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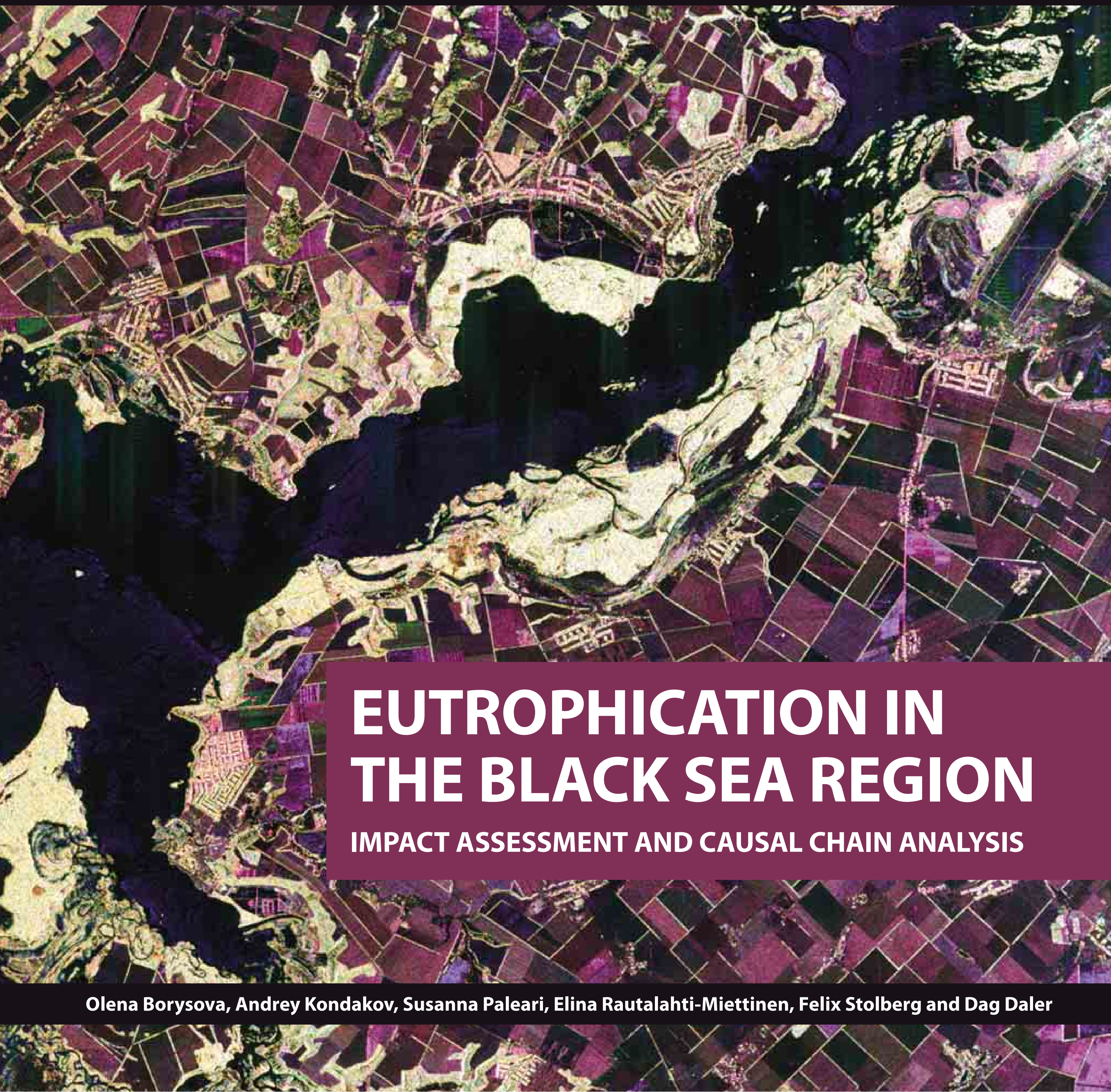

EUTROPHICATION IN THE BLACK SEA REGION

IMPACT ASSESSMENT AND CAUSAL CHAIN ANALYSIS

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Eutrophication in the Black Sea region

Impact assessment and Causal chain analysis

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Preface

This report presents the results of the eutrophication impact assessment for the Black Sea river basins and coastal area. The assessment was carried out by the United Nations Environment Programme (UNEP)/Global International Waters Assessment (GIWA), with an agreement with the GEF-UNDP Black Sea Ecosystem Recovery Project (BSERP), a Global Environment Facility (GEF) project implemented by the United Nations Development Programme (UNDP).

This report provides supporting information to facilitate the assessment of environmental and socio-economic impacts of eutrophication and to analyze the causes behind eutrophication. Provided in this report is an assessment of the state of eutrophication in the Azov and Black Sea marine regions, as well as the river basins of the main tributaries, namely the Danube, Dnipro and Don. The land-based pollution and its main sectoral causes are analyzed by river basins and marine regions, as well as by country. This report describes in brief the major trends in the region with respect to eutrophication.

Further, this report includes an assessment of the legal and institutional framework currently in place that is relevant to the environmental situation in the Black Sea region. As a part of the GIWA assessment, an additional report has been prepared regarding applicability of the EU Water Framework Directive in the Black Sea region.

Dag Daler

Scientific Director, UNEP-GIWA

Executive summary

The Black Sea is one of the world's largest inland seas. The catchment area of the Black Sea covers entirely or partially 23 countries; six countries are located in its coastal zone and 17 countries are closely linked with the sea via the largest European rivers that flow into the sea. Approximately 110 million people live in the Black Sea Basin, and up to ten million tourists visit the region annually.

The Black Sea is one of the most important European seas; it contributes significantly to the regional economy as a source of fisheries, tourism business, oil production and transport. For people living around the Black Sea, the sea is part of their home. It remains a place of natural beauty.

The Black Sea is vulnerable to pressure from land-based pollution from its catchment area that causes the degradation of the sea's aquatic ecosystem through eutrophication. Similar processes are taking place in the Azov Sea, as well as in the rivers flowing into both seas: Danube, Dnipro and Don. Eutrophication of the sea and the rivers has harmful environmental, socio-economic and human health impacts, causing the death of animals and fish, degrading waters used for both drinking and irrigation, impacting recreation, among others. Annual economic losses for the Black Sea from environmental problems were estimated to be approximately 500 million USD in only the fishery and tourism industries.

The immediate cause of eutrophication is an overabundance of nutrients originating primarily from agriculture and municipal sewage: approximately 80% from agriculture, 15% from urban water and 5% from other sources.

The nutrient input into the Danube, Dnipro and Don Rivers increased by approximately 10 times from the 1960s until the 1990s as fertilizer usage was drastically extended in the agricultural sector of the European countries. During the last decade of the 20th century, nutrient pollution in the Black Sea region decreased slightly due to implementation of best environmental practices in the agricultural sector in the EU member states (Danube catchment area). During the same timeframe, the nutrient loading also decreased in the Dnipro and Don catchment areas due to economic recession and the collapse of the USSR, and as consequence, the reduction of agricultural activities in the Newly Independent States.

As for the future, this decreasing trend in nutrient pollution will continue in the Danube region as a result of the implementation of the European Union's (EU) environmental policies. In the catchment areas of the Dnipro and Don Rivers, however, nutrient loading is expected to increase as a result of the development of the agriculture sectors of Ukraine, Russia and Byelorussia.

As a result, the northwestern part of the Black Sea, the Azov Sea and the lower parts of the Danube, Dnipro and Don Rivers will reach the maximal level of eutrophication, or very close to it. This process will increase significantly in the future for the Dnipro River, the Don River, for the Azov Sea and for the southwestern part of the Black Sea. This signifies that efforts for rehabilitation of the Black Sea aquatic ecosystem should be strengthened, and national and international financing should be allocated to implement measures to decrease eutrophication in order to avoid the loss of this unique aquatic ecosystem.

Root causes of eutrophication in the Black Sea Basin have been identified as legal and institutional causes, lack of knowledge, absence of implementation of the best environmental technologies and low economic incentives to address long-term environmental problems. Decentralisation has often taken place before the establishment of a clear legal framework and the development of institutional capacity for environmental management at the regional level. Public authorities across the region point out insufficient funds as the principal reason for their inability to carry out the needed management reforms and infrastructure development. The lack of practical knowledge and skills in water resources management has been placed at the same level of importance as the lack of adequate finances.

Regional definition

Geographical boundaries

The catchment area of the Black Sea is over 2 million km^2, entirely or partially covering 23 countries. These include six littoral states (Bulgaria, Georgia, Romania, the Russian Federation, Turkey and Ukraine) that were the primary focus of this study, and 17 states in the catchment area, whose impacts were mainly studied through their effects on the discharge from the major rivers: Albania, Austria, Belarus, Bosnia and Herzegovina, Croatia, the Czech Republic, Germany, Hungary, Italy, Macedonia, Moldova, Montenegro, Poland, Slovakia, Serbia, Slovenia and Switzerland. The Black Sea is bordered by the Ukraine to the north, Russia to the northeast, Georgia to the east, Turkey to the south, and Bulgaria and Romania to the west. The Black Sea catchment area comprises the Black Sea, the Azov Sea and three main river basins: the Danube, the Dnipro and the Don (Figure 1).

Figure 1 General map of the region, elevations are based on USGS 2002

Physical characteristics of the region

Black Sea

The surface area of the Black Sea is 423,000 km^2. The sea's greatest width is 1,200 km, it contains a total volume of 547,000 km^3 of water and has a maximum depth of 2,212 m. The Black Sea shoreline is approximately 4,340 km long (the Bulgarian coastline is 300 km; the Georgian coastline is 310 km; the Romanian coastline is 225 km; the Russian coastline is 475 km; the Turkish coastline is 1,400 km and the Ukrainian coastline is 1,630 km). The major rivers flowing into the Black Sea and their basins are shown on the map below (Figure 2).

The seafloor is divided into the shelf, the continental slope and the deep-sea depression. The shelf occupies a large area only in the northwestern region of the Black Sea, where it is over 200 km wide with a depth of less than 200 m. In other parts of the sea, the shelf has a width of 2.2 to 15 km; near the Caucasian and Anatolian coasts the shelf is only a narrow strip.

The center of the Black Sea depression consists of a deep-water basin with a depth of 2,000-2,200 m. Salinity of the Black Sea differs strongly dimensionally. The presence of a hydrogen sulfide (anoxic) zone starting from a depth of 100-200 m is a significant feature of the Black Sea. Hypoxia phenomena in shallow otherwise oxic habitats have developed during recent decades in the surface layer of the Black Sea (22).

Geological structure

The watershed of the Black Sea is divided into two nearly equal parts according to surface characteristics. The first part is composed of closed territories where friable deposits of the Cenozoic age reflect the conditions of the newest geological history. They are characteristic for plateau territories (basins of Dnipro and Don, except separate plots; middle and lower flow of the Danube; Black Sea and Rion Lowlands). The second part is composed of geologically open territories of eminences, lowlands and mountains (the remainder of the watershed), containing archaic ores of the Proterozoic era (gneisses, granites), the Paleozoic era (sandstone, quartz, shale, limestone, marble) and the Mezozoic era (of approximately the same composition) which have inclusions and coverings of magmatic and erupted ores (basalt, diabase). The composition of mountain ores forms a complex geochemical environment, which influences the ion composition of the surfacewater drainage. In the regions of mass development of limestone, karst significantly influences the surfacewater drainage (Dinarian and Crimean Mountains, Volyn Podol Eminence).

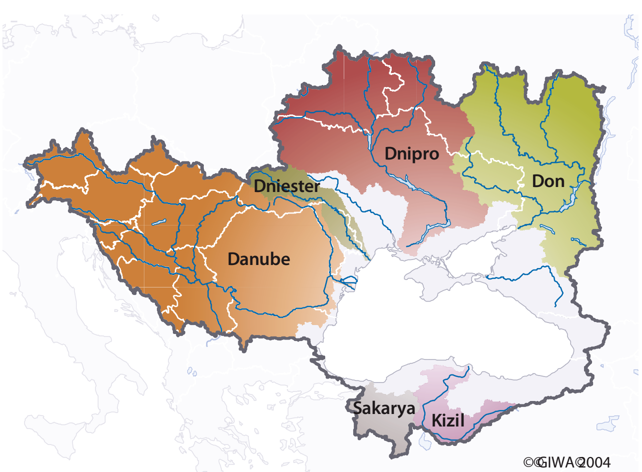

Figure 2 Sub-basin map of the Black Sea.

Climate

A major part of the Black Sea watershed territory is located in the humid moderate climate zone. Only the eastern and southeastern parts are characterised by a sub-arid moderate climate. A subtropical climate is characteristic for the Black Sea coasts of the Caucasus, Anatolia and the southern Crimea. An area of the watershed to the west of the Carpathians has a moderate humid climate of the middle-European type (regular quantity of rainfall with a slight increase in the mid summer and opposite movement of relative air humidity), including a moderate contrast of clearly differentiated seasons and slight episodic snow covering in winter. The eastern part of the European watershed of the Black Sea has a continental climate with a decreasing temperature the further east one moves. In summer, the humidity deficit leads to the increase of evaporation and corresponding change of the structure of the water balance. In the subtropical region of the watershed, one can observe the Mediterranean type of weather regime where maximum rainfall occurs in winter, the average monthly temperature does not decrease to 0°C, and the movement of humidity follows the temperature (Black Sea of the Caucasus) or keeps the opposite to the temperature movement (e.g. the southern Crimea and Istanbul). The high mountains, such as the Alps and Caucasus, have a high mountain type of climate.

In the Bosporus area (Turkish coast), the average winter temperature varies from 0 to 5°C. During the hot and wet summers, the average ambient air temperature is 24-25°C and the absolute maximum of 40°C is reached in July-August. Higher temperatures are caused by winds coming from the coastal mountains. In the Varna area (Bulgarian coast), the average air temperature in winter is 0-3°C, while the average summer temperature is relatively high, reaching 22-23°C in July and August. In the northwestern part of the Black Sea Basin (Ukrainian coast), the average January temperature is -3-5°C (in the Odessa area), and the average July temperature is 19-20°C. In the southern Crimean coast, the average temperature in January is 0-8°C, and the average summer temperature (July-August) is 23-24°C.

The precipitation pattern is also highly variable throughout the region. Precipitation is abundant on the eastern and southern coasts, and is lowest on the northern and western coasts. The total amount of precipitation in the area from the Bosporus area to the Varna area is 500-700 mm per year. The north near Odessa receives approximately 300-400 mm per year, and the southern coast of Crimea (Yalta), 586 mm per year. Annual precipitation significantly increases to the east: 1,600 mm between Novorossiysk and Sukhumi, and 2,465 mm in Batumi. On the Anatolian coast (Turkey), annual precipitation is significantly lower (875 mm per year in Trabzon).

Biodiversity

Given the complexity and heterogeneity of the biotopes in the Black Sea Basin, only marine biodiversity is discussed in this section for purposes of brevity. Approximately 160 species of fish of varying origin make up the ichthyofauna of the Black and Azov Seas. Black Sea ichthyofauna and other invertebrate species consist of marine fish species originating from the Mediterranean Sea (about 60 %). Ichthyofauna also includes the freshwater fish species (more than 20 %) and pontocaspian relicts (about 16 species). It is difficult to state the total number of species in the Black Sea. According to Zaitsev & Mamaev (1997), however, a total of 3,774 species have been identified.

Azov Sea

The Azov Sea is a shallow (maximum depth of 9 m) inland sea on the northern Black Sea. From a hydrological point of view, the Azov Sea is a bay (lagoon) of the Black Sea, and therefore it could be considered to be a part of the Black Sea. Its maximum width and length are approximately 150 km and 300 km, respectively, with a surface area of 35,000 km^2. The total area of the drainage basin is approximately 570,000 km^2. The average natural flow of freshwater into the Azov Sea is 43 km^3 per year, with large yearly fluctuations ranging between 30-50 km^3.

The water exchange with the Black Sea is mainly wind driven and can only take place through the narrow Kerch Strait. The estimated residence time is between 10-20 years, which is much shorter than that of the Black Sea. The quality of the Azov Sea water system is very much dependent upon the quantity and quality of the freshwater runoff from its drainage basin. The main river influencing the sea is the Don (Severskiy Donetz, the Don's tributary, is the most polluted river in Europe), with an average natural flow of 28 km^3 (65% of total flow) per year. The Kuban contributes approximately 12 km^3 (28% of total flow), with the remaining inflow coming from more than 20 small rivers (Table 1). Both the seasonal variations and the yearly variations of freshwater runoff are high, causing frequent shortages of freshwater in the region.

Table 1 Water balance of the Azov Sea (1953-1985), km^3/year (average)

	Mean value	Coefficient of variation
River discharge	35.7	0.24
Including: Don	21.5	0.31
Kuban	12.0	0.25

Geological structure

Like the northwestern shelf of the Black Sea, the Azov Sea is situated in an area of moderate tectonic subsidence along the southern edge of the Russian platform and bordering the Skiff platform. The southern part of the sea hollow is located within the area of active submontane troughs of the Alpine zone.

The areas of bars of the so-called "Azov type" form bays, each of which has its specific features of bottom morphology, and which together represent a range of geomorphologic areas. The major source of sedimentary material into the Azov Sea is the transport of suspended and dissolved substances with the runoff of the Don and Kuban Rivers (more than 19 million tonnes), abrasion of the shores (about 17 million tonnes) and bottom abrasion (more than 11 million tonnes). The total entry of sedimentary material into the Azov Sea reaches up to 52 million tonnes/year.

Climate

The climate of the Azov Sea as a whole is temperate-continental. The winters are relatively cold with thawing and cloudy periods, and the summers are mainly dry and hot. Atmospheric circulation plays an important role in the climate-forming process, transporting marine air masses into the region from the Atlantic and Arctic Seas and continental air masses from Eurasia. The autumn-winter period is influenced by the spur of the Siberian anticyclone and the spur of the Azores high influences the spring-summer period. With the Siberian anticyclone, northeast and east winds with an average speed of 4-7 m/sec dominate. The frequency of strong gale-strength winds increases, which is accompanied by an abrupt fall in temperature. For example, in January, when the air temperature ranges from –2 to –50°C, the Siberian anticyclone may cause the temperature to drop to -25°C or below. With the Azores high, calm, cloudless and warm weather dominates. The average temperature in July is 23-25°C. The maximum temperature (up to 43°C) occurs in July-August.

The Taganrog Bay is the large part of the Azov Sea where algae blooms typically begin. Due to plenty of solar radiation, the Taganrog Bay water has a high average annual temperature (11.2°C). In July-August, the water temperature reaches 24-25°C and may exceed 30°C near the coast. In winter, the water temperature is close to the freezing point. Ice phases are notable for high spatial and temporal variability. The earliest appearance of ice in the Taganrog Bay is registered at the end of October and the ice cover reaches its maximum thickness (40-50 cm) at the end of February or beginning of March on average.

Danube and river basin

The Danube River rises in the Black Forest mountains of Germany, flows about 2,850 km to the Black Sea, drains approximately 817,000 km^2 and includes 300 tributaries (the major ones being the Inn, the Drava, the Tisza, the Sava, the Morava and the Prut). The basin covers the territories of 18 countries: Albania, Austria, Bosnia-Herzegovina, Bulgaria, Croatia, the Czech Republic, Germany, Hungary, Italy, Macedonia, Moldova, Poland, Romania, Slovakia, Slovenia, Switzerland, Ukraine and Serbia-Montenegro. Five of these states (Albania, Italy, Macedonia, Poland and Switzerland) have territories in the basin smaller than 2,000 km^2. The Danube water influx to the Black Sea is approximately 200 km^3/year.

The geography of the Danube River Basin is diverse and includes high mountain chains, wide plains, sand dunes, large forested or marshy wetlands and, specifically, the karst, and the delta. Three sections are usually distinguished in the basin:

- The upper course, which stretches from its source to the gorge, called Hungarian Gates, in the Austrian Alps and the western Carpathian Mountains;
- The middle course, which runs from the Hungarian Gates to the Iron Gate Gorge in the southern Romanian Carpathians;
- The lower course, which flows from the Iron Gate to the delta-like estuary at the Black Sea.

The above-mentioned different physical features affect the amount of water runoff in the three river sections. In the upper Danube, the runoff corresponds to that of the Alpine tributaries, where the maximum occurs in June. In the middle basin, the phases last up to four months with two runoff peaks in June and April. Finally, in the lower basin, all Alpine traits disappear completely from the river regime and the maximum runoff occurs in April.

Soil structure

With reference to geological aspects, dominant soils in the higher Alps are podsolised brown-earths and limestone rendzinas. For the Carpathians and the Yugoslav mountains, except for the highest regions, brown earths on weathered solid rocks are widely distributed. Grey-brown podsolised soils are often found between 300 and 1,000 m, especially around the Carpathians. The Pannonian inner basin is a mixture of loess chernosems (black earth), meadow chernosems and various brown-earths. At the eastern banks of the middle Tisza in Hungary, wide areas of solonetzs (alkaline soil) are found. Ribbons of grey alluvial soils are found along all middle and lower parts of rivers in the basin.

Biodiversity

As the Danube River Basin has a broad variety of landscapes, it is outstandingly rich in biodiversity and is a valuable pool of genetic resources. It serves as habitat for approximately 100 species of fish (compared to about 227 in Europe as a whole), 180 species of birds and 2000 species of higher plants. The variety increases from the source of the rivers to the delta.

Many protected areas have been set aside within the basin (See Table 2). Apart from Slovakia, where the portion of protected areas is high (22% of the national territory) due to the inclusion in the definition of "protection areas" of "landscape protection areas and buffer zones", the share of the registered protected areas in the basin varies between 0.5% (Bosnia-Herzegovina) and 14% (Czech Republic) of the national territories.

Climate

The Danube Basin is in general dominated by a continental climate, primarily in the central and eastern regions. The western parts of the upper basin in Germany are influenced by the Atlantic climate and the southwest of the basin by the Mediterranean climate, however. The Alps in the west, the Dinaric-Balkan mountain chains in the south and the Carpathian bow in the eastern-centre are distinctive morphological barriers that form climatic regions.

The mountain chains receive the highest annual precipitation (1,000-3,200 mm), while the inner and outer basins (Vienna Basin, Pannonian Basin, Romanian and Prut low plains), the lowlands of the Czech Morava and the delta region are dry (350-600 mm per year). The higher elevations in the Alps have 50 to 70 days of annual snowfall, while 1 to 3 days per year of snowfall are recorded in the plains.

