the unique **Black Sea community** that is described by tolerance and broadmindedness. Cultures have been mixed in a strange way and often Black Sea people from different countries understand each other much better than politicians. Though different in origin, Black Sea languages show a remarkable resemblance where food or fish is concerned. One can find Christian and Muslim communities living together in peace almost everywhere around the sea. Folk dances and folk tales in distant coastal regions look quite similar, yet preserving national identity. The democratization of Black Sea countries and the awareness of common interests and goals give good chances to future cooperation. This positive tendency is well visible in common efforts for developing the Black Sea Economic Cooperation and for the sustainable development of the Black Sea region (the Black Sea Commission and the implementation of the Black Sea Strategic Action Plan for the Rehabilitation and Protection of the Black Sea).

Table 6. Geographical Facts about the Black Sea Countries

	Bulgaria	Georgia	Romania	Russian Fed.	Turkey	Ukraine
Population[1]/mln/	7.5	4.9	22.3	144.5	68.1	48.0
Capital	Sofia	Tbilisi	Bucharest	Moscow	Istanbul	Kiev
Length of coastline /km/	378	310	225	430	1595	1442
Language(s) spoken	**Bulgarian** /Turkish, Roma/	**Georgian** /Russian, Abkhaz, Armenian, Azeri/	**Romanian** /Hungarian, German/	**Russian**	**Turkish** /Kurdish, Arabic, Armenian, Greek/	**Ukrainian** /Russian, Romanian, Polish, Hungarian/
Climate:	Temperate	Humid subtropical	Temperate	Temperate (N) and humid subtropical (S)	Temperate - mild and humid (E) to Mediterranean (W)	Temperate continental to Mediterranean (Crimea)
Average daytime temperature /T^0C/	11-12.5 (N-S)	14.7-14.5 (N- S)	Above 11	10-14	12-14	11-13
Max (month, temp) /T^0C/	22-25	23-26	20-28	22-25	20-23	20-24
Min (month, temp) /T^0C/	1 to 3	3-5	–2 to 0	-8 to 5	5-10	-2 to 4
Annual rainfall /mm/	438-550 (N-S)	2800	400-600	400-1400 (N-S)	3000-600 (E-W)	400-1000 (Crimea)
Coastal administrative districts[2]: *Names and population Administrative centres (names and population) Other major cities (names and population)*	***Dobrich-210,900*** *Dobrich* /97,000/ ***Varna-459,900*** Varna /313,000/ ***Burgas-420,600*** Burgas /192,000/	***AR Abkhazia-525,100*** *Sukhumi /137,000/, Gagra, Pitsunda* ***Samegrelo-432,600*** Poti ***Guria-160,600*** Ozurgeti ***AR Ajaria-369,400*** Batumi /140,000/, Kabuleti	***Constanta-746,900*** Constanta /336,000/, Mangalia, Eforie ***Tulcea-262,100*** Tulcea /94,700/, Sulina Sinoe, Vadu	***Rostov- 4,286,200*** Rostov-na-Donu /1,003,482/, Taganrog /284,850/ ***Krasnodar-4,987,600*** Krasnodar /757,150/, Novorossiysk /248,850/, Tuapse, Sochi /395,800/	***Istanbul-8,506,026*** Istanbul /8,260,438/; ***Kocaeli-629,333*** Kocaeli /198,200/; ***Sakarya- 331,431*** Sakarya /183,265/; ***Bolu***-Bolu; ***Zonguldag-239,186*** Zonguldag /106,176/; ***Karabuk-159,967*** Karabuk,/103,806/; ***Bartin***-Bartin; ***Kastamonu***-Kastamonu; ***Sinop***-Sinop; ***Samsun-590,399*** Samsun /338,387/; ***Ordu-393,963*** Ordu /117,699/; ***Giresun***-Giresun; ***Trabzon-419,867*** Trabzon /182,552/; ***Rize***-Rize; ***Artvin***-Artvin	***Odessa-2,431,500*** Odessa /1,010,298/, Ilichevsk ***Kherson-1,151,000*** Kherson /324,424/, Skadovsk ***Mykolayiv-1,241,000*** Mykolayiv /509,102/, Ochakov ***Crimea-2,006,000*** Simferopol /338,038/, Yalta, Kerch **Sevastopol-378,400** **Donetsk-4,726,000** Donetsk /1,007,440/, Mariupol ***Zaporozhya-1,894,000*** Zaporozhya /810,620/, Berdyansk
Total number of people living in coastal districts	1,091,400 /2002- NS/	1,327,100 /1991-NS/	1,009,000 /2001-NS/	9,273,800 /2002,1999 –NS, UN/	12,128,000 /1997 – UN/	13,828,000 /2002, 2001- NS/

Economy: *Main source of energy*	Coal, nuclear	Water	Coal	Coal	Coal, water	Coal, nuclear
Main agricultural products	Wheat, corn, vegetables, grapes, fruits barley, sugar beets, sunflower seeds, livestock	Tea, citrus, grapes, fruits, hazelnuts	Wheat, corn, barley, sugar beets, sunflower seeds, potatoes, grapes, eggs	Wheat, corn, sunflower seeds, milk, grapes, livestock	Tea, citrus, nuts, tobacco, corn, grain, sugar beets, livestock	Wheat, sugar beets, potatoes, beef, milk, vegetables, sunflower seeds, fruits
Main manufactured products	Shipbuilding, processed oil, manufactured chemicals, wine and food products, textiles, machinery	Wine, food products, metallurgy	Shipbuilding, manufactured chemicals, machinery, food products	Machinery, shipbuilding, oil-refining, manufactured chemicals, textiles, cement	Food products, textiles and clothing, metallurgy, manufactured chemicals	Metals (ferrous and nonferrous), machinery, food products, shipbuilding, processed oil, manufactured chemicals, clothing
Mining	Manganese, salt, copper	Manganese, copper	Ferrous and non-ferrous ores	Row materials for cement industry, brick-clay, salts, coal	Coal, copper,	Coal, iron ore, manganese, bauxite, salt
Main fisheries (location of fleet, main species)	**Burgas, Sozopol, Varna** – Sprat, gobies, picked dogfish, mullets, bluefish, horse mackerel, anchovy, turbot	**Batumi, Sukhumi, Poti** – Anchovy, sprat, horse mackerel, whiting, mullets, dogfish	**Constanta, Sulina, Cap Midia, Mangalia, Tulcea** – Sprat, red mullet, anchovy, dogfish, horse mackerel	**Rostov-on-Don, Novorossiysk, Tuapse, Sochi,** etc. – Sprat whiting, mullets, dogfish, gobies, anchovy, scad, sturgeons, turbot	**Istanbul, Trabzon, Samsun, Izmit, Icel,** etc. – Anchovy, horse mackerel, whiting, bluefish, sprat, mullets, turbot	**Odessa, Sevastopol, Kherson, Mykolayiv**, etc. – Sprat, anchovy, mullets, horse mackerel, turbot, whiting, sturgeons, silverside
Estimated annual international tourist visits /millions (and year)	**0.9 /2001 - NS/**	**n.a.**	**0.7 /2001 - NS/**	**0.3 /2002–Eurostat,2003/**	**0.6 /2001 - NS/**	**0.4 /2002–Eurostat,2003/**

[1] CIA World Fact Book 2003 (July 2003, est.)
[2] Official Country National Statistics

Black Sea Physics

Introduction

This text contains a very brief introduction to the physics of the Black Sea. The circulation of the Black Sea has been studied for over 300 years since the Italian Count Luigi Marsigli described the two layer circulation through the Bosphorus in 1681. By the 1930s, a considerable understanding had been obtained of its overall circulation but important details were missing because of the limitations of the instruments available at the time. It was not until the final two decades of the 20th Century that more detailed information began to emerge on the variability in the finer scale circulation of the sea and the longer term changes due to ocean/atmosphere coupling. The present text will examine the most significant aspects of our current understanding.

1. The Black Sea is permanently stratified

Gravity, buoyancy, and wind are the dominant forces acting on the sea and all act together to produce its dynamics of currents, tides and mixing. The gravitational attraction of the moon distorts the ocean surface to produce tides, though in the case of the Black Sea, its surface area is too small for significant surface tides. Buoyancy however, acts to keep less dense layers of water floating on top of denser ones and they remain virtually unmixed unless the buoyancy of either layer changes considerably through warming of the denser layers or cooling of the lighter ones, or if their salt content changes or there is sufficient wind or tidal energy to mix the layers together. Waters of different density can mix together by a process known as molecular diffusion but this is extremely slow and insignificant on the scale of a sea.

The Black Sea has developed two major water layers separated by a strong density gradient, or ***pycnocline*** (see Figure 1). The lower layer, below about 70-150 metres (the depth varies from place to place) is saltier and colder than the upper layer. The average surface salinity is 18.2‰, though it can be much lower near river discharges. The lower layer has an average salinity of 21.8‰. This difference is maintained by the 36‰ Mediterranean water supplying the lower layer through the Bosphorous and rivers and rain diluting the upper layer. 3.6‰ doesn't sound like a huge difference but is sufficient to prevent the bottom, hydrogen sulphide rich water (see Chemistry sheet) from reaching the sea surface and escaping to the atmosphere. For most of the year, this is also helped by the fact that surface waters are usually warmer than deeper ones.

Little by little, bottom water does mix to form the upper layer and the rate of overall mixing can be judged from the water balance through the Bosphorus because this represents the only entrance of sea water to the Black Sea. In the long term (decades), the salt entering must be the same as that leaving otherwise the sea would soon become saltier or fresher. On average, about 300 cubic kilometres of bottom water mixes into the surface layer each year, equivalent to a layer about 2 mm thick of bottom water per day. This suggests that it would take some 1000 – 2000 years for all of the bottom water to be circulated through the pycnocline.

Buoyancy: *The floatation force of a material of lower density than the liquid it is immersed in.*

Salinity: *The amount of dissolved solids in seawater, usually expressed in parts per thousand ‰. The average salinity in the world ocean is 35‰*

Density: *The amount of matter per unit volume. In the sea, this is determined by a combination of salinity and temperature.*

Stratification: *The formation of layers of different density in the sea.*

General Circulation *is the permanent, time-averaged circulation of the ocean.*

Thermohaline Circulation *is the circulation, in the meridional (vertical) plane, driven by density differences.*

However, this may be a huge oversimplification because mixing does not occur everywhere at the same rate. There is considerable mixing in the Bosphorus for example as the narrow stratified channel brings the Mediterranean and Black Sea surface waters into close proximity. The overall water balance in the Black Sea is illustrated in Table 1.

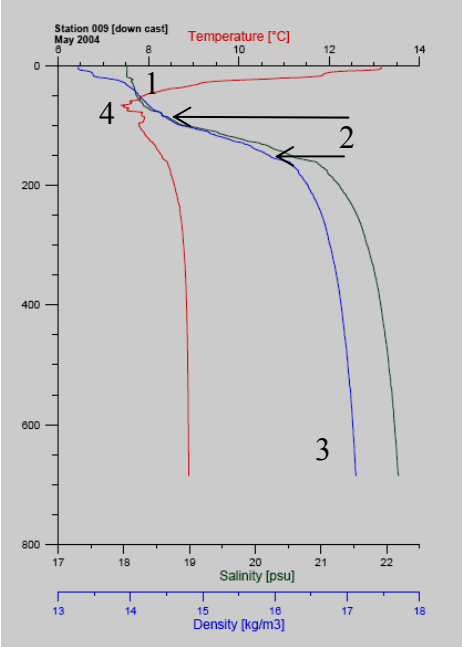


Figure 1. Profile of salinity (green line), temperature (red) and density (blue) in the Western basin of the Black Sea in the 2004 BSERP cruise of the RV Akademik. The layer nearest the surface (1) has uniform density because it is mixed by the wind and waves; it is therefore termed the 'upper mixed layer'. The zone marked '2' is the permanent pycnocline. The deep water region (3) has very little variation in density and until recently it has been difficult to study its mixing and circulation. The temperature profile shows how the water is warmed near the surface (this cruise was in late spring) but quickly cools with depth until a Cold Intermediate Layer of about 7ºC is reached (4). The deeper sea is warmer, partly reflecting the warmer Mediterranean source water and partly heating from geothermal processes below the sea floor.

Table 1. Water Balance for the Black Sea (based on the work of Prof. Umit Unluata).

Water Source		**km^3/year**
Rivers	←	350
Precipitation	↓	300
Lower Bosphorus current	→	300
Evaporation	↑	350
Upper Bosphorus current	←	600

Stratification in the Black Sea is not limited to the separation between the anoxic bottom water and the surface layer however. Another notable feature is the Cold Intermediate Layer (CIL) that can be found in most places just above the permanent pycnocline. It is a layer of colder water than those above or below it and its formation has intrigued oceanographers for many years. It forms in the winter when the sea surface becomes very cold (so cold that ice may form over the sea in the extreme north near Odessa). The cold water is heavier than that further offshore and sinks below it to settle as a thin layer on the denser pycnocline. It may also form in the centre of the Black Sea in cold and stormy winter conditions. Water from the CIL is very important for the biology of the Black Sea because it is richer in plant nutrients than offshore surface water and probably fertilises the sea when it is mixed back to the surface.

See information on biological process in the Black Sea Ecology Fact Sheet.

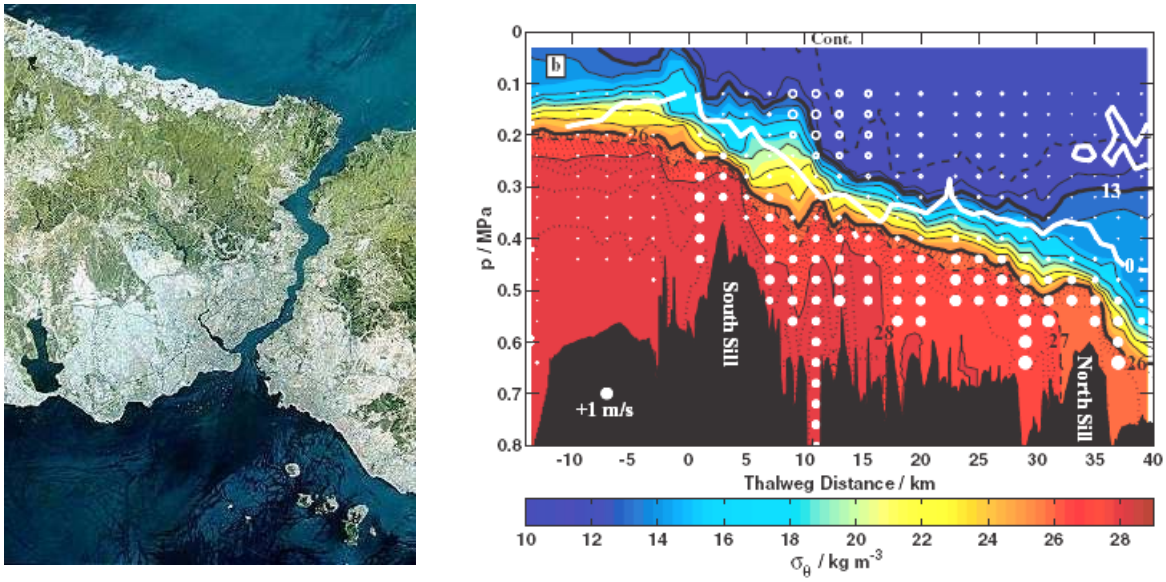


Figure 2. *Left hand side:* Satellite image of the Bosphorus Strait illustrating its narrow (700 metres at it narrowest) and twisting form. The strait pass through the middle of Istanbul, one of the largest cities in Europe. The Bosphorus has a sill depth of only 35 metres, above which there is a two-layer flow of Mediterranean water flowing to the deep Black Sea (lower layer) and Black Sea surface water flowing towards the Mediterranean (upper layer). *Right hand side:* Cross section of density along the Bosphorus from the Marmara Sea (left) to the Black Sea (right) showing how the higher density Mediterranean water (red colours) flows over the sill towards the Black Sea. The Black Sea surface water (blue colours) flows towards the Sea of Marmara. As the two streams begin to mix, the Mediterranean water becomes less salty (and less dense) and the Black Sea surface water becomes saltier. The vertical scale is in units of approximately 100m (i.e. 0.4 = 40m). Work conducted in 1994 by Profs. Emin Ozsoy and Michael Gregg.

2. Horizontal circulation is characterized by gyres

Circulation in the Black Sea is mainly driven by the winds that sweep across it and the buoyancy differences between inflowing freshwater and the saltier Mediterranean inflow. The consequence is a cyclonic circulation throughout the year though not at constant speed. Those that sail in the Black Sea or live by its shores are keenly aware of the intensity of storms that develop in the sea, particularly in winter (see Figure 3). These transfer energy to the circulation causing it to speed up as well as intensifying mixing patterns.

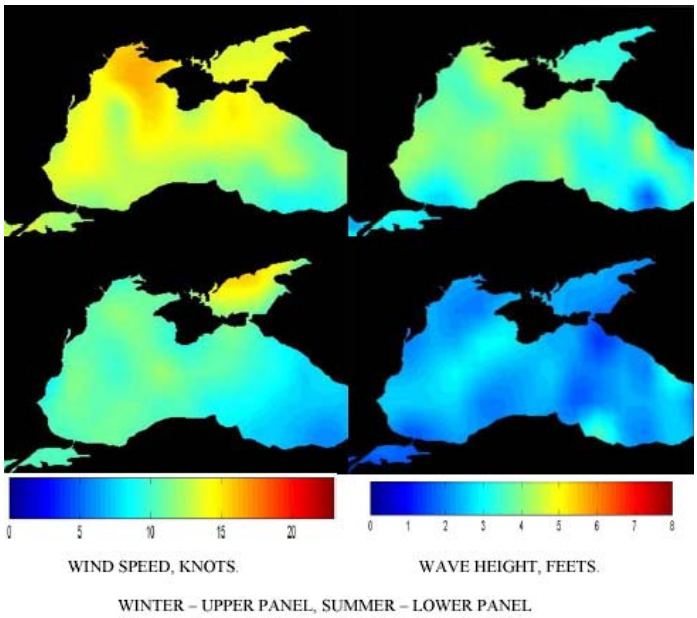


Figure 3. Winter and summer wind and waves. Figure provided by Prof. G. Korotaev.

Wind-Driven Circulation *is the circulation in the upper kilometer of the ocean forced by the wind. The circulation can be caused by local winds or by winds in other regions.*

Gyres *are wind-driven cyclonic or anticyclonic currents with dimensions nearly that of ocean basins.*

Boundary Currents *are currents flowing parallel to coasts. The Black Sea Rim current is a particular kind of boundary current*

A permanent feature of the upper layer circulation is the Rim Current which encircles the entire Black Sea. In places it is several tens of kilometers wide and can attain a maximum speed of 0.8-1 knot (40-50 cm/sec), increasing sometimes up to 1.6 – 2 knots (80-100 cm/sec). This has been determined by direct observations of the current velocity from surface buoys. Figure 4 shows the average circulation of the Black Sea and Figure 5 illustrates the main features of the circulation in schematic form.

Storm Surges *are changes in sea level driven by storms coming ashore on coasts having wide, shallow, continental shelves*

Shelf break: *The edge of the continental shelf (normally at about 200m depth) where it plunges downward along the continental slope to the abyssal plains (the deep sea floor). In the case of the Black Sea, this is usually a very strong feature, reflecting paleo cliffs in some places.*

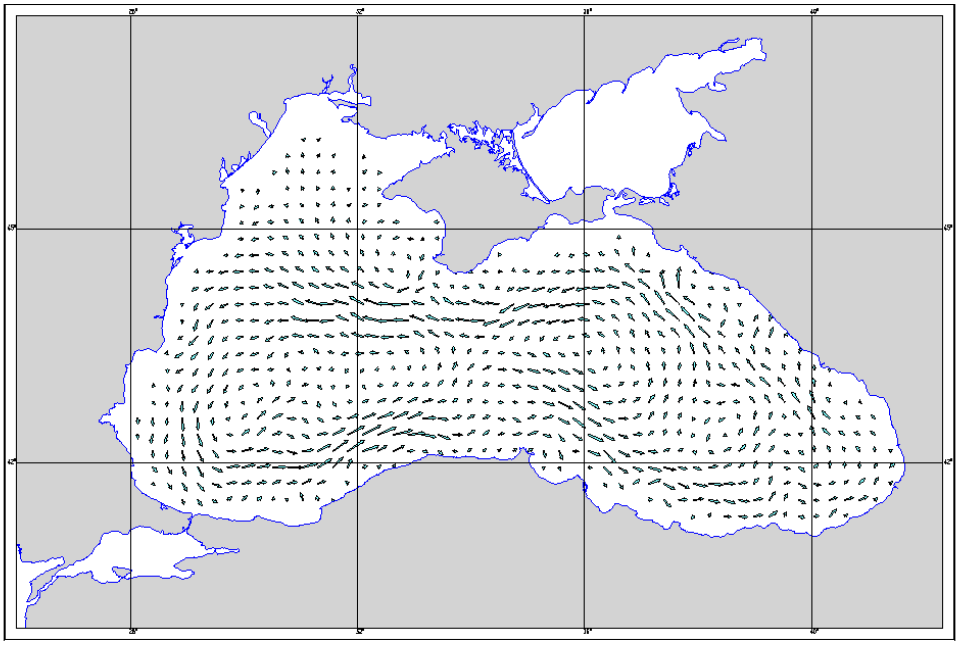


Figure 4: Mean annual circulation pattern in the Black Sea (from Black Sea GIS, BSEP)

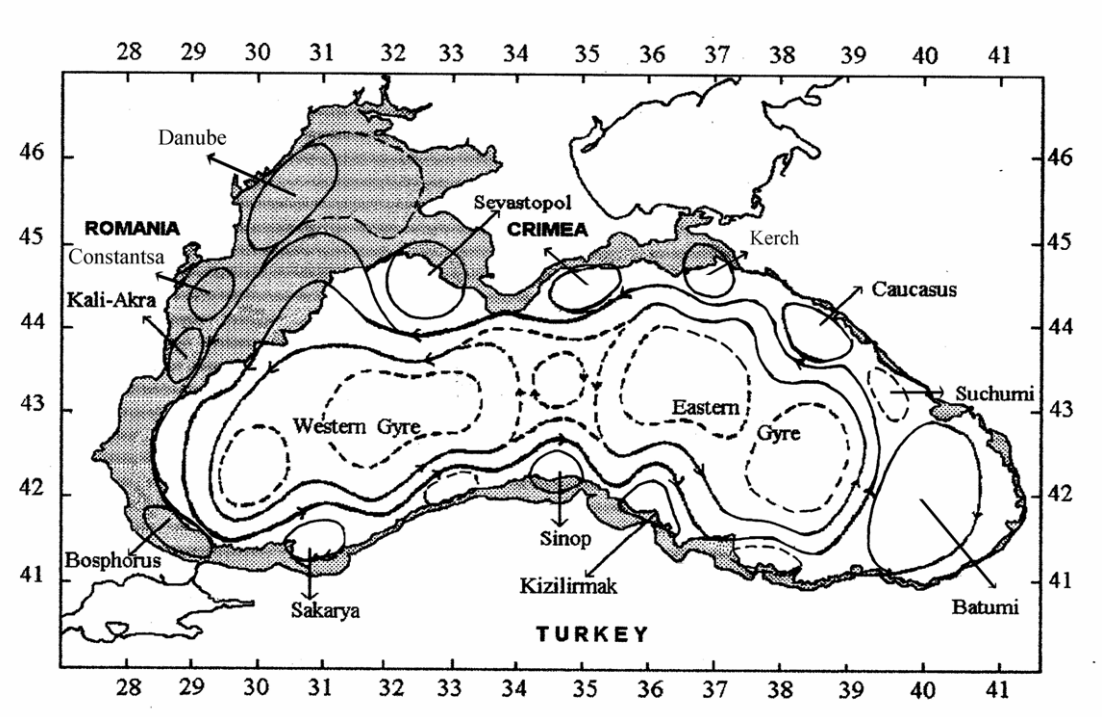


Figure 5 Schematic diagram of the circulation in the Black Sea (Figure provided by Prof. G. Korotaev).

Figure 5 illustrates the nature of the circulation in gyres; the permanent rim current follows the shelf break most of the time. However, the shape of the coast sends it on seawards short cuts in some place, trapping another small gyre between the rim current and the coast. This is the case for the Batumi Gyre which is a permanent feature. On the inside of the rim current, there are two more-or-less permanent gyres shown as the Eastern and Western Gyres. These have import biological significance as they mark the pathway of planktonic larvae and also keep the inner part of the sea (the pelagic zone) as an area with properties that are distinct from the shelf seas region.

Between the rim current and the coast, there are also a series of non-permanent gyres that are sometime seasonal in nature and are also indicated on Figure 5. These are particularly important on the wide and shallow north western shelf where they help to redistribute Danube and Dnipro water and to mix it with Black Sea surface water. Again, these feature help to explain the distribution of many of the animals and plants in the area as they provide a mechanism for keeping their plankton larvae in the same vicinity as adult populations (see Ecology Fact Sheet for further information).

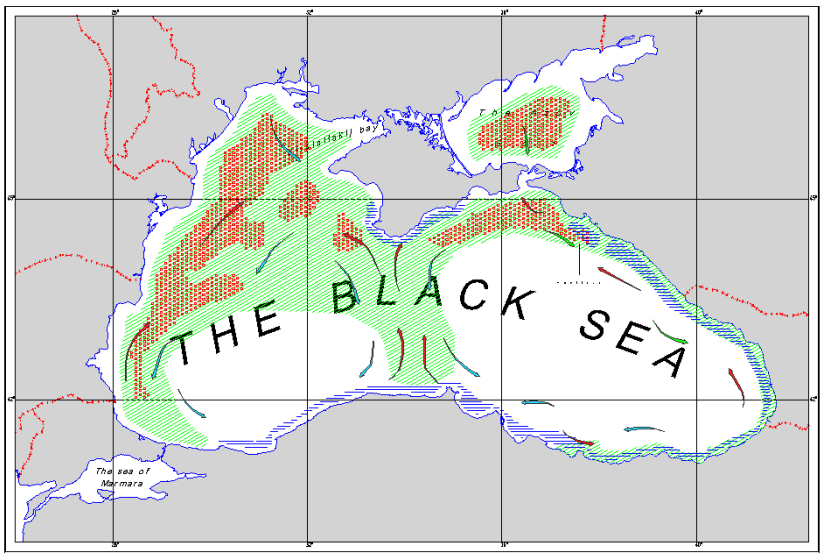


Figure 6: Historical distribution of anchovy in the Black Sea. Feeding areas in green, spawning zones in orange and over-wintering areas shaded blue. The entire cycle follows the currents, partly because larval anchovies are planktonic (cannot swim against the current) and their whole lifecycle has adjusted to the circulation.

3. Waves are not only at the surface

Everyone is familiar with waves on the surface of the sea but not all wave patterns are visible to the eye. Underwater waves can also propagate on the pycnocline as 'internal waves', typically with frequencies of 5-40 cycles/hour and amplitudes as large as 10 metres; these can break when they hit the continent slope in a similar manner to surface waves. There are longer period waves in surface waters however - *seiches* – with amplitudes of 2-15 cm and periods of 3-10 hours.

Much slower cycling changes are being recognized in the Black Sea associated with planetary scale climatic oscillations that include phenomena such as the

***Wave-Height**: vertical distance between a crest and the preceding trough*

***Wave-Length**: the distance in a periodic wave between two points of corresponding phase in consecutive cycles*

***Wave Period**: the time that elapses between the passage of two successive wave crests past a fixed point*

***Spectrum:** A plot of wavelengths against amplitude (or other measures of energy content). For electromagnetic radiation, the spectrum includes everything from gamma radiation and x-rays to radio waves, with visible light in between. For water waves, the spectrum includes everything between wind ripples to tides. For seismic waves, the spectrum ranges from barely noticeable vibrations to the great long-wave oscillations of earthquakes. For climate fluctuations, the spectrum spans from daily temperature fluctuations to annual seasons to the great ice age cycles. The mathematics of spectral analysis are based on the work of the great French physicist and mathematician J.B. Fourier (1768-1830).*

'North Atlantic Oscillation'. Professor Temel Oguz has devised a series of indexes based on observational data that reveal how periodic climate shifts influence the physics and ecology of the Black Sea (see Figure 7).

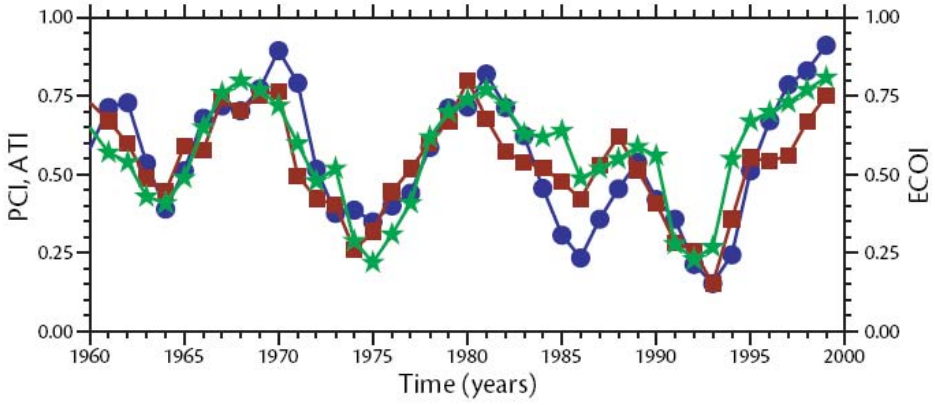


Figure 7. Temporal variations of the atmospheric index (ATI, squares), marine physical climate index (PCI, dots), and ecological index (ECOI, stars) from 1960 to 1999, Note the synchronized oscillations of 10-12 year period. Based on T. Oguz, Oceanography Vol.126 l.18, No.2, June 2005

4. Advances in measurement are improving our understanding of physical processes

Until the 1970s, our knowledge of physical processes in the sea was largely based upon tedious measurements from ships using an ingenious system of open sampling bottles with lids that could be closed when a weight was dropped down the wire suspending them from a ship. These were fitted with thermometers on a frame that turned upside down when the bottles were triggered and maintained the mercury column within them at the position of the temperature of the sea at the moment of reversal. Samples in the bottles were used to measure salinity and dissolved oxygen or other chemical substances. Surface currents were measured by the drift of the ship when it stopped to lower the bottles.

Nowadays, these methods have been replaced with electronic sensors that give continuous records of temperature and salinity (as well as other parameters such as oxygen) when they are lowered. These are coupled with bottles that can be closed at any point in the water column. The data in Figure 1 was obtained in this way. Measurements made this way are still rather slow however and do not represent a 'snapshot' of the conditions in the sea. Advances in space technology have led to arrays of sensors deployed in satellites orbiting the earth and able to measure sea level (and waves) to within a few centimeters resolution, as well as the temperature and colour of the sea (for measuring plant chlorophyll). This is telling us a lot about the sea surface and the small scale fluctuations in its properties (see the image of surface temperature in Figure 8). It is particularly useful for distinguishing features such as mesoscale circulation. However, it does not tell us much about the process below the surface. For this, another kind of technology is required. One technique employed uses drifting buoys that sink gradually through the water column recording temperature and salinity. They are capable of remaining at a great depth, drifting with the current, and can then return to the surface where they transmit their position and data to a satellite before plunging gradually into the depth once again. Several of these 'Argo' drifters are drifting around the Black Sea and revolutionizing our knowledge of it deep waters, revealing unexpectedly strong currents.

Advanced Very-High Resolution Radiometers (AVHRR) *are sensors aboard polar orbiting satellites that measure energy at different frequencies in the visible and infra-red bands. These "skin" (upper few mm of the ocean near-surface) measurements are calibrated with in-situ ocean temperature measurements, mostly from the oceanic mixed-layer, to produce estimates of sea surface temperature. There are Local Area Coverage (LAC) and Global Area Coverage (GAC) data with 1 km and 4 km, horizontal resolution, respectively*

Mesoscale Eddies *are turbulent or wave like flows on scales of a few tens of kilometers.*

Squirts or Jets *are long narrow currents, with dimensions of a few tens of kilometers, that are nearly perpendicular to west coasts.*

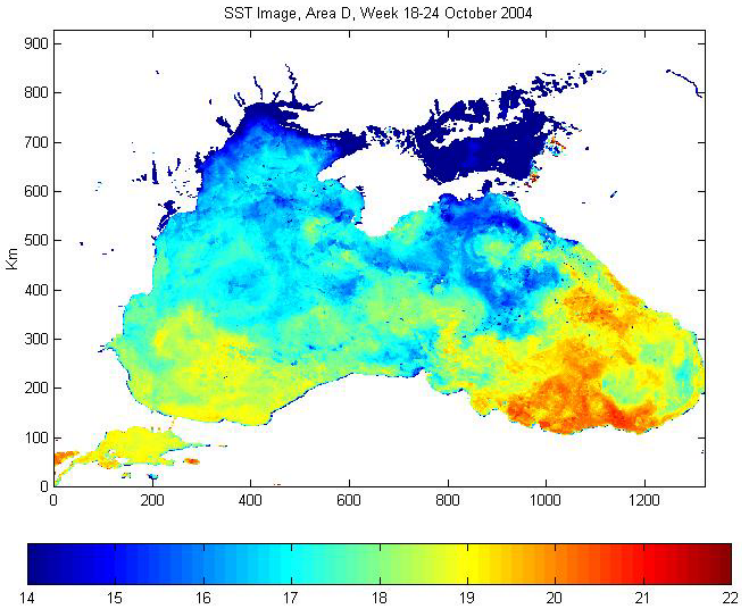
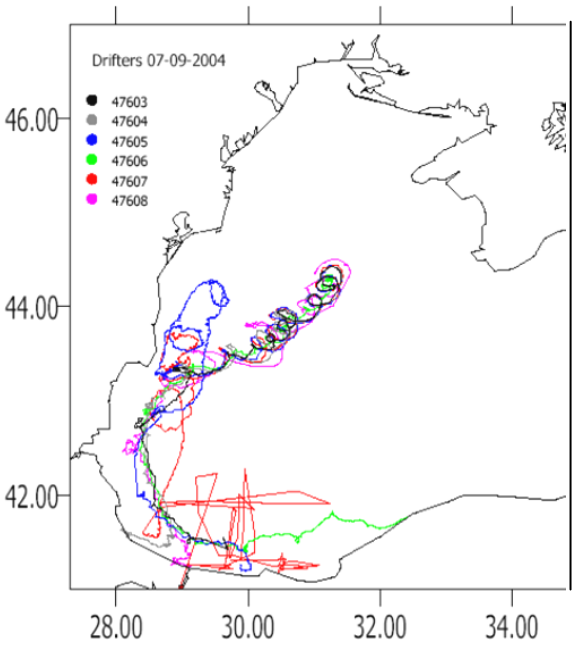


Figure 8. Sea surface temperature measured by AVHRR satellite. The smaller swirls in the image are mesoscale circulation patterns. Photo courtesy of NASA.

Drifting satellite tracked buoys can also be used to trace individual mesoscale eddies. Results of work conducted in the 2004 BSERP expedition on the Bulgarian vessel Akademik are shown in Figure 9. Six drifters were deployed in a single eddy between Crimea and Cape Kaliakra in Bulgaria. The drifters tracked the eddy as it rotated and followed the rim current. Near Cape Kaliakra, the eddy broke up and two of the buoys moved northwards whereas the others continued to track the rim current. One of the buoys was picked up by a fishing vessel; this explains the strange track (shown in red) near the southern coast.



The value of this data is that is shows us how difficult it is to predict the precise movement of a particle of water in the sea. Imagine if the buoys had been an oil spill!

Physical oceanography is a fascinating study and, as we have demonstrated, the chemistry and biology of the sea depend on the physical processes within it.

Figure 9. Tracks during almost five months drifting of satellite drifter buoys released on the BSERP expedition in April 2004. See text for details.

Black Sea Chemistry

Text prepared by Prof Laurence Mee[3]

1. The Black Sea is anoxic below about 100 meters.

The Black Sea has a remarkable chemistry that distinguishes it from every other sea on our planet. What makes it really special is that whereas all other seas and oceans (with a few isolated exceptions) have oxygen dissolved in their waters, there is absolutely no oxygen in the Black Sea below a depth of about 100 metres (Figure 1). Furthermore, the anoxic (oxygen free) water has a large concentration of hydrogen sulphide, a very poisonous gas that smells of rotten eggs. With the exception of a few highly specialised life forms, most animals and plants cannot survive in anoxic conditions. Hydrogen sulphide is also very poisonous to humans. The surface waters of the sea are less dense than the deeper anoxic layers because they are warmer and have a lower salt content. Fortunately for life in and around the Black Sea, this density difference prevents the anoxic bottom waters from ever reaching the sea surface.

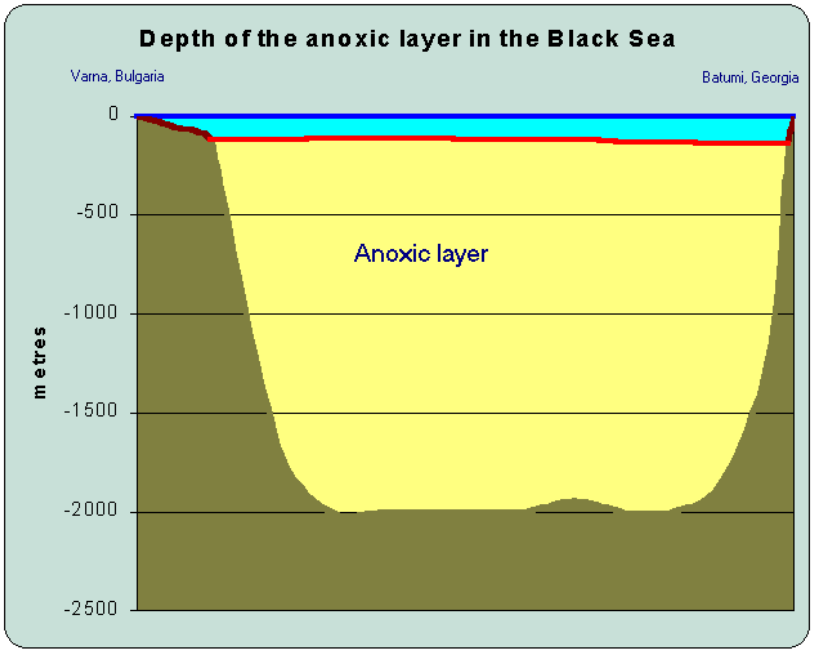


Figure 1. A West-East section of the Black Sea from Varna to Batumi showing the huge volume of anoxic water. Note the shallow shelf off Varna with oxygenated water down to the sea floor ,

How did this situation develop? The deep waters of the Black Sea consist of water that has travelled from the Mediterranean through the Sea of Marmara and the Bosphorus Straits (also known as the Turkish Straits). The Bosphorus too has two layers with outflowing Black Sea water at the top and Mediterranean water at the bottom. The Bosphorus is only about 50m deep (even shallower in places) and 700m wide and the incoming Mediterranean water spills into the deepest part of the Black Sea nearly 2Km below. For the bottom layer of the Black Sea – almost 95% of the Sea's volume – this incoming water is the only source of oxygen and the new water may stay as much as 1000 years in the

[3] Prof. Mee is Director of the Marine Institute of the University of Plymouth, UK. He is currently Chairman of the BSERP International Study Group on the Black Sea.

bottom before eventually mixing with enough fresh water to reach the surface and start its journey back to the Mediterranean.

Plants use the sun's energy to convert carbon dioxide to living matter and oxygen, a process known as photosynthesis. At night the reverse process, respiration, occurs and some of the oxygen and living matter are consumed and energy is released. The same processes apply to the tiny free floating plants – phytoplankton – in the sea or the algae found nearer the shore. The photosynthesis equation, without which there would be no oxygen in our atmosphere is written like this (note that CH2O is used to represent carbohydrates, the most abundant building block for living beings):

(1) $$CO_2 + H_2O \underset{\text{Respiration}}{\overset{\text{Photosynthesis}}{\rightleftharpoons}} CH_2O + O_2$$

The sub-surface layers of the sea receive a constant shower from above of dead plants and animals and their excrement and these are subjected to bacterial decay, also consuming oxygen. In the case of the lower layer of the Black Sea, the oxygen demand from organic debris is much greater than the supply of water rich in oxygen from the Mediterranean. This explains why the lower layer of the Black Sea is anoxic. The hydrogen sulphide in this layer is produced by bacteria that find an alternative supply of oxygen locked up in the sulphate ions that are relatively abundant in seawater:

(2) $$SO_4^{2-} + 2(CH_2O) \xrightarrow{\text{Respiration}} H_2S + 2(HCO^{3-})$$

There are many fascinating processes going on in the deep Black Sea. The environment is thought to resemble that of the early oceans, before there was oxygen on our atmosphere and this fact attracts considerable scientific research. The bottom sediments of the Black Sea for example contain rich deposits of methane that has solidified like ice (methane hydrates) at the low temperatures and high pressures of the sea floor. The methane was produced as a final product of the degradation of thousands of years of accumulated organic matter and may provide a future fuel supply. Even this does not remain intact however. Recently discovered primitive micro-organisms, the archaeans, can slowly oxidise the methane to carbonates forming a crust or chimneys above the sea floor. In some places methane gas is bubbling from the chimneys but this rarely reaches the sea surface as it is dissolved en-route. Stories of the Black Sea 'catching fire' refer to the methane but are unlikely to be true as most of the gas bubbles exchange with dissolved nitrogen gas during ascent through the water column. Most of what emerges would not be flammable. Only a methane seep in shallow water could conceivably be flammable and reports of methane seeps in the Black Sea are usually from water of at least 100m depth.

2. Nitrogen and Phosphorus loads to the Black Sea determine its fertility and have led to eutrophication.

The photosynthesis equation (1) does not fully describe the production of algae and plants in the Black Sea. Plants need other substances in order to grow. These include 'nutrients', compounds of nitrogen and phosphorus and in some cases silica as well as a range of minerals such as iron, manganese and vanadium and organic stimulants such as vitamins. Growth of phytoplankton (the tiny floating plants that are the basis of ocean food chains) may be limited by the supply of nitrogen, phosphorus, silica and iron.

Much of the nutrient supply to marine 'primary producers' (a collective term for photosynthetic phytoplankton, nearshore seagrasses and algae) in the surface waters of the sea comes from recycling. During the process of respiration and bacterial decay, nutrients are released back into the water column and can be taken up by new generations of primary producers. Some nutrients are lost however, flushed

out of the system, permanently buried in the sediments or even removed as fish for human consumption. The loss is compensated by the arrival of new nutrients from rivers, the atmosphere and deep waters. This is where the problem starts for the Black Sea. Human activities on land have increased the flow of nutrients to the sea leading to an enormous boost in primary production; too much for the system to cope with and placing an even larger demand on the limited oxygen supply to break down the excess organic matter. This phenomenon, known as eutrophication, caused serious degradation of the Black Sea ecosystem, particularly its North-West Shelf, since the 1970s. It resulted in seasonal hypoxia (very low levels of oxygen) and occasional anoxia on the previously well-oxygenated NW Shelf.

Of the limiting nutrients, nitrogen has the most complex chemistry. In well-oxygenated waters, the nitrogen in natural organic matter is eventually oxidised to nitrate (NO32-) and this is the most abundant nitrogen compound in the sea. The less oxidised form, nitrite (NO2-), is also present however, particularly where oxygen concentrations are low. The reduced form of combined nitrogen, ammonia, is exuded by many marine organisms and is the most stable form in anoxic waters such as those found in the lower layer of the Black Sea. It exists as an equilibrium between the gaseous and ionic forms:

(3) $$NH_3 + H_2O = NH^{4+} + OH^-$$

Dissolved nitrogen gas is abundant in the sea but very few marine organisms are capable of using it as a nutrient source. The 'nitrogen fixation' process requires a large amount of solar energy and dissolved iron; both are in limited supply in the Black Sea.

The human activities causing eutrophication are mostly related to the way we produce our food and dispose our sewage. Annual fertiliser use in the Danube basin rose from 1.3 million tons per year in 1961 to 4.8 million tons in 1981 and an increasing proportion of the population was connected to sewerage (but not to sewage treatment plants!). Intensive agricultural activities made the problem even worse. The nutrient runoff to the Danube has declined again in recent years because of the economic costs to farmers of applying large amounts of fertilisers and the decline of large collective farms. There is concern that it will rise again as economies become stronger but better farming practices can help to keep excess nutrients where they belong, on the land.