Dnipro and river basin

The Dnipro River is the third largest in length in Europe (after the Volga and the Danube) and the second-largest river emptying into the Black Sea. It drains an area of 511,000 km^2 and has a total length of 2,200 km. The Dnipro River is a transboundary system, with 20% of the river basin

Table 2 Environmental protection areas in the Danube River Basin countries

Country	Environmental protection areas		Remarks
	Total area (ha)	**Share of country territory** (%)	
Bosnia-Herzegovina*	28 000	0.5	Target: 16-24% protection areas by the year 2025
Bulgaria**	138 000	3.0	
Croatia	/	/	High number of national parks and nature reserves
Czech Republic**	300 000	14.0	
Hungary	804 000	8.6	
Moldova**	49 000	2.2	
Romania**	85 000	0.4	
Slovakia*	1 080 000	22.0	Including landscape protection areas and buffer zones
Slovenia*	140 000	8.0	60 000 ha in the Danube River Basin
Ukraine	/	/	No data
Yugoslavia**	635 000	7.0	Target: 15% protection areas by the year 2020
Germany**	128 000	2.3	23 major protection areas
Austria	/	/	No data

** Figures for total country; **Figures for the Danube River Basin part of the country*

(Source: DPRP, Socio-economic effects of water pollution in the Danube River Basin, 1999)

within the territory of the Russian Federation, 23% in Belarus, and the largest portion, 57%, in Ukraine.

Administrative and territorial division

The following administrative and territorial divisions are located within the Dnipro Basin: 30 oblasts, 385 districts, 220 cities/towns, 447 townships and 28,020 rural settlements.

Geological structure

The Dnipro Basin includes structures from the proterozoic eastern European Platform, overlain by Cenozoic sediments.

Table 3 Annual precipitation in selected Danube River Basin countries

Country	Total annual precipitation in 2002 (mm)	Relative annual precipitation in 2002 (%)
Germany	1 329	113
Austria	1 115	109
Czech Republic	765	107
Slovakia	841	110
Hungary	567	93
Slovenia	1 307	93
Croatia	685	105
Romania	636	98

(Source: ICPDR, Annual report on the activities of the ICPDR in 2002)

Table 4 The major Dnipro tributaries

Major Dnipro tributaries	Countries	Reach
Berezina River	Belarus	Upper
Pripyat River	Ukraine, Belarus, Ukraine	Upper
Desna River	Russia, Ukraine	Upper
Psyol River	Russia, Ukraine	Middle
Vorskla River	Russia, Ukraine	Middle
Inhulets River	Ukraine	Lower

Climate

The eastern part of the European watershed of the Black Sea including the Dnipro Basin has a continental climate with a decreasing temperature the further east one moves. In summer, the humidity deficit leads to an increase in evaporation and corresponding change in the structure of the water balance.

Mineral resources

The main mineral resources located in the Dnipro Basin in the Republic of Belarus include oil, natural gas, peat, potassium salts, rock salt, building stone, ferruginous quartzite and rare-metal deposits.

The basin area in the Russian Federation contains iron-ore deposits, ferruginous quartzite, low-grade coal and peat, building materials (chalk, marl, sand, sandstone, clay and tripoli) and building stone.

In Ukraine, 4,464 (or 57% of the country's total) mineral resource deposits are located in the Dnipro Basin; 1,759 of them are exploited. Key mineral resources include oil, gas, brown coal and coal, peat, iron ore, manganese ore, titanium/zirconium ore, kaolin, bentonitic clay and building materials. The Dnipro Basin contains 29.5% of the country's coal reserves, 53% of its oil reserves, 67% of its natural gas reserves, 84% of its iron ore reserves, 85% of its brown coal reserves, and 100% of its titanium/zirconium ore reserves.

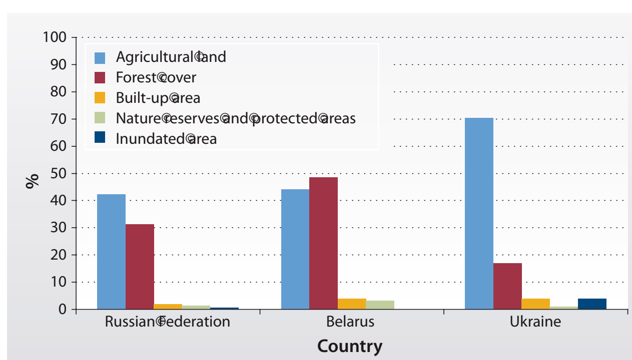

Figure 3 Land use in the Dnipro Basin

Land uses

The land resources of the Dnipro Basin have been intensively used for a number of different purposes (See Figure 3). The area of arable land totals 283,000 km^2 (55.4%). Forests cover 172,400 km^2 (33.8%) and wetlands cover an additional 41,900 km^2. Urbanised or built-up areas make up 18,100 km^2 of the basin. The total drained land area is 7.38 million ha and the irrigated land area is 2.64 million ha.

The Russian part of the Upper Dnipro Basin occupies the central, western and southwestern parts of the Central Russian Upland, consisting mainly of extensive areas of hills and plains intersected by lowland rivers, gorges and valleys. Soil cover in this part of the basin is represented by fertile loamy soils lying in the north, dark-grey and grey forest soils in the western part of the Central Russian Upland, and very fertile black-earth soils in the southwest.

The Belorussian Polessie, extending into the southern part of Belarus, consists mainly of lowland wetlands and marshes and represents one of the major wetland resources in Europe. Between the mid-1960s and 1980s, a major land drainage scheme was implemented in this part of the basin to provide over 2 million hectares of land for agriculture, which has led to a loss of over 50% of the natural wetland area. Currently, former peat bog soils in this area are depleted, leading to a continuous reduction of crop productivity. Land drainage activities have had a profound impact on the environment, manifested in large-scale soil erosion, land degradation and a higher susceptibility to flooding effects resulting in the contamination of water resources.

The land resource of the Ukrainian part of the Dnipro Basin is 29.14 million hectares, or 48.6% of the country territory. Of that, 32.8% lies in the Ukrainian Polessie zone, 39.9% in the Forest Steppe zone and 26.6% in the Steppe zone. Generally, the land resources within the Forest Steppe and Steppe zones have been intensively used for arable agriculture, urban and industrial development purposes.

Area of protected territories

The Republic of Belarus has 3,100 km^2 of protected areas, or 3.0% of its total territory. The Russian Federation has 1,300 km^2 (1.3%) and Ukraine has 3,200 km^2 (1.1%) of their territories under protection.

The Dnipro Basin sustains rich biodiversity, much of which can be found within nature reserves and protected areas. There are more than 35 nature reserves and protected areas in the Dnipro Basin occupying approximately 1.6% (8,100 km^2) of the catchment area. Due to severe budgetary constraints, however, an adequate protection regime has not been properly maintained in the majority of these areas.

Biological resources

The Dnipro Basin is a unique Eastern European ecosystem sustaining rich biological diversity and featuring an ecological network with a stable pattern of natural processes (28). The Dnipro Basin has been recognised as one of the major wetland areas in Europe. It provides a habitat for various birds and animals and is a powerful barrier against flooding events and water percolation. It also operates as a major carbon sink. Sections of the basin also enjoy international recognition and special protection under the Ramsar Convention. These include the Mid Pripyat State Landscape Zakaznik, the Pripyat River floodplain and the Dnipro River Delta.

Biodiversity in the basin consists of over 90 fish species (60 of them inhabiting the Dnipro River itself), approximately 182 bird species and over 2,500 plant species.

Water resources per capita: Republic of Belarus - 7,580 m^3/person; Russian Federation - 2,640 m^3/person; Ukraine - 3,520 m^3/person.

Population in the Dnipro Basin: In 2001, the total population in the Dnipro Basin was 32.1 million with an average density of 64 persons/km^2.

Table 5 Economic characteristics of the countries in the Dnipro Basin (1998-2000)

Country	GDP	GNP growth	Real GDP per capita	Industrial output growth	Agriculture
Republic of Belarus	9,134 million BR	105.8%	2,198 USD	107.8%	-6%
Russian Federation	95.9 billion RR	118%	832 USD	119%	68% of the 1990 level

Table 6 Industrial production output of the Ukrainian part of the Dnipro Basin

Industry	Output (%)
Energy (electric power)	12.4
Ferrous and non-ferrous metallurgy	32.0
Machine-building and metal fabrication	13.2
Food processing	17.2

Table 7 Surface waters

Country	Internal flow (km^3/year)		External inflow (km^3/year)		Flow discharge (km^3/year)		Hydrographic network (km)
	MAF[1]	LFY[2]	MAF	LFY	MAF	LFY	
Republic of Belarus	16,9	10,7	19,1	9,1	36,0	19,8	45,400
Russian Federation	15,5	10,7	-	-	15,5	10,7	39,500
Ukraine	22,1	9,0	31,9	22,1	52,01	31,14	78,500

[1]Mean Annual Flow. [2]Low-flow Year (95%)

Table 8 Groundwater (usable reserves)

Country	Projected reserve (km³/year)	Explored reserve (km³/year)	Groundwater abstraction (km³/year)
Republic of Belarus	9.27	1.117	0.687
Russian Federation	2.31	0.681	0.379
Ukraine	12.80	n/a	1.027
Total	24.38	n/a	2.093

Table 9 Population characteristics

Country	Population characteristics						
	total (2001)	urban		rural		Population growth, (persons/year)	Life expectancy (HDI Report, 2000)
		million people	%	million people	%		
Republic of Belarus	6 300 000	4 600 000	73	1 700 000	27	-25 000	68.1
Russian Federation	3 600 000	2 400 000	66.7	1 200 000	33.3	-35 000	66.7
Ukraine	22 200 000	14 920 000	67.2	7 280 000	32.8	-222 500	69.1
Total	32 100 000	21 920 000		10 180 000		-	-

Table 10 River network of the Don Basin

The name of the basin's parts	Tributaries of more than 10 km in length		Tributaries of fewer than 10 km in length		Catchment area in km²	Coefficient of the river net density
	number	total length in km	number	total length in km		
Don (up to the Khoper)	473	15 134	1 651	9 906	107 123	0.23
Khoper	262	9 112	1 867	6 402	61 120	0.25
Don (between the Khoper and Seversky Donets)	257	10 551	1 181	7 086	88 700	0,.20
Seversky Donets	453	14 526	2 041	12 246	99 557	0.27
Don (between the Seversky Donets and the mouth)	242	8 611	1 451	8 706	86 000	0.20
The whole basin	1 687	57 934	7 391	44 346	442 500	0.23

Don and river basin

The Don River, with a length of 1,980 km, is the 4th longest river in the European part of Russia. It is the third largest river by area of reservoir (422,500 km²) after the Volga and the Dnipro, making it the largest waterbody in the European part of the CIS. The Don River originates in the northern part of the Central Russian upland, at an elevation of about 180 m above sea level, and runs into the Taganrog Bay of the Azov Sea, forming a delta of an area up to 340 km². The long-term average volume of its runoff is 39.5 km³.

The basin of the Don and its tributaries is mainly situated on the slightly hilly East-European Plain. Not far from its source, flowing on the Middle-Russian Height and Oka-Don lowland, the Don forms numerous bends. Farther to the south, the Don River flows around many obstacles in the form of changing elevations and other geological structures, thus forcing the river to change the direction of its riverbed four times. Because of this, the Don's real length exceeds the direct line connecting its source with its mouth by a factor of 2.5. The general slope of the Don riverbed is less than 0.0001, which conditions the low speed of its current.

The largest tributaries of the Don River are: the Krasivaya Mecha, Bistraya Sosna and Voronezh in the upper reaches; the Tikhaya Sosna, Bityug, Khoper, Medveditsa and Ilovlya in the middle course; the Tchir, Tsymla, Severskiy Donets, Sal, Manych and Tuzlov in the lower course. The Volga-Don navigation canal connects the Don with the Volga.

At its mouth, the Don forms a delta. The length of the delta on a straight line from its beginning to the Taganrog Bay is approximately 30 km, and the width between its extreme branches is 23 km. The total area of the delta is 340 km². The delta is densely indented by channels and eriks (lades). An active sea navigation canal passes on a southern large branch (Old Don).

The Don and its tributaries are typical plain-steppe and forest-steppe rivers. Their water regime is determined by the features of their feed: conditioned by seasonal effluent of thawed snow waters providing a high water period during the spring. This snowmelt makes up to 65-70% of the total annual discharge. The size of the underground feeding does not exceed 25-30%, and rainfall makes up no more than 3-5% of the total discharge.

Because the Don's current flows from the north to the south, melting of the snow cover in the lower part of the basin usually begins earlier than in its top part. Thus, there are two waves of high water. In 1951, the Don's current was regulated by a dam that forms the Tsymlyanskoe water reservoir. Prior to the dam's construction, the Lower Don experienced continuous spring floods of great strength. Total discharge from March through May 2004 at the location of stanitsa Razdorskaya was 7,83 km³, which is almost at the level of average long-term values between 1952-2000. This is 2,3 times less than the natural volume prior to the building of the dam (measured from 1911-1951), which was 18,4 km³.

Geology and sediments

The flat relief of the Don Plain was generated on geological structures of vastly differing ages – the ancient East Europe platform and younger Scythian plate. In the upper streams of the rivers (on the Russian Plain), the most ancient outcrops are nearly horizontal. The Don passes through strata of the Donetsk range, which are raised by orogenic folds. Development of the Don River valley was connected with numerous changes of the sea level where the modern Black Sea exists. The sea's intersection with the land formed a delta, washing away earlier deposits and leaving them on slopes as ledges of river terraces. During the period of the lowest sea level, the Don had advanced far in the western direction, forming the modern Gulf of Taganrog.

The sequestration of the carbon pool of the Don sediments is distributed rather widely. Bottom carbon in natural exposures is found southwest of east Donbass and in the Tizlov river basin. Outcrops of carbon reach the city of Kamensk – where it is excavated. Outcrops of the top strata of the Cretaceous of the Mesozoic group are widely distributed in a valley of the rivers Don, Severski Donets, Miyc, Tizlov and Kagalnik.

Climate

The climate of the Don plate is moderate-continental, with cool and sometimes severe winters: cool and damp in the west and more severe in the east. The evenness of the plane territories, only occasionally broken by low rises in elevation and superficial downturns, promotes quiet development of climatic processes. Continental and tropical air masses prevail in autumn periods, bringing warming and rains from southern areas. The Asian air masses coming from the deserts of Kazakhstan cause hot, dry and dusty weather in the summers, quite often accompanied by dry winds. Sharp drops in temperature, cloudy weather with drizzles and fog define the cold season. The average annual air temperature within the river basin ranges from 3,7° in the north up to 9,5° in the south.

The maximum temperature of the year, falling in July, ranges from 33° in the upper plain up to 43° in its lower reaches. The annual minimum temperature, falling in January, has a smaller range in the basin: from–40° in the north to–32° in the south. Because of the vast expanse of the plain, precipitation is distributed non-uniformly. The greatest quantity of mid-annual precipitation (more than 550 mm) falls in the northwest region of the upper Don. The extreme east, Privolszskaya heights, receives up to 350 mm of precipitation. The average wind speed is 2-5 m/s, with maximum speeds reaching 35-40 m/s. It is important to note the climatic influence of the artificial Tsymlyanskoeo water reservoir. The territory adjoining the reservoir has a longer spring, with 5-6° lower temperatures on the coast. Autumns are longer with temperatures 3-4° higher than in the adjoining territory.

Biodiversity

In the Don River Basin, the steppe biotope prevails, forming a strip stretching from Moldova and Ukraine to East Mongolia. The faunal richness results from not only features of the area's genesis, but is also connected to the variety of ecosystems in the steppe zone. Specific complexes of plants and animals were developed on Cretaceous exposures, which are found on the right coast of the Don and its tributaries. The vegetation here is characterised by a variety of endemic and rare species. The fauna of the Don steppes is the major biodiversity component of the plain, and upon which the health and well-being of the region's population depends.

Political and socio-economic characteristics

Political structure

The Black Sea Basin covers a region characterised by a mixed and complicated political history. During the last two decades, the political map of the region has undergone a dramatic re-shaping. Currently, three out of six littoral states that were the primary focus of this study (Georgia, the Russian Federation and Ukraine) are Newly Independent States (so-called NIS countries) that gained independence after the collapse of the Soviet Union in 1992. Since then, the countries have developed into democratic states with elected parliaments, directly-elected presidents as heads of state, and the political structures necessary to become a modern European State. Two others, Bulgaria and Romania, belong to the so-called CEE (Central and Eastern European countries) and are aiming to join the EU in the next decade. Turkey, with its unique position as an European-Asian country, has the ambition to demonstrate the viability of a modern Muslim state with a market economy and democratic political institutions. The seventeen European states located in the basins of the rivers flowing into the Black Sea represent a broad political spectrum of Central, Eastern and Western Europe, with different stages of market economy and democratic development.

Economic structure

The countries belonging to the Black Sea catchment area are characterised by varying degrees of economic development, including great disparities in national GDP in terms of absolute figures, per capita values, sectoral composition and annual growth (see Annex II).

The most important sectors affecting the water environment are industry and agriculture

In the immediate area of the Black Sea and in the river basins, virtually every type of heavy industry is represented: oil refining, ferrous and nonferrous metal refining, chemicals, pulp and paper production, food processing, fish meal plants, as well as production of coal, iron ore, and oil and gas (Figure 4).

Figure 4 Heavy industry in the Black Sea area.

All of the types of industry shown in Table 11 contribute to the heavy pollution of the Black Sea via wastewater discharge, runoff from waste dumps or air pollution that is then deposited in the waterways by rainfall.

Dominant industries in the Black Sea Basin countries

All industries are flourishing in the Black Sea catchment area, including water-consuming ferrous and non-ferrous metallurgy (Ukraine, Bulgaria, etc.); chemical and petrochemical plants (Bulgaria, Romania, Ukraine, Hungary, Austria, etc.); power plants, some of them nuclear (all countries, but highest laden are Bulgaria, Romania, Ukraine, Russia, Hungary and Austria); machine engineering (all countries); and the food industry (all countries).

Agriculture is a major polluter of the Black Sea of nutrients and, to a lesser degree, chemicals. Where intensive agriculture is practiced,

Table 11 Dominant industries in the littoral countries

Country	Dominant Industry
Bulgaria	Energy, coal industry, metallurgy, chemical industry
Georgia	Energy
Romania	Energy, coal industry, metallurgy, chemical industry, machine-building, oil industry, petroleum refining industry
Turkey	Energy, chemical industry
Russian Federation	Energy, coal industry, metallurgy, chemical industry, machine-building
Ukraine	Energy, coal industry, metallurgy, chemical industry, machine-building, oil industry, petroleum refining industry

it inevitably leads to runoff of nutrients and agricultural chemicals. For example, the Russian Federation's Ministry of Natural Resources found that substantial damage was caused to the Azov Sea by runoff from rice growing in the Slavyansk district of Krasnodar. The Kuban River discharges this runoff, which contains considerable amounts of nutrients and pesticides, into the Black Sea. Although fertilizer use has decreased in the region in recent years, mineral fertilizer storage and application is still a serious problem. Inappropriate storage (often in the open air) and excessive application leads to leaching into rivers and pollution of groundwater, which can affect human health.

The transportation system is well developed in the Black Sea Basin. Transport on the Danube, Dnipro, Dniester and Don Rivers to the Black and Azov Seas involves ships of the "river-sea" type. Sea ships include the ocean ships, such as dry cargo ships, and the tankers for the transportation of oil products. Water transportation adversely impacts water quality in the region during normal operations and represents a serious potential risk during accidents such as spills. Motor transport prevails in the western part of the Black Sea Basin where there is a highly developed road network, while railway transportation is better developed in the eastern region (Ukraine, Russia and Georgia). The extensive transportation network and intense mobility of the population and goods in the region affects the water quality negatively through such avenues as spills of oil products on the roadways and the use of inadequate technologies to treat wastewater coming from the industries servicing the transportation network.

Population

Approximately 162 million people live in the catchment area of the Black Sea (Figure 5), with urban residents accounting for more than 60% of the total population. Many state capitals and other major cities are situated in the basins of the Black Sea rivers. Cities with a population of more than 1 million inhabitants include Budapest, Vienna, Sofia, Bratislava, Belgrade, Kyiv, Minsk, Donetsk, Kharkov, Rostov-on-Don and Krasnodar. The coastal zone of the Black and Azov Seas is heavily populated. Such significant cities and ports as Istanbul, Varna, Constanza, Odessa, Sevastopol, Yalta, Kerch, Sochi, Sukhumi, Batumi and others are situated here.

The population is unevenly distributed in the countries and sub-basins. According to the European Commission, the population of the Black Sea region is about 110 million, with Ukraine, Russia and Romania counting together for more than 80% of the total (see Table 12). This figure includes the population of Bulgaria and Romania that are part of both the Black Sea region and of the Danube sub-basin.

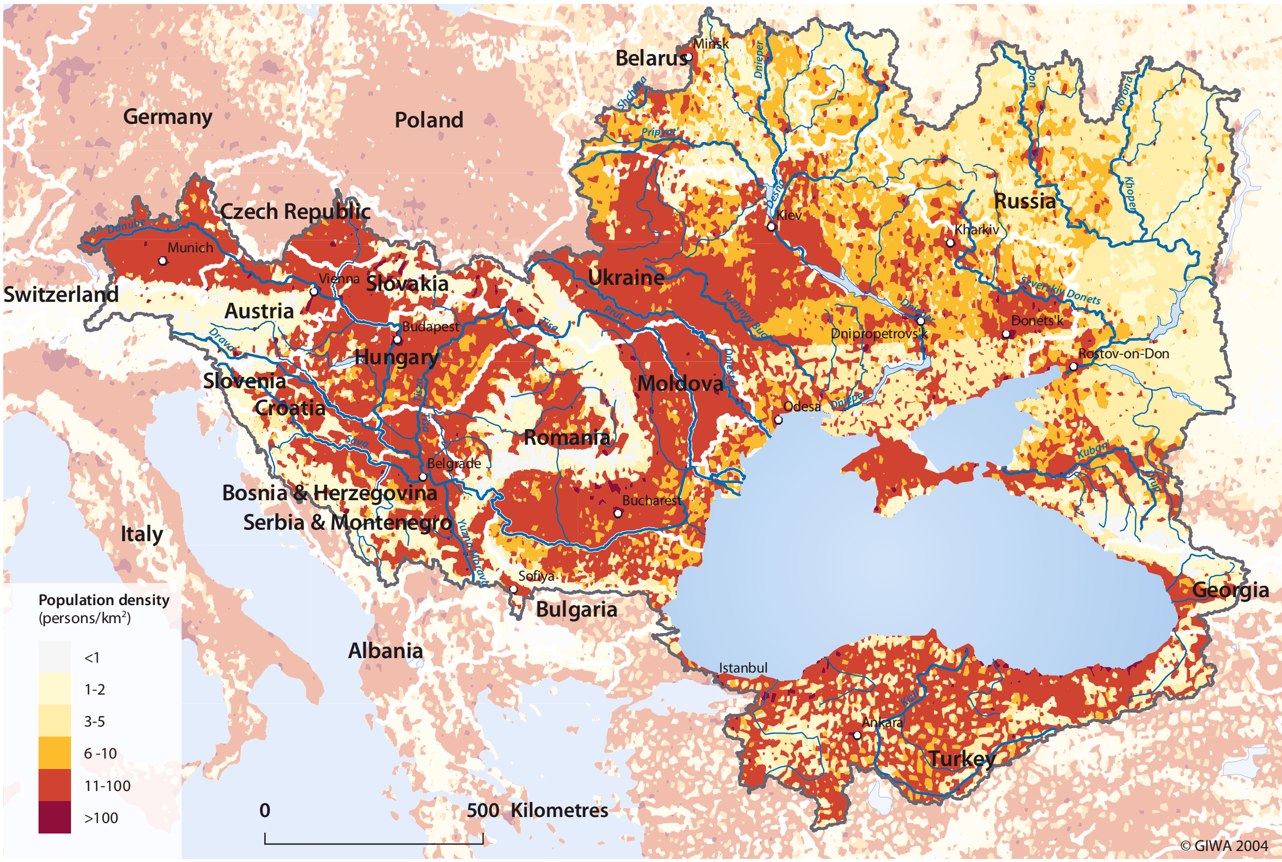

Figure 5 Population density in the Black Sea catchment area.