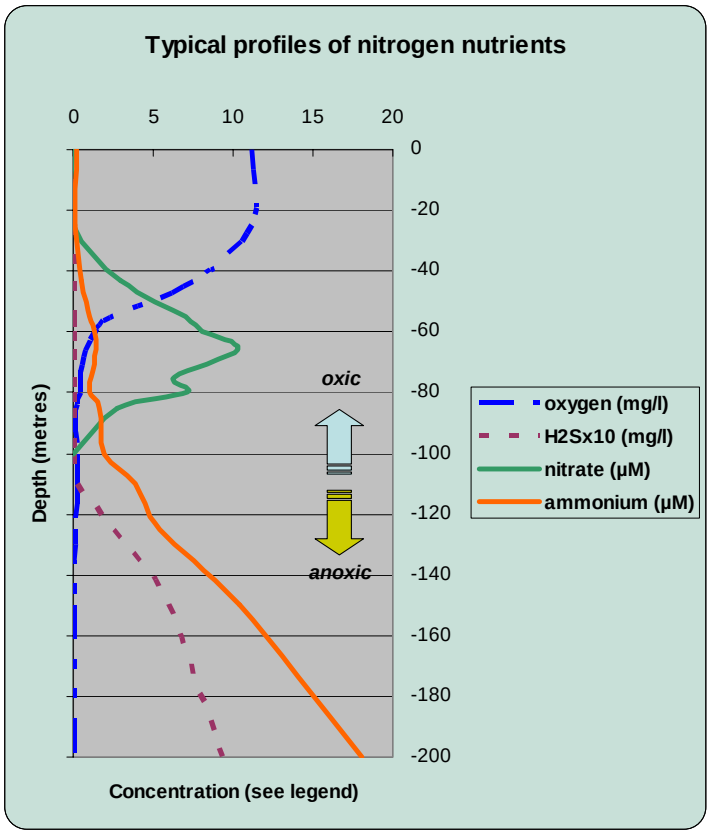


Fig 2. A typical profile of oxygen, hydrogen sulphide, nitrate and ammonium from the western Black Sea. Surface nitrate is low because it is consumed by phytoplankton (data from Yakubenko and Lukashev, cited by Sorokin, 2002)

3. Chemical (including oil) pollution is not as bad as we first imagined but risks of serious incidents are increasing.

Pollution occurs when chemicals or energy (noise or heat) released into the environment cause damage to any form of life or to the value of the environment to humans (for amenities or other uses). There is plenty of evidence that many rivers discharging to the Black Sea were seriously polluted in the decades of the 70s and 80s. Some of the sources of pollution, heavy industries and agrochemicals such as pesticides, have now declined due to the economic collapse that affected many countries in the 1990s and to a lesser extent due to better industrial processes and waste treatment. Oil shipments through the Black Sea have risen sharply however and there is a constant risk of oil spills through accidents or operational discharges (leaky pipes, careless handling, and illegal washing of ships' tanks). Pollution can be prevented in all cases, it is the result of accidents and the intentional use of the environment as a means to dispose of waste.

The main classes of potential pollutants are shown on Table 1:

Table 1. Potential pollutants to the Black Sea

Pollutant class	Source	Situation in the Black Sea
Synthetic organic chemicals *Several thousand chemicals including very toxic substances such as:* • *Pesticides* • *Solvents* • *Dioxins (from burning plastics)* • *Polyaromatic hydrocarbons (PAHs)*	**Agriculture:** Pesticides are sometime applied in large quantities to kill unwanted insects or to remove weeds or fungus infections. Some of these compounds are very persistent and toxic. **Industry:** Industrial process use and produce thousands of different chemicals. Without proper care, these can be released to the environment as waste during production or later on when the product is used somewhere else **Home:** We use large amounts of chemicals at home. Some plastics for example, will release toxic dioxins when they are burned – avoiding excessive waste and its proper disposal is very important.	It is very difficult, time-consuming and expensive to measure organic chemicals that may cause pollution. Our knowledge of their concentration and distribution in the Black Sea is poor. We do know that pesticide concentrations are currently lower than most other European Seas because of the economic difficulties for farmers to purchase them.
Oil *Crude oil contains thousands of different hydrocarbons. These are compounds of carbon and hydrogen that may be* ***saturated*** *(contain no double bonds),* ***unsaturated*** *(contain double or triple bonds and therefore more reactive) or* ***aromatic*** *(contain benzene rings)* ***In general terms, the larger the number of benzene rings or double or triple bonds in an oil component, the more toxic it is likely to be.***	**Maritime transport**: Most of the oil entering the sea from ships does not come from large oil spills but smaller more frequent discharges through emptying ballast water, cleaning tanks and bilges (bilges are the bottom part of a ship where any water or other spilt liquids will gather) and broken connections when loading and unloading. Of course, large spills produce spectacular local damage. **Production and refining** Oil based lubrication is sometimes still used when drilling oil and gas wells. This causes a major local impact. Refineries occasionally discharge oil products but sufficient technology exists to prevent this from occurring. **Urban sewage** This is the biggest single source of oil to the sea. Careless disposal of car engine oil down the drain is a major factor but there may be contributions from public transport and industry.	Though shipments of oil have increased significantly it is fortunate that there have been few major oil spills in the Black Sea. However, oil is frequently found on bathing beaches and the concentration of dissolved oil is higher than the neighbouring Mediterranean. This appears to be the result of two factors: A large number of operational discharges from maritime transport (ballast tank discharges are thought to be a major problem) Urban sewage and industrial waste discharged to rivers and the sea. Very large amounts of oil enter the sea from its tributary rivers but the same is occurring in coastal towns and cities. ***For more information see the study sheet on shipping***

Heavy metals *Heavy metal is a term loosely used to describe transition elements and their compounds (such as lead, copper, cadmium, mercury, tin, zinc, etc.)* *Heavy metal pollution is a major problem in fresh waters (serious health consequences for humans drinking contaminated water) but is less widespread in the marine environment. There have been serious local problems with mercury pollution however and the use of the organotin compound tributyl tin (TBT) is severely restricted owing to its effects on marine life.*	**Mining** Mining operations and the disposal of mine waste is a major source of heavy metals. Waste is sometimes stored in open ponds that can overflow into rivers. **Industry** The metallurgical industry is a source of heavy metals but many other industries use metal compounds and produce waste. The leather processing (tanning) industry for example uses large amounts of toxic chromium for example. **Transport** In order to prevent marine organisms from growing on ship's hulls, antifouling paints are often employed and these traditionally contained copper. TBT was found to be more effective but has serious consequences for the marine environment. **Energy** Batteries often contain large amounts of heavy metals, typically lead or cadmium. Proper disposal is essential but they are commonly included in household or industrial waste.	There is little evidence of general serious heavy metal pollution in the Black Sea but there are some local areas of local contamination associated with industry or mining. Accidents such as that of the Baia Mare mine in the Danube basin (massive spillage from a gold mine waste pond that killed all animals in over 200 Kms of the river Tisa) are a risk in many Black Sea countries
Radionuclides *These are elements that emit radioactivity. They can be naturally occurring lathanides and actinides or human produced transuranic elements. Elements such as uranium occur in nature and a certain 'background' level of radioactivity is always present.*	**Mining** The production of nuclear fuel (for reactors, medical and industrial use or weapons) requires the processing of very large amounts of uranium ore. This releases large amounts of radioactive waste to the environment. **Nuclear energy** Normally emissions from nuclear reactors are very tightly controlled. There is an accident risk however and long-term storage of spent fuel is difficult and costly. **Other activities** Medical, military and industrial uses may produce some contamination but this is limited compared to other sources	The Chernobyl nuclear accident in 1986 caused immense human suffering and environmental contamination, particularly on parts of the Dnieper river that drains to the Black Sea. The dams in the river prevented most of the pollution from reaching the Black Sea however. Because of this accident and other operational discharges, the Black Sea has approximately double the radioactivity than the Mediterranean but these levels are well below those that would cause significant damage to humans and animals
Solid waste *The presence of garbage in the sea is a major problem as it damages amenities and habitats. Plastic waste is a particularly difficult problem.*	**Urban and ship waste disposal** Garbage mostly comes from packaging materials that are disposed of by householders or industry	Many Black Sea beaches are seriously littered with garbage. This comes from poor urban disposal, improper disposal of ship's waste and careless citizens. There is little information on garbage at the bottom of the sea.

Black Sea Ecology

Introduction

This study sheet[4] condenses some of the work of a number of leading ecologists in the Black Sea region who are also educators, amongst whom Prof. Yuvenaly Zaitsev (Odessa), Prof. Marian Gomoiu (Constanta) and Dr. Alexander Vershinin (Orlyonok, Russia) are given special thanks. This study sheet will explain the main features of the Black Sea ecosystem and how humans are having an increased role in determining its future.

1. Current populations of living organisms in the Black Sea reflect its geological history

The Black Sea has undergone huge changes in the past few million years (see the Geology Study Sheet) and its current inhabitants reflect the wide range of physical conditions found in the past 20,000 years or so, though their origins are much older. Each new condition brought entirely new species or forced existing ones to adapt; only the hardiest of the early settlers have survived and new species now continue to arrive as a result of human activities. Table 1 provides a guide to the groups of settlers that now inhabit the Black Sea and interact within its ecosystem.

Table 1 gives us many insights into the modern Black Sea. It would be a mistake to imagine the Sea as a 'melting pot' of all of the groups listed. Each of the first four groups has a particular niche within the system though some are capable of living in a wider range of conditions. In some cases, species leave the conditions characteristic of their group in order to enjoy the opportunities for foraging in the wider Black Sea but then return to the conditions they evolved in for reproduction. Thus sturgeon return to spawn in rivers and mackerel return to the Mediterranean conditions of the Marmara Sea, though both can be found in the Black Sea at other times.

Despite the wide range of conditions to be found in the Black Sea, it has less than half of the biological diversity of the neighbouring Mediterranean. The Sea has changed from a lake to a sea in a few thousand years and its biota are still adapting to the new conditions. This makes it particularly susceptible to 'invasion' by 'exotic' species brought from similar habitats in the ballast or on the hulls of ships. In the Black Sea they find abundant food and few predators. There is no doubt that humans are having a huge impact on its species composition. The term 'Anthropocene' – the era where humans are causing planetary change – is particularly apt under these circumstances.

Ecosystem: *The complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space.*

Plankton *are the tiny floating plants and animals in the sea that are carried by its currents. This leads to their wide distribution.*

Nekton *are animals (e.g. fish, squid) that can swim at greater speeds than the sea's currents.*

Phytoplankton *are microscopic plants that convert solar energy and dissolved carbon dioxide into living organic matter. This process also requires other inorganic and organic nutrients (see Chemistry fact sheet) including nitrogen and phosphorus compounds.*

Zooplankton *consists of a wide range of microscopic animals including the larvae of larger animals such as fish, bivalves and bottom living crustaceans.*

Copepods *are tiny zooplanktonic crustaceans typical of cold-water oceanic ecosystems.*

[4] Prepared by Prof. Laurence Mee.

Description	When they arrived	Conditions at the time	Examples of the organisms remaining today
1. Neoeuxinian Lake species or 'Pontian relics'	They were dominant 18,000 – 20,000 years ago at the end of the Würm glaciation but originated much earlier before the Black, Caspian and Azov Seas were formed	The Black Sea was a huge almost freshwater lake supplied by melting glaciers. It was isolated from the Mediterranean	A number of bivalve molluscs, polychaete worms, shrimps and, most notably, the kilka (small fish caught in the Sea of Azov), sturgeon and some gobies. These inhabit the lowest salinity regions of the current Sea
2. Cold water marine species; the 'Boreal-Atlantic relics'	Not clear. They may have entered during the early stages of Bosporus opening when the Mediterranean was much colder than today. The Bosporus probably opened and closed many times during successive ice ages.	These are cold water species, more typical of the Atlantic Ocean than the current Mediterranean Sea.	Copepods such as *Calanus*, the Ctenophore *Pleurobrachia*, the spiny dogfish, the sprat, flounder, whiting and Black Sea salmon-trout. These species are only found in the upper layers of the sea in winter, early spring and autumn; in the summer remaining in cooler sub-surface waters.
3. Mediterranean species	Probably during and since the current opening of the Bosporus (around 7,000 years ago)	Warmer water saline conditions. Most of the species would have arrived with the Mediterranean inflow through the Bosporus. Not all could adapt to the low salinity in the Black Sea however.	Some 80% of the current species in the Black Sea. They are present in all taxa and include sponges, jellyfish, polychaetes, molluscs, crustaceans, echinoderms and over 80 fish species.
4. Freshwater species	They are continuously arriving from the major rivers that discharge to the Black Sea	Even when the Black Sea was a huge enclosed lake, its waters were slightly salty. However, around river mouths freshwater conditions are found allowing some freshwater species to live in the sea.	Blue and green algae are sometimes seen downstream from the Danube discharge. Fish such as carp and perch and even crustacean crayfish can be found in nearshore waters.
5. Exotic species and human disturbance of ecosystems. The 'Anthropocene'	Human impact became significant about 100 years ago and increased sharply since 1970	We are disturbing the ecosystem by excessive fishing, habitat destruction and eutrophication. Exotic species are introduced by ships (unintentional) or through aquaculture (intentional)	The proportion of exotic species is relatively small but their impact has been colossal. For example, the predatory gastropod (sea snail) *Rapana*, introduced in the mid 20th century, eliminated entire populations of native benthic species. The ctenophore (comb jelly) *Mnemiopsis* reached a total biomass of about one billion tons (wet weight) in 1990 hugely altering pelagic food chains at that time.

Table 1: Basic groups of Black Sea biota, in chronological order of arrival.

2. Pelagic and benthic components of the Black Sea ecosystem depend upon different but interconnected food webs

In the offshore areas of the Black Sea, most new organic matter is produced by phytoplankton. Below some 20-50 metres there is usually insufficient light for significant phytoplankton growth. Phytoplankton includes a large number of species with different requirements for light and nutrients. Diatoms for example, have external skeletons of silica resembling little glass boxes. Dinoflagellates on the other hand are often capable of limited movement and have no requirement for silica. As environmental conditions change during the year, individual phytoplankton species tend to 'bloom' and fade in a continuous 'boom and bust' sequence. The larger phytoplankton cells are often 'grazed' by small zooplankton such as copepods. There are smaller zooplankton however - ciliates and even smaller heterotrophic nanoflagellates - typically less than 10µm (there are 1 million µm in a metre). These graze on smaller nanophytoplankton or even heterotrophic bacteria. The smallest zooplankton are consumed by larger ones (such as copepods) and these, in turn, may become the food of small pelagic fish such as anchovy or sprats. Larger predator fish like mackerel or bluefish consume small pelagic species. At the top of the food chain are the 'apex predators' of which dolphins and humans are the most notable in the Black Sea. Hundreds of thousands of dolphins were killed by humans from most Black Sea countries in the 1950s – 1970s for food or though the perception that they threatened fish stocks.

The pelagic food web is illustrated in Figure 1. It would be naïve to show it as a linear chain because of heterotrophs and omnivores that can span more than one trophic level. In a stable ecosystem, the populations of organisms at each trophic level would be balanced by the supply of food from lower trophic levels and the intensity of predation from higher ones. Humans can affect this balance by increasing the supply of nutrients (eutrophication) or overfishing predator species. Eutrophication results in increased phytoplankton populations. Removal of predators results in increased small pelagic fish stocks and decreased zooplankton numbers. This may also increase phytoplankton numbers. The consequences are described in the chemistry fact sheet. The Black Sea has suffered from serious eutrophication in the past as a consequence of large nutrient loads from rivers. These loads result from agricultural fertilizers, animal and human sewage and certain industrial and domestic effluents.

In the Black Sea, large benthic organisms can only live in water that does not contain hydrogen sulphide. The north-western shelf of the Black Sea and the Sea of Azov are the largest areas suitable for benthic communities (some 20% of the overall area of the Black Sea) but there is a narrower band of shallow water around the entire Black Sea where these communities can develop.

Most benthic organisms have the advantage of not needing to spend much energy on constantly swimming to stay in a particular place or to catch their prey. A large number of them are sessile or stay close to a particular habitat but this makes them vulnerable to predators or to sudden changes in environmental conditions. Many benthic animals live in shells or have developed sophisticated defence mechanisms.

Pelagic *refers to the open sea; away from the bottom.*

Benthic *refers to the bottom of the sea.*

Food chain (also trophic chain): *The sequence of transfers of matter and energy from organism to organism in the form of food. Food chains intertwine locally into a food web because most organisms consume more than one type of animal or plant. Plants, which convert solar energy to food by photosynthesis, are the primary food source and termed* ***primary producers****.*

Marine food chains are rarely linear and show complex relationships; we describe them as ***food webs****.*

Autotroph*: Primary producer requiring sunlight and inorganic nutrients to make organic matter*

Heterotroph*: Consumer requiring pre-formed organic material to make organic matter*

Trophic level*: A trophic level in a food web contains organisms that obtain their nourishment in a similar way and from a similar source*

Omnivory: *The ability of an organism to obtain nourishment from more than one trophic level*

Sessile: *organisms that are fixed to the bottom or another solid object.*

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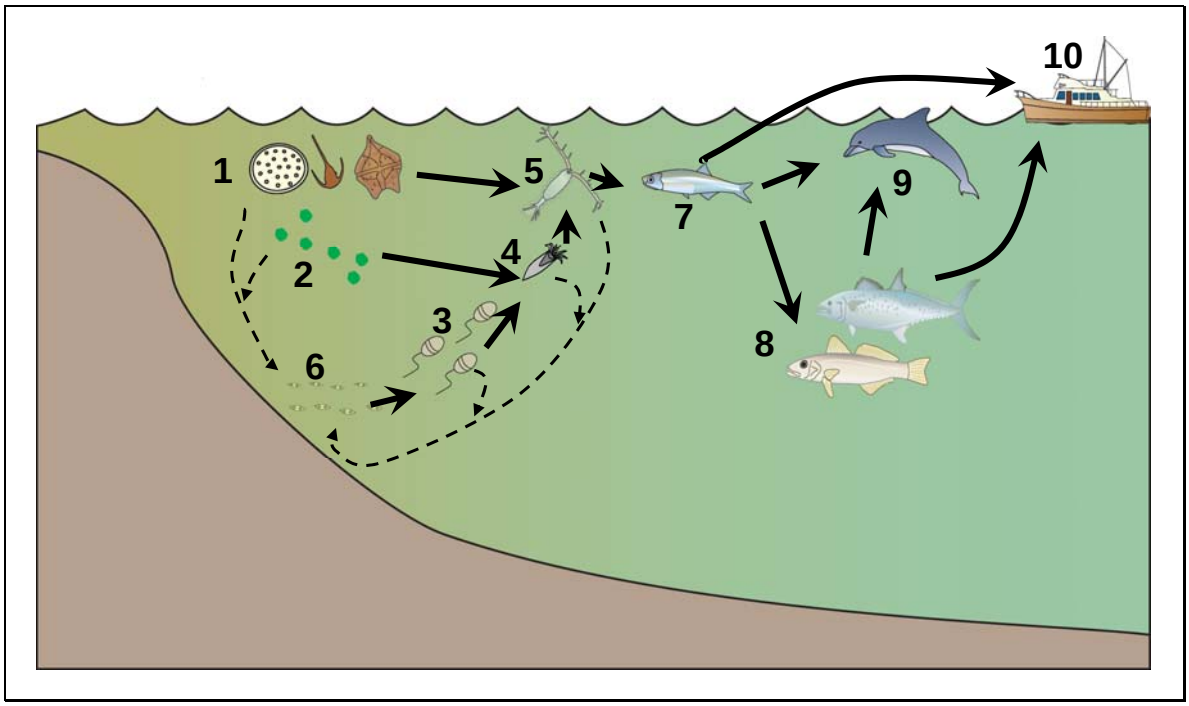

Figure 1. Simplified pelagic food web in the Black Sea showing food chain from phytoplankton to apex predators (solid lines) and the 'microbial loop' (dashed lines) where dissolved organic matter and faeces are recycled back into the food chain via heterotrophic bacteria. **Key** (note these are not drawn to scale): Autotrophs: (1) Large phytoplankton including diatoms and dinoflagellates), (2) Nanoplankton (cells typically about 10 μm); Heterotrophs: (3) Nanoflagellates, (4) Large ciliates, (5) Zooplankton (copepod illustrated), (6) Heterotrophic bacteria; Fish: (7) Small pelagic fish (anchovy as an example); (8) Predator fish (mackerel and whiting illustrated); Apex predators: (9) Dolphins, and (10) Humans.

Benthic food webs are more complex than pelagic ones. Where light levels are sufficient and wave or current energy is low, benthic macrophytes may develop. These provide another source of organic matter and also act as a habitat for a large number of animals. The other special feature of the benthic food web is the use of organic matter that collects on the sea floor, some of it from decaying macrophytes and plankton, some from terrestrial systems and rivers that discharge to the sea, and some from the metabolic products and faeces of animals in the water column and sea floor. This organic matter and the heterotrophs that live on it, provides food for a great variety of animals such as shrimps, mullet and carp, as well as filter feeders such as mussels and oysters (these also feed on plankton). Some of these in turn, provide food for larger animals notably fish such as sturgeon or turbot or some crustaceans such as the swimming crab (another introduced species).

On the next page, there is an illustration of an overall food web for the Black Sea (Figure 2). This is a schematic representation - the reality is even more complex – but it helps to understand the interactions between the various components of the ecosystem and humans as one of the apex predators (along with dolphins and, to some extent, some seabirds). A similar diagram drawn thirty years ago would have included monk seals as an apex predator. Human pressure (including disturbance of their breeding sites) has probably led to their extinction in the Black Sea; there have been no reliable reports on their presence in the last decade.

Habitat: *the place where organisms live*

Marine ***benthic macrophytes:*** *plants or algae that grow at the bottom of the sea. In the Black Sea they include algal species such as Cystoceira (brown), Ulva (green) and Phyllophora (red), and sea grasses such as Zostera (Eelgrass).*

Filter feeders*: organisms that filter small particles from seawater for food.*

Apex predators: *The animals at the top of the food chain that are not controlled by predation (other factors control their population size including the availability of food)*

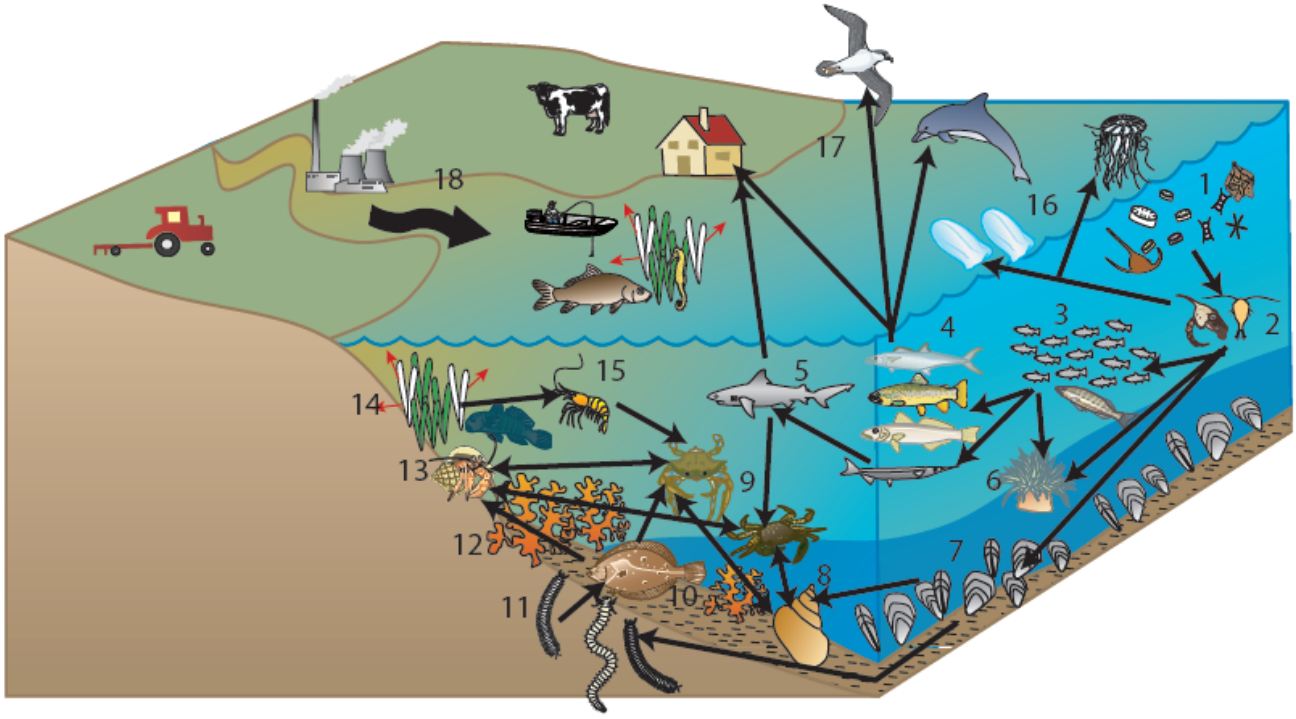

Fig 2. Illustration of some of the pathways in the Black Sea shelf ecosystem. The diagram is not a complete picture of the system and is designed to show typical interactions; there are many more!
The **pelagic system** (see also Figure 1) includes phytoplankton (1), zooplankton (2), small fish such as anchovies (3) and larger predator fish (4) and also larger predators such as the spiny dogfish (5). The pelagic system is coupled with the **benthic system** in a number of ways; examples shown here are through sea anemones (6) and mussels (7) feeding on small fish and plankton respectively (as well as heterotrophic bacteria in the case of some bivalves). Mussels have a few predators such as the sea snail Rapana (8) but contribute to the **benthic food chain** mostly through the production of detritus supplying bacteria and worms such as polychaetes (11). Many invertebrate **benthic predators** such as Rapana, crabs (bottom living and swimming crabs are illustrated, 9, as well as hermit crabs, 13) can feed off one another at different stages of growth and compete fiercely for space (some are also omnivores). Bottom living fish such as the flatfish (10) graze small benthic animals. Benthic macroalgae (12) and sea grasses (14) act as a habitat for a wide variety of animals (gobies and shrimp are illustrated, 15) and also provide a source of detritus for supplying the benthos with organic matter. One of the pelagic pathways, the pathway from zooplankton to jellyfish (17), leads to a 'dead end' since they have no obvious predators in the Black Sea. Jellyfish are a normal part of the Black Sea fauna but the ctenophore species *Mnemiopsis leidyi* (left hand of 16) was introduced from the ballast water of ships in the mid 1980s. It now has a predator, *Beroe ovata* (not shown) another ctenophore introduced in the same way as its prey. Humans, dolphins and some seabirds share a place as **apex predators** (17) of the system. Not all of the pathways to humans are illustrated; they also remove benthic fish, crabs, sea snails, bivalves and small pelagic fish. Humans are also responsible for many of the sources of organic matter and nutrients that flow from the land to the sea, as well as many contaminants (18). This diagram is based on the work of Dr. Alexander Vershinin (in Life of the Black Sea, p145, Moscow, 2003, in Russian). Tools for graphics (also Fig. 1) were kindly supplied courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science.

3. The Black Sea provides a range of habitats for assemblages (biocenoses) of marine organisms

The distribution of benthic marine organisms is largely determined by physical and chemical factors including the substrate (rocky, sand, mud, etc.), the wave or current energy, the salinity (amount of salt in the water), the oxygen content, illumination by sunlight, temperature, the supply of organic matter and the amount of nutrients in the water column. These factors contribute to their rather patchy distribution. Assemblages of plants and animals tend to form in particular range combinations of the above conditions (biotopes). In some senses they can be regarded as small ecosystems within the overall Black Sea system.

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

Assemblage *or* ***Biocenosis:*** *A community of organisms occupying a biotope*

Substrate: *the surface upon which aquatic animals can settle*

Bivalve*: Mollusc with two hinged shells*

Each assemblage is usually characterised by a few 'keystone' species that are completely indispensable to its existence; remove them and the assemblage can no longer survive. Table 2 illustrates one interpretation of the benthic assemblages on the north-western shelf of the Black Sea (this is fairly representative of the entire Black Sea). With one exception, the key species cited are either bivalves or macrophytes. Both types of organism are vulnerable to environmental condition; macrophytes are limited by the available light and bivalves cannot survive for prolonged periods without dissolved oxygen.

Depth (m)	Habitat	Name of assemblage	Type of key species	Key species
0 - 1	Mediolittoral sandy beach	Donacilla + Ophelia	*Bivalve/ polychaete*	*Donacilla cornea, Ophelia bicornis*
2 - 5	Sandy bottom	Nana + Diogenes	*Gastropod/ Hermit crab*	*Nana neritea, Diogenes pugilator*
0.2 - 5	Sandy bottom	Zostera	*Sea grass*	*Zostera marina, Z. noltii*
0.5 - 15	Rocky shore	Cystoseira	*Brown algae*	*Cystoseira barbata*
2 - 20	Sandy/muddy bottom	Lentidium	*Bivalve*	*Lentidium mediterraneum*
3 - 16	Sandy/muddy bottom	Mya	*Bivalve (softshell clam)*	*Mya arenaria*
7 - 30	Sandy bottom	Venus	*Bivalve*	*Chamelea gallina*
12 - 28	Muddy bottom	Melinna	*Bivalve*	*Melinna palmata*
20 - 25	Muddy bottom	Mytilus	*Bivalve*	*Mytilus galloprovincialis*
10 - 60	Muddy bottom	Phyllophora	*Red Algae*	*Phyllophora nervosa*
60 - 125	Muddy bottom	Phaseolinus	*Bivalve*	*Modiolus phaseolinus*

Table 2: Types of assemblage found on the north-western shelf of the Black Sea. The assemblages are ordered by depth but there are a number of other factors determining their presence, notably the substrate type and the oxygen availability. Adapted from Kiseleva M.I. (1979) Bottom biocoenoses and their biomass. In: Fundamentals of biological productivity of the Black Sea. Kiev: Naukova Dumka, pp 218-239 (in Russian).

It was this vulnerability that led to the massive loss of a major part of the biota on the north-western shelf in the early 1970s. One of the consequences of eutrophication is impaired light penetration to the bottom of the sea (eutrophication increases phytoplankton and debris concentrations in the water, blocking the passage of light). As eutrophication increased, macrophytes beds shrank in size. Zernov's *Phyllophora* field on the north-western shelf (the largest

Acad. Sergey ***Zernov*** *was a Russian marine biologist who described Black Sea 'biocenoses' during the first half of the 20th century.*

red algal community in the world) collapsed spectacularly during the 1970s (see Figure 3). The loss of *Phyllophora* and increased eutrophication led to even greater loading of organic matter to the bottom of the sea and decreased oxygen (see Chemistry fact sheet). Soon, much of the north-western shelf became hypoxic and even anoxic during summer months of each year and this led to the decline of many of the bivalve assemblages in the region. Thousands of tons of dead animals were washed up onto the shores of Romania and Ukraine.

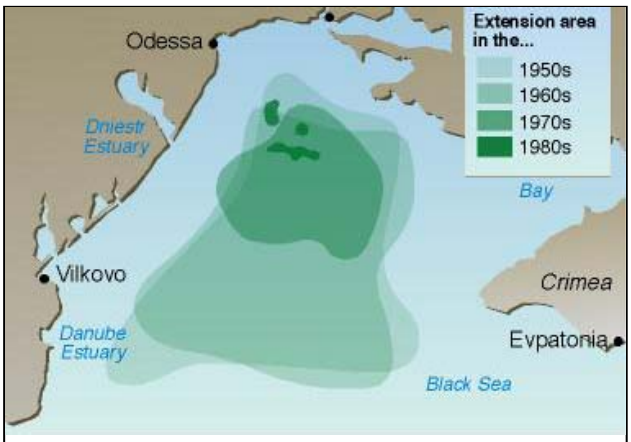

Figure 3. Spectacular reduction of Zernov's *Phyllophora* field in the 1970s (data from Zaitsev, 1992)

***Hypoxia** means "low oxygen." In aquatic ecosystems, low oxygen usually means a concentration of less than 2-3 milligrams of oxygen per liter of water (mg/l). A complete lack of oxygen (0 mg/L) is called **anoxia**.*

Eutrophication and hypoxia are not the only reason for the decline of many Black Sea benthic communities. Introduced species have caused major changes in their structure. The softshell clam *Mya arenaria* (the keystone species of an assemblage cited in Table 2) was introduced in the second half of the 20th century, possibly from the North Sea. The voracious predatory sea snail *Rapana thomasiana* arrived in the middle of the 20th century and led to the massive loss of many benthic communities. Another reason for decline has been human disturbance by dredging for shellfish, the extraction of *Phyllophora* for agar and by the indiscriminate use of heavy trawls for fishing. Dumping of waste from some countries also occurred in the Black Sea in the past.

***Agar:** A key ingredient for pharmaceutical and food products (e.g. ice cream) that can be obtained from harvested Phyllophora.*

*The **colour guide** to Black Sea species in this Study Pack (prepared by Prof Yu. Zaitsev) provides useful information on the association of key Black Sea species with particular habitats and illustrates many of the species cited in the present text.*

Despite all of these serious environmental problems, the Black Sea appears to be in gradual recovery from the worst period of eutrophication during the period from 1973 to 1990 (see section 4 of this fact sheet). This is more a consequence of economic problems in some of the coastal countries than good management however.

4. Marginal ecotones are important areas of the Black Sea

***Ecotone**: An area of intergradation between two biological communities or associations*

*The 1992 UN Earth Summit in Rio de Janeiro defined **biological diversity** (or **biodiversity**) as "the variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems".*

The region where the land and sea meet is often occupied by wetlands, aquatic areas that have their own special vegetation and characteristic fauna but are also places where interactions are possible between land and sea life. River deltas in the Black Sea include extensive wetland areas in the form of lagoons and marshes. The Danube Delta is Europe's second largest wetland area and much of it is protected as a biosphere reserve. There are smaller wetland areas in every Black Sea country. Wetland habitats provide nursery grounds for a number of species of fish and invertebrates and are particularly important as habitats for birds, resident and migratory. Extensive areas of reed bed provide shelter for birds and protection from their predators. They also filter the water that passes through them, removing nutrients (and other contaminants) The Danube delta, for example is recognised internationally for having the northernmost colony of Dalmatian pelicans. However, wetlands are particularly vulnerable to development. Some people regard them as a nuisance, as they harbour mosquitoes and seem to present a constant flood risk. Others exploit their rich organic soils for growing crops after isolating and draining them. Such actions result in a loss of habitat and

decrease in biological diversity and also increase the risk of flooding because wetlands effectively absorb sudden pulses of river water. In the medium term, conserving wetlands makes more sense than destroying them and this logic has led to the decision to re-flood a number of drained wetlands in the Danube Delta.

***Convention on Wetlands of International Importance (Ramsar Convention** 1971). Ramsar seeks to ensure the sustainable, wise use of wetland resources including designation of wetland sites of international importance and to ensure that all wetland resources are conserved, now and in the future.*

Fig 4. Map of major Black Sea wetland areas (from BSEP, Black Sea GIS, 1996)

A recent (1998) survey of birds in the 2600 km^2 Sivash lagoon complex in Crimea (see map) registered over one million birds. A National Nature Park is being created in the region.

The survival of many species of wading bird depends on the use of Black Sea wetlands as a resting place during their migration between the Arctic and Africa. The Black Sea is one of the most important migratory flyways in the world and there are indications that the number of birds in transit has decreased by over 50% in the past few decades.

5. Human degradation of the Black Sea ecosystem can be controlled and prevented

***Convention on Biological Diversity** (1992). The Convention aims at the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources and to provide for appropriate funding.*

***Bucharest Convention** on the Protection of the Black Sea Against Pollution. Signed 21 Apr 1992, in force 1994 This Convention includes a Protocol on Biological and Landscape Diversity (signed in 2003).*

There are many reasons why the Black Sea ecosystem deteriorated so rapidly from the 1970s. Eutrophication was a major factor, but not the only one. Many scientists believe that the current intensity of fishing in the Black Sea will not allow the full recovery of its food webs and are also concerned at the pace of destruction of marginal ecotones, including wetlands. Black Sea countries have joined a number of conventions designed to give additional protection to its biodiversity. These conventions include the Ramsar convention on wetlands, the UN Biodiversity Convention and the Bucharest Convention. There are a number of important initiatives to create protected areas (e.g. by the designation of coastal Ramsar sites) in all Black Sea countries. Unfortunately, there are also alarming accounts of wetlands and wild coastal areas being developed in a thoughtless way that puts the short-term profit of some people before the longer-term (and ethically and economically wiser) objective of development in harmony with nature.

One of the key tools for protecting marine ecosystems is the creation of networks of marine protected areas (MPAs). These areas act as a refuge for marine life and enable representative biotopes to be maintained in the hope that these will enable the entire system to recover when other stresses are removed. As yet, there are very few of these MPAs in the Black Sea and those that exist are very small in

size and lack sufficient staff and funding to be fully effective. Hopefully, programmes such as the Black Sea Environmental Programme (of which the Global Environment Facility's Black Sea Ecosystem Recovery Project is part) will help the governments in the region to take appropriate measures to implement the various agreements they have signed up to.

The main lessons from this very brief introduction to the ecology of the Black Sea are:

- Marine ecosystems are constantly adapting to natural changes in geology and climate.
- The Black Sea's biota is a result of tens of thousands of years of adaptation but it has suffered impacts of unprecedented severity in the past 50 years due to human activities.
- There is recent evidence that some of the biotopes are beginning to recover in the last decade, which demonstrates that something can really be done to protect the sea from further deterioration.
- However, the components of the ecosystem are linked in a complex manner and action to protect it must take into account these linkages.
- We humans are part of the ecosystem and it makes good sense to respect its complexity when we are planning activities that may damage it.

Black Sea
Geology and Archaeology

Text prepared by Prof. Nicolae Panin[5]

1. General setting and geological structure

The Black Sea is one of the largest enclosed seas in the world: its area is about 4.2x105 km^2, the maximum water depth - 2.212 m, the total water volume of 534,000 km^3 and the volume of anoxic deep water contaminated with H_2S (see Chemistry study sheet), below the depth of 150-200 m, 423,000 km^3. The connection of the Black and Mediterranean seas is limited to the Bosphorous-Dardanelles system of straits. The Bosphorous is a rather narrow (0,76 – 3,6 km wide) and shallow strait (presently 32 – 34 m at the sill) restricting the two-way water exchange between the brackish Black Sea (the salinity of the Black Sea water is about 17‰ at the surface and 22 ‰ at the bottom) and the very saline Mediterranean Sea (38 – 39 ‰). The Black Sea basin can be divided into four physiographic provinces: shelf (about 29.9% of the total area of the sea), basin slope (27.3%), basin apron (30.6%), and abyssal plain (12.2%) (fig.1).

A physiographic province is a region in which all parts are similar in geologic structure and which has consequently had a unified geomorphic history; a region whose pattern of relief features or landforms differs significantly from that of adjacent regions

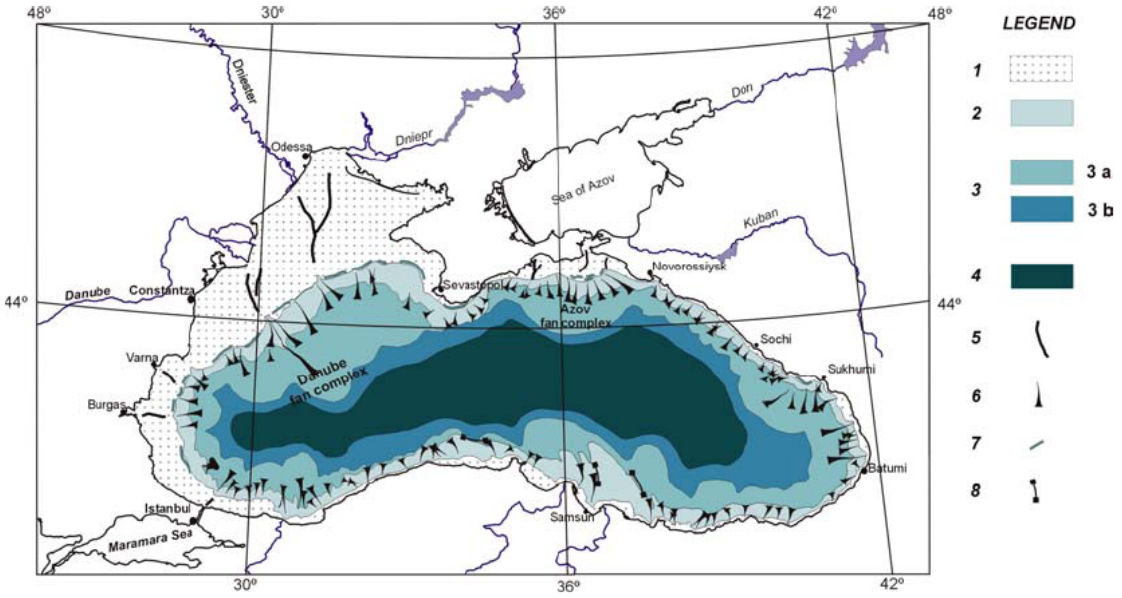

Fig. 1 – Geomorphologic zonation of the Black Sea (after Panin & E. and G. Ion, 1997)
Legend; 1, continental shelf; 2, continental slope; 3, basin apron: 3 a - deep sea fan complexes; 3 b - lower apron; 4, deep sea (abyssal) plain; 5, paleo-channels on the continental shelf filled up with Holocene and recent fine grained sediments; 6, main submarine valleys - canyons; 7, paleo-cliffs near the shelf break; 8, fracture zones expressed in the bottom morphology.

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One of the most prominent physiographic features is the very large shallow (less than 200 m deep) continental shelf within the north-western Black Sea (about 25 % of the total area of the sea).

Continental shelf: Shallow, gradually sloping zone extending from sea margin to a depth at which there is marked or rather steep descent into ocean depths down continental slope.

The Black Sea is located within a complex of high folded mountain chains of the Alpine system, which is represented by the Balkanides-Pontides belt to the south and by Caucasus, Crimea and the North Dobrogea Mountains to the north, north-east and the north-west respectively. Only in the north-west, there are low-standing plateaux and the Danube delta lowland.

Geologists consider the Black Sea a back-arc marginal extensional basin, which originated from the northward subduction of the Neo-Tethys along the southern margin of the Eurasian plate under a Cretaceous-Early Tertiary volcanic arc, as a result of the northward movement of the Arabic plate (fig.2).

Back-arc marginal basins are a feature associated with the collision between an oceanic and a continental tectonic plate. Volcanic arcs are lines of volcanoes associated with the zone of collision.

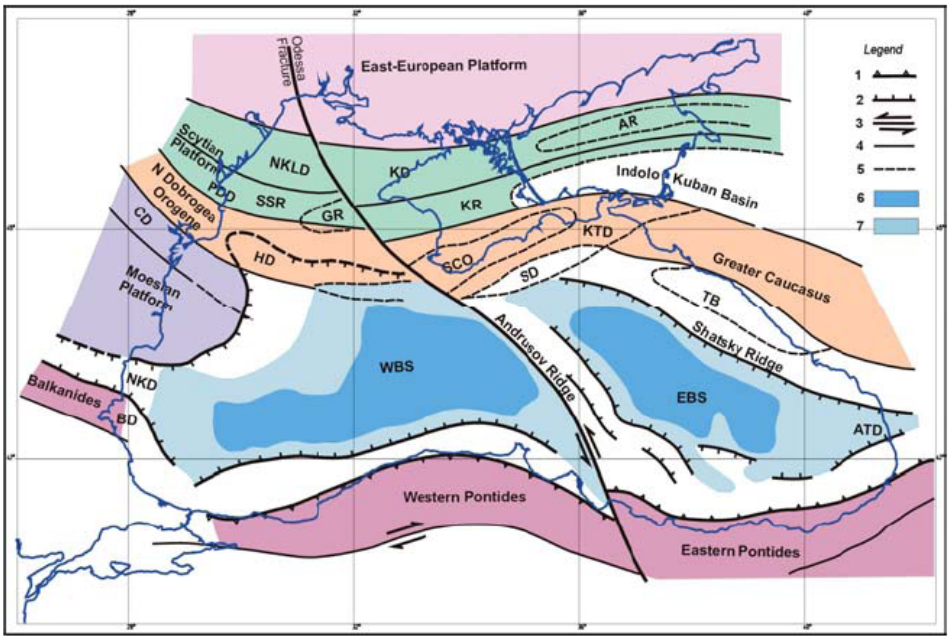


Fig.2 – Tectonic sketch of the Black Sea Region (after Dinu et al., 2003; Panin et al., 1994)

Legend: 1, Orogene overthrust front; 2, Gravitational faults of the rift; 3, Major strike-slip faults; 4, Major faults; 5, Limits of depressions and/or ridges; 6, Zone without granitic crust; 7, Thinned crust.
Explanation of abbreviations: I. Platform regions: East European, Scytian, Moesian: II. Orogenic regions: North Dobrogea Orogene, Greater Caucasus, South Crimea Orogene – SCO, Balkanides, Western and Eastern Pontides; III. Depressions and ridges: PDD – Pre-Dobrogean Depression; NKLD – North Kilia Depression; KD – Karkinit Depression; HD – Histria Depression; SD – Sorokin Depression; KTD – Kerci-Taman Depression; NKD – Nijne-Kamchiisk Depression; BD – Burgas Depression; ATD – Adjaro-Trialet Depression; TB – Tuapse Basin; SSR – Suvorov-Snake Island Ridge; KR – Krymskyi Ridge; AR – Azov Ridge; GR – Bubkin Ridge; IV. WBS – Western Black Sea; V. EBS – Eastern Black Sea;

Since about 120 million years ago, the area has been a sea basin, with extremely dynamic development and huge sediment accumulation up to 13 km of bottom sediment thickness in the central part of the basin. In the Black Sea, there are two extensional sub-basins with different geological history (Fig.2): the Western Black Sea Basin, which was opened by the rifting of the Moesian Platform some 110 Ma ago (Late Barremian) followed by major subsidence and probable oceanic crust formation about 90 Ma ago (Cenomanian) and the Eastern Black Sea Basin, with rifting beginning probably in the Late Palaeocene (about 55 Ma ago), and extension and probable oceanic crust generation in the Middle Eocene (ca.45 Ma ago).

Ma = Millions of years
Ka = Thousands of years
BP = Before Present

2. Past Environmental and Sea Level Changes in the Black Sea

Large-scale sea level changes and consequently drastic reshaping of land morphology, large accumulation of sediments in the deep part of the sea and modifications of environmental settings occurred all along the Black Sea geologic history. The Quaternary was especially characterised by very spectacular changes, which have been driven by the global glaciations and de-glaciations.

The Quaternary began 2 to 3 million years ago and extends to the present. It consists of two grossly unequal epochs; the Pleistocene, up to about 10,000 years ago, and the Holocene since that time. The Quaternary was originally designated an era rather than a period, with the epochs considered to be periods, and it is still sometimes used as such in the geologic literature.