The Black Sea littoral countries, with the exception of Turkey, have experienced decreased production levels and resulting decreased socio-economic parameters, in part causing a decrease in the region's population. For example, between 1996 and 2000, the population of Ukraine dropped from 52 to 50 million people. Since 1980, the total national population has slightly decreased in Bulgaria and Ukraine, remained stable in Georgia, slightly increased in Romania and Russia, and substantially increased in Turkey. Between 2000 and 2015, the average annual population growth rate is expected to be negative in Bulgaria (-0.6%), Georgia (-0.3%), Romania (-0.3%), Russia (-0.5%) and Ukraine (-0.6%). Only Turkey is expected to experience a positive growth rate (+1.2%). Life expectancy is low compared with developed European countries.

Most coastal territories are densely populated and even over-populated during the summer season. According to different estimates based on national census statistics, permanent human population distributed along the Black Sea shores came to 16-20 million in the 1990's, with an extra 4-12 million tourists per year. These data do not cover people inhabiting the coasts of the Azov and Marmara Seas, however. These figures also exclude the citizens of Istanbul, the largest Black Sea urban agglomeration situated on both the European and the Asian sides of the Bosporus, and containing a resident population of over 7.3 million and a high number of migrants and visitors.

Water sector

In terms of the territorial distribution of water resources, the Dnipro Basin features two major zones. The first is the flow formation zone located within the Republic of Belarus and the Russian Federation, which is characterised by very low water consumption. The second is the flow transit zone starting downstream of Kyiv and extending throughout the Ukrainian part of the basin, which has minor side

Table 12 Black Sea population per riparian country

Country	Population	%
Bulgaria	5.5	5
Romania	23	20.6
Ukraine	47.1	42.2
Turkey	7.8	7
Russia	26.1	23.4
Georgia	2	1.8
Sub-total for riparian countries	111.5	100
Other countries of the basin	50.5	
Total	162	

flow inputs and a high water demand. Water usage in the region is characterised by the significant amount of dams on the major rivers (Dnipro, Don, Danube) built for agricultural and urban water supply and electricity production (Figure 6).

Water withdrawal, water consumption, wastewater discharge, wastewater treatment, water tariffs

Overview. Water resources are critical and are used for a variety of purposes in the region. The first priority use is of potable water for drinking and household needs, which receives 15-40% of the total volume. Irrigation requires 5% to 40% of potable water, depending on the level of its development. In industrialised areas, manufacturing consumes 40 -50%, and in agrarian areas up to 10-15%. Pond pisciculture takes 1-3%, and agricultural water supply an additional 1-3%.

Russia and Ukraine may be used as a typical example of water usage in the region (Table 13).

The Black Sea region is generally well provided with freshwater resources, including those suitable for drinking water. Heavy pollution

Table 13 Usage of water resources in some of the Black Sea Basin countries, 1999.

		Consumption (million m³)	%
Russian Federation	Drinking and household needs	321.8	36
	Manufacturing	371.9	40
	Irrigation	2.2	2
	Agricultural water supply	100.0	11
	Sea water	1.3	1
	Other	91.5	10
	Total	**888.7**	**100**
Ukraine	Drinking and household needs	3 566	25
	Manufacturing	7 304	51.1
	Irrigation	2 327	16.2
	Agricultural water supply	641	4.5
	Pond pisciculture	315	2.2
	Other	132	1
	Total	**14 285**	**100**

Figure 6 Dams in the Black Sea region.

of the rivers, however, has led to a sharp decline in the water resources available for the drinking supply and necessitates costly technologies for water treatment. Usage of groundwater for drinking purposes is not possible everywhere because of a lack of resources; this particularly applies to the southern part of the Black Sea region. As a result, the current drinking water supply issue in the region could be characterised as problematic.

Wastewater treatment is not sufficient in the region; untreated or insufficiently-treated sewage is the main source of pollution from coastal cities and villages. Municipal wastewater contributes significantly to the load of organic materials and nutrients, as well as to the spread of diseases. Microbiological pollution is primarily a local problem. Although it is well known that there are, for example, high concentrations of *E. coli* in coastal waters, there are few published data on microbiological pathogens (disease-causing microorganisms) in the Black Sea region. One reason for this is that in the cases where there are data, they are often considered confidential. There are many reports on water-related epidemics, however.

The Russian coast of the Black Sea is typical in the region in its inadequate wastewater treatment. The population of approximately 14.5 million increases by roughly 15 percent in the summer. At present, wastewater treatment plants in most of the 175 towns in the area do not function adequately. In some towns, there is no wastewater treatment at all. Only 14% of all wastewater undergoes full biological processing and is treated so that it meets the established standards. Some major cities such as Sochi, Krasnodar, Rostov-on-Don and Taganrog cannot meet the standards because of plant overloads, low efficiency, physical wear and violation of regulations for industrial wastewater discharge into the municipal sewerage system.

Similar problems exist in virtually all coastal cities around the Black Sea. Wastewater from Odessa, Ukraine (1.2 million inhabitants) goes almost untreated into the sea. In no city along the Turkish Black Sea coast is there any treatment of wastewater. As a result, the quality of drinking water is in many cases compromised by contamination from polluted wastewater. Construction of sewage treatment plants for several Turkish cities including Istanbul is continuing, however.

The large and medium-size sewage treatment plants currently operating in the the Black and Azov Sea region primarily belong to municipal authorities of the littoral countries, with the exception of large works at Mariupol steel works, Krasnoperekopsk chemical complex, etc. These works have a standard full biological purification process. They treat over 95% of household and industrial effluent fed to municipal works. The design efficiency of such works is sufficiently high and meets local standards (BODs at outlet - 10-20 mg/l, suspended solids - 10-25 mg/l, ammoniacal nitrogen 1-5 mg/l).

At the same time, some acute problems exist. The first problem is that more than 50% of the plants do not meet design efficiency standards due to worn-out equipment as they have been operating for more than 25 years, investments for updating are not apportioned, and assets are lacking for acquisition of modern flocculants. The second problem is that no structures exist to remove effluent far from the shore (for instance, 3 miles). Thus, the coastal area of the sea is polluted. The third problem is the destruction of obsolete sewage networks in the coastal area, which results in the discharge of impure effluent to the sea (Odessa, Sevastopol, etc.).

Municipal and corporate sewage works in the water catchment area outside the coastal zone can be characterised as follows. The large cities of Bulgaria, Georgia, Russia, Romania and Ukraine mostly have full biological treatment works, which in general operate with a sufficient efficiency. Thus, in Ukraine, the largest and most populated country of the Black Sea Basin, sewage works of cities with more than 1 million inhabitants (Kyiv, Kharkiv, Donetsk, Dnipropetrivsk, etc.) operate quite efficiently. The most urgent problem of Black Sea countries is the necessity to completely update sewage works due to worn-out equipment. An example of such an update is the Zaporizhya (population 890 000) sewage update project being carried out using EBRD credit.

EC countries adjacent to the Danube have recently finished construction of a large number of full biological treatment works according to EC directives, which guarantees an optimal level of purification for the next 10-15 years.

Danube Basin

Most data available on the water sector in the Black Sea Basin refer to the Danube Basin as it is the most studied part of the region in terms of water management. Table 14 covers domestic freshwater withdrawal by population connected to water supply systems in the Danube River Basin (usually including withdrawal by private households and by the commercial, institutional and tourist sectors). It must be underlined that part of the population of the Danube countries is still supplied by alternative water sources such as dug wells, pipe wells, rain water tanks, etc. In particular, only 29% of the Moldovan population in 1995 and 45% of the Yugoslavian population in 1991 were connected to central water supply systems. The highest per capita withdrawals are recorded in Bulgaria and Romania (mainly due to breakdowns in water supply networks, lack of water metering, water losses and water wastage), while the lowest are recorded in Ukraine and Moldova.

Regarding domestic wastewater generation, there is a principal differentiation between populations using individual wastewater solutions (e.g. septic tanks) and populations connected to central sewerage systems.

According to the available data, the share of population in the basin using individual systems for wastewater collection treatment and discharges varies between 11% (Germany) and 87% (Moldova). In six countries, more than 50% of the population uses some kind of individual solution; in the rural areas of some countries this share is higher than 95%. The main problem of the individual wastewater solutions is that the privately owned facilities are often not properly maintained and, therefore, constitute a permanent or periodically relevant hazard of soil and groundwater contamination. Another general problem is that there are usually no appropriate methods and facilities for adequate disposal of sludge from septic tanks. The aggregated annual wastewater generation by the population in the basin using individual systems is unknown.

According to the figures provided by National Review Reports (1998) to the International Commission for the Protection of the Danube River (ICPDR), the aggregated annual wastewater generation by the population in the basin connected to central sewerage systems is on the order of 2,500 million m^3. The per capita wastewater generation varies between 80 l/c/day (Czech Republic) and 202 l/c/day (Slovakia).

Table 14 Water withdrawal by population connected to central water supply systems in the Danube River Basin

State	Year	Total withdrawal (Mln m^3/a)	Per capita withdrawal (l/c/d)	Population connected to central systems (%)	Range of losses (%)
Bosnia and Herzegovina	1997	153	250	57	40
Bulgaria	1996	622	439	98	43
Croatia	1997	184	254	62	35
Czech Republic	1995	201	248	80	26
Hungary	1996	546	147	96	27
Moldova	1995	21	177	29	20
Romania	1996	2 062	409	61	22
Slovakia	1997	361	245	78	23
Slovenia	1995	100	196	81	28
Ukraine	1997	136	172	70	17
Yugoslavia	1991	372	255	45	30
Germany	1997	750	230	98	/
Austria	1997	586	242	86	/
Total		6 093			

(Source: PCU, Transboundary Analysis Report, 1999)

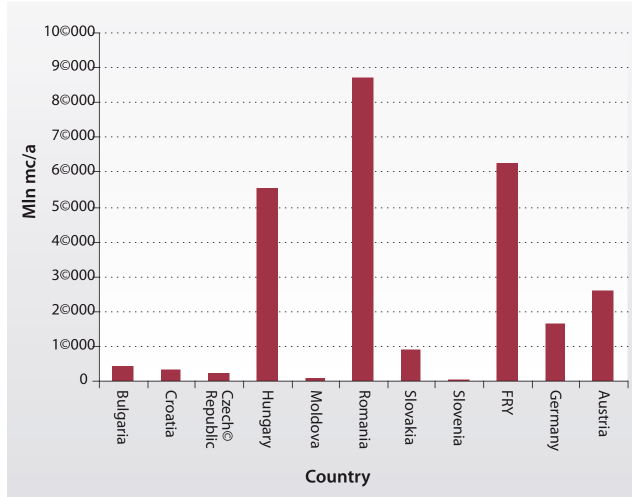

Figure 7 Total national water abstraction from the Danube River Basin

The aggregate wastewater generation is anticipated to increase to about 3,900 million m^3 per year by 2020, which is about 56% higher than the present wastewater generation.

The extent and the standard of wastewater treatment greatly differ from country to country. According to the figures provided by National Review Reports (1998), the share of wastewater discharged without any treatment ranges from 0% (Germany) to 86% (FRY). From this point of view, the Danube countries can be categorised as follows:

- Germany, Austria, Slovakia and the Czech Republic: less than 10% of non-treated wastewater discharge;
- Hungary, Moldova: between 10 and 20% of non-treated wastewater discharge;
- Romania, Ukraine, Bulgaria and Slovenia: between 30 and 40% of non-treated wastewater discharge;
- Croatia, Bosnia-Herzegovina, FRY: more than 80% of non-treated wastewater discharge.

The range of water and wastewater tariffs for population and industry in the Danube countries is illustrated by Table 15. Water tariff is the price a customer connected to a central water supply system has to pay to the water utility for one m^3 of water consumed. Wastewater tariff is defined as the price a customer connected to a central sewerage system has to pay to the utility for the discharge of one m^3 of wastewater.

These figures show that both water supply and wastewater treatment tariffs are extremely different from country to country and that there is usually a significant gap between the relatively low (and often still subsidised) tariffs for population and the high (in some cases extraordinarily high) tariffs for industry. In many accession countries

Table 15 Range of water supply and wastewater treatment tariffs in the Danube countries

	Water supply	Wastewater treatment
Tariffs for population, (US$/m^3)		
Minimum	0.02 (Moldova)	0.01 (Moldova)
Maximum	0.79 (Slovenia)	0.80 (Hungary)
Tariffs for industry (US$/m^3)		
Minimum	0.07 (Yugoslavia)	0.01 (Yugoslavia)
Maximum	2.95 (Hungary)	4.22 (Hungary)

(Source: PCU, Strategic Action Plan for the Danube River Basin 1995-2005, Revision 1999)

Table 16 Total annual freshwater consumption in the Dnipro Basin (2000)

Country	Industry (%)	Of that, energy	Agriculture (%)	Of that, irrigation	Municipal sector (%)	Other sectors (%)	Subtotal (km^3/year)
Republic of Belarus	29.4		8.7	0.4	43.8	18.1	1.040
Russian Federation	55.4	36.5	16.4	0.4	28.2		0.715
Ukraine	58		14.9	9.7	22.1	5	8.87
Total (km^3/year)							10.63

there was a marked increase in prices during transition, resulting in lower water use. In Hungary, for example, household water prices increased 15-fold after subsidies were removed, which led to a reduction in water use during the 1990's of about 50%.

Dnipro Basin

The Dnipro is a vital water artery for the economies and populations of the three nations in its basin. Table 16 provides statistical data on water consumption in the Dnipro Basin in 2000.

The total volume of water extraction in the Dnipro Basin in 2000 was 10.6 km^3. This can be broken down by country as follows: 6% in the Russian Federation, 8% in the Republic of Belarus, and 86% in Ukraine. Ukraine is by far the largest water user in the basin with the Dnipro covering about 60% of the national demand for freshwater (a breakdown by sector is shown in Figure 8).

Wastewater discharge (point sources) in the Dnipro Basin (2000). Republic of Belarus - 0.818 km^3/year; Russian Federation - 0.425 km^3/year (0.243 km^3/year of polluted wastewater); Ukraine - 5.6 km^3/year.

Water-related engineering

Water reservoirs in the Dnipro Basin. The Republic of Belarus has 102 reservoirs (the total water surface area is 345 km^2 with a capacity of 1.044 km^3) and 730 ponds (the total water surface area is 93 km^2 with a capacity 0.164 km^3). The Russian Federation has ponds (the total water surface area is 180 km^2). Ukraine has 564 reservoirs, including 6 major ones (the total water surface area is 688 km^2 with a capacity

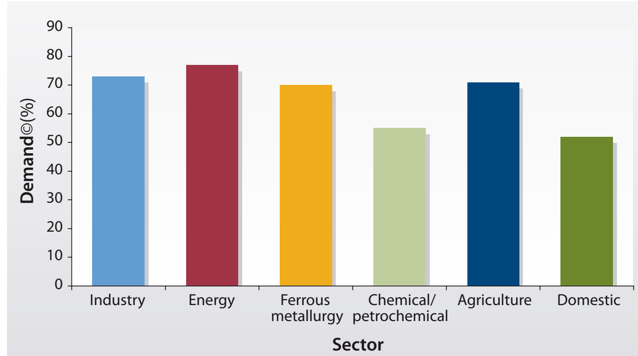

Figure 8 National demand for water (%) from the Dnipro Basin in Ukraine (by sector). Agricultural sector demand supplies 85% of water for irrigation.

of 43.8 km^3) and 13,283 ponds (the total water surface area is 12 km^2 with a capacity of 1.8 km^3). About 30% of the total abstracted volume is supplied to arid areas of the basin via water diversion channels. In Belarus, 0.04-0.06 km^3/year is diverted annually via the Dnipro-Buh Channel.

Flow diversion to other basins. Republic of Belarus - 2 schemes (0.29 km^3/year); Russian Federation – none; Ukraine - 6 channels, 5 water ducts, 3.14 km^3/year.

Agriculture appears to be the most intensive water user, being responsible for 69% of total non-returnable water consumption in the basin. A large proportion of this abstracted water is supplied to irrigation systems. Seasonally, about 56% of the total annual water abstraction occurs between May and August, which is attributed to intensive irrigation of arable farmland downstream of the Dniprovsky hydropower dam.

Water losses during transmission.

Republic of Belarus - 380 million m^3/year; Russian Federation - 22 million m^3/year; Ukraine - 1,660 million m^3/year.

Water protection expenditures.

Republic of Belarus - 49,240 million BR (61. 5 million USD); Russian Federation - 75 million RR (2.4 million USD); Ukraine - 136.6 million UAH (25.5 million USD).

Water reservoirs in the Don Basin.

All significant water reservoirs of the Don Basin are located in the Rostov region. The biggest of these, Tsimlyanskoe, is situated directly in the Don plate. In addition, there are 3 supporting dams below the Tsymlyanskaya Dam providing navigation on the Lower Don (Nikolayevskaya, Konstantinovskaya, and Kotchetovskaya).

Table 17 Major diversion channels in the Ukrainian part of the Dnipro Basin

Diversion Channel	Million m³/year
The Dnipro-Donbass Channel	228
The North-Rohachitska irrigation scheme	58
The Kakhovka irrigation system	513
The North-Crimean Channel	2 004
The Inhulets irrigation scheme	191
The Dnipro-Kirovhrad water conduit	59
The Dnipro-Mykolaiv water conduit	87
Total	3 140

Table 18 The main reservoirs of the Don River

The name of the reservoirs	River	Usage	Volume mln m³	Water surface area km²
Tsimljanskoe	Don	irrigation navigation fishing	23 860	2 702
Proletarskoe	Western Manich	irrigation navigation fishing	2 031	798
Veselovskoe	Western Manich	irrigation navigation fishing	893	246
Ust'-Manichskoe	Western Manich	irrigation navigation fishing	72	73

Flow diversion to other basins.

The Tsimlyanskoe water reservoir serves as the main power supply of irrigation systems. Water delivery is carried out with the help of the Don Main Channel (DMC) and the Generalovskaja and Khoroshevskaja irrigating systems. Through DMC, water is supplied for irrigation, for filling the Sal River, and for feeding and desalination of the Manich water reservoirs. The planned capacity of DMC is 250 m^2/sec. DMC is connected with the Nizhne-Donskaya, Verkhne-Sal'skaya, Bagayevsko-Sadkovskaya and Proletarskaya irrigation systems. In the recent past, water from the Tsymlyanskoye water reservoir was used to irrigate 290 000 hectares of land.

Health status related to water

The condition of the population's health is affected by a number of factors, including the poverty level, the development of and access to medicine, and environmental conditions. This last factor determines the condition of water resources and water consumption, as well as the condition of soils, vegetation and fauna. Relatively low levels of income and high levels of environmental pollution in developing countries have been correlated with poor health conditions compared to the developed countries.

According to the official definition of the European Regional Bureau of the World Health Organisation (WHO), water-borne diseases mean any significant and widely spread negative effect on human health (death, disability, disease or disorder) that is directly or indirectly caused by the state or changes in quantity or quality of any water resource. In general terms the main health hazards mediated by water from the Danube River system can be summarised as outlined in Table 19.

Table 19 Water-borne diseases in the Danube River Basin

Health hazards	Water related causes	Sources of problems
Communicable diseases - Dysentery - Hepatitis - Salmonellosis - Cholera	Pathogens in: - Drinking water - Recreational water - Irrigation water - Fish consumption	Insufficient water supply Sewage contamination Manure
Acute intoxication and chronic diseases	Toxic substances in: - Drinking water - Irrigation water - Fish - Recreation water	Inadequate water treatment Sewage contamination Manure Agrochemicals Industry, hazardous wastes River/road traffic
Allergies and skin irritations (from bathing)	Proliferation of toxic cyanobacteria	Nutrient overloading from: - Sewage contamination - Manure - Agrochemicals
Skin and eye infections and infestations	Insufficient household hygiene	Insufficient water supply

(Source: Danube Pollution Reduction Programme, Socio-economic effects of water pollution in the Danube river basin, 1999)

Investigations carried out with support from the European Commission and the WHO shows the significant influence of eutrophication on human health. Algal toxins are observed in freshwater and marine ecosystems where they can accumulate in shellfish, and more generally in seafood, reaching dangerous levels for human and animal health. People may be exposed to toxins through the consumption of contaminated drinking water, direct contact with fresh or marine water, or the inhalation of aerosols. Toxins induce damage in animals and humans by acting at the molecular level and consequently affecting cells, tissues and organs. The nervous, digestive, respiratory and cutaneous systems may be affected. Secondary effects can be observed in numerous organs. Age or physiological conditions of the affected individual may determine the severity of the symptoms. A variety of symptoms, depending on the toxins implicated, are observed such as fatigue, headache, diarrhea, vomiting, sore throat, fever and skin irritations.

Water-borne diseases in the Dnipro Basin

There is a continuous threat of outbreaks of waterborne diseases in the Dnipro River Basin. Available data show numerous limited outbreaks of diseases caused by exposure to or consumption of poor quality water containing pathogenic bacteria that are responsible for transmitting various contagious diseases.

In 2000-2001, 10 outbreaks of contagious viral and bacterial diseases were officially recorded within the Russian part of the Dnipro Basin, attributed to microbial contamination of drinking water. The total number of people affected was 307, about 38% of whom were children under 14 years of age. Enteric fever, A, B, and C-paratyphoid and bacterial dysentery are the most frequent water-borne diseases. In the Kaluga, Orel and Bryansk Oblasts, the incidence of dysentery, hepatitis A and other acute contagious diseases is higher than the country average.