During these changes the Black Sea level behaviour was influenced by the restricted connection with the Mediterranean Sea through the Bosphorous – Dardanelles straits. When the general sea level lowered below the Bosphorous sill, the further variations of the Black Sea level followed specific regional conditions, without being necessarily coupled to the ocean level changes. One of the main consequences of the lowstands was the interruption of the Mediterranean water into the Black Sea, which became an almost freshwater giant lake.

The main glacial periods of the Quaternary in Europe corresponded to the regressive phases of the Black Sea, with lowstands of the water level down to –120 m. As mentioned above, the regressions represent phases of isolation of the Black Sea from the Mediterranean Sea and the World Ocean. Only the connection with the Caspian Sea could sometimes continue through Manytch valley. Correspondingly, during regressions, under fresh water conditions, the particularities of fauna assemblages had a pronounced Caspian character. On the contrary, during the inter-glacials, the water level rose to levels close to the present level; the Black Sea was reconnected to the Mediterranean sea, and the environmental conditions as well as the fauna characteristics underwent marine Mediterranean influences.

For example, during the Karangatian phase (since 125 ka BP to ~ 65 ka BP) of the Black Sea, which corresponds to the warm interglacial period (fig.3), the water level exceeded the present-day level by 8 to 12 m . The saline Mediterranean water penetrated through the Bosphorous, and the Black Sea became saline, covering the lowlands in the coastal zone.

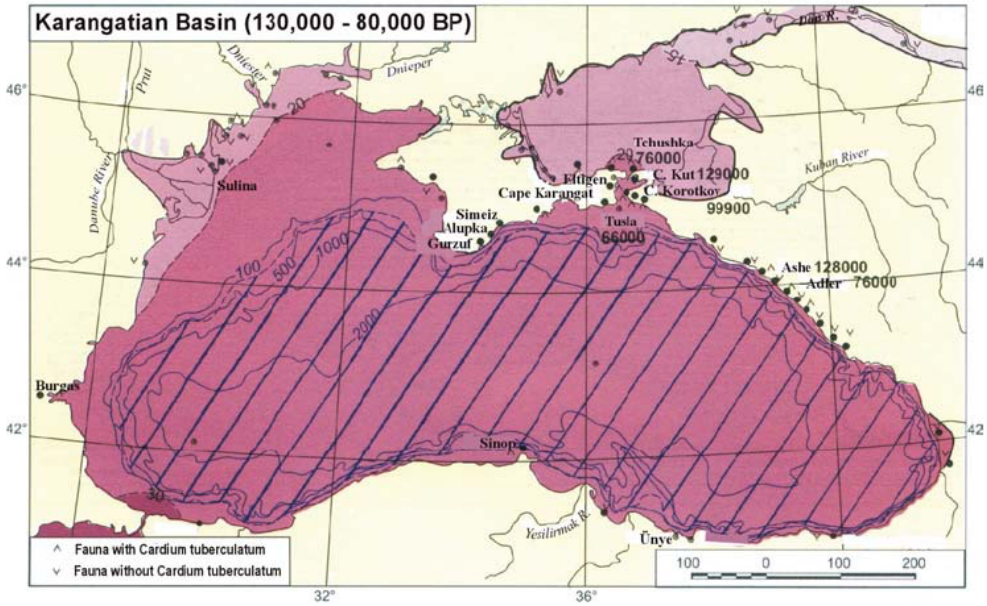


Fig.3 – Paleo-geographic reconstruction of the Black Sea during the Karangatian phase (Riss-Würmian or Mikulinian interglacial) (After Tchepalyga, 2002)

The last Upper Würmian glaciation (Late Valdai, Ostashkovian) corresponds to the very low-stand phase of the Black Sea, when the shoreline moved far away from the present-day position, especially in the north-western part of the Black Sea, and large areas of the continental shelf were exposed (fig.4).

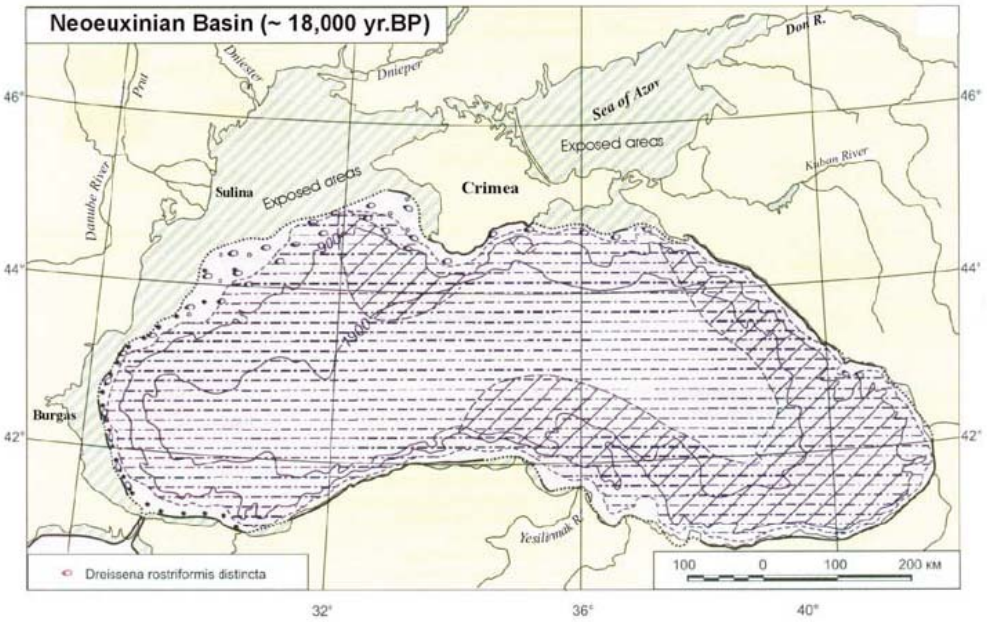


Fig. 4 – Palaeo-geographic reconstruction of the Black Sea during the Neoeuxinian phase (Upper Würmian) (After Tchepalyga, 2002)

At the beginning of the Holocene, some 9-7.5 ka BP, when the Mediterranean and the Black Seas have reached the same level (close to the present day one), the two-way water exchange was established, and the process of transformation of the Black Sea in an anoxic brackish sea started.

In the late 1990s, a new hypothesis was formulated by Ryan, Pitmann et al. (1997). The authors consider that, when the de-glaciation started during a short episode, the level of the Black Sea was high enough, and the fresh Pontic water flowed towards the Aegean Sea. At about 12 k.yr BP, the retreat of the ice-sheet front determined the reorienting, for a limited period of time, of the melt-water supply towards the North Sea. The Black Sea, without the income of the ice-melting water during the Younger Drias cooling (~11 ka BP) until 9 ka BP, under more arid and windy climate, experienced a new lowering of the level (down to -156 m). At the same time, the Mediterranean Sea continued to rise, reaching by 7.5 K.yr BP the high of the Bosphorous sill, and generating a massive input of salt water into the Black Sea basin. The flux was several hundred times greater than the world's largest waterfall, and it caused a rise of the level of the Black Sea, some 30 to 60 cm per day topping up the basin in few years time.

This new hypothesis is still under debate: numerous data from the straits of Bosphorous and Dardanelles, Marmara and Aegean seas and the Danube Delta do not support the new Ryan's hypothesis. These data indicates that the "classical" scenario of Black Sea water outflow is rather credible. There are also some hydraulic incompatibilities for accepting a catastrophic flooding event in the Black Sea, as well as a different time scale for reaching the present day salinity of the Black Sea waters.

3. Water and Sediment River Supply

The Black Sea has an enormous drainage basin of more than 2 million km^2, collecting the water from almost all the European countries, except the westernmost ones. The north-western Black Sea receives the discharge of the largest rivers in Black Sea drainage area – the Danube River with a mean water discharge of about 200 km^3/yr and the Ukrainian rivers Dniepr, Southern Bug and Dniestr contributing with about 65 km^3/yr (Table 1).

Rivers	Length (Km)	Drainage basin Area (Km^2)	Water discharge (Km^3/yr.)	Sediment discharge (Mt/yr.)
I. North-Western Black Sea				
o **Danube**	2,860	817,000	190.7	51.70**
o **Dniestr**	1,360	72,100	9.8	2.50*
o **Dniepr**	2,285	503,000	52.6	2.12*
o **Southern Bug**	806	63,700	2.6	0.53*
Sub-total I:		1,455,800	255.7	56.85
II. Sea of Azov				
o **Don**	1,870	442,500	29.5	6.40*
o **Kuban**	870	57,900	13.4	8.40*
Sub-total II:		500,400	42.9	14.80
III. Caucasian coast rivers			41.0*	29.00*
IV. Anatolian coast rivers			29.7	51.00*
V. Bulgarian coast rivers			3.0*	0.50*
T O T A L :			372.3	152.15

Table 1. Fluvial water and sediment discharge into the Black Sea
*Data from Balkas et al., 1990; ** multiannual mean discharge before damming the River Danube after Bondar, 1991; Panin, 1996.

Presently, the Danube influence is predominant for the sedimentation on the north-western Black Sea shelf area. The Danube role extends far southward up to the Bosphorous region, as well as down to the deep sea floor. The other three tributaries of the north-western Black Sea (Dniestr, Dniepr and Southern Bug) are time not significant suppliers of sediments presently because they are discharging their sedimentary load into lagoons separated by beach barriers from the sea. After the damming of the Danube river at Iron Gates I and II the river sediment discharge diminished by almost 40-45 % and the real sediment load brought by the Danube into the Black Sea is not larger than 30-40 million t/yr, of which only 10-12 % is sandy material, which takes part at the littoral sedimentary budget of the delta front zone.

4. Changing Coastline of the Black Sea

The length of the Black Sea shoreline is about 4,100 Km. The Black Sea coastal zone can be divided in 17 main zones characterised by different geology and morphology, as well as specific littoral water circulation, sediment drift systems and sedimentary budget. In a more general approach the Black Sea coast zone could be subdivided into three main morphodynamic categories, with very specific characteristics and behaviour: (1) Low, accumulative coasts mostly related to the main rivers mouth zones; (2) Erosive coasts within low standing plateaux and plains, with active cliffs in loess and loess-like deposits sometimes with very narrow beaches in front of the cliffs; (3) Mountainous coasts, with cliffs, certain number of marine terraces, land slides, sometimes with sandy or gravely beaches.

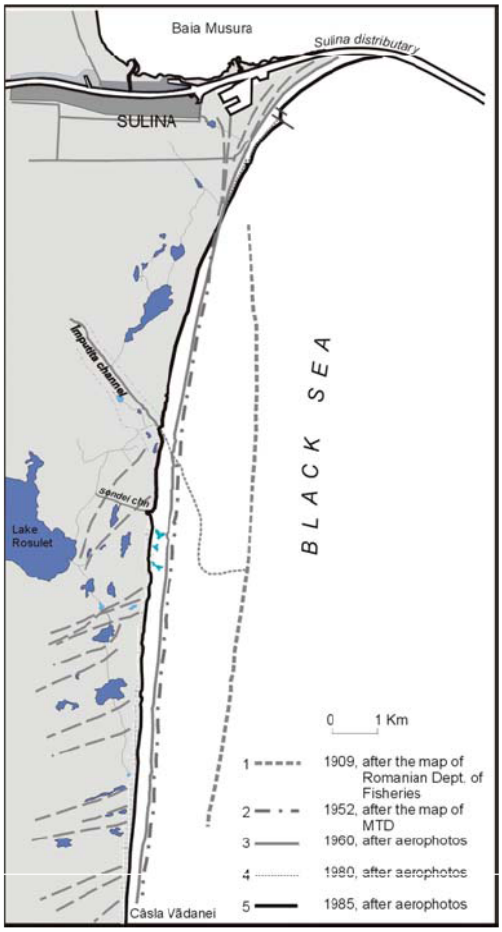
Morphology (in geology) is the observation of the form of lands

A terrace is a nearly level surface, relatively narrow, bordering a body of water and terminating in a steep bank

The coastal erosion in the Black Sea represents one of the main environmental concerns of the riparian countries: Bulgaria, Georgia, Romania, Russian Federation, Turkey and Ukraine. The erosion is controlled by:

- Global and natural factors. The coast erosion will depend on synergetic effect of factors controlling the littoral processes (meteorological regime, wave energy regime, water circulation, sediment supply and drift etc.), global changes and the consequent modification of the energetic level of the coastal sea, general sea level rise and regional characteristics as shoreline morphology, elevation and geologic constitution, subsidence or/ and neotectonic regime.
- Anthropogenic factors. The coast zone erosion and the state of the coastal sea ecosystems are strongly affected by the anthropic activities, the effect of which is added to the impact of natural factors. The anthropogenic changes of large rivers hydrologic characteristics (water and especially sediment supply, regularisation of floods etc.), men-made littoral structures as breakwaters, dykes, harbours etc. which are modifying the littoral circulation cells, the uncontrolled use of beach sand, dredging of sand too close to the beaches or within the river mouth bars and many other activities are causing an enhancement of coastal erosion and endangering of the coastal ecosystems.

Figure 5. Recession of the Danube Delta beach line



Anthropogenic refers to changes caused by humans.

The low, accumulative coasts (the first category described above) are the most influenced by the global changes, specifically by the sea level changes and by the changes in the river sediment inputs. The decreasing of sediment supply and changes in littoral sediment drift due to anthropic activities (river damming, hydrotechnical regularisation, littoral structures etc.), especially when the sandy beaches are low, added to the rising of the sea level and the increasing of littoral sea energy could determine in certain conditions a very active and almost continuous recession of the beach line up to 20-30 m/y, as it happens in some sections within the Danube Delta littoral (fig.5). This process is causing land losses, environmental changes and economic degradation of the coastal zone. If the region represents the coastal zone of an important delta, which plays essential role in the normal structuring, and functioning of ecosystems, any changes of delta/sea interaction zone environments could be fatal and irreparable.

5. Archaeological evidences of environmental changes in the Black Sea.

It is obvious that the ancient populations were influenced by different environmental changes. The people migrations were also driven in many cases by such changes. The coastal zone excursions accordingly to the sea level position were, probably, followed by migrations of Palaeolithic and Neolithic settlements, which searched favourable live conditions along the valleys or by the littoral zone. It might be that at the Neoeuxinian (Würmian) regression of the sea when the entire continental shelf zone was exposed (the water level at about –120 m) the Upper Palaeolithic or Epi-Palaeolithic settlements were located far away offshore from the present-day coastline. The assessment of these settlements, which are in most of cases buried under a blanket of recent and Holocene sediments, is very difficult and little is known about them.

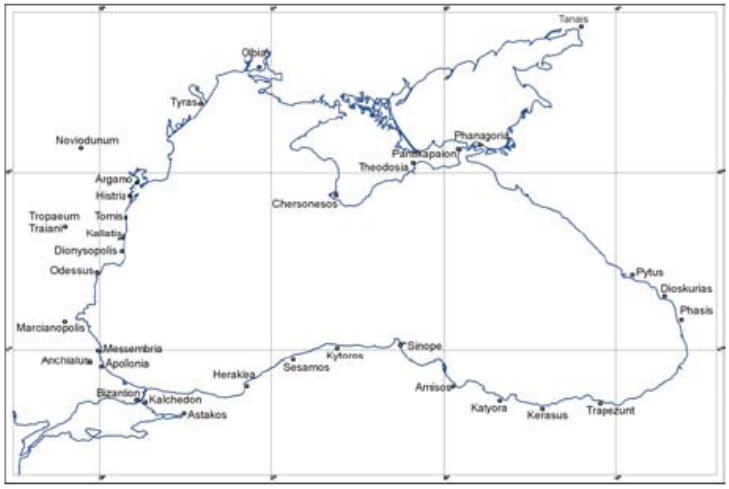


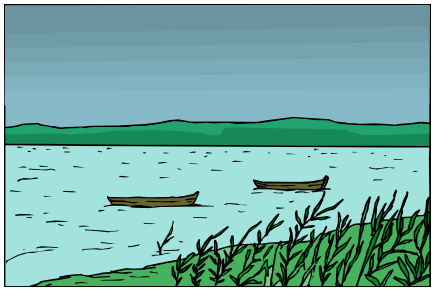
Fig.6 – Greek colonies around the Black Sea established in 7 – 5 centuries BC

On the contrary, for the last 2000 to 3000 years there is a large and useful information about the sea-level changes and coastline position in many areas. There is also information about the coastline and palaeo-geography in different places around the Black Sea. The ancient Greeks and Romans in their expansion eastward gave very interesting description of Black Sea coast zone connected mainly with the colonies established since the 7-th century BC (fig.6). One of the best-described areas was the Danube Delta and lagoons and the Danube River mouth zone.

Part Two

Black Sea Study Sheets

Coastal Zone Management



Coasts are areas rich in plant and animal life, much of it vulnerable and unique. Over 60% of the world's human population lives within 100Km of the coast. About 90% of the fish to supply the world's fisheries are caught within 100Km of the coast. Ports provide the route for most of the trade in food, minerals, manufactured products and energy. The coast is the most popular tourism destination.
How can all of these things exist together? Only wise management can provide the answer.

Introduction.

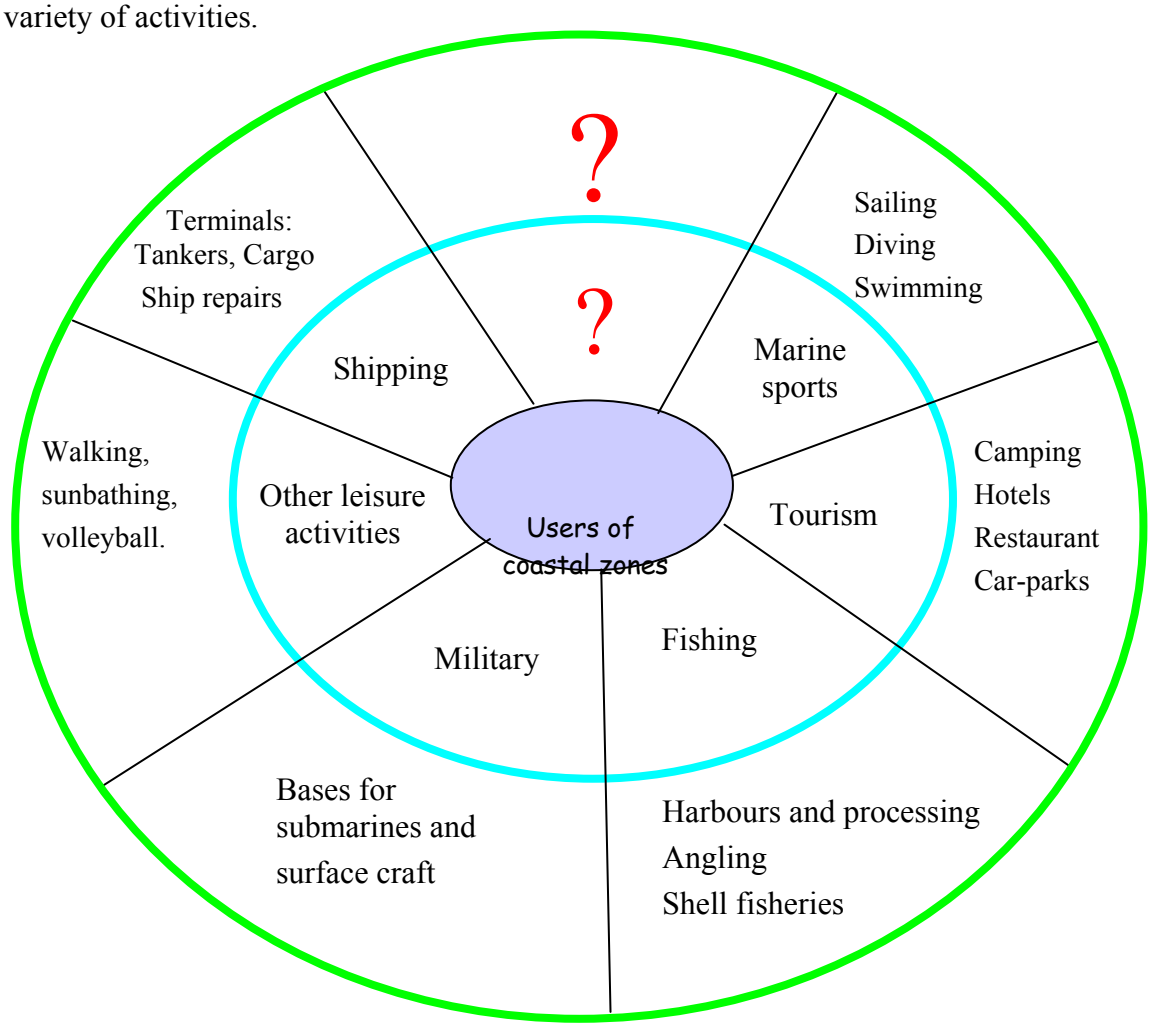
The area beside the sea is known as the Coastal Zone. This area is particularly important because there are many plants and animals that depend on the contact between the sea and the land. It is also important to humans as we rely on the coast for building harbours and it is the place where many of us like to spend our holidays. Soils are often fertile in the coastal zone and agriculture flourishes. Harbours have attracted commerce and industry and major cities have grown for many different reasons – administrative centres, ports, tourist resorts, industrial complexes, agricultural centres, and aquaculture and fisheries development. The problem is that many of these uses compete with one another and the natural environment is often the loser! People often fail to realise that there is a limit to the available space for development in the coastal zone, and that any plans need to take into account all users of the space.

The future of many plant and animal communities which inhabit the coastal zone depends on wise decisions about the development of these sensitive areas. There is much evidence of unwise planning along the coastline of the Black Sea due to a number of pressures. Different sectors of public and private administration often carry out their business without consultation with each other, which is not good practice. Coastal zone management is all about helping people to work together to plan for a sensible balance between their immediate needs without compromising the vision of sustaining natural ecosystems now and in the distant future.

Make a table called "*Coastal animals and plants*" with two columns. One is headed "*I live on land or in rivers and depend on the sea*" and the other, "*I live in the sea and depend on the land*". Which human activities would make your life impossible?

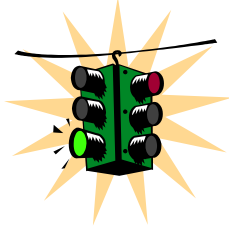
Pressures in the Coastal Zone.

The diagram below shows how many different groups of people use the coastal zone for a variety of activities.



See how many more users you can identify to expand this diagram.

You can make another ring around the circle and note down the possible conflicts between the different users, and the impact each group could have on the coastal zone.



And now to the Black Sea …

On the next pages you will see some examples of positive and negative management of coastal zones in the Black Sea (they were provided by local teachers). Take a look at them and think of some examples of wise and unwise practices in your own town/region.

Romania:

+ *Sewage treatment*

Investment in 2 sewage treatment plants (Constanta South and Mangalia), which will improve the quality of the marine water in the shore area.

- *Development of infrastructure for tourist resort*

Buildings, houses, bars, restaurants in the 2 Mai - Vama Veche area (near the Romanian - Bulgarian border), have been constructed directly on the beach or on the foreshore, without any approval from the local beach management authorities. The effect is the degradation of a very beautiful area of the Romanian Black Sea shore.