Over the period of 1994-2001, 12 outbreaks of contagious waterborne viral and bacterial diseases were recorded in the Belorussian part of the Dnipro Basin. The total number of people affected was 1,135 with over 50% of them children under 14 years of age. In addition to contagious viral and bacterial diseases, human health in the Dnipro Basin is threatened by parasitic invasions. In the Pripyat River Basin, parasitic invasion levels are relatively low. This is because fish have never dominated the local food pattern, with only between 2% and 9% of the local population engaged in non-commercial fishing. The incidence of *opisthorchiasis* is different in the Dnipro River Basin where as much as 20% of the local population is engaged in such activities. In this area, fish is consumed in large quantities, particularly dried and pickled. Inadequate existing water treatment and disinfection technologies are considered to be the major causes of water-borne disease outbreaks.

In Ukraine, contaminated water is considered to be one of the major causes of enteric infections. There is a direct relationship between the increasing contamination of water and the incidence of water-borne diseases (enterocolitis, dysentery, salmonellosis, viral hepatitis À, etc). Results of studies carried out in the Dnipro Basin suggest that microbiological contamination of drinking water is the major contributor to the growing frequency of contagious disease incidence (Table 20).

Table 20 Percentage of cases of contagious diseases attributed to microbiological pollution

Contagious disease	% of total cases attributed to microbiological contamination
Dysentery	41
Salmonellosis	62-77
Hepatitis A	72
Enterocolitis	45

Between 1990 and 2000 the incidence of human disease has been growing at an average annual rate of 0.7%. Notably, the incidence of diseases related to or associated with environmental pollution has been growing at a significantly higher rate.

This picture varies across the basin. For example, the highest disease incidence rate has traditionally been recorded in the Central Ukrainian Oblasts with disease patterns being dominated by circulatory system diseases and respiratory diseases. This, in some part, can be attributed to the ageing population of this region. Malignant tumours are frequent in the industrialised areas of the basin (Dnipropetrovsk, Zaporizhzhia and Kirovhrad Oblasts), which can be attributed to higher levels of environmental pollution.

The incidence of endocrine and digestive system diseases remains high in the central and northwestern areas of the basin, where thyroid adenoma has been a serious issue. Since 1999, the situation has become even more complicated due to higher incidence of hyperplasia of the thyroid gland, indicative of the impact of the Chernobyl accident.

Legal and institutional framework at the national level

With regard to national water laws and institutions, the countries of the Black Sea Basin can be divided into four main groups: Austria and Germany, the new EU member states and the candidate countries, the Balkan countries, and the Newly Independent States (NIS).

The first group, Austria and Germany, as EU member states, have aligned their laws and institutions with the strict requirements established in the framework of the EU water policy. This entails the implementation of several Directives, such as the Water Framework Directive (2000/60/EC), the Bathing Water Quality Directive (76/160/EEC), the Drinking Water Quality Directive (80/778/EEC), the Urban Wastewater Treatment Directive (91/271/EEC), the Nitrates Directive (91/676/EEC), among others.

The new EU member states of central and eastern Europe (the Czech Republic, Hungary, Slovakia and Slovenia) were also required to adopt the *acquis communitaire* before accession, even if all of them had already concluded some transitional arrangements concerning different pieces of EU water legislation[1]. The same criterion for membership applies to Bulgaria and Romania, which will join the EU in 2007, and to Turkey that is expected to open its negotiations with the EU by the end of 2004. Prospects for EU accession have thus prompted most of the above-mentioned countries to improve their water resources management legislation and to develop sound water policies and strategies. Fragmented approaches to water resources management are being replaced with integrated and/or river basin management or catchment approaches. The challenges ahead are to improve cooperation among the different administrative bodies (decentralisation has in fact in some cases been accompanied by disintegration, as existing legislation does not clearly specify responsibilities and functions) and to improve

[1] The Czech Republic, Hungary, Slovakia and Slovenia have concluded transitional arrangements related to the Urban Wastewater Treatment Directive (91/271/EEC). Slovakia has also concluded a transitional arrangement related to the Dangerous Substances Directive (74/464/EEC).

the capacity, at various levels, to implement/enforce the regulations effectively.

The southeastern European states (Bosnia-Herzegovina, Croatia and Serbia-Montenegro) have made significant efforts, after the end of the war, to establish legal and institutional frameworks for water resources management. Croatia, in particular, which applied for EU membership in 2003, is adapting its national laws and acts, as well as its institutions, to regulate many areas of water resources management (WRM) with EU water directives. Although new institutional arrangements for WRM were established in all the countries in the 1990's and at the beginning of this century, the degree of effectiveness varies across countries. Some areas of concern that need to be tackled in the immediate future include: a) revision of legal frameworks to ensure proper delegation of functions and responsibilities among different institutions and ministries; b) development of a legal basis for a river basin management approach; c) adequate resources allocation for water institutions; and d) implementation of plans for restructuring existing water institutions.

Finally, NIS countries (Belarus, Georgia, Moldova, Russia and Ukraine) have also issued a number of laws and regulations for the protection and management of water resources. Nonetheless, legislation still needs to be updated in order to take full account of good international practices and principles in WRM and to specify responsibilities of various institutions and the different water uses. A river basin planning management approach as opposed to a sectoral planning approach needs to be promoted, especially in the Dnipro Basin where conflict among users seems to be increasing. Russia has a long tradition of integrated river basin management, but the overall status of utilisation and protection of water resources in the country is still unsatisfactory, due to the low level of implementation of the existing legislation.

Legal and institutional framework at the international level

In the Black Sea Basin there are two main legal and institutional frameworks related to transboundary water protection and management concerning the Black Sea coastal states and the Danube River Basin.

Environmental cooperation in the Black Sea is based on the Convention on the Protection of the Black Sea against pollution, which was signed in 1992 by the six coastal states and entered into force in 1994. Three protocols form an integral part of the Convention: the Protocol on the protection of the Black Sea marine environment against pollution from land-based sources; the Protocol on cooperation in combating pollution of the Black Sea marine environment by oil and other harmful substances in emergency situations; and the Protocol on the protection of the Black Sea marine environment against pollution by dumping. The Convention provides for the establishment of a Commission for the Protection of the Black Sea against Pollution (CPBSP), which promotes its implementation. To this end, the Commission is supported by a Permanent Secretariat and by different Advisory Groups, Activity Centres and national focal points. In 1996, the Black Sea countries approved a Strategic Action Plan, in order to define policy measures, actions and timetables for setting up and achieving the environmental objectives of the Bucharest Convention. The Strategic Action Plan focuses on three major issues that are closely interrelated: the reduction of pollution, the management of living resources and sustainable human development.

The first initiative for cooperation in protecting the water environment in the Danube River Basin was taken with the signing of the Bucharest Declaration in 1985. Afterwards, in 1994, the Convention on the Protection and Sustainable Use of the Danube River was adopted, which, with its entry into force in October 1998, became the key legal instrument for regulating cooperation and transboundary water management in the basin. To facilitate its implementation, the International Commission for the Protection of the Danube River (ICPDR) was set up as the main decision-making body of the Convention. The Commission's work is supported by a Permanent Secretariat and by different Expert Groups and Working Groups. In 1994, the Danube countries prepared a Strategic Action Plan, which provides directions for achieving the goals of regional integrated water management expressed by the Convention. The Strategic Action Plan was reviewed in 2000 under the ICPDR, through the establishment of the Joint Action Programme, which covers the 2001-2005 period. The main aims of the Joint Action Programme are: the improvement of the ecological and chemical status of the water, the prevention of accidental pollution events and the minimisation of the impact of floods.

Institutional cooperation between the Black Sea and the Danube countries started in 1997 when representatives of the CPBSP and the ICPDR, with the assistance of UNDP/GEF and UNEP, set up a Joint ad-hoc Technical Working Group (JTWG). The JTWG has recently supported the adoption of the so-called Memorandum of Understanding between the CPBSP and the ICPDR, which identifies a long-term and an intermediate goal for the Black Sea region. The long-term goal is to reduce the loads of nutrients and hazardous substances discharged to such levels necessary to permit the Black Sea to recover to conditions similar to those observed in the 1960s. The intermediate goal is to avoid that the loads of nutrients and hazardous substances discharged into the Black Sea and the Azov Sea exceed those that existed in the mid-1990s. An informal Task Force for cooperation on water-related issues in the

Danube/Black Sea region (DABLAS Task Force) has also been created to promote the implementation of the Memorandum of Understanding, provide suggestions to the CPBSP and the ICPDR concerning further strategic priorities, and develop a series of concrete activities, including a short list of prioritised projects for the rehabilitation of the waters in the region.

Finally, with regard to the Dnipro River Basin, it has to be highlighted that in 1995 Belarus, Russia and Ukraine signed a Memorandum by which they applied to UNDP for assistance in developing an international programme on environmental rehabilitation of the basin. The UNDP/GEF Dnipro Basin Environmental Programme started in 1996. Its goals are: a) remedying the serious environmental effects of pollution and habitat degradation of the basin; b) ensuring sustainable use of its resources; and c) protecting biodiversity. Among its specific objectives are the creation of a transboundary management regime and coordinating body, the formulation of a Strategic Action Programme (SAP) and the building of the capacity needed for SAP implementation. In 1998, the Transboundary Diagnostic Analysis was published that was to serve as a basis for the preparation of the SAP. Moreover, on May 2003, the three Ministers of the Environment of Belarus, Russia and Ukraine signed a new Declaration on cooperation in the sphere of environmental rehabilitation of the Dnipro Basin. In this document, they expressed their readiness to prepare an international agreement, which will serve as the main organisational mechanism for ensuring stable international cooperation among Dnipro countries and which will define the general principles, goals, objectives and commitments of the signatories for the Dnipro Basin environmental rehabilitation.

Impact assessment, eutrophication

Environmental impacts

Eutrophication is a complex process, which occurs both in fresh and marine waters, where excessive development of certain types of algae disturbs the aquatic ecosystems and becomes a threat for animal and human health. The primary cause of eutrophication is an excessive concentration of plant nutrients originating from agriculture or sewage treatment. Eutrophication is commonly linked to algal blooms, "red tides", "green tides", fish kills, inedible shellfish, blue algae and public health threats (Figure 9).

A brief description of the mechanisms of eutrophication development is as follows (Figure 10). The main cause of eutrophication is the large input of nutrients to a water body and the main effect is the imbalance in the food web that results in high levels of phytoplankton biomass in stratified water bodies. This can lead to algal blooms. The direct consequence is an excess of oxygen consumption near the bottom of the water body. Additional factors supporting this process can be divided into two categories depending on whether they are linked to the nutrient dispersion and the phytoplankton growth, or to the oxygen cycle near the bottom of the water body (for example, containment, light and water movements). Various effects can be observed depending upon the severity of the eutrophication.

Figure 9 Algae bloom in the Black Sea.

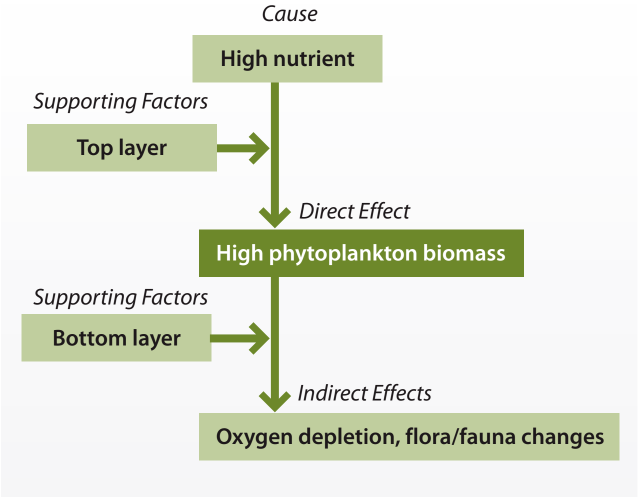

Figure 10 The process of eutrophication in the Black Sea.

The enrichment of water by nutrients can be of natural origin, but it is often dramatically increased by human activities. This occurs almost everywhere in the world. There are three main sources of anthropogenic nutrient input: runoff, erosion and leaching from fertilised agricultural areas, and sewage from cities and industrial wastewater. Atmospheric deposition of nitrogen (from animal breeding and combustion gases and coals) can also be important.

Main consequences of eutrophication

The major consequence of eutrophication concerns the availability of oxygen. Plants, through photosynthesis, produce oxygen in daylight.

On the contrary, in darkness all animals and plants, as well as aerobic microorganisms and decomposing dead organisms, respire and consume oxygen. These two competitive processes are dependent on the development of the biomass. In the case of severe biomass accumulation, the process of oxidation of the organic matter that has formed into sediment at the bottom of the water body will consume all the available oxygen. Even the oxygen contained in sulphates (SO_4^{2-}) will be used by some specific bacteria. This will lead to the release of sulphur (S^{2-}) that will immediately capture the free oxygen still present in the upper layers. Thus, the water body will loose all its oxygen and all life will disappear. This is when the very specific smell of rotten eggs, originating mainly from sulphur, will appear.

In parallel with these changes in oxygen concentration other changes in the water environment occur, such as changes in algal population and changes in zooplankton. During eutrophication, macroalgae, phytoplankton (diatoms, dinoflagellates, chlorophytes) and cyanobacteria, which depend upon nutrients, light, temperature and water movement, will experience excessive growth. From a public health point of view, the fact that some of these organisms can release toxins into the water or be toxic themselves is important.

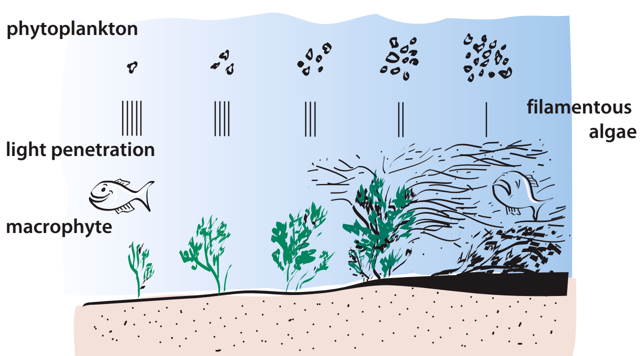

Figure 11 Development of plant life in coastal waters with increased level of nutrients

Where eutrophication occurs, fish and shellfish populations are the first to demonstrate changes. Being most sensitive to oxygen availability, these species may die from oxygen limitation or from changes in the chemical composition of the water such as the excessive alkalinity that occurs during intense photosynthesis. Ammonia toxicity in fish, for example, is much higher in alkaline waters.

Black Sea

Eutrophication can adversely affect the diversity of the biological system, the quality of the water and the uses to which water may be put in the Black Sea region. The Black Sea is known to be one of the marine water bodies most affected by eutrophication in the world (Figure 11).

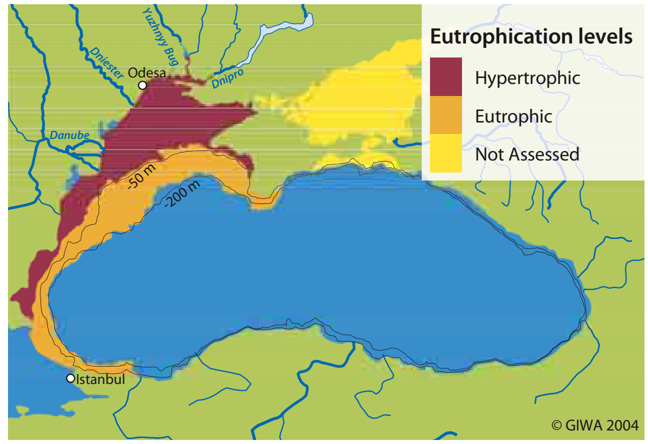

Figure 12 Eutrophication levels in the Black Sea (hypertrophic – red, eutrophic – orange, mesotrophic – yellow and blue).

Adverse changes in the structure and functioning of the water ecosystems

Eutrophication severely influences the structure and functioning of the water ecosystem. 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 myriad of animals which live attached to the sea floor or arrive as visitors, sometimes remaining during an important stage in their reproductive cycle.

The northwestern part of the Black Sea is largely below one hundred meters depth and has always received a good supply of nutrients from the Danube and Dnipro Rivers, Europe's second and third largest rivers. It was virtually covered with underwater meadows. One species alone, red algae *Phyllophora,* dominated an area with the combined size of Belgium and the Netherlands. 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, humans also harvested the red algae for their agar. These sea grass and algal beds of the northwestern shelf were unable to absorb large amounts of nutrients, however, and large quantities of phytoplankton began to grow, shading the light from the larger plants below. Deprived of light, the meadows began to die.

Algae blooms

As the base of the marine food chain, phytoplankton is an important indicator of change in the seas. These marine floras, in the process of photosynthesis, also extract carbon dioxide from the atmosphere, and, as a result, play an important role in the balance of greenhouse gases that control global climate. Though incredibly small as individual cells, their vast numbers influence both the primary production of the

Table 21 Increase in phytoplankton blooms. Phytoplankton concentration in the northwestern Black Sea

№	Species	1960-70		1980-90	
		Cell densities (10 cells)	Number of blooms	Cell densities (10 cells)	Number of blooms
1.	Skeletonema costatum	10-18	3	10-90	8
2.	Sceletonema subsalsum	-	-	10-19	2
3.	Cyclotella caspia	-	-	23-300	2
4.	Chaetoceros similis	-	-	22	1
5.	Cerataulina pelagica	-	-	5-6	3
6.	Nitzschia delicatissima	6-21	4	17	1
7.	Nitzschia closterium	-	-	13	1
8.	Nitzschia tenuirostris	-	-	75	1
9.	Leptocylindrus danicus	7	1	-	-
	Total diatoms	**7-21**	**8**	**5-300**	**19**
10.	Prorocentrum cordatum	17-51	4	10-810	9
11.	Prorocentrum scutellum	-	-	7	1
12.	Scripsiella trochoidea	-	-	26	1
13.	Heterocapsa triquetra	-	-	5-12	3
	Total dinoflagellates	**17-51**	**4**	**5-810**	**14**
14.	Eutreptia lanowii	-	-	-	6
15.	Total Euglenophytes	-	-	-	6
16.	Emiliania huxleyi	-	-	220-300	2
17.	Chromulina sp.	-	-	1 000	1
	Total prymnesiophytes	**-**	**-**	**220-1 000**	**3**
	Total blooms	**-**	**12**	**-**	**42**

oceans and the world's climate. Phytoplankton blooms that occur near the surface are readily visible from space, enabling a global estimation of the presence of chlorophyll and other pigments using satellite

The contemporary condition of spring phytoplankton is characterised by a reduced percentage of diatoms (75% in average) in total volume of biomass and an increased role of peridinia as compared to 1954-1960 data. For the first time, substantial quantities of *Gleccapsa* blue-greens and *Inkistredesmus* and *Scenedesmus protococci* appeared in the Dniester and Danube estuaries. "Florescence" of typically maritime *Sceletonema costatum* Cl., *Chaetoceros socialia f. radians* is observed every year, whereas previously scanty freshwater diatoma *Stephanodiscus hantzsohii Grun* was seen in the sea near the Dnipro estuary.

Intense growth of peridinia has become typical for the summer period: they made up only 19% of biomass in 1954-1960, but have increased to 54.5% in recent years. Many new peridinia species have also appeared. Summer water is "blooming" almost permanently and a new phenomenon of "red tide" determined by Ex.cordata has been observed. Acantoica acanthus Schill was scarce earlier, but now develops in outbreaks.

In the Dnipro-Bug Estuary, area summer "blooming" was determined by Microcystis aeruginesa Kuts et Elenk, Aphanizomenon flos aquas Ralfs blue-greens in 1954-1960. At present, however, both the quantities and composition of mass species in freshwater phytoplankton have changed. Eutreptia lanovii Steuer green algae have become common. The percentage of diatoms in total summer phytoplankton has increased up to 40%.

Expansion of hypoxic and anoxic zones.

The presence of a sulphur hydrogen (anoxic) zone starting from the depth of 200 m is a very significant feature of the Black Sea. Hypoxia phenomena in shallow otherwise oxic habitats have developed during the recent decades in the surface layer of the Black Sea (Figure 13).

After studying the geography in the bottom layer zones of the northwestern shelf of the Black Sea that experienced an oxygen deficit, three characteristic sites were revealed where hypoxia was registered most often: "Odesa", "Central" and "Danube". "Central" refers to the area between the Dniester and Danube rivers. The geographic position of the other sites is indicated by their names.

In the year 2000, the total area exposed to hypoxia reached 14 thousand km^2 (38 % of the area of the northwestern shelf). This is much less than the 1983 figures when more than 50 % of the northwestern shelf of the Black Sea was exposed to hypoxia.

Reduction in biodiversity and in fish resources.

Eutrophication and other types of ecosystem degradation have led to reduced biodiversity and imbalanced ecosystems in the Black Sea. In the past 25-30 years, the Black Sea has been transformed from a diverse ecosystem supporting varied marine life to a eutrophic plankton culture

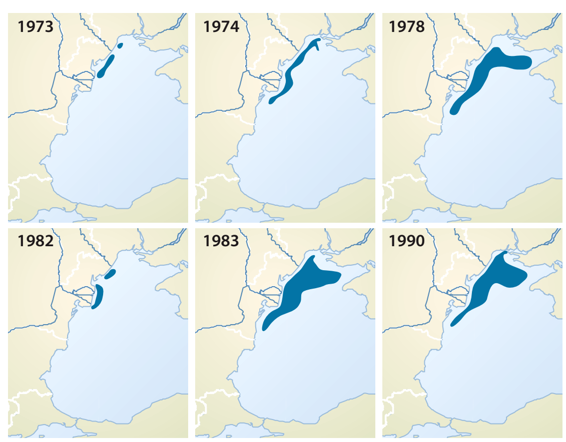

Figure 13 Expansion of hypoxia and anoxia zones in the northwest of the Black Sea.

Note: Eutrophication was so strong that it caused temporary hypoxia events on the sea bottom that resulted to the mass mortality of benthic animals in the relatively shallow northeastern Black Sea.

Source: Y. Zaitsev and V. Mamaev, Marine biological biodiversity in the Black Sea: A study of change and decline, United Nations Publications, New York, 1997.

- environmental conditions unsuitable for most organisms higher in the food chain.