Bulgaria:

+ *"Poda" a wetland south of Burgas.*

This area on the Via Pontica is a nesting place/temporary habitat for a great number of birds including rare and protected species. The locally-designed management plan provides efficient use of the area as a biosphere reserve/site for scientific investigations, for bird-watching and eco-tourism, fishing, etc.

- *"Cabacum" - north of Varna*

The combination of a sandy beach and a steep slope behind it creates favourable conditions for landslides. In the region of Cabacum, the slope is used as a recreation zone with private summer-houses and small hotels. Poor drainage for domestic and rain waters combined with several rainy seasons activated severe landslides. Large quantities of soil slid down the hill, damaging the main road and the beach. Most of the private houses and a number of small hotels were ruined or damaged. A program for investments was developed and restoration activities began in 2000-2001 but the available funds are not sufficient to complete this work.

Russia:

+ *Construction of a ring road around Sochi:*

In order to minimise the impact of heavy transport along the coast road, and also to lower the level of air and noise pollution in the city, a ring road was constructed around Sochi. Much of it was built by tunnelling under the steep hills rather than damaging the landscape.

- *Building materials:*

Pebbles and rocks from the beaches are used in the construction of buildings, which destroys the beaches and promotes coastal erosion.

Turkey:

+ *Uzungöl-Trabzon.*

This place is a natural park, a protected area so this can be viewed as a positive example of coastal zone management. Problems remain however, such as overfishing and tourism (over-population and an increase in the construction of summer houses)

- *Trabzon solid waste:*

Household garbage is discharged into the sea in Trabzon. The costs of constructing a landfill site for proper disposal are regarded as an excessive burden on the local taxpayers but the value of the sea and its resources and amenities has not been taken into full account during planning.

Georgia:

+ *Kolkheti National Park.*

The area near Poti includes a wetland and lake (Lake Paliostomi) that are considered of global importance for their fauna and migratory birds. They are under great pressure from illegal loggers and fishers as well as legal hunters. Complicating matters further the system is shared between 5 different administrative districts, each with its own policies and priorities. After considerable discussion they appreciated the value of working together and agreed to create a National Park with its own management plan.

- *Kulevi oil terminal:*

This was constructed without official permission and the necessary studies to determine its impact on the natural environment. There were strong protests by environmental organisations when they discovered that the huge project was underway. The Georgian Government ordered the construction to be stopped when the irregularities were discovered but work had almost been completed.

Ukraine:

+ *Tiligul liman (30km east of Odessa).*

The liman (lagoon) is approximately 80km long, up to 4.5 km wide and 21m deep. It has natural and economic significance, being a centre for recreational activity, aquaculture and wildlife, together with natural resource extraction such as sand for building. It has attracted large number of visitors and the nearby construction of 40,000 summer houses. By gradually bringing together all of the people concerned with its future and explaining the principles of Coastal Zone Management, a plan is emerging that will allow for a balance between development and conservation.

- *Odessa waste-water treatment:*

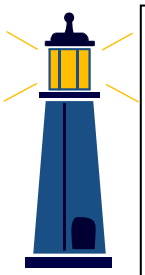
The lack of treatment of sewage has long been a problem in Odessa and bathing beaches have often been closed in summer in order to protect local people from illness. Though management of existing disposal facilities has improved in recent years, a long-term solution is still needed if the coastal zone is to be enjoyed by all.

What does coastal zone management involve?

Coastal zone management is a process of bringing together representatives of all of the groups of people involved in the problems and their possible solutions and the jointly developing and implementing a plan. That sounds easy on paper but in reality can be very difficult as it may involve changing people's economic interests or personal influence. On the other hand, when people fully appreciate how vulnerable the coast is (and that their own future is at risk) they are more willing to cooperate. Somebody has to take charge of organising the plan (often an inspired person in the local government); then the basic steps in the process are:

1. To identify the groups of people who should be involved (often known as *the stakeholders*) and to ask them to send representatives to a series of meetings.
2. To jointly identify the human pressures on the coastal zone and the environmental, social and economic interests that are affected.
3. To agree on a vision for the future of that part of the coastal zone.
4. To look at all the practical things that can be done to achieve the vision and to decide which of them should be done first, by whom, when, and how they should be paid for - this is the *management plan*.
5. To make everybody aware of the plan and to agree who will check that the plan is working and update it in the future.

The moral maze – protected areas - what do you think?



There are many species and habitats that are very vulnerable to human presence. Seals for example, have virtually disappeared from the Black Sea because they are easily disturbed by humans. Many wetland areas have been lost because they are not regarded as valuable by people and, as a consequence, birds have lost their wintering or breeding grounds. In many parts of the world, protected areas are being created to conserve the diversity of life on the planet. Unfortunately few such areas exist in the Black Sea, partly because there are so many competing interests on the coast and nature cannot speak with a human voice. There are various degrees of protection normally used. Absolute nature reserves exclude all humans except for wardens and some scientists. These areas are surrounded by "buffer zones" where human activity is restricted (especially hunting and new construction). Partial protection is provided through nature parks where people can enter but are obliged to respect the wildlife habitats and keep to prescribed paths and beaches. The sea too requires protected areas: some types of fishing are particularly destructive of the bottom communities only seen by divers. Wherever they are, protected areas need to be big enough for the animals within them to range freely, out of danger, and should not be regarded as zoos – nature should be cared for everywhere but sometimes *specially protected*. Try to find out where the nearest protected area is to your home. Is it large enough? Who is responsible for it? Do you think it is effective?

Your chance to negotiate a coastal zone management plan!

Just along the coast from where you live, there is a town called 'Everypol' (perhaps you didn't know about it, but close your eyes and make it appear!). Everypol is a town of 200,000 people with a port that exports locally produced steel and imports oil. It also has a fishing industry in Everypol Bay. The Bay is a popular tourist destination for people from the capital and the beaches are crowded in the summer but the sewage treatment plant is insufficient for them all. Just 1km from the city is a wetland area important for migratory birds. It has been declared as a nature reserve. The tourists are sometimes complaining about oil arriving on the beaches as well as the frequent beach closure due to sewage pollution. They would like to move further away from the city centre but tourist facilities are not allowed in the nature reserve. The nature reserve manager is also upset because waste from the factories sometimes finds its way down the streams leading to the wetland and kills many fish and birds. Fisheries are also declining, partly because of all the waste going into the bay and partly because of overfishing. The mayor says that there just isn't enough money to solve the problems but lots of people are building new summer houses.

You will be divided into small groups and given a card by your teacher. It will identify you with one of the stakeholders and tell you something about your role. Conduct a debate to:

(1) Decide on a common 'vision' – how you want the bay to look in the future (try not to exclude anyone from the vision)
(2) How will each of you make changes to reach the agreed vision?
(3) Where will the money come from and who will make sure the plan is working?

Coastal Zone Management

PEDAGOGICAL NOTES

This section is a classroom exercise that does not require any outside activities. It is combined with a group discussion and debate that bridges several disciplines and should appeal to teachers of geography in particular. Coastal zone management is a process that depends upon a creative and ordered dialogue between responsible citizens; simulation of the dialogue in the classroom helps young people to understand the challenges facing planners and environmentalists in their quest for sustainable development.

Group exercise 1: Coastal animals and plants

This exercise is designed to demonstrate dependence of many coastal species on adjacent land and sea habitats. The table is best written on the blackboard on the basis of contributions for the students. The left hand column is marked '*I live on land or in rivers and depend on the sea'*. Here are some ideas in case the students need prompting:

- Shore crabs
- Sea birds without webbed feet (e.g. wading birds)
- Salt-loving plants (halophytes) found in wetlands
- Eels (spend most of their time in rivers but spawn at sea)

Perhaps humans could also be added to the list! Some ideas for the right hand column - marked '*I live in the sea and depend on the land'* – are:

- Sea birds with webbed feet (e.g. seagulls). Note that not all birds with webbed feet can stay in the water. Cormorants, for example, become waterlogged as their feathers are not waterproof and they need to perch on land to dry them occasionally.
- Sturgeons and salmon-trout (spend most of their time in the sea but spawn in rivers).
- Monk seals (maybe there are already none remaining in the Black Sea)
- Near-shore underwater seagrasses and algae (they require stable shores)

Since most of the nutrients, essential to near-shore marine plant growth, come from the land, it could be argued that most of marine life near the coastal zone depends upon the land. In the Eutrophication study sheet, you will see what happens when the supply is excessive however. During the discussion, it will be possible to identify a number of human activities that would make life impossible for these animals and plants. The removal of wetlands, for example, denies sea birds breeding sites or resting areas. Damming or pollution of rivers blocks migratory fish from reaching their spawning grounds in the sea or rivers. Construction of beach resorts left monk seals without breeding sites.

Group exercise 2: Pressures in the coastal zone

This is a relatively simple exercise. The inner circle shows the activity and the outer circle shows the kinds of observable pressure on the coastal zone. Many activities and pressures have been intentionally omitted. Typical examples are:

Activity	**Pressure**
Industry	Factories and industrial complexes
Urban development	Towns and cities
Coastal agriculture and aquaculture	Farms, factory farms, fish farms
Mining	Mine pits, tailings

The students should discuss the activities in their own region, removing those that do not apply and adding new ones. Try to decide which are the most important and how they might affect the coastal zone on land and sea.

And now to the Black Sea…

The examples given here are from corroborated reports by teachers or from the Black Sea Environmental Programme. They demonstrate that successes and difficulties are common to all Black Sea countries. You may wish to add your own local examples and discuss how they could be solved with the students.

The moral maze – protected areas

The purpose of the 'moral maze' sections is to trigger some deeper questioning by the students. This example serves to examine our relationship with nature. Should we restrict our care of nature to small reserves? How can we act as 'stewards' of nature when there a so many competing pressures? Who will act in defence of the habitats and plants that form the Black Sea ecosystem?

Your chance to negotiate a coastal zone management plan!

This is a group debate exercise giving an opportunity for students to role play and to try to solve a typical situation that is faced by coastal zone managers. Try to memorise the hypothetical case study described in the study sheet (or at least keep it at hand for reference). On the next page, you will find a sheet containing a number of cards with stakeholder roles. We suggest you make a photocopy of the sheet and cut out the cards. Divide the class into X groups. You know the dynamics of your own class, so the distribution of roles should be according to your own judgement. Each group has to appoint a spokesperson who should explain this group's perspective and then a general discussion can take place. We suggest that the debate is time-limited. A spokesperson is allowed to speak for no more than one minute, and there should be no interruptions during this period. The items for debate should be marked on the blackboard for everyone to see. You may wish to bring a stakeholder from your own local community to give his/her own opinions. It is not essential, but it gives a touch of authenticity to the debate, which make it more fun and realistic for students.

Further reading:

The European Union for Coastal Conservation (EUCC) is an excellent source of material. Check their website: http://www.eucc.nl/en/home/index.htm

1. DEPARTMENT OF TOURISM

Your team is working closely with the local tourism industry to encourage tourism in Everypol and to make sure that tourists have the best possible facilities available.

2. LOCAL ENVIRONMENTAL ORGANISATION

Your organisation has 72 members in the Everypol district. They are concerned at the state of the local environment and want people to do more to protect nature and to keep the city clean and tidy.

3. NATURE RESERVE MANAGERS

Your small team has responsibility for managing the nature reserve near Everypol. It is an important wetland for nesting birds which are easily disturbed. The area near the beach has rare plants and butterflies.

4. LOCAL FISHERMEN'S ORGANISATION

Your organisation represents all the local fishermen. They haven't been doing very well recently; catches are down and they have been accused of overfishing. Fishermen are angry about pollution in the bay.

5. MANAGERS OF STEELMAKING PLANT

Your company is only just making a profit. If it loses money, people will lose jobs. Though they express concerns about the environment, they also say they cannot afford a new wastewater treatment plant.

6.PORT AUTHORITIES

The port is the major source of income for Everypol. It has a large oil terminal but its equipment is out of date and small accidental spills of oil are common. You don't want to lower your profits to buy new equipment.

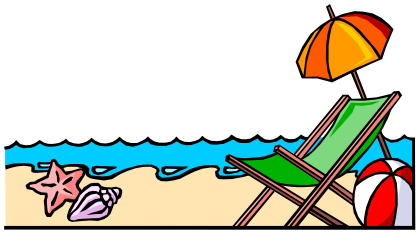
7. MAYOR AND DEPUTY MAYORS OF EVERYPOL

You have been elected by the city because you promised to make it a happy place where everyone would have a better income as well as good health facilities and a clean environment.

8. POLLUTION INSPECTORATE

Your job is to check that people are obeying the law and not polluting the rivers and sea. You have few people to help you and there are too many small discharges of pollution.

Tourism and the Black Sea



For over half a century, the Black Sea has been a popular tourist destination, particularly for residents of the former Soviet Union and of the countries in Central Europe. The warm summer climate, sparkling waters of the Black Sea and top level entertainment, provided a welcome break from life in the city or on the farm. Much of this development was at high cost to the environment however. With greater opportunities for international travel, Black Sea resorts now have to compete with other destinations. Some people are now investing in Black Sea tourism to make it attractive again. How can this industry be developed in a way that does not destroy the environment on which it depends?

Introduction.

Most people like to visit the seashore when they are on vacation. There are many different reasons for this, some of which depend on a clean environment and some that can seriously damage it. Here are some examples in a table:

Reason for wanting to be near the sea	***Because***	***But***
Good place to swim or do watersports	Swimming, and most other watersports are healthy and fun.	Poor sanitary facilities introduce microbiological pollution that can make swimming dangerous. Some watersports (e.g. water scooters) disturb wild animals.
Beautiful landscape	The most attractive landscapes are usually the natural ones. People often enjoy being close to nature. Well-planned or conserved towns or archaeologi-cal sites can also be attractive.	Bringing many people to the coast requires additional services (roads, hotels, restaurants, etc.) and housing for the people working on them. If this is not planned properly, it can ruin the landscape and destroy nature.
Beaches to play on	Everyone likes to be on a clean beach. Small children like to play in the sand. A dirty beach is unattractive and can be dangerous.	People generate garbage when they visit the beach. If they do not dispose of it properly, the beach will quickly become very dirty. Wildlife easily become entangled in garbage.
Good place to rest	The sea air and pleasant views, good hotels, healthy food and little stress are relaxing.	Too many people, untidy cluttered development, noisy polluted streets and stressful formalities add up to a poor quality vacation.
Entertainment and party atmosphere	Successful seaside resorts attract high-level entertainment	Poorly planned facilities can damage the landscape, deter other tourists, destroy natural habitats and deter wildlife.

Tourism therefore, may be an attractive way to raise revenue and local employment, but it is also dependent on our ability to sustain the natural environment. Experience in many parts of the world has shown that in poorly managed tourism development the environment gradually deteriorates, people pay less and less to visit the place and the locality has less revenue to repair the damage. In some places around the Black Sea this has already happened.

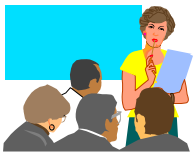
What is sustainable development?

There are many different definitions of this concept but the basis of these is that improvements in the quality of life should not be gained at the expense of the natural environment or that of future generations. If a tourist development destroys the natural environment, it cannot be regarded as sustainable.

Factfile

Tourism is now the world's largest industry. By 2007 it will be generating 383 million jobs and a revenue of US$ 7,100,000,000,000 ($7.1 trillions)!

Exercise: Your chance to have a say …



In a coastal resort near your school, someone has proposed the development of a new hotel complex. In order to make sure that everyone has the chance to put forward all their ideas about the development, the local council has decided to hold a community meeting to debate the issue.

Stage 1: Divide into small groups and prepare your arguments for or against the complex.

Some important points to consider in the debate:

In favour of the complex…..

- Potential to increase revenue from tourist industry
- Benefit to local economy
- Provide a needed facility
- Good publicity for the area

Against the complex…..

- Visual impact of the new development
- Increase in pollution from sewage, litter etc.
- A disturbance on local ecosystems from the construction

Other points to consider.

- Proximity of any areas of conservation / Distance to neighbouring hotels
- Waste reception facilities, and other recreational facilities in the area

Stage 2: Hold a debate in the class about the project. If possible, invite one or more guests from your local community to join the debate and comment on it (this kind of debate is required in most places before a project can go ahead). Hold a vote on whether or not the project should proceed. How are such projects discussed in your community?

The importance of clean water and beaches

How do you know whether or not the sea is clean enough to swim in? When sewage enters the sea, many of the sewage microbes remain alive for days or even months. Some of these can cause serious infections if they are accidentally taken inside the body through the mouth and nose or through cuts and scrapes. Microbes that can cause human diseases are known as pathogens and the main risk in the sea is from bacteria and viruses. They are all too small to be seen without a microscope and though the water looks clean, it may be contaminated.

It is not very difficult to prevent pathogens from entering the sea by using sewerage systems (a network of pipes collecting sewage from houses, public buildings and businesses) connected to wastewater treatment plants. These plants remove solid waste, promote bacterial fermentation of the organic matter and sometimes include stages of treatment to remove chemicals. The plants are quite expensive to operate however. Sometimes municipalities cannot afford to purchase and maintain a treatment plant or people may be unwilling or unable to pay the costs of having their waste treated properly. This is where hotels and other tourism enterprises can help. By understanding the value and importance of clean water for their own businesses they can be asked to contribute to the costs of proper sewage treatment. New hotels should not be constructed if proper treatment facilities are not in place.

How important do you think good bathing water is for attracting tourists to your area?

Sometimes it is difficult to obtain reliable information on the quality of bathing waters. There are national and international standards for water quality designed to protect the public and beaches may be closed if the standards are not being met. Try to find out where you can get information about this for your nearest beach. Is the information readily available? It is important that these measurements are taken very frequently, so it is common for samples to be taken weekly during the summer season. This is necessary because any sudden failure in the water treatment system could cause the bathing waters to become unsuitable to recreational users very quickly indeed, and long periods between monitoring times may miss such an event.

The problem of cleanliness is not simply restricted to the water. Dirty beaches covered with garbage are unsightly and can be dangerous. A broken bottle in the sand can ruin a vacation for a small child running barefoot on the beach. Flies attracted to discarded food or excrement can spread disease. Plastic waste can kill wildlife (how?). Keeping a beach clean require co-operation between users of the beach (picking up their garbage) and the local municipality (providing somewhere to throw the garbage and disposing it properly). In order to encourage tourism in places where the water and beaches are reliably clean, there is an international award scheme known as the 'Blue Flag' given to beaches of a reliably high standard. Several Black Sea beaches have already received the award. Find out if there is an award scheme in your area.

The **European Blue Flag** for beaches is awarded annually and awards are valid for a single year. Both national and international juries examine the applicants. They examine:

- *Water quality based on analysis at least every two weeks,*
- *Coastal quality including clean beaches and safe paths, steps and other features,*
- *Good environmental education and information including at least five educational activities every season,*
- *High safety standards with rules restricting access by dogs, no dangerous sports, good garbage collection.*

The current situation in the Black Sea

With the exception of Turkey, every Black Sea country has a major Black Sea coastal tourist industry. The case of Turkey is a special one as the rainy and rather rocky Black Sea coast cannot presently compete with the attractive alternative of Turkey's Mediterranean or Aegean resorts.

Factfile

Resorts around the Black Sea coast can accommodate approximately five million tourists each year. The industry probably generates over US$1 billion revenue every year.

Every summer, millions of tourists flock to the Black Sea. What are their expectations? Are they satisfied with their vacation? Do they know anything about the Black Sea's unique habitats and wildlife or care about their protection? There are some interesting and fun outdoor exercises that can help to answer some of these questions. Your teacher will help to decide which of these your group can undertake.

Practical exercise, alternative 1.

Carry out a survey at the beach to see what kinds of people use the facilities there, and what recreation activities are taking place. You can use the form below to record your observations.

Where are you?

Name of the beach…….
Date of survey……
Time of survey……
Weather conditions……

Favourite Activities.

Tick the box if you see this activity taking place.	**How many people are taking part?**
☐ Sunbathing	……
☐ Snorkelling	……
☐ Swimming	……
☐ Sailing	……
☐ Walking	……
☐ Playing beach games	……

What activities are taking place near the beach?

Ports
Restaurants
Commercial fishing
Industry
Others?

Did you see any streams or drains flowing into the sea (describe)?

……

What impacts do you think these activities could have on the environment? Explain your thoughts to the rest of the group.

Practical exercise, alternative 2.

Interviewing visitors to your region.

Introduction

Much information about a beach and its suitability for various functions can be obtained by interviewing a sample of visitors. It is important to gather information about what they think of your local coastal area as a vacation place. The information is recorded on a questionnaire sheet so that the data can be analyzed at a later stage.

Procedure *(teachers, see pedagogical notes before undertaking this work)*

a) Select an area of beach where there are 10-100 persons present.
b) Interview a sample of not less than 10 person groups (individuals or a group of not more than 4), trying to form a cross-section of the people present (older visitors, younger visitors, visitors with children, first time visitors, etc.).
c) Explain to the visitors who you are and why you would like to request permission to ask them some questions to determine their views on the attractiveness of the beach area.
d) Ask your questions. You may determine your own questions or use the questions given below. The purpose of the questions is to determine the attractiveness of the beach for visitors.
e) Back at the school, you should analyze the results you have obtained from the interviews. Prepare a poster illustrating the results of the interview, and as a class make your own recommendations on how to improve the attractiveness of the beach to visitors.

Possible questions to ask

Why did you choose to come to this particular beach?
Is this your first visit to this beach? If not, how many times have you been here before?
Is this a "good" beach? To determine this, please rate the beach on a scale of 1-4, (1=poor, 2=average, 3=good, 4= exceptional) in terms of:

- Ease of access
- The facilities provided for visitors
- Location (view, shielded from the wind, etc.)
- Quality of the beach (quality of the sand, etc.)
- Cleanliness of the sea
- Cleanliness of the beach
- Cleanliness around the various facilities (shops, restaurants, etc.)
- Cleanliness of toilets
- Suitability for children (safety, etc.)
- Suitability for swimming (current, size of waves, etc.)

What would you say is the worst feature of this beach?
What improvements do you think would make the beach a more attractive place?

Green tourism

There's much more to the Black Sea than sea and beaches. An increasing number of visitors are attracted to the forests and wetlands to observe the wildlife and enjoy the clean air. Some are hikers, painters, photographers or just want a quiet place to read and write. This new and fast-developing 'green tourism' can only exist if nature is properly protected. Write a list of green tourism opportunities near your home.

Tourism and the Black Sea
PEDAGOGICAL NOTES

This section is designed to be participatory in nature and to include a field exercise for the summertime. It should therefore be scheduled to overlap with the tourist season if at all possible. The section aims to help the student integrate ideas from geography and science and to develop participatory skills (forming a rational argument, debating with others and reaching a consensus). The impact of tourism on the coastal zone ties in closely with coastal zone management, and discussions on these issues will raise a number of similar topics.