As species diversity is reduced, often as a result of eutrophication, opportunistic settler species, brought in the ballast water of ships, can easily find an ecological niche in which to flourish. The first documented case was that of the predatory sea snail *Rapana thomasiana*, probably carried from Japan on ships' hulls or in ballast in the late 1940s and widely held responsible for the demise of commercially-harvested oyster populations and a general decrease in biodiversity. Ironically, in recent years, it has itself become the target of heavy fishing, with the harvest exported to Japan, and stocks are now declining. Another one was the soft-shelled clam, which first appeared in the late 1960s and successfully competed against the local species, *Corbula mediterranea*, to achieve densities of more than 1,000 per square meter (about 1 kilogram per square meter) on the Romanian shelf. These large populations may actually improve the capacity of the ecosystems for self-purification. But large banks of clams and mussels have now been eliminated by the effects of anoxia.

Benthic vegetation.

Benthic vegetation includes seagrasses and seaweeds and micro-phytobenthos biomass. At the present time, a small Phyllophora field, situated at a depth of 10-15 m in the eastern part of the Black Sea, still develops normally. A loss of the Phyllophora field would be disastrous because of its valuable resources and more importantly because of its unique biocenoesis with its specific red color fauna (*Phyllophora fauna*) and its importance as a source of oxygen.

The Black Sea brown alga, *Cystoseira barbata*, that inhabits rocky coasts, began disappearing from the coastal waters of Ukraine and Romania in the 1980s. This large perennial alga, unable to endure the eutrophic costal waters, was replaced by filamentous green and red algae. Due to a recent reduction of pollution pressures on coastal waters, a reoccurrence of the *Cystoseira barbata* was reported by Ukraine.

Benthic fauna.

The development of large-scale eutrophic phenomena and the resulting depletion of oxygen occurred due to decay of massive quantities of dead algae and due to sedimentation building up on benthic communities. This provoked frequent occurrences of hypoxic and anoxic conditions on the Black Sea shelf. First observed in 1973, oxygen poor zones have since been observed frequently every year in summer and autumn. A mass mortality of benthic animals has been caused by this phenomenon. The biological losses over 18 years (1973-1990) were estimated to be 60 million tonnes of living marine resources, including 5 million tonnes of fish. As a consequence, the largest community of mussels in the Odessa Gulf that were exported in the beginning of the 20th century has completely lost its commercial significance in recent years.

Damage to and destruction of habitats.

The commercial fish stocks strongly depend upon the availability of wintering and feeding resources and undisturbed spawning and nursery grounds. Although different fish species depend upon different wintering and main feeding areas, the Black Sea shelf and in particular Ukrainian Black Sea shelf is the most important of these wintering and feeding habitats.

The quality of nursery and spawning grounds plays a crucial role in the reproduction of fish stocks. The construction of dams and hydraulic structures has kept anadromous species such as sturgeons from their natural spawning grounds in the estuaries of the Danube and Dnipro Rivers. As a result, these anadromous fish species currently depend upon industrial breeding for their survival. The most intensive work to industrially breed sturgeon is being done in the Azov Sea in the Russian Federation. Fishing activities during the spawning period are strictly prohibited in all Black Sea states. Illegal fishing is common under the current economic conditions, however, and damages the success of breeding efforts, in particular in the cases of sturgeons and turbots. Most of these species require special protection and remedial measures in order to safeguard the successful replenishment of fish stocks in the Black Sea.

Significant evidence of the destruction of critical habitats resulting from eutrophication is the catastrophic loss of the "Zernov" phyllophora field in the northwestern Black Sea.

Increased water turbidity.

Phytoplankton blooms increase the water turbidity and isolate the bottom seagrasses from sunlight. After the cells die, a large quantity of detritus settles on the sea bottom covering the seagrass and preventing its development.

Azov Sea

The major constituents of the Taganrog Bay water balance are the Don River runoff and water exchange with the open part of the Azov Sea. The Don River runoff on average contributed about 27.3 km^3/year up to the middle of the 20th century, 18.4 km^3 or almost 70% of which occurred during the spring flood. Since being regulated by dams, the annual runoff of the Don River contributes only 21.5 km^3, which is 5.8 km^3 (20%) lower than would naturally occur, and 8.0 km^3 lower in the spring period. This is 2.4 times lower than the norm prior to regulation through dams and exceeds the natural minimum by only1.2 km^3.

In June 2003, maximum concentrations of mineral and organic phosphorus were noted in the areas most influenced by river runoff: the Taganrog Bay and along the coastline of the Temryuksky and Yasensky Bays. The levels of phosphate phosphorus were 146-154 mg/l, and the levels of total phosphorus were 162-175 mg/l. Thus, the entry of organic phosphorus from the river runoff was low, at the level of 10-12% of the total amount.

The Don River runoff is less rich in nitrogen compounds than the Azov Sea water mass itself. Mobilisation of the nitrogen in the Azov Sea sediments by storm action is a source for elevated levels of nitrates. Many scientific publications describing the patterns of the formation of the sea's hydrochemical regime illustrate the unique role of runoff from the Don and Kuban Rivers in the eutrophication of the basin. A decrease in the use of mineral fertilizers in the catchment area has obviously led to a decrease in the delivery of oxidised nitrogen forms into the Taganrog Bay.

Between 1971 and 1991, average levels of ammonium nitrogen in the Taganrog Bay water were 198 mg/l in April and 146-166 mg/l in July. In 1992, an average concentration in the Azov Sea water area was 30 mg/l. In 1998 (June) an average concentration in the Taganrog Bay was 32.5 mg/l.

The changes in the hydrophysical and hydrochemical regime in the Azov Sea in the summer season has a range of features that influence the phytoplankton community and primary production processes. Episodic reconfiguration of the system of currents, influenced by wind and wave activity, and intensive turbulent mixing, cause changes in the structure of the hydrophysical and hydrochemical fields that have different ecological effects: rapid replenishment of reserves of mineral forms of biogenic substances from subterranean solutions and the destruction of the water stratification; a short-term decrease of the euphotic layer due to a drastic decrease of the water transparency; and a temporary decrease in the inflow of freshwater and halophilous microalgae from the Black Sea. Such non-recurrent restructuring of oceanographic fields is difficult to assess. However, in contrast to deepwater and stratified water bodies, the Azov Sea is supplied with the main biogenic substances for microalgae vegetation even during the summer period.

Between 1985 and 1995, the average annual level of nitrogen molecular forms in the Azov Sea as a whole was 819 mg/m^3, the level of phosphorus was 42 mg/m^3, and the level of dissolved silicic acid was 578 mg/m^3. This is lower than the levels of the same substances in the period 1952-1981 (N-22%, P-38%, H_2SiO 3-4.1%).

Due to the intensive assimilation of nitrates by phytoplankton, their concentration in the sea over the period 1996-2000 decreased on average to 19 mg/m^3, compared to 46 mg/m^3. A decrease in the nitrate levels in the Taganrog Bay (to 80 mg/m^3 on average from 200-300 mg/m^3 in 1985-1990) has resulted from both biologic factors and decreased anthropogenic pressure. A downtrend in the phosphate levels in the Azov Sea manifested itself later (since 1997); levels are 8.7 mg/m^3, or 1.3 times lower than in the first half of the 1990s (Aleksandrova 2001). On the other hand, changes in concentrations of biogenic substances result from the natural desalination of the Azov Sea. This has led to a decrease in the amount of diatoms, which have been crowded out by the algae not consuming silicon, including Cyanophyceae.

The Don and Kuban Rivers are responsible for 90% of dissolved substances flowing into the Azov Sea. Nitrogen takes the leading place in the structure of the discharge of these substances. During the period 1981-2000, long-term average annual transport of total mineral nitrogen from the Don River into the Azov Sea varied from 8 000 tonnes to 30 000 tonnes, from the Kuban River – from 12 000 t to 33 000 t, and from the Mius River – from 200 to 1 300 t. Mineral nitrogen discharge from the Kuban River water is comparable with that from the Don River, though the water discharge of the Kuban is only half that of the Don. This shows more intensive pollution of the Kuban River by nitrogen. The transport of mineral nitrogen by the Mius and other rivers is dozens and even hundreds times lower.

During the period 1981-2000, the volumes of mineral phosphorous discharged into the Azov Sea constituted: from the Don River – from 1 400 to 2 000 t, from the Kuban River – from 100 to 400 t, and from the Mius River – from 20 to 100 t. The ratio of mineral phosphorous to total phosphorous varied from 1:2 to 1:3. In the 1980s, the volume of the phosphorous transport in the Don Basin increased by a factor of 3, and in the Kuban Basin it increased by a factor of 2 compared to the background period. In the 1990s it remained at the level of the 1980s. The transport of mineral phosphorous by the Mius River decreased by a factor of 2 in the 1990s compared to the 1980s.

According to assessments made by FAO experts, the annual economic damage of *Mnemiopsis leidyi* to the states of the Black Sea coast equals $250,000. During the period of 1981-2000, the instability of the marine ecosystem was discovered; the high intensity of the introduction of alien species (approximately one species a year) caused changes in the productivity of deepwater and bottom marine communities of

Table 22 Variation in the levels of organics in the Sea of Azov (The Taganrog Bay), mg/m^3

	1958-1968	1969-1976	1977-1987	1988-1998
Mineral nitrogen (N_{min})	81-161	129-242	125-325	102-174
Mineral phosphorous (P_{min})	6.2-10.5	8.1-11.3	8.7-12.7	9.7-20.2
Total nitrogen (N_{tot})	1 150-1 293	906-1 249	1 079-1 393	774-659
Total phosphorous (P_{tot})	97.7-104.3	70.3-88.3	47.3-64.8	38.9-62.4
Silicon	604-999	471-980	526-961	521-986
N_{min}:P_{min}	13.4:10.3	16.9:21.4	12.9:25.5	10.5:8.6
N_{tot}:P_{tot}	11.8:12.4	12.8:14.1	22.8:21.4	19.8:10.6
N_{org}:P_{org}	11.7:12.1	12.5:13.1	25.3:20.5	23.0:11.5

(These are the lower and upper limits. There are no analogical published data for the Black Sea)

the Black Sea. It can be stated that changes of the ecosystem state, when the trophic status increases in the course of the eutrophication, have upset the stability of ecological niches formed by invasive highly-productive species, which are most adapted to new conditions. Ballast water was a main source of the introduction of alien species during that period.

In fact every introduced species can have both positive and negative effects on local species. For example, brown alga, *Desmarectia viridis* introduced from the North Atlantic excretes cell sap, which destroys other alga species. This feature has not yet been studied in the Black Sea, however. Diatom alga, *Rhizosolenia calcar-avis,* introduced from the boreal part of the Atlantic, is one of the phytoplankton species that causes water bloom in the Black Sea. This species produces more negative than positive effects as it is not consumed by zooplankton, and pelagic fishes like anchovy avoid *Rhizosolenia* blooming areas. It can have positive effect as well, however, such as producing oxygen. The Bivalve mollusk, *Anadara inaequivalvis (Cunearca cornea),* was introduced into the Black Sea from the coast of the Philippine Islands in 1981, then it penetrated into the Azov Sea. *Anadara inaequivalvis* is a self-acclimatiser, resistant to changes in oxygen regime in bottom water. It survives under conditions of hypoxia when other mollusks die. In the Azov Sea, *Anadara inaequivalvis* forms its own biocenose on sandy and sandy-shell bottom, forcing out some local bivalve species. The rate of growth of *Anadara inaequivalvis* exceeds the rate of growth of an aboriginal Azov species, *Cerastoderma rhombodes,* by 25% on average. Since the shell of *Anadara inaequivalvis* is half as wide again than the shell of *Cerastoderma rhombodes* of the same size, the mollusk is eaten by fish only when 1-2 years old and then becomes unavailable for bottom-feeding fishes of the Azov Sea. The crab, *Rhitropanopeus harrisi tridentate,* introduced from the Atlantic Ocean, is a bottom predator that also eats dead organisms and serves as an additional source of food for bottom fishes such as bullheads, flounder and turbot. In the Black Sea, this introduction has had more positive than negative effects. In the Azov Sea it has forced out the local crab, *Brachynotus sexdentatus,* from its habitat. Unintentional introduction of *Beroe ovata* has a positive impact since these organisms are antagonistic to *Mnemiopsis*, whose population decreased after the introduction of *Beroe ovata* into the local ecosystem. Current data show a cardinal restructuring of copepod taxocene in the Taganrog Bay.

Don

The Don River runoff is less rich in nitrogen compounds than the Azov Sea water mass itself. Subterranean solutions mixing with the pelagic water mass, when bottom sediments are roiled up, are a source for elevated levels of nitrates here.

Danube

It is generally recognised that eutrophication constitutes a problem for the Danube River, even if much more attention is usually paid to the river's contribution to the total nutrients load (and hence to eutrophication) of the Black Sea.

With regard to the environmental impacts of eutrophication, the Joint Danube Survey (JDS) collected some interesting data in 2001[2]. Concerning macrophytes, a clear dominance of higher plants, i.e. free floating and floating leafed plants, was observed particularly in the lower Danube from 537 river km to the delta. The dominance of these two plant groups is determined by light availability (which, in turn, depends on transparency) and by nutrients. The majority of the plant species collected during the JDS are indicators of eutrophic conditions and others such as *Ceratophyllum demersum, Potamogeton crispus* and *Zanichella palustris* are common signals of significant nutrient loads. The species group of Characea (Phycophyta) usually serves as an indicator of oligotrophic (low in nutrients) habitats, providing high transparency values. Such preferred conditions occurred in some parts of the Iron Gate Reservoir where this specific group could be found.

Phytoplankton biomass and, specifically, the concentrations of chlorophyll-a were also assessed. High values of biomass/chlorophyll-a indicated eutrophic conditions in the middle Danube reach, particularly downstream of Budapest. For the tributaries, the highest concentrations of phytoplankton biomass were found in the Iskar, the Velica Morava, the Ipoly, and the Sio, where high eutrophic status was accompanied by high nutrient concentrations and oxygen-hypersaturation. Despite the fact that the Jantra, the Russesky Lom, the Arges, the Siret and the Prut were also found to have high concentrations of nutrients or biodegradable organic matter, the phytoplankton biomass was found to be low, probably due to retarding or toxic effects. In contrast, a high concentration of phytoplankton biomass was observed in the Drava,

[2]The Joint Danube Survey was conducted from August to September 2001 and has produced a consolidated picture of the Danube and its major tributaries in terms of water quality, providing comparable data about the entire course of the river on over 140 parameters.

despite the low concentration of nutrients. Chlorophyll-a concentration was also measured by the Trans-National Monitoring Network (TNMN)[3] in the 1996-2000 period. Spatial coverage of the Danube Basin by TNMN data is not complete, however, as only the upper part of the Danube and the main tributaries were monitored between 1997 and 2000, while few data were obtained from the Bulgarian section. For the upper part of the Danube, statistical values resulted the I-III class[4]; results from the lower part of the Danube were in class I-III as well. Among the tributaries, only the Sio River was in class IV.

Other indicators commonly used to assess the environmental impacts of eutrophication were evaluated by the TNMN. In particular, dissolved oxygen concentrations generally showed positive results, with only 7.4% of values below the quality target in the Danube River, and 8.6% in selected tributaries. Oxygen concentration decreased from the upper to lower part of the Danube River, reaching the lowest values in the section from Danube Bazias to Danube-Novo Selo/Pristol. From the tributaries, low oxygen content was also identified in those located in the lower part of the river basin.

Biochemical oxygen demand (BOD) data indicated that 13.3% of the values were above the target in the Danube River (mainly in the middle and in the lower sections), and 35.9% were above the target in the tributaries. Organic pollution expressed by BOD increased along the Danube, reaching its maximum in the section from Danube-Dunafoldvar (rkm 1560) to Danube-Pristol/Novo Selo (rkm 834). Tributaries most polluted by degradable organic matter were Morava, Dyie and Sio in the upper/middle part, and Russenski Lom and Arges in the lower part.

Suspended solids, which give a measure of the turbidity of water, slightly increased in content from the upper to the lower Danube section. Some of the tributaries showed significantly higher concentrations of suspended solids than the Danube River itself (Tisza, Russesky Lom, Arges, Siret and Prut).

In general terms it can be noted that for the 1992-1996 period, total nitrogen load in the Danube River was estimated to be between 537,000 and 551,000 tonnes per year, depending on the estimates for removal by de-nitrification, while total phosphorus load was 48,900 tonnes per year. The size of these loads is large compared to other important rivers in Europe, such as the Rhine or the Seine.

Dnipro

Eutrophication in the Dnipro has developed as a result of the following factors: large organic and nutrient pollution loads entering the Dnipro Basin water bodies in the territories of the three riparian countries, excessive flow regulation, and the presence of extensive shallow-water sections in the Dnipro reservoirs. The current status of Dnipro waters in Ukraine is presented in Table 23 from the National Report on the Status of the Environment in Ukraine (2001):

Table 23 Current status of surface waters in Ukraine (extract)

Waterbodies	Trophicity (dominating type)*	State value of ecosystem
Dnipro	in winter: oligotrophic; in summer: off Nedanchichi village - eutrophic; Kherson, Nova Kakhovka - meso-eutrophic.	Stressed environment
Tributaries of the Dnipro	Oligotrophic: r. Styr; Mesotrophic: r. Mokra Moskovka; Meso-eutrophic: r. Ustja; Eutrophic: rr. Desna, Ros, Irpin; Eu-polytrophic: rr. Teteriv, Unava.	rr. Styr, Ustja, Irpin, Unava, Desna, Ros - stressed environment; r. Mokra Moskovka - stressed environment with elements of degradation
Reservoirs:		
Kyjivske	Meso-eutrophic - eutrophic	Stressed environment
Kanivske	Mesotrophic -eutrophic	Stressed environment
Kremenchukske	Mesoeutrophic; in summer, off Svitlovodsk - eu-polytrophic.	Stressed environment
Dniprodzerzhynske	Meso-eutrophic	Antropogenically stressed environment
Dniprovske	Oligotrophic- Mesotrophic	Antropogenically stressed environment with impairments in spring
Kakhovske	Mesotrophic - eutrophic	Antropogenically stressed environment

Notes:

*Trophicity (dominating type)	Phytoplankton biomass, mg/l
oligotrophic, oligo-mesotrophic	<0.5
mesotrophic	0.5-1.0
meso-eutrophic	1.1-2.0
eutrophic	2.1-5.0
eu-polytrophic	5.1-10.0
polytrophic	10.1-50.0
hyperpolytrophic	>50.0

Eutrophication can result in the following impacts:

- Deterioration in water quality due to intensive algal blooms;
- Changes in redox capacity;
- Changes in the structure and functions of aquatic ecosystems;
- Changes in species composition and the productivity of native fish species.

The diagram below illustrates how this issue is linked to other transboundary issues (Figure 14).

The impacts of this issue are linked closely with those of a number of other issues including changes in the groundwater regime, flooding events and elevated groundwater levels, and modification and loss of ecosystems and ecotones. The impacts of other water resource

[3] The Trans-National Monitoring Network has collected data on physicochemical and biological determinants in the 1996-2000 period.

[4] The following classification scale was used: class I< or = 25 µg/l; class II < or = 50 µg/l; class III < or = 100 µg/l; class IV< or = 250 µg/l; class V > 250 µg/l

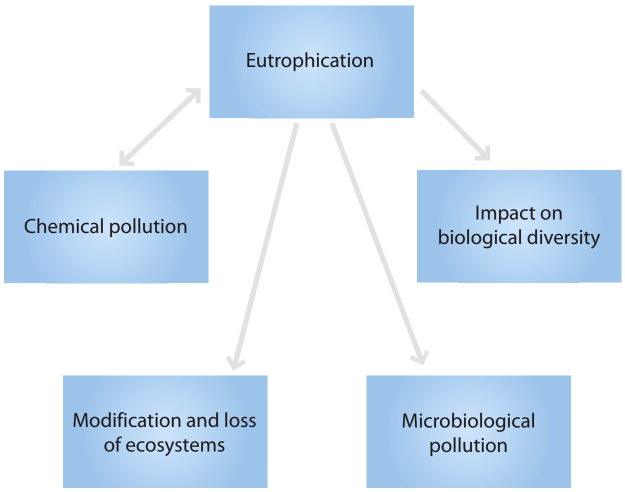

Figure 14 Linkages between eutrophication and other transboundary issues

pollution issues such as suspended solids, chemical pollution and microbiological pollution are also closely linked.

Deterioration of water quality due to intensive algal blooms.
Reduced flow circulation and extensive shallow-water sections in the reservoir chain in Ukraine have intensified the effects of water pollution in the Dnipro Basin. The most visible indication of pollution is the increased frequency of algal blooms related to high loads of nutrients (especially nitrogen and phosphorus) entering the Dnipro and its reservoirs. Within Ukraine, the total area of shallow-water sections in the reservoir chain is 1,341 km^2 (Table 24). Of that, aquatic vegetation covers 480 km^2 with a total mass of over 300,000 tonnes/year. Higher aquatic plants (reed, rush, cattail, etc.) occupy approximately one-third of the total shallow-water area. Reduced water circulation and expansion of shallow-water sections, however, frequently leads to (virtually annual) algal blooms, stimulated by high loads of nutrients (nitrates and phosphates) received by the Dnipro reservoirs. As a result of this, large quantities of dead algae fall to the bottom, representing a source of secondary pollution. Shallow-water sections are also conducive to siltation and swamping, leading to the excessive growth of higher aquatic plants and blue-green algae.

Table 24 Shallow-water sections in the Dnipro reservoirs

Reservoir	Area	
	km^2	% of area
Kyiv reservoir	312	34.0
Kaniv reservoir	167	26.0
Kremenchug reservoir	410	18.0
Dniprodzerzhinsk reservoir	182	32.0
Dniprovsky reservoir	160	39.0
Kakhovka reservoir	110	5.1
Total	1 341	19.1

Changes in species composition and productivity of indigenous fish species.
Acute and major changes in the condition of aquatic ecosystems have been associated with the construction of reservoirs in the Belorussian part of the Dnipro Basin. Flowing rivers have been converted into stagnant water bodies with altered flow and temperature regimes, resulting in changes in species diversity. Valuable indigenous species have disappeared and have been substituted by opportunistic species of low or no value.

In Ukraine commercial fish yields significantly increased by up to 20,000-23,000 tonnes immediately after the construction and filling of the reservoir chain. However, valuable fish species including sturgeon, herring and sabre carp (*Pelecus cultratus L.*) have virtually disappeared since this period and currently only can be found in the Dnipro Estuary. Semi-submerged vegetation thickets have intensively developed in the shallow-water sections over the course of the operational life of the reservoirs. The high density of this vegetation affects light and air penetration, causing anoxic conditions in the bottom water layer, thus reducing the fish spawning value of the ecosystem. Spawning and fattening areas in the Dnipro and its reservoirs have been reduced by three-fold.