Notes

Introductory table

There are five main topics to be addressed on the subject of tourism and the coastal zone:

Human Activity	Water sports	Sewage
Litter	Disturbance	

The table in the study sheet attempts to provide a rational matrix for examining some examples of positive and negative consequences of development. It is designed as a starting point for a class discussion rather than a prescriptive formulation.

Exercise: Your chance to have a say …

This role-play exercise[6] allows students to investigate the impacts of tourism from a variety of viewpoints**.** The text provides the framework of the exercise but it is important to fill in the details with relevant local information. You may wish to avoid controversy by keeping to a hypothetical example of a development project but making it as realistic as possible. One way to carry out this exercise would be to start off with a "brain-storming" session to identify the different groups of people who should be represented in this debate. There should be representatives from the local residential and business communities who may be affected by the new development. An "identity" should be assigned to each group, which should then be given time to prepare a short presentation to the rest of the class. One student may be appointed "chairman" for the debate. Students should be encouraged to present well thought out ideas. For example, the group of students representing the developers of the hotel complex should outline exactly what is to be constructed, what facilities will be

[6] This role-play task and subsequent beach survey are based on exercises from the Coastal Fieldwork Enquiries resource pack (Welton).

available for visitors, and how they intend to lessen their impact on the local environment.

Bringing some local people (from the local administration, NGOs etc.) helps to make the debate more authentic. Alternatively some parents or other teachers may be willing to play the role of some authoritative adults. It is important to impress on young people that a debate should not merely generate 'winners' and 'losers' – where possible the outcome should be broadly acceptable to everyone. In the real world it is better to try to reach a consensus than to put matters to a vote even if this results in compromises. Sometimes however, positions are so far apart that a vote is unavoidable but all the parties involved must previously agree to respect the outcome.

Practical exercise, alternative 1.

This is a very straightforward exercise that should not present major complications. Students should conduct the work in small groups, never alone. Results can be shown graphically and compared between groups. This activity could be used to spark a discussion about how different groups of people have different uses for the same area, much the same as the conflict investigated under the topic of Coastal Zone Management.

Practical exercise, alternative 2.

This is a somewhat more complex but more rewarding exercise. It requires careful planning and can best be achieved with the co-operation of parents. For safety reasons, students should not conduct questionnaire surveys alone – it is better to work in groups of three. The exercise is adapted from the Unesco south-eastern Mediterranean Project: worksheets for students, 1996-7. When examining the results, the following discussion points may be useful:

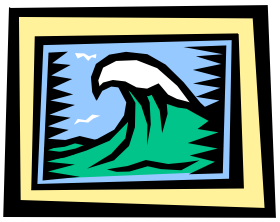
What do tourists look for?

- Why is perception important when we are discussing tourism?
- How do we gain these perceptions?
- How might overseas tourists perceive the Black Sea destination?
- How can we improve the impression tourist will gain of a place?

Green tourism

This short section is designed to link the need for nature protection with the new opportunities provided by 'environmental' tourism. This is not simply an academic connection – green tourism is one of the most rapidly expanding areas. It is hoped that this discussion will provide a positive conclusion to the session.

Eutrophication of the Black Sea



Introduction.

When the morning sun rises over the sea, a myriad of tiny floating plants – too small for the eyes to see – start to capture the solar energy that fuels marine life. These plants, known as phytoplankton, are nothing like the plants we see on the land (known as vascular plants), though they are relatives. They have evolved in ways that enable them to stay in the shallow part of the sea and/or to find the essential nutrients they require for growth. Some species have little appendages known as flagella that enable them to swim slowly; others can even produce toxic substances to ward off the animals that predate on them (zooplankton).

The essential nutrients that phytoplankton need to help them to grow include compounds of nitrogen, phosphorus, iron and in some cases, silicon. Phytoplankton also need several organic compounds such as vitamins. You can find more information about all of these substances in the Fact Sheet on chemistry in the Study Pack. There are three major sources of these substances:

(1) their release by phytoplankton at night, dead phytoplankton, or from other marine organisms (as waste products);
(2) arrival from deeper waters of the sea by mixing; and,
(3) transport from land by rivers and streams and through the atmosphere.

Though (1) and (2) are the main source of nutrients in the Black Sea, a significant amount of nutrients come from the land, either directly or through the major rivers draining parts of 17 countries across Europe.

In the past, before humans caused massive alterations in the landscape of our continents, the amount of phytoplankton in the sea depended mainly on the degree of mixing of deeper, nutrient rich, water with the shallow layer where sufficient light penetrated to allow these plants to grow (this layer is known as the euphotic zone). There were seasonal variations according to the climate as this governs the amount of wind energy for mixing, variation in the temperature, rainfall and the strength of the sun. The overall system adjusted to these changes. Fish for example, spawn just prior to seasonal increases in phytoplankton so the small larval hatchlings would have plenty of food to eat and a better chance of survival.

On the land, plants also need nitrogen and phosphorus compounds in order to grow. These are usually supplied by the soil but continuous cultivation depletes these substances in the soil and reduces the capacity of the land to produce crops. About half way through the 20th century, relatively inexpensive ways of making nitrogen and phosphorus fertilisers were discovered. When these are added to the soil, plants grow more quickly and crop yields increase. Adding fertilisers however, also results in changes to soil quality, making it more susceptible to erosion as the plants gradually use up the natural organic matter present.

Question for group discussion: How did farmers maintain agricultural production before chemical fertilisers were introduced?

Another problem however, is that some of the nitrogen and phosphorus added to the sea gets washed into streams and rivers and eventually to the sea. In the sea, it enhances the natural growth of phytoplankton causing a 'bloom' – a dense patch of phytoplankton that may change the colour of the sea to green, red of brown. Decaying cells from patches consume oxygen (see the Chemistry fact sheet for details) and can lead to the death of all animals that require oxygen and that cannot escape from the area. The phenomenon of over-enrichment is called ***eutrophication***.

Classroom quiz: Divide the group into two teams, A and B and stand in two lines. There are two lists below. The first is a list of human activities or substances that may introduce nutrients to the environment and the second is a list of possible ways of avoiding or reducing them. The teacher will write the second list on a board in a place that both teams can see and explain the options. He/she will then read out the items in the first list one at a time. The objective is to decide whether or not the activity or substance could contribute to eutrophication in the Black Sea. Group A will answer the first question with 'yes' or 'no'. If they are wrong they will lose a member of the group to the other team. If the substance or activity can contribute to eutrophication, Team B will then be invited to suggest a good option for removing the risk from the list on the board. If they are wrong they will lose a team member to group A. The second question will be directed to Team B and team A will be allowed to suggest a solution if appropriate. The questions are asked to alternative teams until the list is finished. The team with the most players at the end of the game is the winner.

List one:	List two
1. Human sewage	1. Wastewater treatment plant
2. Traffic exhaust	2. Use of alternative substance
3. Bus factory	3. Restoring a wetland
4. Washing detergent	4. Applying waste to fields
5. Animal farms	5. Improving agricultural practices
6. Nuclear power station	
7. Oil refinery	
8. Potato farm	

Another alternative for producing food

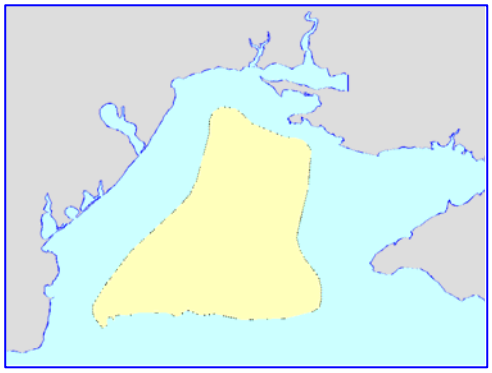
A technique known as organic farming (or ecological farming) is becoming an increasingly popular way to produce food that has a high nutritious value and a low environmental impact. This is based on traditional methods of farming combined with low-cost modern technology and requires no added chemical substances. Soil quality is improved by adding animal manure and compost and by changing the crops planted in each field every year. In some years, plants such as beans or clover are planted that can use nitrogen from the atmosphere and convert it to forms that remain in the soil and can supply other plants the following year. Organic farming requires great skill and much more effort than 'chemical' farming but crops can be sold for higher prices.

Eutrophication in the Black Sea

During the late 1960s, there was a major change in agricultural production often called the "Green Revolution". This involved the use of large amounts of fertilisers and pesticides to sustain high crop yields. Intensive animal farms were also established to provide a cheaper source of meat (one farm in Romania, for example, had more than a million pigs). Discharges of waste nutrients from these agricultural activities, and from domestic and industrial sources across the Black Sea basin, entered rivers and streams and eventually found their way to the Black Sea itself. The seagrass and algal beds of the north-western shelf (see the box on Zernov's field) were unable to absorb such large amounts of nutrients and large quantities of phytoplankton began to grow, shading the light from the larger plants below. Deprived of light, the meadows began to die. The huge amount of additional decaying organic matter at the sea floor and the associated bacteria, used up the dissolved oxygen. This resulted in a dead-zone where the entire bottom dwelling fauna was asphyxiated.

The effects of eutrophication were felt across the entire Black Sea. Though it is estimated that 70% of the dissolved nutrients produced by human activity came from the Danube River alone, there are no innocent countries and coastal eutrophication is observed in areas well away from the influence of the Danube. Indeed, the whole sea suffered changes in the structure of its ecosystem during the last three decades and eutrophication is one of the factors which have contributed to this change. Organisms which are specialised in feeding on surplus organic matter have appeared in large numbers all around the Black Sea coast but these are often regarded as "dead end" species as they do not serve as fodder for zooplankton and the rest of the food chain. In many respects, the "fertilisation" of the sea with nutrients has made it poorer and not richer.

An underwater meadow called Zernov's field …



In shallow areas of the sea, where the seabed is bathed in light, larger plants and algae may grow in underwater meadows. These too can form the base of a food-chain but also provide shelter for a large number of animals which live attached to the sea floor or close to it, or arrive as visitors, sometimes remaining during an important stage in their reproductive cycle. The North-western part of the Black Sea is largely below one hundred metres depth and always received a good supply of nutrients from the rivers Danube and Dnieper, Europe's second and third largest rivers. It was virtually covered with underwater meadows. One species alone, a red algae called *Phyllophora*, dominated a vast area. The meadow, named Zernov's field after its Russian discoverer, was the home to a unique and highly productive ecosystem of plants and animals. Incidentally, the red algae were also harvested by humans for their agar, used as an ingredient for ice cream!

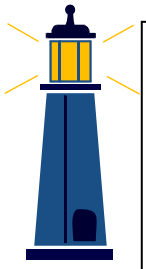
Sadly, the above text uses the word "was". During the 1970s and 1980s, as a consequence of eutrophication, the NW Shelf ecosystem rather suddenly and catastrophically collapsed. Vast amounts of dead plants and animals covered the beaches of Romania and western Ukraine; between 1973 and 1990, losses were estimated as 60 million tons of bottom animals including 5 million tons of fish. At market prices, the fish alone might have been worth US$ 2 billions, but a monetary value cannot be placed on the real loss of such a unique ecosystem.

Studies by the Danube Basin Environmental Programme suggest that about half the nutrients discharged to the river are from agriculture, one quarter from industry and a similar proportion from domestic sources. Because of economic difficulties in the downstream countries and improved environmental controls in the upper basin countries, in recent years the current loads of nutrients entering the Black Sea from the Danube has fallen. The Black Sea ecosystem is gradually recovering but the reprieve may be a temporary one. It is widely considered that nutrient discharges are likely to rise again, with consequent damage to the Black Sea, unless action is taken to implement nutrient discharge control measures as part of the economic development strategies.

Eutrophication from space

On the photograph shown on the opposite page, there is an image taken from a satellite orbiting the earth. The colours are enhanced to show the chlorophyll concentration in the sea. Chlorophyll is the light collecting substance that exists in all plants, terrestrial and marine. In the sea, more chlorophyll indicates more phytoplankton. In the photograph, higher concentrations of chlorophyll are shown by darker green colours. This beautiful image clearly shows the eutrophication associated with river inputs such as the Danube and Dnipro (Dnieper) and in the Sea of Azov. It shows how the whirlpool-like eddies carry the nutrient-rich water deep into the Black Sea. The deeper blue water near the coast of Crimea indicates the least eutrophic water of the Black Sea.

The moral maze – working to reduce eutrophication - what do you think?



There is a close relationship between the way we live and the problem of eutrophication in the sea. Farming techniques that use fertilisers may keep the cost of food down but this is often at a high cost to the environment through eutrophication. Losses of nutrients to the environment can be avoided with better farming techniques but these have to be paid for by increased food prices. Nutrients from human sewage can be reduced by full sewage treatment but this is also quite expensive to operate. Removal of phosphate from detergents has been achieved in many parts of the world but this also results in higher prices. Much of our current lifestyle is achieved by using rivers and the sea as a cheap alternative for disposal.

For some politicians, it is regarded as acceptable to pollute the environment in order to achieve badly needed economic recovery and reduce poverty. They argue that the mess can be cleaned up when the economy has recovered. Others argue that this is unacceptable and that it is better to slow down the rate of recovery but to make it sustainable from the beginning. This may result in many people being poorer for a longer time. What do you think? Are there any other alternatives?

Source: SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE

Eutrophication

PEDAGOGICAL NOTES

This section is a classroom exercise that does not require any outside activities. It should appeal to science teachers in particular. The group exercise is designed to make the learning process more lively and entertaining for the students. The final exercise is deeply thought provoking and no prescribed outcomes are given. Eutrophication is an issue that requires wide cooperation and student and teachers requiring additional information are recommended to examine the material produced by the Black Sea Commission and the Black Sea Ecosystem Recovery Project (see reading list). Care has been taken in the presentation to avoid assigning blame to any state of sector. This is not for diplomatic purposes; this really is a shared problem – assigning blame is unhelpful.

For enterprising biology teachers an addition exercise to grow phytoplankton is included in this section.

Group exercise: Classroom quiz

This is an alternative approach to teaching this often proves effective for groups of all sizes. It is important to rehearse your answers (or to take your own written notes to the classroom). You should find the following notes helpful:

List one:	**Comments**
1. Human sewage	This is a major source of nutrients in some places (both nitrogen and phosphorus). Of course sewage also introduces bacteria that may cause sickness to humans using the marine environment for recreation.
2. Traffic exhaust	The release of nitrogen oxides from engines burning fossil fuels (oil, coal) results in increased nitrates in the atmosphere and in rainfall and contributes to eutrophication.
3. Bus factory	This is unlikely to have any serious contribution to eutrophication.
4. Washing detergent	Washing detergent in most Black Sea countries has high levels of phosphate and certainly contributes to eutrophication.
5. Animal farms	Animal waste from intensive 'factory' farms is often discharge to rivers. For animal grazing in open fields, much nitrogen is emitted as ammonium from urine and faeces and this reaches rivers via rainfall.
6. Nuclear power station	This is one kind of pollution that cannot be caused by nuclear power stations!

7. Oil refinery	Surprisingly, oil refineries produce quite large amounts of nitrogen and phosphorus compounds in their waste. Efficient power station will treat the waste before disposal.
8. Potato farm	All farming introduces nitrogen and phosphorus to the environment. The amounts depend on the technique employed

List two	**Comments**
1. Wastewater treatment plant	A treatment plant can remove all traces of nitrogen and phosphorus but this is often very expensive to operate. Many of the sewage treatment plants around the Black Sae are designed to remove solid wastes and dangerous bacteria but do not efficiently remove nutrients.
2. Use of alternative substance	In the case of detergents, alternative products exist but are slightly more expensive than conventional ones.
3. Restoring a wetland	This can reduce the nutrient loads to rivers and the sea. It is not a substitute for other reduction techniques but certainly helps to remove nutrients from agriculture and sewage. The area of wetlands has to be quite large however and there are certainly not enough wetlands around the Black Sea to remove all the nutrients added by human activities.
4. Applying waste to fields	This helps to lower the impact of animal waste and reduce fertiliser requirements. Application of human sewage is not recommended however as some human pathogens may enter the food supply.
5. Improving agricultural practices	This one of the best ways of reducing nutrients from farming. Techniques used include leaving a belt of unfertilised pasture land around fertilised fields to capture excess nutrients or planting winter crops to avoid soil loss during rainy periods.

Further reading:

The web sites of the Black Sea and Danube Commissions and GEF projects have valuable information free of charge:
http://www.blacksea-environment.org
http://www.icpdr.org

For the enterprising biology teacher:

You may wish to try this experiment:

Eutrophication in your own classroom

Materials

- 4 glass jars (the 2-3 litre ones used for pickling)
- 3 one litre flasks that can be used for heating
- 10 litres of Black Sea water (or pond water if you don't live near the sea)
- 1 cup of fresh soil from a fertile field or garden
- a coffee filter or a piece of filter paper
- some vitamin pills containing thiamine (B1), biotin and cyanocobalamine and iron (preferably as NaFeEDTA)
- a few grams of fertiliser containing both nitrogen and phophorus

Engage

Ask students what they remember about the oxygen cycle-most early elementary students are familiar with photosynthesis as the oxygen/carbon dioxide exchange between plants and animals. There are no trees in the Black Sea. So, where's the oxygen coming from? Encourage speculation.

Explain/Explore

At the lowest end of the food web are phytoplankton, the "food" of tiny marine animals called zooplankton (some of which are fish larvae). Phytoplankton make their food through photosynthesis. Fuelled by the energy of sunlight, they convert carbon dioxide and water into simple, sugary food. During photosynthesis, they release oxygen as a waste product. They also incorporate carbon dioxide.

In order to grow, plants need light and 'nutrients': nitrogen, phosphorus and tiny quantities of minerals (such as silica, iron and manganese) and vitamins. When they die, they release this material back into the water enabling another generation of plants to grow. We can make our own microcosm by using some grass (the terrestrial relative of phytoplankton) to provide the essential components for a phytoplankton culture. Then we can find out what happens when material from the land is washed into the sea….

Procedure

Make a culture medium:

1. Boil the soil in two cups of fresh water for ten minutes and then filter the mixture through the coffee filter or filter paper.
2. Dissolve about 1g of fertiliser in 100 ml of cooled boiled water
3. Dissolve one vitamin pill in a litre of cooled boiled water

Conduct the experiment:

4. Fill the jars with some water from the Black Sea (or a pond if you live a long way from the sea). Make sure it is as 'clean' as possible by avoiding inclusion of sand or slime.
5. Add 10 ml of soil extract for each litre of water in the jars to all of the jars
6. Add 1 ml of the vitamin solution per litre of sea water in each of the jars
7. Add different amounts of fertiliser to each of the jars, 0, 0.5 ml, 1 ml, 5 ml.

8. Stand the jars close to a well-lit window in your classroom. Make sure they are not in a place where they get very hot. Stir the tanks gently once a day. The sea is never warmer than 30 degrees and phytoplankton grow best when it is 20 degrees or less.
9. Record the colour of the water - greener will indicate more growth. Photos may be taken to keep track of colour changes: make sure to write a date on a small piece of paper and stick it on the jars at the time of taking a photo, so that it appears on the picture for later reference.
10. After a few days, the water in the tanks should be looking a little green. Follow the colour for several days and record the difference between the jars.
11. Record findings in a brief lab report: how can you explain the differences?

Hints

Like all plants, the phytoplankton cultures take a little time to get started (scientists call this the 'lag phase'). Don't be surprised if nothing happens for 2/3 days. Once they begin to grow however, growth is exponential and the greening should occur very quickly. When the phytoplankton run out of nutrients, they die (the 'decay phase') and the water becomes clear again.

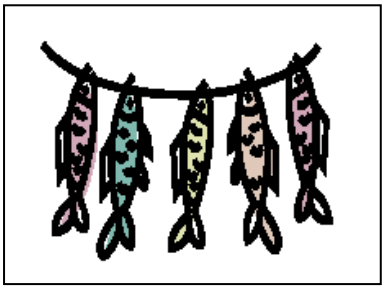
The combination of soil and fertilisers is typical of coastal seawater. Compare the jars with fertiliser added to those that only contained soil extract.

Fisheries

The major challenge facing world ocean fisheries is overfishing and depletion of stocks. Industrial trawlers of huge companies ply new regions and new depths of world oceans in search for new resources. Limiting the fishing effort of this capital intensive fishing is inherently difficult since the boats often operate in a jurisdictional vacuum where no single state can enforce national legislation. Moreover, there are huge technical and practical challenges concerning the supervising of mobile boats on the vast open seas. In the Newfoundland cod fisheries, overfishing has led to common ruin for all fishers. Why do not fishers cooperate in order to avoid common ruin and sustain the stocks and secure income also in the future? What can be done to develop ecologically sustainable yet economically profitable fisheries?

Black Sea fisheries exemplify well these problems and challenges. There are few industrial trawlers in operation in the Black Sea and, unlike many other world seas, there are no fishing boats coming from the outside to exploit the resources of the sea. However, regulating fishing among the six states that surround the sea is enough of a challenge. Turkish purse seine fishing boats currently employ last model international fishing technology and often have very powerful engines. It is increasingly common that boats endeavour outside of the national waters. Yet, overfishing is not currently an all-encompassing problem in the Black Sea fisheries. Some species such as the Black Sea salmon and the sturgeon are seriously threatened; mackerel and swordfish have totally disappeared; while other species, such as the sprat, are exploited well below capacity. Scientists also agree that while too high fishing effort may have contributed to the dramatic reduction in anchovy catches in the years around 1990, the accidental introduction of *Mnemiopsis leidyi* was the main culprit (see Alien Species). While fishing presently does not threaten to seriously disrupt the Black Sea ecosystem in general, individual species and region/local ecosystems are certainly under heavy pressure from fisheries. Moreover, the ecological balance of the sea is very fragile so that overfishing of anchovy, for instance, would have serious consequences for other parts of the ecosystem.

A pause for thought:



Who owns the fish? Discuss what the major differences between agriculture and fishing are.

Seafood from the Black Sea has for several millennia been an important source of nutrition and delight for people living close to the sea. The Black Sea is a very productive sea and supports huge stocks of small pelagic species of fish and sizeable amounts of valuable bottom fish such as turbot and red mullet. In addition, bonito and sea bass swarm into the Black Sea through the Bosporus to fatten themselves during a hectic migration far into the sea. Many places around the Black Sea fish and seafood have achieved an important position in culinary culture and folklore, and there are living traditions of fishing that employ hands-on knowledge passed down though centuries. To this day, the vocabulary of fish and fishing retains a baseline of Italian and Greek words.

Try to make a list of the fish and other seafood you commonly eat. Which of the species are caught in the Black Sea?

The Soviet Union started to **develop** a **fishing industry** in the 1930s and by the 1960s and 70s they had by far the largest fleet of big fishing boats in the Black Sea. Technological advances and economic development in the Turkish fisheries only started from the 1950s. In all Black Sea states development in the fisheries was stimulated by an active state policy of planning and support for the fishing industry and the infrastructure, including harbours, fish processing plants and so forth. By the mid-1980s numbers of boats in the Black Sea peaked and catches were record high. Then two major ruptures occurred in the years before and after 1990. One rupture was ecological: the accidental introduction of *Mnemiopsis leidyi* resulted in a complete collapse of anchovy fisheries. The other rupture was political and economic: the collapse of the USSR and its economic structure of state controlled economies. Economic crisis and restructuring dramatically decreased catch capacity. In these countries Black Sea fishing used to be owned and controlled by the state through cooperatives. This is has now mostly changed, and the sector is adapting to private property and market forces. Most fishing boats in Turkey are owned and operated by small and medium size family companies. They are often organised into cooperatives that, however, have little practical meaning except as a formal vein in interaction with the State.