Regional analyses and trend of eutrophication processes

Period up to the 1960s:
This period was characterised by moderate growth in population size and water consumption for domestic, agricultural and industrial purposes. There was only insignificant water flow regulation in the main river basins for the purposes of energy production, irrigation and transport.

Sewerage water treatment systems and agriculture practices did not provide for the reduction of the influx of nutrients to the Danube, Dnipro and Don Rivers. Nitrogen remained the limiting nutrient for the algae blooms in the fresh and marine water systems.

Period from the 1960s up to the 1990s:
Stable population and water consumption for domestic and industrial purposes characterised this period. Strong regulation (dams construction) of the water flow in the Dnipro, Don and Kuban Rivers for the purposes of energy production, irrigation and transport was undertaken during this timeframe. Rapid growth (up to ten times) of fertilizer usage occurred in the Black Sea Basin including the Danube,

Dnipro and Don River systems. Sewerage water treatment systems and agriculture practices did not provide for the reduction of the influx of nutrients to the Danube, Dnipro and Don Rivers. The Black Sea tributaries and Azov Sea experienced a rapid increase of nitrogen influx from rural territories. Phosphorous became the limiting nutrient for the algae development in the Black Sea Basin. Harmful algae blooms became evident in the Black Sea Basin.

Period from the 1990s through the present:

This has been a relatively stable period in terms of urbanisation and agriculture practices in the Danube Basin. The Don and Dnipro Basins have experienced stable population and water consumption levels, and a significant reduction fertilizer usage. This has resulted in a reduced influx of nitrogen to the fresh and marine water systems from rural areas, so that nitrogen became the limiting nutrient for the algae growth in the Black Sea waters. Sewerage water treatment systems and agriculture practices do not allow reduction of the input of nutrients to the Danube, Dnipro and Don Rivers. There has been little reduction of the eutrophication phenomena in the Black Sea Basin.

Forecast for coming decades:

If the projected figures for surface water extraction provided by eight Danube countries in 1998 are representative, it can be anticipated that the overall volume extracted from the Danube Basin could increase by approximately 100% between 1997 and 2020. The extraction of raw water from the Danube River system, however, will depend on the quality and availability of surface water at the river stretches and locations where the water is needed.

If the projected figures for wastewater discharge provided by nine Danube countries in 1998 are representative, it can be anticipated that the total volume discharged into the Danube River system could increase by about 50% between 1997 and 2020.

Implementation of the best available technologies and best environmental practices in the states of the Danube Basin is anticipated. This would result in a reduction of the nutrient influx and trophic level of the Danube River system. Significant increase of fertilizer usage and water consumption for irrigation purposes in the Dnipro and Don River Basins is forecast. The treatment facilities of settlements' sewerage waters and agriculture practices will not suffice to reduce the influx of nutrients, resulting in an increase in the trophic levels of these basins. Phosphorous will become the limiting nutrient for algae growth in the Black Sea waters. The trophic level will grow and harmful algae blooms will therefore expand in the Black Sea Basin.

Economic, health impacts and other social and community impacts

Pilot assessment of socio-economic damage of eutrophication in the Ukrainian part of the Black Sea Basin (pilot version)

Over the last 30 years the environmental quality of the Black Sea has deteriorated due to the eutrophication of the waters, resulting in alarming algal overgrowth. Between 1973 and 1990, fish deaths were estimated at five million tonnes, representing 2 billion USD at market cost. A further consequence is that tourist visits to the Black Sea coast have decreased, leading to economic losses for the tourist industry. A study performed within the framework of the Black Sea Environmental Programme (BSEP) estimated that in 1995 the annual economic loss due to tourist disaffection in this region was close to 360 million USD for a 10% decrease in the environmental quality. Thus, the annual losses due to Black Sea environmental problems, including eutrophication, could be approximately estimated as 500 million USD.

Table 25 The scenario trophic levels of the Black Sea main river basins

Basins	Years			
	Till the 60th	Since 60th till 90th	Since 90th till the present time	Coming decades
Danube and its tributaries	I - II	I – III	I - III	I - II
Dnipro and its tributaries	I - II	I-III	I-II	I - III
Don and its tributaries	I - II	I - IV	I - III	I - IV

For the purposes of this study, additional research was carried out to assess different impacts of eutrophication at the local level. Socio-economic damage caused by eutrophication is understood to be a sum of additional expenses spent to obtain products and services of proper quality in the industrial, agricultural and municipal sectors. The conception of seasonal changes of water quality and the influence of these changes on the costs of services and products and on the quality of the resources (expressed in monetary value) is the basis of the assessment of the above-mentioned additional expenses.

The methodological framework of the present study consists of research conducted by the University of Essecs team and the research described in the Methodology of Assessment of the Damage of the Consequences of the Emergency Situations of Technogenic and Natural Origin, studies of the National Academy of Ukraine, and on the recommendations of the Ministry of Environment of Ukraine in environmental economics from 1994 – 2001.

This present study is one of the first attempts to assess, in economic terms, damage caused by eutrophication to the economy of Ukraine. Geographically, the scope of the pilot study is limited to the 5 Southern regions of Ukraine (Republic of Crimea, city of Sevastopol, Odes'ka, Mykolaevs'ka and Khersons'ka regions); methodologically, the study is limited by the scarcity of data, novelty of the approach and limited time and space for reporting. Results obtained should be considered tentative and further research is obviously needed.

Main damage indicators:

1. Reduced commercial values of the water bodies (fisheries and other water bodies products);
2. Reduced biodiversity of the water bodies;
3. Increased costs of drinking water treatment;
4. Clean-up costs of waterways (dredging, weed-cutting);
5. Reduced recreational and amenity value of water bodies for water sports, (bathing, boating, windsurfing, canoeing), angling, and general amenities (picnics, walking, aesthetics);
6. Net economic losses for commercial aquaculture and shellfisheries;
7. Negative ecological effects on biota (arising from changed nutrient status, pH and oxygen content of water), resulting in both changed species composition and loss of key or sensitive species;
8. Costs of legislation compliance arising because of negative impacts of nutrient enrichment.

Assessment of the indicators:

(Methods of calculation are provided in the Annex; only the monetary assessments are presented here.)

1. Reduced commercial values of the water bodies (fisheries and other water bodies products)

A reduction of commercial value has been taking place during the past 30 years with the increasing anthropogenic pressure on the Dnipro Basin and Ukrainian share of the Black Sea Basin. This process takes place with an increased efficiency, and eutrophication plays a significant role in it. Impact of the eutrophication has a seasonal character and may be, by our estimation, assigned a range of 5 – 7% of total loss. Thus the annual damage is estimated to be: D_1 = 2.1945 mln UAH or 0.41 mln USD (by rate UAH /USD).

2. Reduced biodiversity of the water bodies.

The economic value of the decrease in biodiversity has been assessed on the basis of provisions of the Cabinet of Ministries of Ukraine and taking into account studies conducted by experts. The decrease of one species is assessed on the basis of the average number of individuals, or, if the above is not possible, on the basis of the average costs of maintaining one species' perseverance, which is 20 mln USD (Reimers approach, 1994). (*Eudontomyzon mariae Berg, Acipenser nudiventris Lovetzky, Huso huso ponticus Salnikov et Malatski, Umbra krameri Walbaum,Vimba vimba tenella, Barbus barbus borysthenicus Dybowski, Chalcalburnus chalcoides mento, Gobio uranoscopus, Barbus tauricus Kessler, Hippocampus guttulatus microstephanus Slastenenko, Lucioperca marina, Gymnocephalus schraetser, Zingel zingel, Zingel streber streber, Callionymus belenus Risso, Acipenser ruthenus Linnaeus, Umbrina cirrosa, Trigla lucerna Linnaeus*).

Based on the described approach, annual damage is estimated to be: D_2 = 57.24 mln UH[5] or 10.78 mln USD.

3. Increased costs of drinking water treatment.

The costs of drinking water treatment were assessed on the basis of the average cost of water to the consumer in the municipal sector and the volume of water consumption in the regions affected by eutrophication.

Experimental studies show that eutrophication damage is meaningful for the southern part of Ukraine during 4 months in the year. Using the same approach as when calculating the increase in fisheries costs, the value of the coefficient is assessed to be 0,945. Thus, economic damage caused by eutrophication via increased costs of drinking water for the region equal D_3 = 7.2402 mln UAH or 1.36 mln USD annually.

4. Clean-up costs of waterways (dredging, weed-cutting).

Costs were assessed based on the data of the enterprises involved in the clean-up works of the water bodies and waterways. The majority of such work is carried out in Ukraine by the "Ukrrechflot" company. The annual assessment is calculated as: D_4 = 0.2 mln UH or 0.038 mln USD.

5. Reduced recreational and amenity value of water bodies for water sports (bathing, boating, windsurfing, canoeing), angling and general amenities (picnics, walking, aesthetics).

This indicator is difficult to calculate since the majority of such changes in the priorities of the tourists are not reflected in the statistics. Several recreational industry studies, however, show a relationship between a reduction in tourist visits to a water body and eutrophication. We assume that the majority of economic damage is borne by the small private businesses serving the tourists. Literature shows that the income may decrease by up to 10-15% during an algae bloom. Thus, the assessment of the damage D^5 is assesed as: D_5 = 0.43 mln UAH or 0.81 mln USD.

6. Net economic losses for commercial aquaculture and shellfisheries.

Losses for commercial aquaculture are directly connected with changes in habitats. Shellfish yield has dropped by 7 times compared to the 1970 level. Aquaculture and shellfisheries are scattered and non-organised in the Ukrainian part of the Black Sea Basin, however. As a result, statistics are scarce and this assessment is based on experts' judgment.

Eutrophication impacts on the decrease of aquaculture income are assessed to be 8-12%. Decrease of the area of traditional aquaculture is

[5] *Damage is quite significant; however it represents "monetary value" approach towards biodiversity decrease that does not have "reverse dynamics" in the future regardless any financial and organisational efforts of the humans.*

assessed according to the national standard to be 17,000 per ha. Thus, eutrophication impacts on aquaculture and shellfisheries may be assessed as: D_6 = 0.29 mln UAH or 0.05 mln USD.

7. Negative ecological effects on biota (arising from changed nutrient status, pH and oxygen content of water), resulting in both changed species composition and loss of key or sensitive species.

It is complicated to assign monetary values to negative impacts on biota, in part because they are reflected already in the results of economic activities associated with the water bodies (e.g., decrease in fisheries, biodiversity and commercial aquaculture). For this report, negative consequences to the biota have been assessed by analysing environmental protection costs at the regional level and by defining the weight of the costs for preservation of the biodiversity of the water bodies, with the consideration of the relative value of eutrophication. Expert assessment suggests that for the protected areas in Ukraine, the impact of eutrophication on decreased biodiversity of the water bodies is 30-45% (...2002). Thus, negative ecological effects on biota are assessed as: D_7 = 17.22 mln UAH or 3.24 mln USD.

8. Costs of legislation compliance arising because of negative impacts of nutrient enrichment.

The costs of legislation compliance arising due to nutrient enrichment have never been studied and are not reported in the official statistics. According to the assessment of the officers of the Main Ecological Inspection of the Ministry of Environment of Ukraine, these costs constitute not more then 10% in seasonal form (where the season is the whole eutrophication cycle, namely for the 8 months of March through October). Therefore, these costs are assessed to be: D_8 = 0.75 mln UAH or 0.14 mln USD.

The total value of the economic damage resulting from eutrophication impacts for the 5 studied regions in Ukraine is 85.647 mln UH per year, or 16.13 mln USD. This figure exceeds the income portion of the consolidated budget of the environmental protection funds of Ukraine (including the state fund and regional and local funds) by two times, clearly illustrating the necessity of tackling the eutrophication problem on the national, regional and international levels. *This pilot assessment is in line with the internationally-recognised assessment of environmental damage to the regional economy as 500 mln USD annually and represents only a portion of the research on economic damages of eutrophication*.

Health impacts and other social and community impacts

In addition to the health impacts from Harmful Algae Blooms (HABs) resulting from eutrophication described in Section 1.3.4.3, local authorities in some specific areas are forced to use treated eutrophic waters for drinking purposes, posing a threat to human health. There are two major health risks associated with using such waters:

1. Risks linked to the presence of organic matter: Treating raw water with high levels of organic matter is always technically difficult. It can lead to the creation of carcinogenic by-products (Trihalomethanes (THMs), other chlorinated components or ozonides) as a result of their reaction with disinfectants. If the water is eutrophic, then in addition to the organic matter that would be present under normal circumstances, there will also be the organic matter produced by the cyanobacteriae (toxins and intracellular materials). An apparent association between bladder cancer and THMs has already been demonstrated. As chlorinated water contains a large number of by-products, however, it is not possible from such epidemiological studies to conclude that specific THMs are human carcinogens.

2. Risks linked to the presence of specific cyanobacteria in fresh waters: When eutrophication leads to the development of cyanobacteria that are potentially toxic, the elimination of these toxins is complex. When faced with eutrophication of a water reservoir, the best option, where possible, is to rely on an alternative water supply source. If it is not possible, then some changes can be made to the existing treatment chain, but there is no guarantee that the end product will be completely safe. It is necessary to inform the receiving population of the potential risks and distribution of bottled water to the population at risk can be an option to consider.

Scoring and list with justification of the priority impacts for the Black Sea Basin

Environmental impacts

GIWA Methodology enables the implementation of expert qualitative assessment procedures to rank the importance of factors if there are not sufficient quantitative data available. The ranks of relative importance, intensity or magnitude of different factors or activities are chosen in accordance with Saaty's fundamental scale. According to this approach, a rank of zero is given to the activity (impact, factor) that has no importance for the issue under question. The activity (impact, factor) of the lowest importance gets a rank of 1. Ranks of other activities are introduced in accordance to the pair-wise comparisons based on the experts' experience and the scale shown in Table 26.

The national experts' points of view on the relative importance of different indicators for the environment impacts of eutrophication are listed in Table 27 and 28.

Socio-economic impacts

There are many societal impacts of eutrophication through HABs resulting in significant economic commitments in both the EU and the Black Sea sub-region toward reducing threats to local economies, living resources and public health. The human health threat posed by HAB toxin production is by far the most important, exerting a high cost due to necessary monitoring programmes for toxins in shellfish, fish, and drinking waters designed to reduce public exposure. Both acute illnesses and mortality are now well established, while long-term debilitating symptoms associated with chronic exposures to low toxin levels, although of great concern, are less known and subjected to increasing investigation. In addition to direct human health concerns, public perception of coastal health in general, and thereby safety for consumers and coastal inhabitants more specifically, is intimately linked to water color, clarity and odor; fish and shellfish abundance; and governmental advisories for unseen microbes and toxins.

Table 26 Saaty's fundamental scale

Intensity (rank) of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Putting a cost on eutrophication as an environmental problem is a complex task for the simple reason that there is no absolute definition of when nutrient enrichment becomes a problem - that is, when it has adverse effects. Algal and higher plant growth is determined by a combination of interdependent hydrochemical, geographic and climatic factors, and so a given level of nutrients in one water body may give rise to adverse effects with associated costs, but in another water body, or the same one at a different time, there may be no effects and thus no costs. Moreover, the threshold at which nutrient enrichment becomes a problem varies. The central problem is the nature of the relationships between nutrient enrichment, the resultant effects, and the costs. These can be difficult to define.

Drinking water treatment costs (to remove toxins, algal decomposition products and nitrogen from fresh water for human health and ecological reasons).

Nutrient enrichment and algal blooms incur significant costs for fresh water supply and sewerage treatment operators. Some of these costs

Table 27 Environmental Impacts of Eutrophication of the Black Sea basin

Impact indicators	Years		Environmental Impacts		
	1960-1970	1980-1990	Adverse changes in structure and functioning of the water ecosystems	Reduction in biodiversity and in fish resources	Damaging and destruction of habitats
Algae blooms					
- abundance	North-West Black Sea	North-West Black Sea	7	5	5
- timing	spring-summer, 12 events	spring-summer, 42 events	5	3	3
- duration	0.5 month	0.5-1.5 months	1	1	1
Change in dissolved oxygen concentration	Hypoxic area was about 7 700 km^2 in 1996	Hypoxic area was about 14 000 km^2 in 2 000	5	5	5
Change in nutrient concentration		Increase of nitrates concentrations in two-three times	7	3	3
Increased water turbidity			1	1	1

Table 28 Environmental Impacts of Eutrophication of the Azov Sea basin

Impact indicators	Years		Environmental Impacts		
	1960-1970	1980-1990	Adverse changes in structure and functioning of the water ecosystems	Reduction in biodiversity and in fish resources	Damaging and destruction of habitats
Algae blooms		Azov Sea			
- abundance	Average part	Average part	6	5	7
- timing	summer	summer	4	5	3
- duration	0,5-1 month	1 month	1	1	1
Change in dissolved oxygen concentration	?	?			
Change in nutrient concentration			7	7	6
Increased water turbidity			7	7	7

are for complying with established national and European regulations, especially for nutrient concentrations, while others relate to the adverse effects of algal blooms and their decomposition products. In reservoirs, the effects of eutrophication can be costly, particularly if they mean the closure of treatment plants. In the process of water purification, filtration and straining measures can cope with large numbers of small algae, but can become blocked when large algae are present, thus reducing their effectiveness for water treatment. When purification has to be stopped for filter cleaning, supply problems can occur, with consequent increased costs for water companies and receiving households and/or shareholders of water companies.

Reduced recreational and amenity value of water bodies for water sports (bathing, boating, angling) and general aesthetics.

Many standing and running fresh and marine water bodies are used extensively for recreational and amenity purposes, such as bathing, boating, windsurfing and canoeing, and for waterside activities, such as angling, dog-walking, rambling and picnics. Eutrophication results in a loss of recreational and amenity value, particularly if water becomes turbid, emits unpleasant odours and is affected by algal blooms. Such blooms may be simply unpleasant, with green slimy margins to the water, or toxic if blue-green algae are present. But such blue-green algal blooms do not affect all recreational users in the same way. At high risk of harm are those engaged in swimming, diving, wind-surfing and water-skiing. At medium risk are canoeists, sailors and walkers, and at low risk would be those engaged in boating and pleasure cruising (some of whom may not even notice the presence of a blue-green algal bloom). There is no national database recording how eutrophication affects the recreational and amenity value of water bodies.

Economic losses for commercial aquaculture, fisheries and shellfisheries.

Although the eutrophication of lakes and rivers increases the biomass of fish present, the associated changes in species composition due to ecosystem changes frequently result in a reduction in the economic value of the fishery. In addition, shell-fisheries can be adversely affected by toxins from algal blooms and extreme eutrophication can result in deoxygenation that kills all aquatic life. Thus, the livelihoods of those involved in commercial fishing can be adversely affected, even though revenues from some fishing activities (e.g. recreational) may rise. Commercial fisheries have declined in the Dnipro reservoirs due to eutrophication.

Health costs to humans.

Eutrophication poses three potential health risks to humans, livestock and pets. These arise from the high nitrate content of drinking water, toxic algal blooms and an enhanced presence of bacterial pathogens. Algal blooms in eutrophic water bodies pose a potential health hazard to humans and animals in contact with the water. There are 25 species of cyanobacteria that produce a variety of toxins including neurotoxins, hepatotoxins and lipopolysaccharides. A further risk arises amongst people prone to allergic reactions coming in contact with water containing cyanobacterial blooms. In addition, water high in dissolved organic carbon, a byproduct of dense algal blooms, can produce potentially carcinogenic and mutagenic trihalomethanes when disinfected by chlorination. In the tropics, eutrophic waters can contribute to the spread of diseases such as cholera and typhoid, and produce an environment in which mosquito larvae flourish, so encouraging malarial infection. As these events appear to be rare, these costs in this category can be taken to be close to zero.

Expert assessments of socio-economic damage of eutrophication for Ukraine are presented in Tables 29 and 30.

Table 29 Socio-Economic Impacts of Eutrophication of the Black Sea basin

Impact indicators	Economic Impacts	Health Impacts	Social and community Impacts
1. Reduced biodiversity of water bodies	5	0	7
2. Drinking water treatment costs	4	2	4
3. Clean-up costs of waterways	1	0	1
4. Reduced recreational and amenity value of water bodies for water sports	2	1	2
5. Net economic losses for commercial aquaculture, fisheries, and shell-fisheries	3	1	5
6. Health costs	0	1	0

Table 30 Socio-Economic Impacts of Eutrophication of the Azov Sea basin

Impact indicators	Economic Impacts	Health Impacts	Social and community Impacts
1. Reduced value of waterside dwelling	1	1	1
2. Reduced value of water bodies for commercial uses	0	0	0
3. Drinking water treatment costs	0	0	0
4. Clean-up costs of waterways	4	1	5
5. Reduced value of non-polluted atmosphere	2	0	1
6. Reduced recreational and amenity value of water bodies for water sports	0	0	0
7. Net economic losses for formal tourist industry	2	0	3
8. Net economic losses for commercial aquaculture, fisheries, and shell-fisheries	3	3	4
9. Health of humans	0	2	2

Causal chain analysis

Introduction to methodology

Causal Chain Analysis (CCA) traces the cause-effect pathways from the socio-economic and environmental impacts back to their root causes. The GIWA CCA aims to identify the most important causes of each concern prioritised during the scoping assessment in order to direct policy measures at the most appropriate target to prevent further degradation of the regional aquatic environment.

Root causes are not always easy to identify because they are often spatially or temporally separated from the actual problems they cause. The GIWA CCA was developed to help identify and understand the root causes of environmental and socio-economic problems in international waters and is conducted by identifying the human activities that cause the problem and then the factors that determine the ways in which these activities are undertaken. However, because there is no universal theory describing how root causes interact to create natural resource management problems and due to the great variation of local circumstances under which the methodology will be applied, the GIWA CCA is not a rigidly structured assessment, but should be regarded as a framework to guide the analysis, rather than as a set of detailed instructions. Secondly, in an ideal setting, a causal chain would be produced by a multidisciplinary group of specialists that would statistically examine each successive cause and study its links to the problem and to other causes. However, this approach (even if feasible) would use far more resources and time than those available to GIWA[6]. For this reason, it has been necessary to develop a relatively simple and practical analytical model for gathering information to assemble meaningful causal chains.

Conceptual model of the CCA

A causal chain is a series of statements that link the causes of a problem with its effects. Recognising the great diversity of local settings and the resulting difficulty in developing broadly applicable policy strategies, the GIWA CCA focuses on a particular system and then only on those issues that were prioritised during the scoping assessment. The starting point of a particular causal chain is one of the issues selected during the Scaling and Scoping stages and its related environmental and socio-economic impacts. The next element in the GIWA chain is the immediate cause; defined as the physical, biological or chemical variable that produces the GIWA issue. For example, for the issue of eutrophication the immediate causes may be, inter alia:

- Enhanced nutrient inputs;
- Increased recycling/mobilisation;
- Trapping of nutrients (e.g. in river impoundments);
- Run-off and storm waters.

Once the relevant immediate cause(s) for the particular system has (have) been identified, the sectors of human activity that contribute most significantly to the immediate cause have to be determined. Assuming that the most important immediate cause in our example had been increased nutrient concentrations, then it is logical that the most likely sources of those nutrients would be the agricultural, urban or industrial sectors. After identifying the sectors that are primarily responsible for the immediate causes, the root causes acting on those sectors must be determined. For example, if agriculture was found to be primarily responsible for the increased nutrient concentrations, the root causes could potentially be:

- Economic (e.g. subsidies to fertilisers and agricultural products);
- Legal (e.g. inadequate regulation);
- Failures in governance (e.g. poor enforcement); or
- Technology or knowledge related (e.g. lack of affordable substitutes for fertilisers or lack of knowledge as to their application).

Once the most relevant root causes have been identified, an explanation, which includes available data and information, of how they are responsible for the primary environmental and socio-economic problems in the region should be provided.

[6] This does not mean that the methodology ignores statistical or quantitative studies; as has already been pointed out, the available evidence that justifies the assumption of causal links should be provided in the assessment.

Immediate causes

Nutrients in river discharged into the Black Sea system

From the year 1950 until 2000, the use of mineral nitrogen in fertilizers for agriculture in the 15 EU member states has increased tenfold, from 1 to 9-10 million tonnes.

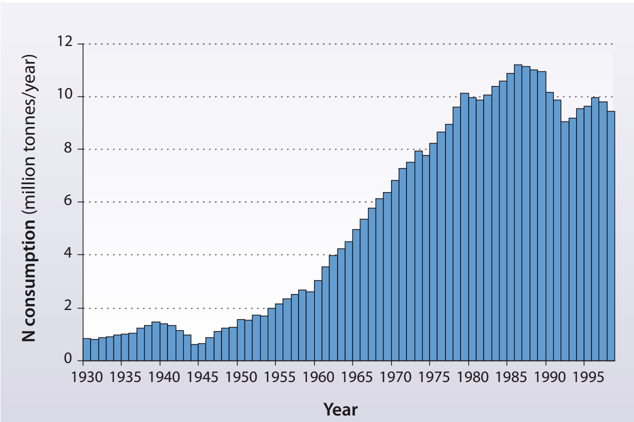

Figure 15 Mineral nitrogen (N) fertilizers consumption – E.U.15 Member States, from 1930 to 1999.

The Black Sea littoral countries also followed this trend in using increasing amounts of mineral nitrogen and phosphorus. During the same timeframe, the amount of nitrogen released by animal husbandry rose to nine million tonnes. The nitrogen pressure on the environment currently reaches 18 million tonnes solely from agriculture. Agricultural practices have also led to a reduction of permanent grassland and other "buffer" areas such as ditches, hedges and wetlands, a situation which favours erosion, run-off and quick drainage of nutrients to the water bodies.

Nutrient loads from rivers and coastal states.

Based on available scientific assessments and findings of the Transboundary Diagnostic Analysis (1995), the overall yearly input of nutrients from human activity amounts to 647,000 tonnes of nitrogen and 50,500 tonnes of phosphorus (Black Sea Pollution Assessment, 1998). These estimates also included the river discharges.

The input of nutrients and other pollutants from land-based sources is reflected in data sets presented in the national reporting to the Black Sea Commission for the period 1996-2000. The available data, although not presented in a harmonised manner, explicitly shows a steady decline in the discharges of wastewaters and individual pollutants and nutrients in the territorial waters of the Contracting Parties.

Table 31 The Estimated Input of Total Nitrogen into the Black Sea

Country	Inputs, thousand tonnes per year			
	Domestic *	Industrial *	Riverine	Subtotal
Bulgaria	2.5	71.0	19.2	92.7
Georgia	0.9	44.4	132.0	177.3
Romania	9.5	31.0	36.3	78.6
Russian Federation	0.4	0.0	62.3	62.7
Turkey	1.6	0.0	0.0	1.6
Ukraine	5.4	0.6	32.0	38.0
Other countries				198.3
Sub Total	20.3	146.9	281.8	647.3

**direct discharges of nutrients to the Black Sea from its coastal zone*

Table 32 The Estimated Input of Total Phosphorus to the Black Sea

Country	Inputs, thousand tonnes per year			
	Domestic	Industrial	Riverine	Subtotal
Bulgaria	0.7	0.0	1.9	2.6
Georgia	0.3	0.3	11.6	11.6
Romania	2.6	1.7	5.7	9.9
Russian Federation	0.5	0.0	6.1	6.6
Turkey	0.4	0.0	0.0	0.4
Ukraine	2.2	0.1	3.6	5.9
Other countries				13.6
Subtotal	6.7	2.0	28.2	50.5

According to the assessment of the Southern Scientific Center of the Academy of Science of Russia, 32.5 thousand tonnes of nitrogen and 3.2 thousand tonnes of phosphorous were discharged by the Don to the Taganrog Bay of the Azov Sea. The impact of the Don discharge on the nutrient content in the Taganrog Bay was the most significant during spring time. This discharge defined the high concentration of nitrogen and phosphorous compounds in the delta of Taganrog Bay: ammonia ions: 70-9-, nitrites – 17-20, nitrates – 520-600, phosphates – 70-80 mg per cubic meter.

Increased recycling/mobilisation, trapping of nutrients, runoff and storm waters.

Based on available scientific assessments and findings of the Transboundary Diagnostic Analysis (1995), the atmospheric input of total nitrogen to the Black Sea is estimated to be 400 thousand tonnes per year and is comparable in magnitude to the total input of this nutrient from rivers, domestic and industrial sources. If these estimates are correct, the air emissions are significant sources of nitrogen input into the marine environment.

Table 33 Emission of nitrogen oxides from the stationary sources in Ukraine

Branches of Industries	Emission (hundred tones)		Change in 2001 versus 2000	
	2000	2001	(hundred tones)	%
Agriculture, Hunting and related services	1.1	1.1	-0.1	-9.1
Mining	13.6	14.5	+0.9	+6.6
Manufacturing	97.0	105.5	+8.5	+ 8.8
Energy production	186.3	184.5	-1.8	-1.0
Construction	1.2	1.4	+0.2	+16.7
Other brunches	20.8	21.2	+0.4	+1.9
Total	320.0	328.1	+8.1	+2.5

Data on the emission of nitrogen oxides from stationary sources of pollution in Ukraine are listed in Table 33.

Analysis and selection of the 2-3 most significant immediate causes

An expert team was used to identify the most significant immediate causes of eutrophication in the Black Sea region. These experts developed separate rankings of the immediate causes of eutrophication for the Black and Azov Seas. Since it was recognized that the immediate causes of eutrophication of the seawaters and of the rivers may be different, separate scores were introduced for these components. According to the Causal Chain Analysis Methodology, the expert team had the task of identifying the causes considered to be the most significant at the basin scale, which would then be further analysed. Expert team opinion is based on published research data and international reports (see: Sources).

The expert assessments of different immediate causes of eutrophication in the Black Sea Basin are presented in Table 34. According to these estimations, the most important immediate causes of eutrophication are "discharges of effluents from agriculture and municipal wastewater" from settlements and "runoff and storm waters from coastal zone" of rural territories.

Sector analysis

Main sectoral causes for agriculture

The greatest sources of diffuse pollution are related to agricultural activities, to households not connected to sewer systems and to atmospheric depositions. Inadequate land use and the excessive application of mineral and organic fertilizers result in high nutrient inputs into the rivers and ultimately into the Black Sea.

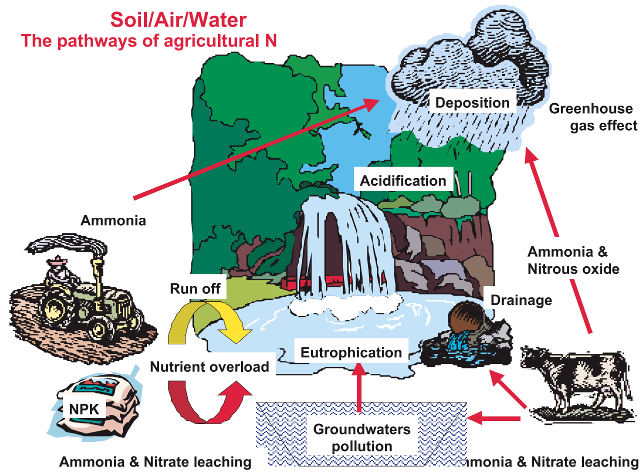

Figure 16 The agricultural nitrogen air/soil/water exchanges and possible impacts.

The quantities of inorganic fertilizers used in those Black Sea states with transitional economies were drastically reduced in the 1990s due to high prices and to the inability of the population involved in the agricultural sector to pay for fertilizers. For example, in Georgia the quantity of inorganic fertilizers used in the Black Sea catchment area constituted 300 - 370 thousand tonnes annually prior to 1989. In 1999, the applied volume of nutrients (N and P) amounted to 39.1 thousand tonnes of N and 36.9 thousand tonnes of P. Demand for mineral fertilizers in Ukraine is estimated at 7 million tonnes a year. Even in the most successful year, demand for mineral fertilizers was not covered by local production. Currently, even though three Ukrainian plants (Vynitsa, Sumy and

Table 34 Immediate Causes of Eutrophication

Assessed area A- sea water B- fresh water		Immediate Causes					
		Discharge of effluents from agriculture and municipal waste water	Discharge of solids	Runoff and storm waters from coastal zone	Increased recycling/ mobilisation of nutrients	Trapping of nutrients	Atmospheric deposition
Black Sea	A	5	1	3	2	3	4
	B	5	1	3	2	3	1
Azov Sea	A	5	3	5	1	2	3
	B	2	3	2	1	2	1

Donetsk) produce approximately 600 thousand tonnes of phosphorus fertilizers a year, this is not sufficient to meet the country's needs. Total application of pesticides was reduced from 62.3 thousand tonnes in 1993 to 46.5 thousand tonnes in 1994. The high prices for fertilizers and pesticides and inability of the population to pay were major causes of reduced loads of discharges from diffuse pollution sources.

The area of arable land in the Dnipro Basin is 283,000 km^2, or 55.4% of the total basin area. Serious structural changes have taken place in the agricultural sector of the three riparian countries of the basin over the last decade, leading to a continuous reduction in the proportion of arable agricultural land compared with total agricultural output. Mineral fertiliser application has significantly increased over recent years, however, and livestock production has stabilised following a period of steep decline. Private sector involvement schemes have been set up, resulting in a 6% increase in the area of farmland allocated for individual farming activities. One of the major causes of the loss of arable land is deterioration of soil quality, with 50% of agricultural land being swamped or acidified due to insufficient levels of lime. Large areas of agricultural land have also been inundated with shrubs. Erosion is also a continuing problem and inherent to agricultural fields located on slopes with gradients of greater than 1.5–2°. This has been aggravated because simple anti-erosion practices, such as lateral slope tillage, have been applied on only a third of this erosion-susceptible land.

Numerous studies also recognise (see: Sources) that agricultural practices that are not friendly towards the environment, and towards water bodies in particular, are deeply rooted in the post-Soviet countries, and, to a lesser extent, in the post-socialist countries, as a heritage of the centralised planned economy of Soviet/socialist times. In order to change the attitudes and introduce agricultural techniques that would reduce nutrient discharge, public awareness must be significantly raised, from the decision-making level down to the agricultural practitioners and farmers.

Main sectoral causes for urbanisation

Municipal sewerage waters are the most important source of sea pollution by nutrients; industrial discharges are less important. For example, demand for municipal biological wastewater treatment facilities in towns and settlements of the Autonomous Republic of Crimea, cities of Mykolaiv, Odesa, and Sevastopol exceeds capacity by 273 thousand m^3 per day. In the centralised water sewer system of the coastal zone settlements, almost 25% of sewer pipelines are dangerously worn out.

Centralised water supply systems are available in virtually all urban areas located in the Dnipro Basin (e.g. in Belarus, 95% of all municipalities are covered by such systems). They are poorly developed in the majority of the rural areas, however, particularly within the Ukrainian part of the basin.

In Ukraine, a centralised water supply service is available in 100% of cities/towns, 89% of townships, and about 20% of rural settlements. Centralised sewerage services are available in 94% of cities/towns, 50% of townships, and about 3% of rural settlements. About 62% of the population is connected to a centralised sewerage service, mainly in the urban areas. The highest level of coverage is provided in the Zaporizhzhia (81.4%), Dnipropetrovsk (74.5%), Sumy (62%) and Kherson Oblasts, as opposed to the Volyn and Rivne Oblasts where coverage is low (less than 27%). According to expert estimates, this coverage is extremely low when compared to Western Europe.

In general, major water supply/sewerage systems are in poor repair and have reached a high level of depreciation. The total length of sewage mains within Ukraine is 33,840.9 km, with about 10% of the pipework reaching the highest level of depreciation. In addition, about 2,160 km is in extremely poor repair and requires urgent replacement. The poor state of municipal utilities in the Dnipro Basin is illustrated by the fact that wastewater discharges from municipal wastewater treatment plants have been recognised as a major (immediate) source of pollution.

The municipal utility sector accounts for a significant proportion of the total volume of effluents received by the Dnipro Basin water bodies. Therefore the state of wastewater treatment plants and related operation/maintenance costs are considered to have a significant effect on the actual treatment level and quality of municipal effluents entering the water bodies of the Dnipro Basin. For example, in Ukraine, the actual capital expenditure in the water utility sector is currently only 15–20% of the required amount. As a result, municipal wastewater discharges accounted for 40%, or over 0.5 billion m^3, of the total amount of insufficiently treated or untreated wastewater received by the basin water bodies in 2001 (over 1.3 billion m^3).

Apart from technical and economic problems, the level of available technologies and willingness of the society to apply these technologies are both very low. Eutrophication is traditionally considered by the local and regional authorities responsible for water quality to be an issue that is not feasible to address:

1. Eutrophication is considered to be an unavoidable seasonal hazard, which is impossible to tackle;

2. Accepting the negative consequences of the eutrophication, authorities often at the same time demonstrate unawareness of the possibilities to manage eutrophication on the local and regional levels.

As a consequence, motivation for eutrophication management is very low. Local effective financial and administrative mechanisms that would decrease the negative impacts of eutrophication on the regional economy and population are practically absent. The public is also unaware of the negative economic, environmental and social impacts of eutrophication, and therefore, is not participating in eutrophication management.

Eutrophication as such is of low concern to the authorities and the public, except for the narrow circle of representatives of the scientific, engineering and educational communities.

Analyses of the sectoral causes of eutrophication in the Black Sea region

The summarised picture of sectoral causes of eutrophication in the Black Sea region is presented in the Conceptual Model of the CCA for the Black Sea Basin (Figure 17).

Root causes

Economic drivers, legal and institutional causes

The past ten years have seen rapid and massive changes in the political and administrative systems of the Black Sea states and in the way in which responsibilities and costs for freshwater and coastal water management are distributed. State domination has been replaced by governance structures based on decentralisation and greater levels of autonomy at the regional level. Water and river management are actually in the hands of several authorities and private individuals, landowners and companies.

Countries in the Black Sea region can be divided into two main groups: the Balkan countries (Bosnia-Herzegovina, Croatia, Serbia and Montenegro plus Albania and Macedonia, which share a very limited part of the Danube catchment area) and the Newly Independent States (NIS), which include Belarus, Georgia, Moldova, Russia and Ukraine. Our further analysis is focused on the last group since it has the most significant impact on the water quality. However, taking into account the basin approach to the water management required by the recent EU Water Directive and other international water initiatives, policy option analysis shall focus only on this second group, which is not linked to the EU Water Directive.

In Black Sea countries, many industrial plants were closed during the last ten years. Industrial restructuring is usually not feasible and shifting to cleaner technologies is even harder; technologies currently used are outdated and highly polluting. Water treatment facilities quite often are unable to meet the demand in water maintenance because of out-of-date methods and treatment technologies, the gap between treated volume and existing demand and low quality of communications.

Decentralisation has often taken place before the establishment of a clear legal framework and the development of institutional capacity for environmental management at the regional level. Basic water laws and regulations have been generally subject to repeated adjustments and modifications. These have made long-term planning and financing difficult and are not in the interest of private investors.

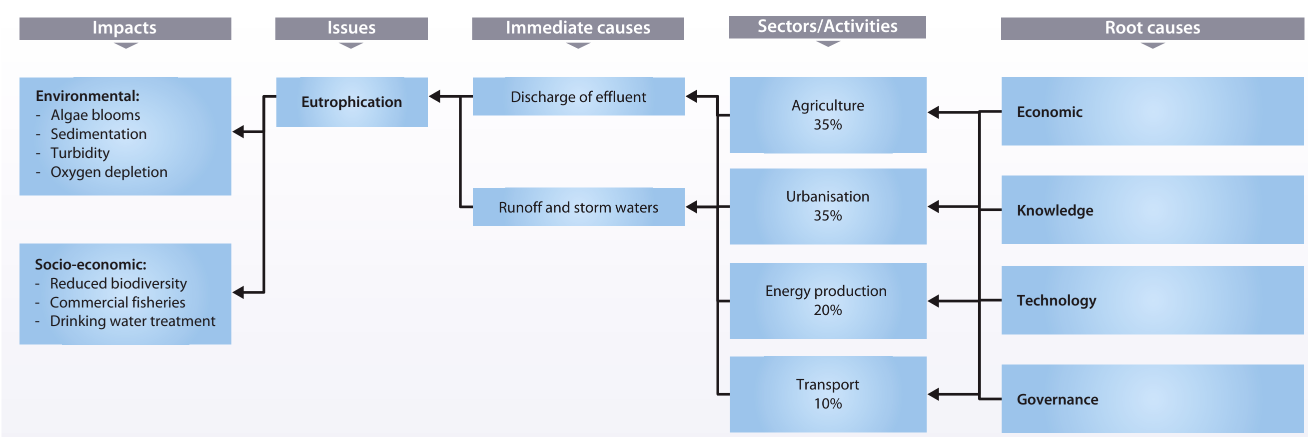

Figure 17 Flow Chart Diagram of the CCA for the Black Sea region

Decentralisation has in some cases been accompanied by disintegration. New ownership structures and the transfer of control of water and sewage facilities to regional authorities have made the system more unstable and decreased the level of security and effectiveness of water resources management. Eutrophication as such is of low concern to the authorities and the public, except for the narrow circle of the representatives of the scientific, engineering and educational communities.

Most of the public authorities across the region point out insufficient funds as the principal reason for their inability to carry out the needed management reforms and infrastructure developments. Since international resources are limited, most regional authorities still rely on support from the state for both construction and maintenance of infrastructure and subsistence operational costs.

A pilot study of the economic damage caused by eutrophication in 5 Southern regions of Ukraine has demonstrated that state financing is insufficient to tackle the problem. Total eutrophication economic damage for the studied region has been roughly assessed as 16.13 mln USD per year. This figure exceeds the income portion of the consolidated budget for environmental protection activities in Ukraine by two times, clearly indicating the necessity of involving private business and international initiatives in solving this acute regional problem.

Economic instruments, including appropriate water tariffs, are a necessary element of effective water management that needs to be strengthened in the whole Black Sea region. The involvement of the private sector in the construction, operation and management of water and wastewater facilities can be an important source of financing, efficiency and innovation.

Finally many public authorities report a severe lack of practical knowledge and skills in water resources management and place this problem at the same level of importance as the lack of finances. This requires both funding and the commitment on the part of the authorities themselves to build up their capacity in this field.

Analysis of current situation and trends based on the EU Water Framework Directive

Black Sea basin countries are not unrelated to the implementation of the EC Water Framework Directive (WFD) for several important reasons. First, each of them receives EU financial assistance in order to improve national water infrastructures/management and the conditions under which such assistance is provided reflect the fundamental principles of the EU water policy. Second, most of the countries are contracting parties to the Danube River Protection Convention (DRPC), the Bucharest Convention, or both. The International Commission for the Protection of the Danube River (ICPDR) and the Black Sea Commission are currently working on the implementation of the Directive. In particular, the Danube countries have committed themselves to making the necessary efforts to implement the WFD within their territory (ICPDR 3rd Plenary Session, 27-28 November 2000), while, from the official point of view, the position of the Black Sea littoral countries is less clearly defined.

It has to be added that a report on harmonisation of environmental legislation of the Dnipro River countries with the legislation of EU Member States has been recently produced within the framework of the Dnipro Basin Environment Programme. The report suggests that the Draft Programme of harmonisation of the environmental legislation of Ukraine with the legislation of the European Union, developed in 2001 under the agreement with the Ministry of Ecology and the Natural Resources Ukrainian Research Institute of Environmental Problems, can be recommended for all three Dnipro River countries. Taking into account that water codes of the three Dnipro countries have a common foundation, as well as the fact that this legislation did not undergo radical changes, the authors underline that there is good reason to believe that there should not be significant differences between the Draft Programme for Ukraine and the ones to be prepared for Belarus and Russia.

Based on their importance for the Dnipro countries, six top-priority documents were selected out of the EU water and environmental legislation and the EU environmental legislation relevant for the water sector, to be compared with national legislation. The WFD was recognised to have the higher priority.

Therefore, taking into account the basin approach employed by the WFD, and the requirement of cooperation with the Black Sea littoral countries in the development of integrated water management in the river basins, a high level of integration and coordination between both riparian countries and the countries lying in the Danube watershed is to be expected in regards to the environmental protection activities, and water management in particular.

International projects and financing: general trends and analysis

Identifying the sources of financing of environmental and water expenditures in the Black Sea countries is quite difficult.

One interesting policy issue is to what extent the countries rely on their domestic funds in financing such expenditures. Among EECCA

(Eastern Europe, Caucasus and Central Asia) countries, the domestic share of total environmental-related-expenditures (EEE) varies widely from country to country. According to the United Nations Economic Commission for Europe (UNECE), Russia, Moldova and Ukraine finance more than 90% of EEE from domestic sources. Georgia seems to be more dependent on foreign sources of financing, which account for 62% of total national EEE.

For many Southern and Eastern European (SEE) countries, foreign sources of financing are playing the dominant role in financing environmental investments. This is especially true for Albania, Bosnia-Herzegovina, and Serbia-Montenegro, while in Croatia and Macedonia domestic sources are relatively more important.

Finally in EU candidate countries, external sources of financing, in particular pre-accession funds of the EU, are relevant especially in small countries (such as Slovenia).