Case study 1 – anchovy fisheries

Anchovy catches make up roughly two thirds of total catches in the Black Sea. This small pelagic species undertakes annual migrations around the Black Sea, spending the summer dispersed in the cooler water of the northern shelves of the sea while moving in shoals towards the southern and eastern coasts during the winter. Thus, the anchovy passes through the territorial waters of most of the Black Sea states. However, since the anchovy gathers in denser shoals and tends to pause at certain locations during the winter, it is easier to catch the fish in Turkish and Georgian waters. Anchovy fishery is the lifeline of the Turkish Black Sea fisheries and also constituted a major share of USSR catches in the Black Sea. Until 1989 USSR anchovy catches in the Georgian waters amounted to roughly half the total Turkish catches of anchovy. However, the ecological and political ruptures of the late 1980s and early 1999s dramatically changed this. Also, new national borders barred Ukrainian and Russian boats from continuing the USSR practice of catching anchovy

off the Georgian coasts. When the anchovy stocks recovered during the mid 1990s, the Turkish catch capacity had increased while the anchovy fisheries of the former USSR states had all but collapsed. When catches were not good in Turkish waters some boats were tempted to follow the anchovy into Georgian waters. In one incident a Turkish fisherman was shot dead by Georgian coast guards. With the nascent restoration of the Ukrainian and Russian fishing fleets and new agreements with Georgia, there can soon be large-scale anchovy fisheries in the Georgian waters again. Competition for the resource will increase, but there are at present no international agreement or convention to regulate this. The ecology of the anchovy covers all the Black Sea. Sound management of the anchovy will therefore require cooperation between the Black Sea states.

While state policies have focused on the 'industrial' sector of the fisheries, there are also thousands of **small boats** that pursue a multitude of different kinds of fishing all around the Black Sea. Nobody really knows how many boats and men and women are involved in this, but the economic importance is probably considerable. Small boat fishing is often combined with other kinds of income, and is usually more energy efficient and tends to be less harmful to the environment than big boat fishing (but see case 2). All in all, many thousand men and women secure income and livelihood from Black Sea fisheries and provide protein rich nutrients for the populations of the countries surrounding the sea.

Turkish Alametre, pulling a whiting net

Case study 2 – Changes in small boat fishing

On the eastern Black Sea coast of Turkey small boat fishers used to secure a large share of their income from catching red mullets during an intensive fishery in early summer. The fish is very valuable in the Turkish market and moderate catches could secure a fair income for the fishers. The bottom nets were set parallel with the coastline and the fishing was so popular that there was competition for the best locations. It was deemed unfair to set a net outside of another net since that would hinder fish moving towards the net that was cast first. Many fishers tended to set their net continuously for one month on the same location and even market their position with a buoy. Fishers spoke of this as 'owned positions', and there was a common understanding among fishers - that were not organised in any way - about a set of general rules pertaining to this particular kind of fishing. In many kinds of small boat fishing around the Black Sea there are similar forms of agreement between small boat fishers. However, this particular fishery for red mullet collapsed in the mid 1990s. The culprit was the increasingly common fishing, often by the very same fishers, of the invader sea snail *Rapana*. In this region the sea snail is mostly caught by metal frame dredges that 10m/100Hp 'small boats' (see photo above) use to comb the narrow stretch of bottom along the coast, thereby destroying the habitat of, among others, the red mullet. Economically, the sea snail is now the backbone in the economy of many small boat fishers. One unfortunate consequence of this development is that the boats used for dredging sea snails are also suitable for small scale bottom trawling – which is highly illegal put still pursued under the veil of night darkness. Small boat fishers generally lack education and property (e.g. fields) and therefore creatively seek new opportunities for income. Poverty is one reason for illegal and unsustainable fishing practices.

If possible, meet some local fishers and ask them about the ownership and organisational structures in the fisheries. Find out what kinds of restrictions on fishing apply and who are responsible for supervision. Discuss with the fishers whether regulations are sufficient and efficient. Write up a short report.

The organizational and political challenge - what do you think?

A simple thought experiment: In a little lake there is a small stock of a valuable species of fish. Two fishers regularly cast their nets to catch the fish and secure a livelihood for themselves and their families. Then, both of them manage to buy new and more effective equipment, which in effect means that if both fish as much as they can the fish stock will soon be depleted, resulting in economic ruin for both of them. If one of them restrains himself and, for example, casts his net only three days each week, he has no guarantee that the other fisherman behaves similarly. Both the fishers may realise that if they continue to fish as much as they possibly can, it will eventually lead to ruin for both. Yet, if they are unable to reach an agreement, the result may be that they become locked into a 'rat race' where both try to catch as much as possible before the stock collapses. And then, what if another man also buys a boat and starts fishing in the lake…

While it is not uncommon that small boat fishers who have face-to-face relations with each other do manage to strike agreements that limit fishing effort in an equitable manner, this is much more difficult to achieve in large scale fisheries. When the boats operate totally independently of each other, the fishers will not reduce their own catches to protect the stocks. They calculate, very logically, that 'if we don't take the fish, someone else will'. Clearly, cooperation and supervision at multiple social layers is necessary to contain this destructive process; within fishery cooperatives, within national fisheries where bureaucratic and scientific bodies are given special authorities to guide the fisheries, as well as between states. The laws, economies and politics of this can be arranged in multiple ways. Moreover, these politics involve more than the concern about fish stocks and marine ecology. Can you think of what other concerns are involved? What do you think would be the best way to organise the fisheries?

Fisheries

PEDAGOGICAL NOTES

This section includes both classical classroom exercises and an outside activity combined with a writing exercise. The exercises primarily try to stimulate students to discuss organisational and political challenges with regard to fisheries management and should therefore appeal to teachers of social sciences.

Group discussion 1: Who owns the fish? Discuss what are the major differences between agriculture and fishing.

These admittedly challenging questions are selected to motivate the students to reflect on the special character of fishing as compared to for example agriculture. Due to its ecology, it is difficult to put a fence around the fish and make it personal and inheritable property. Since fish are mobile and cross territorial borders they usually become the property of persons/companies only once they are caught. Formally, most resources in the sea are the property of the State. However, there is a tendency among groups of fishers to try to control fishing territories in coastal fishing. Sometimes such control is acknowledged by the state and given formal recognition in laws and regulations, but more often it remains informal. It is also relevant to discuss fish farming and (individual) fishing quotas as strategies for increasing private control and ownership of fish.

Group exercise: field study

If possible, meet some local fishers and ask them about the ownership and organisational structures in the fisheries. Find out what kinds of restrictions on fishing apply and who are responsible for supervision. Discuss with the fishers whether regulations are sufficient and efficient. Write up a short report.

This task presupposes that it is feasible in practice to actually meet with fishers. If this is not possible, the teacher may consider whether communicating with fishers by using telephone or sending a letter can be possible alternatives. Another option may be to visit or otherwise communicate with public offices responsible for supervision and control. At a methodological level, the exercise is meant to make the students more sensitive to the challenges of transforming observation into general knowledge. At the substantive level, the aim is to increase the students' awareness of local conditions and the difficulties of having clear cut information about matters such as fishers organisations and fisheries management. The reports should be presented in class and commented on by the teacher and members of other groups. It may be mentioned that there are often discrepancies between statements and practice. For instance, fishers may claim that cooperatives are democratic bodies jointly responsible for loans and interaction with the authorities. In practice, a few influential fishers may dominate.

The organisational and political challenge

This section is an invitation to abstract thinking that builds on insights acquired in the two previous exercises. The students are asked to think schematically about the challenge of fishery management. With the teacher's guidance, students should be able to notice that fishing practice is not only an outcome of the fishers' attitudes, but is importantly shaped by the social arrangements of fishing. Fishers are often aware that they participate in a 'rat race' and acknowledge that the outcome of the race most likely is common ruin. However, they do not perceive it to be within their powers to change the rules of the game ('race') and therefore continue to catch too much. Environmental awareness among fishers may be a prerequisite for sustainable practices in the fisheries, but a concern with awareness should not blind us to the organisational and political challenges. For fisheries management to be effective it is important to acknowledge that these challenges not only concern environmental sustainability, but also issues such as political legitimacy, fairness etc.

Further reference material for teachers about Black Sea fishing can be found on *The Black Sea Ecosystem Recovery Project* website: http://www.blacksea-environment.org/text/default.htm (click on 'Environmental aspects of fisheries). For general information about world fisheries as well as fishing in regional seas tha FAO Fisheries website is a good starting point: http://www.fao.org/fi/default_all.asp.

Se also:

Knudsen, S. (1997) A comparative study of fishing communities and public awareness in Turkey and Ukraine, *Black Sea Environmental Programme.*

Knudsen, S. (2003) Black Sea Fishery Management; from Ignorance to Politics, *Journal of Southeast European and Black Sea Studies*, 3(1):46-62.

This material is available free of charge to teachers from the Black Sea Environmental Programme office in Istanbul.

Alien Species

When ships navigate from place to place, they sometimes carry tiny uninvited passengers – plants and animals that stick to their hulls or are carried in ballast water. These organisms often find new homes along the ship's route and may flourish in huge numbers thanks to a lack of predators. Sometimes, people also intentionally introduce new species hoping to improve fisheries. The shores and waters of the Black Sea support large numbers of "introduced" species from other parts of the world. Some of these are truly unwelcome guests. What can be done to prevent them from arriving?

Introduction

The unintentional and intentional transport of animals from place to place is not a new problem. Throughout human history, people have introduced domesticated animals into non-native environments as part of farming. Do you know where chickens, turkeys and cows originally came from? Sometimes though, people have made serious mistakes such as introducing rabbits to Australia without understanding that there were no predators able to control their numbers. The rabbits have seriously damaged the natural environment and destroyed huge areas of crops. Conditions on early ships were often rather poor and rats found places to hide on board. They were spread to many islands where they caused extinctions of native birds and animals. Unbeknown to the sailors however, their ships were also transporting many marine species that clung to the hulls.

A pause for thought

How do you prevent rats from jumping off a ship? They will not normally jump into the water. Think of some of the ways they could get off a ship and how we can prevent them from doing so.

It is only in the last hundred years or so that we have become aware of the spread of marine alien species by ships. Ancient ships were slow, allowing only a few hardy species such as barnacles, worms and algae to cross the oceans. Modern ships travel from place to place very quickly. The biggest change however, is that many modern cargo vessels transport ballast water. What is ballast water? Some ships such as oil tankers and bulk carriers (of raw materials from mining or agriculture) are like huge empty boxes when they are not loaded. They float so high out of the water that their propellers are at the sea surface and the ship cannot navigate safely and economically.

This is why they take seawater into their tanks (special tanks on modern ships) from the place where they unloaded their cargoes; enough water to enable efficient and safe operation of the ship. When they arrive to the place where they load up a new cargo, they pump the water back into the sea … but this may be in another continent! Imagine the number of animals and their eggs and larvae, tiny plants, bacteria and even smaller viruses that can be transported in a 100,000-ton tanker!

Factfile

It is estimated that about 10 billion tonnes of ballast water are transferred globally each year (International Maritime Organisation, 2001).

And now to the Black Sea

The Black Sea's low salinity and fertile coastal waters resemble the conditions in many of the estuaries and coastal seas where major ports are located in other parts of the world. This makes it particularly vulnerable to invasions.

Try to make a list of some of the places around the world that may be linked to the Black Sea by trade with oil tankers and large bulk carriers.

There have been over one hundred known invasions of exotic species to the Black Sea. Some were quickly accommodated into the ecosystem and other caused huge problems. Two case studies help to understand the issues involved:

Case study 1 – a giant sea-snail!

In 1946, a Russian scientist, E.I. Drapkin discovered a beautiful new pink sea-snail, *Rapana thomasiana* in Novorossiiysk Bay. The snail had arrived mysteriously from the Sea of Japan. Soon, large numbers of the animals began to appear. *Rapana* is a voracious carnivore that feeds on oysters, mussels and other bivalves (bivalves are molluscs with two hinged shells). It rapidly destroyed the native oyster and mussel beds in the Eastern Black Sea and seriously depleted those on the Bulgarian and Romanian side. In the 1980s a lucrative new industry emerged; to fish for *Rapana* and export it back to Japan and Korea where it is considered a great delicacy! This sounds like a perfect solution to the problem. The first *Rapana* fisheries were by diving and hand collecting with little or damage to life around it. Then heavy dredging equipment started to be employed. This destroys everything in its path and can turn the *Rapana* headache into an ecological nightmare.

Case study 2 – an alien rainbow comb jelly!

Some time in the early 1980s, a cargo of ballast water brought from the East Coast of North America was discharged into the Black Sea. With the water a beautiful translucid rainbow-like tubular organism found its way to the Black Sea. The new arrival was *Mnemiopsis leidyi*, commonly know as a comb jelly. This 10cm swimming creature lives by filtering small marine animals from the sea and can produce over 1000 eggs per day, enabling it to spread very quickly. With no natural enemies in the Black Sea, it is hardly surprising that a huge population developed with as much as 1.2 Kg of animals in a single cubic metre in 1990! At the same time, the presence of such a huge and hungry population resulted in a complete collapse of anchovy fisheries; anchovy larvae were probably part of Mnemiopsis's diet.

There was a major debate on whether or not Mnemiopsis could be controlled (see Moral Maze below). One of its few natural predators is an even larger comb jelly called Beroe. In 1997 Beroe also arrived in the Black Sea, probably in ballast water. By that time, Mnemiopsis numbers had already begun to decline but the presence of Beroe seems to have reduced number still further. Both Mnemiopsis and Beroe will now probably become permanent residents of the Black Sea ecosystem.

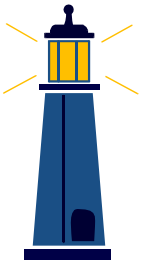
Controlling the Invasions.

Keeping rats from jumping off a ship is not easy but imagine how difficult it is to prevent marine organisms from being transported from place to place! Ship owners have struggled for centuries to keep what they describe as 'fouling' organisms from the hulls of ships. These organisms collect on the bottom of a ship turning it into a mobile underwater garden and slowing it down, increasing maintenance and operational costs. The invention of toxic 'anti-fouling' paints reduced the problem but recent formulations with organic tin compounds have also seriously polluted some coastal areas and killed vulnerable species. Some of these compounds are now banned, forcing ship-owners to seek safer products or to return to the copper-based products used for over a century.

With ballast water, the situation is more complicated. The amount of water transported is vast and, despite efforts to develop new water treatment technology, treating it all on board to remove all living organisms does not appear to be realistic. The International Maritime Organisation, a United Nations body based in London, is asking ship-owners to try a simpler approach. Ships should pump out the ballast water (originally taken from the harbour of departure) in mid-ocean and gradually replace it with cleaner ocean water that is not so likely to contain undesirable species. When they arrive at the port of destination, they will be discharging water with mid-ocean species that are less able to thrive in coastal waters. This is not a perfect solution, but it may help to stop a serious and growing world problem; a problem that may have permanently changed the Black Sea's ecosystems.

Ship-owners are currently not legally obliged to exchange ballast waters in mid ocean. Think of some good arguments to persuade them to do this and write a letter to the owner of an oil tanker that travels between America and the Black Sea asking him to ensure that his ship follows the guidelines.

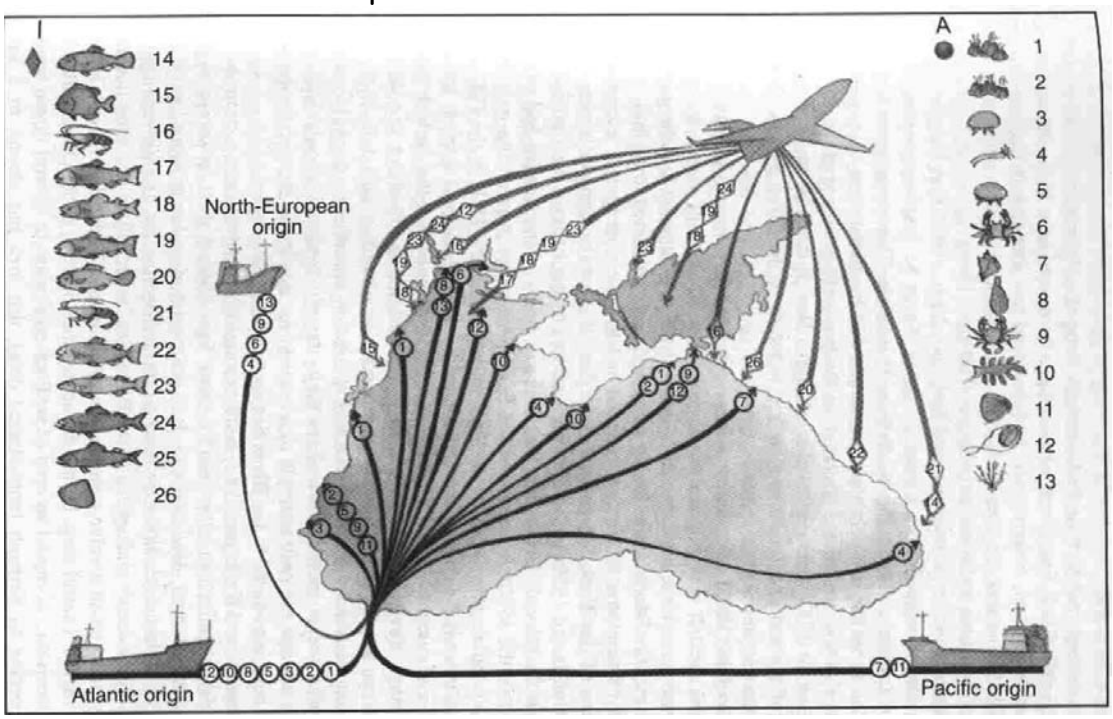
The moral maze – what do you think?



When the invasion of Mnemiopsis occurred, scientists tried to find a solution. The amount of Mnemiopsis was greater than the entire world annual capture of fish so physical removal of the animals was impossible. On the other hand, some scientists suggested introducing one or more new species of fish that might be able to consume the invaders. The problem was that nobody really knew what would happen to the ecosystem with the additional new species. Would human intervention make the situation better or cause a new problem? Some scientists were frustrated that no action was taken, others were outraged that fellow scientists could tinker with nature. Eventually no action was taken; people felt that the **uncertainty** was too great. Nature took its course, with a little help from another invader (see Case Study 2 above).

There are many cases like this at present. Some companies for example, are developing genetically modified plants that they claim will improve our future agriculture. Other experts consider the risk of altering natural systems as being too great. There is no unequivocal evidence for or against. What do we believe in and how do we chose? Do we need to establish a code of environmental ethics to help us make such decisions?

Illustration of invasive species



Here is a diagram showing some species carried to the Black Sea by ships or introduced intentionally (shown with an aeroplane). This is from the work of Academician Yuvenaly Zaitsev from Odessa in Ukraine, one of the world's leading experts in the field.

Alien species
PEDAGOGICAL NOTES

This section is a classical classroom exercise that does not require any outside activities. It is combined with a writing exercise and discussion on ethics that should appeal to teachers of science or equally of language.

Group discussion 1: How do we prevent rats from jumping off a ship?

This example was selected to promote a classroom discussion and later lead to a discussion on how much more difficult it is to control marine species. There are several ways for rats to jump ship. The following list illustrates the main ones:

- Down the main gangway. This can be raised so that it doesn't touch the quayside and guard posted to check who gets on and off the ship, human or non-human!
- Along the ropes tying the ship to the quay. These can be fitted with rat guards shaped like empty cones with the open end facing towards the ship – the rats cannot climb over.
- On the cargo. Large items of cargo have to be inspected before being unloaded.

Of course, the students might come up with innovative solutions. Why not keep a ship's cat? This used to be a practice but a cat is no match for a ship infested with fierce rats. When a ship is seriously infested it may be quarantined (not allowed to tie up at the port) until the rats are eliminated.

Group exercise

Ship-owners are currently not legally obliged to exchange ballast waters in mid ocean. Think of some good arguments to persuade them to do this and write a letter to the owner of an oil tanker that travels between America and the Black Sea asking him to ensure that his ship follows the guidelines.

This is an exercise in creative writing that could be set as homework. In 1993, the International Maritime Organisation introduced a set of voluntary guidelines for ship-owners aimed at minimising the environmental damage of ballast water discharge. These guidelines are voluntary at present, and include recommendations that ships should discharge their ballast water in open sea and not in ports. Ensuring compliance with voluntary guidelines is not easy. The letter might contain arguments showing that invasory species have caused huge damage in the past and that the measures

proposed would help to prevent the loss of species and habitats and would also protect the income of the many people that rely on the Black Sea. It could mention that the measures proposed are not expensive and should not delay the ship form operating. Students should learn that to be persuasive does not require threatening or strong language but an appeal to the better side of human nature.

The moral maze

This section has been included in order to trigger a wider debate and help students to discuss questions of ethics. Science cannot guarantee that a particular vision of ecosystem intervention will lead to the best outcome. This is because ecosystems are highly complex in nature and our understanding of their function is far from complete. All decisions are therefore accompanied by a degree of uncertainty. The issue of uncertainty however, has often been ignored or understated in science education. The scientific method itself is based on continuous questioning that sometimes results in the overturning of previous theories.

One response to uncertainty has been the Precautionary Principle that was widely recognised at the time of the Earth Summit in Rio de Janeiro in 1992. In its marine context, the Principle affirms that *preventative measures are to be taken when there are reasonable grounds for concern that an activity may increase the risk of presenting hazards to human health, harm living resources and marine ecosystems, damage amenities or interfere with other legitimate uses of the sea, even when there is no conclusive evidence of a causal relationship between the activity and the effects*. In other words, **greater caution is required to protect the environment when information is uncertain, unreliable or inadequate**. In terms of this principle, scientists and politicians were right to disallow the introduction of new species to the Black Sea as the uncertainty with the fish species in question was considerable.

The Precautionary Principle has not been introduced into the student text. It is felt that they themselves should probe the need for a written ethical code. The teacher can introduce the Principle as a way of helping a positive outcome to the debate.

Further reference material for teachers can be found on the IMO website at the address below, in English and Ukrainian:
http://globallast.imo.org/AwarenessMaterials.htm

Prof. Zaitsev's material can be found in:
Zaitsev, Yu and V. Mamaev (1997). Biological Diversity in the Black Sea: A study of change and decline.
Zaitsev, Yu. (1998) Vol. 6. The Most Blue in the World, (an introduction to the Black Sea). Black Sea Environmental Series Vol. 3. (Russian), UN Publications, New York.
This material is available free of charge to teachers from the Black Sea Environmental Programme office in Istanbul.