Considering international environmental assistance to the Black Sea region, we have to distinguish between bilateral donors (including individual countries, but also other institutions and organisations such as the European Commission) and International Financial Institutions (IFI) loans. In the 1996-2001 period, the total bilateral environmental assistance to EU accession countries amounted to about 2.5 billion €, and to EECCA countries 0.8 billion €. Environmental assistance to EU accession countries increased in 2000 and 2001 with the pre-accession financial instruments to support investments. Moreover, EU pre-accession funds have been slowly replacing bilateral environmental assistance from individual countries. This trend, coupled with the overall growth in bilateral assistance to EECCA countries, suggests that some "refocusing" towards EECCA has taken place.

The total volume of IFI loans committed to environmental projects in the period 1996-2001 amounted to almost 4 billion € in EU accession countries and 1.3 billion in EECCA countries. Time trends in commitments of IFI loans show larger annual variations due to fewer but larger projects, programming and project development cycles and local conditions (such as the Russian financial crisis in 1998).

Examining per capita figures, we have to note that the EU accession countries have received much more commitments of environmental bilateral assistance per capita than EECCA countries. The most successful beneficiaries were small countries. However, also the candidate counties that have received fewer per capita commitments (the Czech Republic and Hungary) still are better assisted than the highest aided EECCA countries. Thus, although some refocusing towards EECCA has begun, there is still a long way to go before EECCA countries would absorb similar levels of environmental assistance as the EU accession countries in the past.

The difference between the EU accession and EECCA countries is even more apparent when looking at per capita IFI commitments to environmental projects over the period 1996-2001. Among the Black Sea basin countries, Czech Republic is at the forefront of the absorptive capacity of multilateral environmental loans. EECCA countries show instead low per capita commitments that can be attributed to the low demand for environmental investments and to the significant impact of the Russian financial crisis in 1998, from which borrowing capacity of the region is only slowly recovering. Surprisingly, the highest per capita environmental borrowing can be found among some of the lowest income countries in the region (such as Georgia).

Among the SEE countries, the highest per capita level of environmental assistance was received in the 1996-2001 period by Macedonia, followed by Albania and Croatia.

In the EU accession countries, environmental assistance accounted in the 1996-2001 period for a larger share of total assistance than in EECCA countries (21% and 6%, respectively). This indicates a potential for enhancing environmental assistance to EECCA countries without increasing it. However, refocusing priorities in international co-operation programs towards the environment would require a clear demand by EECCA countries themselves that needs to be agreed upon and articulated at the highest levels of the government.

There can be observed no general pattern for division of environmental assistance to different media. In EECCA countries, however, it can be noted that water (supply and sanitation) seems to be a dominant focus of bilateral assistance, while, with regard to IFI loans, the largest sums seem to be associated with environmental components of non-environmental projects financed in power generation and agriculture.

Conclusion

The Black Sea environment is of paramount value in terms of regional development and quality of life for the local inhabitants. It is one of the most, if not the most, important European seas and yet the Black Sea is one of the most anthropogenically-loaded seas in the world.

The Black Sea ecosystem is known to be valuable and diverse, but at the moment it is also considered to be vulnerable as it is experiencing significant pressure from land-based pollution. One of the leading issues of environmental quality deterioration in the region has been identified as eutrophication caused by an overabundance of nutrients and leading to numerous environmental and socio-economic problems.

Analysis of current trends shows that, although nutrient pollution is likely to decrease in the Danube Basin due to the implementation of EU environmental policy, such important tributaries as the Don and Dnipro will still carry heavy nutrient loadings into the southwestern part of the coast. This implies that the whole Black Sea ecosystem will be endangered if necessary efforts are not undertaken at the regional and international level.

Pilot assessment of eutrophication economic damage for the 5 southern regions of Ukraine shows that the figure is twice as much as the consolidated budget of the environmental protection funds of Ukraine**.** This corresponds to the already cited figure of 500 mln USD annual loss caused by environmental quality deterioration in the Black Sea region.

Root causes of eutrophication in the Black Sea Basin are identified as a lack of knowledge and information, insufficient management techniques and low economic incentives to tackle long-term environmental problems. Combined local, regional and international efforts are needed for further research and policy development in order to rehabilitate one of the most valuable marine ecosystems in the world.

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Annexes

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Annex II Socio-economic indicators of the countries of the Black Sea catchment area[1]

AUSTRIA				
	1975	**2001**	**2015**	
Total population (millions)	7.6	8.1	8.1	
Urban pop (%)	67.4	67.4	71.0	
Rural pop (%)	32.6	32.6	29.0	
	1998	**1999**	**2000**	**2001**
GNI per capita (current US$)	26,69	25,70	25,23	23,94
GDP total (billions of current US$)	211.12	209.51	188.72	188.54
Agriculture value added (%)	2	2	2	2
Industry value added (%)	33	33	33	33
	1998	**1999**	**2000**	**2001**
GDP growth (annual %)	4	3	3	1
	1975-2001	**2001-2015**		
Annual population growth rate	0.3	n.a.		

BULGARIA				
	1990	**2000**	**2015**	**2020**
Total population (millions)	8.72	7.95	6.82	6.47
Urban pop (%)	66	67	69	71
Rural pop (%)	34	33	31	29
	1990	**1994**	**1999**	**2000**
GDP per capita (constant 1995 US$)	1716	1503	1443	1544
GDP total (billions of 1995 US$	15.0	12.7	11.6	12.3
Share from agriculture (%)	18	11	17	n.a.
Share from industry	51	33	27	28
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	-4.2	3.6		
Of population (%)	-0.7	-0.6		

BELARUS				
	1990	**2000**	**2015**	**2020**
Total population (millions)	10.26	10.19	9.67	9.51
Urban pop (%)	66	71	73	74
Rural pop (%)	34	29	27	26
	1990	**1994**	**1999**	**2000**
GDP per capita (constant 1995 US$)	3,045	2,172	2,543	2,703
GDP total (billions of 1995 US$	31.1	22.4	25.5	27.0
Share from agriculture (%)	24	15	13	n.a
Share from industry	47	37	39	37
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	-4.0	5.9		
Of population (%)	-0.1	-0.1		

CROATIA				
	1990	**2000**	**2015**	**2020**
Total population (millions)	4.78	4.65	4.62	4.58
Urban pop (%)	54	58	64	67
Rural pop (%)	46	42	36	33
	1990	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	5438	4059	4969	5146
GDP total (billions of 1995 US$	26.0	18.8	21.7	22.5
Share from agriculture (%)	10	11	10	n.a.
Share from industry	34	33	33	33
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	-2.2	2.0		
Of population (%)	0.4	0.0		

BOSNIA AND HERZEGOVINA				
	1990	**2000**	**2015**	**2020**
Total population (millions)	4.31	3.98	4.28	4.24
Urban pop (%)	39	43	51	54
Rural pop (%)	61	57	49	46
	1994	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	439	546	1.479	1.526
GDP total (billions of 1995 US$	1.5	1.9	5.7	6.1
Share from agriculture (%)	36	25	14	n.a.
Share from industry	27	26	25	26
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	48.8	12.4		
Of population (%)	0.1	4.1		

CZECH REPUBLIC				
	1990	**2000**	**2015**	**2020**
Total population (millions)	10.36	10.27	10.03	9.90
Urban pop (%)	74	75	76	78
Rural pop (%)	25	25	24	22
	1990	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	5,270	5,037	5,157	5,311
GDP total (billions of 1995 US$	54.6	52.0	53.0	54.6
Share from agriculture (%)	6	5	4	n.a.
Share from industry	49	45	41	41
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	0.0	0.1		
Of population (%)	-0.1	-0.1		

1 Albania, Italy, Macedonia, Poland and Switzerland, which hold in the basin territories smaller than 2,000 km^2, are not covered by the Annex. Sources: for Austria and Germany -WB Data Query and UNDP, Human Development Report, 2003; for all the other countries - International Bank for Recostruction and Development and the World Bank, Volume II – Country Water Notes and Selected Transboundary Basins, 2003

GEORGIA				
	1990	**2000**	**2015**	**2020**
Total population (millions)	5.46	5.26	4.78	4.58
Urban pop (%)	55	56	61	64
Rural pop (%)	45	44	39	36
	1990	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	1,232	351	493	502
GDP total (billions of 1995 US$	6.7	1.9	2.5	2.5
Share from agriculture (%)	32	52	36	21
Share from industry	33	24	23	23
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	10.6	2.6		
Of population (%)	-0.4	-0.3		

GERMANY				
	1975	**2001**	**2015**	
Total population (millions)	78.7	82.3	82.5	
Urban pop (%)	81.2	87.7	89.9	
Rural pop (%)	18.8	12.3	10.1	
	1998	**1999**	**2000**	**2001**
GNI per capita (current US$)	26,63	25,69	25,13	23,56
GDP total (billions of current US$)	2,144.48	2,103.39	1,866.13	1,846.06
Agriculture value added (%)	1	1	1	1
Industry value added (%)	32	31	32	31
	1998	**1999**	**2000**	**2001**
GDP growth (annual %)	2	2	3	1
	1975-2001	2001-2015		
Annual population growth rate (%)	0.2	n.a.		

HUNGARY				
	1990	**2000**	**2015**	**2020**
Total population (millions)	10.37	9.97	9.25	9.02
Urban pop (%)	62	65	69	71
Rural pop (%)	38	35	31	29
	1990	**1995**	**1998**	**2000**
GDP per capita (constant 1995 US$)	4,857	4,343	4,849	5,326
GDP total (billions of 1995 US$	50.3	44.7	49.6	54.4
Share from agriculture (%)	15	7	6	n.a.
Share from industry	39	32	34	n.a.
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	-0.7	4.9		
Of population (%)	-0.3	-0.5		

MOLDOVA				
	1990	**2000**	**2015**	**2020**
Total population (millions)	4.36	4.30	4.15	4.11
Urban pop (%)	47	42	45	48
Rural pop (%)	53	58	55	52
	1992	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	1,056	713	623	637
GDP total (billions of 1995 US$	4.6	3.1	2.7	2.7
Share from agriculture (%)	51	33	28	28
Share from industry	31	31	19	20
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	-11.8	-2.7		
Of population (%)	-0.1	-0.2		

ROMANIA				
	1990	**2000**	**2015**	**2020**
Total population (millions)	23.21	22.44	21.44	21.03
Urban pop (%)	54	55	59	61
Rural pop (%)	46	45	41	39
	1992	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	1,377	1,564	1,461	1,489
GDP total (billions of 1995 US$	31.4	35.5	32.8	33.4
Share from agriculture (%)	18	21	15	13
Share from industry	44	42	36	36
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	-1.6	-1.8		
Of population (%)	-0.4	-0.2		

RUSSIA				
	1990	**2000**	**2015**	**2020**
Total population (millions)	148	145	133	130
Urban pop (%)	73	73	74	75
Rural pop (%)	27	27	26	25
	1992	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	2,967	2,280	2,255	2,471
GDP total (billions of 1995 US$	441.2	337.7	329.9	359.6
Share from agriculture (%)	7	8	7	6
Share from industry	41	37	35	39
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	-6.8	2.9		
Of population (%)	-0.1	-0.4		

SERBIA AND MONTENEGRO				
	1990	**2000**	**2015**	**2020**
Total population (millions)	10.53	10.55	10.31	10.19
Urban pop (%)	49	52	55	58
Rural pop (%)	47	48	45	42
	1990	**1994**	**1999**	**2000**
GDP per capita (constant 1995 US$)	n.a.	1,167	1,181	1,240
GDP total (billions of 1995 US$	n.a.	12.3	12.6	13.2
Share from agriculture (%)	31	31	25	n.a.
Share from industry	40	39	38	n.a.
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	n.a.	-2.9		
Of population (%)	0.1	-0.1		

SLOVAKIA				
	1990	**2000**	**2015**	**2020**
Total population (millions)	5.3	5.4	5.4	5.4
Urban pop (%)	56	57	62	65
Rural pop (%)	44	43	38	35
	1992	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	3,211	3,426	4,075	4,160
GDP total (billions of 1995 US$	17.0	18.4	22.0	22.5
Share from agriculture (%)	5	5	4	4
Share from industry	38	37	32	31
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	-0.1	2.7		
Of population (%)	0.3	0.1		

SLOVENIA				
	1990	**2000**	**2015**	**2020**
Total population (millions)	1.9	2.0	1.9	1.9
Urban pop (%)	50	49	52	54
Rural pop (%)	50	51	48	46
	1992	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	8,331	9,419	11,160	11,659
GDP total (billions of 1995 US$	16.6	18.7	22.2	23.2
Share from agriculture (%)	5	5	4	3
Share from industry	41	38	38	38
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	0.9	4.6		
Of population (%)	0.6	-0.1		

TURKEY				
	1990	**2000**	**2015**	**2020**
Total population (millions)	56.1	66.7	79.0	82.9
Urban pop (%)	61	66	72	74
Rural pop (%)	39	34	28	26
	1992	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	2,670	2,794	2,975	3,147
GDP total (billions of 1995 US$	154.6	169.3	191.4	205.5
Share from agriculture (%)	15	16	16	15
Share from industry	30	28	25	25
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	4.4	1.7		
Of population (%)	1.8	1.6		

UKRAINE				
	1990	**2000**	**2015**	**2020**
Total population (millions)	51.9	49.6	43.3	41.5
Urban pop (%)	67	68	70	72
Rural pop (%)	33	32	30	28
	1992	**1995**	**1999**	**2000**
GDP per capita (constant 1995 US$)	1,621	953	840	896
GDP total (billions of 1995 US$	84.5	49.1	41.9	44.4
Share from agriculture (%)	20	15	14	14
Share from industry	51	38	38	38
	1991-1997	**1998-2000**		
Average annual growth				
Of GDP (%)	-11.6	1.2		
Of population (%)	-0.3	-0.9		

Annex III Water resources in the Black Sea countries

BELARUS				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	37.2	37.2	18.0	18.0
External water resources (BCM)	20.8	20.8	0.0	
Total water resources (BCM)	58.0	58.0	18.0	18.0
	1990	**1993**	**1995**	**2000**
Total water consumption (BCM)	2.8	2.5	1.9	1.7
Agriculture	0.4	0.3	0.3	0.2
Industrial	1.7	1.5	0.9	0.8
Domestic	0.7	0.7	0.7	0.8
	1990	**1995**		
Watewater produced (BCM)	1.98	1.33		
Wastewater biologically treated (BCM)	0.92	0.84		

BOSNIA AND HERZEGOVINA				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	36.0	n.a.	n.a.	n.a.
External water resources (BCM)	2.0	n.a.	n.a.	
Total water resources (BCM)	38.0	n.a.	n.a.	n.a.
	1990	**1993**	**1995**	**2000**
Total water consumption (BCM)	0.8			
Agriculture				
Industrial				
Domestic				
	1990	**1995**		
Watewater produced (BCM)	n.a.	n.a.		
Wastewater biologically treated (BCM)	n.a.	n.a.		

BULGARIA				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	21.0	20.1	6.4	5.5
External water resources (BCM)	0.3	0.3	0.0	
Total water resources (BCM)	21.3	20.4	6.4	5.5
	1988	**1997**		
Total water consumption (BCM)	13.0	3.1		
Agriculture	7.2	0.3		
Industrial	4.9	1.4		
Domestic	0.9	1.4		
	1990-91	**1998**		
Watewater produced (BCM)	1.73	1.14		
Wastewater treated (%)	42	57		

CROATIA				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	37.7	27.2	11.0	0.5
External water resources (BCM)	33.7	33.7 (does not include border flows)	0.0	
Total water resources (BCM)	71.4	60.9	11.0	0.5
	1990	**1996**	**1995**	**2000**
Total water consumption (BCM)	2.65	1.42		
Irrigation/fishponds	0.42	0.43		
Industrial/cooloing	1.76	0.46		
Domestic	0.47	0.53		
	1997	**2000**		
Watewater produced (BCM)	0.29	n.a.		
Wastewater treated (%)	20	12%		

CZECH REPUBLIC				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	13.2	13.2	1.4	1.4
External water resources (BCM)	0.0	0.0	0.0	
Total water resources (BCM)	13.2	13.2	1.4	1.4
	1991	**1995**	**1997**	
Total annual water used (BCM)	2.74	2.47	2.50	
Irrigation	0.25	0.17	0.17	
Industrial/thermal power	1.86	1.70	1.37	
Domestic	0.63	0.60	0.95	
	2001			
Volume of wastewater (BCM)	0.57			
Volume treated (%)	94.8			

GEORGIA				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	58.1	56.9	17.2	16.0
External water resources (BCM)	5.2	5.2	0.0	
Total water resources (BCM)	63.3	62.1	17.2	16.0
	1987	**1990**	**1996**	**2000**
Total annual water withdrawn (BCM)		3.47	2.49	
Irrigation		2.04	1.47	0.98
Industrial	1.5	0.70	0.26	
Domestic		0.73	0.76	0.67
	1998			
Watewater produced by households (BCM)	0.6			
Percentage treated	13			

HUNGARY				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	6.0	6.0	6.0	6.0
External water resources (BCM)	98.0	98.0	0.0	
Total water resources (BCM)	104.0	104.0	6.0	6.0
	1990	**1995**		
Total annual water withdrawn (BCM)	6.02	6.70		
Irrigation	1.00	1.01		
Industrial	4.33	4.82		
Domestic	0.69	0.87		
	1999			
Population with sewerage connection (%)	60			
Population with wastewater treatment (%)	22			

MOLDOVA				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	1.0	1.0	0.4	0.4
External water resources (BCM)	6.3	6.3	0.0	
Total water resources (BCM)	7.3	7.3	0.4	0.4
	1990	**1991**	**1995**	**1996**
Total annual water used (BCM)	3.83	2.98	1.87	1.77
Agriculture	1.03	0.51	0.49	0.35
Industrial (thermal power)	2.52	2.20	1.14	1.17
Domestic	0.27	0.27	0.25	0.24
	1993-94			
Domestic and industrial wastewater discharge (MCM)	350			
Wastewater treated to required standards (%)	51 (only 18% municipal wastewater)			

ROMANIA				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	42.3	42.0	8.3	8.0
External water resources (BCM)	169.6	169.6	0.0	
Total water resources (BCM)	211.9	211.6	8.3	8.0
	1989	**1999**		
Total annual water used (BCM)	19.40	8.57		
Agriculture	8.17	1.03		
Industrial	9.03	5.70		
Domestic	2.20	1.84		
	1999			
Watewater discharge requiring treatment (BCM)	3.0			
Subject to treatment (%)	40			

RUSSIA				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	4,313	4,037	788	512
External water resources (BCM)	186	186	0	
Total water resources (BCM)	4,498	4,222	788	512
	1991	**1993**	**1995**	**1997**
Total annual water used (BCM)	88.4	77.6	68.8	64.0
Agriculture	20.9	17.0	14.9	12.0
Industrial	52.8	46.0	39.7	38.4
Domestic	14.7	14.6	14.2	13.6
	1999			
Watewater discharge requiring treatment (BCM)	22.0			
Treated to required standards (%)	10.8 (Although 75% is treated)			

SERBIA AND MONTENEGRO				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	25.1	23.5	3.0	1.4
External water resources (BCM)	164.5	164.5	0.0	
Total water resources (BCM)	189.6	188.0	3.0	1.4
	1997			
Total annual water used (BCM)	8.40			
Agriculture	0.76			
Industry/cooling	6.23			
Domestic	1.41			
	1999			
Watewater discharge requiring treatment (BCM)	2.86			
Subject to adequate treatment (BCM)	0.16			

SLOVAKIA				
	Total	Of which surface water (BCM)	Of which groundwater (BCM)	Overlap between surface and groundwater
Internal water resources (BCM)	13	13	2	2
External water resources (BCM)	38	38	0	
Total water resources (BCM)	50	50	2	2
	1991	**1997**		
Total annual water used (BCM)	1.9	1.3		
Agriculture	0.3	0.1		
Industrial (cooling)	1.0	0.8		
Domestic	0.6	0.5		
	1998			
Watewater discharge requiring treatment (BCM)	1.14			
Treated biologically (%)	36 (36% is untreated)			

SLOVENIA				
	Total	**Of which surface water (BCM)**	**Of which groundwater (BCM)**	**Overlap between surface and groundwater**
Internal water resources (BCM)	19	19	14	13
External water resources (BCM)	13	13	0	
Total water resources (BCM)	32	32	14	13
	1994	**1997**		
Total annual water used (MCM)	237.4	333.2		
Agriculture	3.4	3.4		
Industrial	76.0	71.4		
Domestic	158.0	258.4		
	1998			
Watewater discharge requiring treatment (BCM)				
Treated (%)	75%			

TURKEY				
	Total	**Of which surface water (BCM)**	**Of which groundwater (BCM)**	**Overlap between surface and groundwater**
Internal water resources (BCM)	196.0	192.8	20.0	16.8
External water resources (BCM)	4.7	4.7	0.0	
Total water resources (BCM)	200.7	197.5	20.0	16.8
	1990	**1995**	**1997**	**2000**
Total annual water used (BCM)	30.6	31.6	33.5	42.0
Agriculture	22.0	23.1	24.7	31.5
Industrial	3.4	3.5	3.5	4.1
Domestic	5.1	5.1	5.3	6.4
	1998			
Watewater discharge requiring treatment (BCM)	2.40			
Treated (BCM)	0.1			

UKRAINE				
	Total	**Of which surface water (BCM)**	**Of which groundwater (BCM)**	**Overlap between surface and groundwater**
Internal water resources (BCM)	53	50	20	17
External water resources (BCM)	86	86	0	
Total water resources (BCM)	140	137	20	17
	1991	**1994**	**1997**	**1998**
Total annual water used (BCM)	26.7	22.3	14.6	13.0
Agriculture	10.2	9.0	4.5	3.6
Industrial	12.8	9.5	6.5	5.9
Domestic	3.7	3.8	3.6	3.5
	1991	**1997**		
Municipal watewater discharge (BCM)	4.0	3.6		
Treated according to standards (%)	43	38		

Annex IV Economic estimation for the damage of eutrophication for 5 Southern regions of Ukraine

For the purposes of this study, socio-economic damage caused by eutrophication is understood as a sum of additional expenses spent to obtain products and services of proper quality in the industrial, agricultural and municipal sectors.

Conception of seasonal changes of water quality and influence of these changes on the costs of services and products and on the quality of the resources (expressed in the monetary values) is the basis of the assessment of the above additional expenses.

The methodological framework of the present study consists of the research of the University of Essecs team (>>) and our research mainly described in the Methodology of assessment of the damage of the consequences of the emergency situations of technogenic and natural origin (>>), studies of the National Academy of Ukraine, and on the recommendations of the Ministry of Environment of Ukraine in environmental economics in 1994 – 2001.

The present study is one of the first attempts to assess, in economic terms, damage caused by eutrophication to the economy of Ukraine. Geographically, the scope of the pilot study is limited to the 5 Southern regions of Ukraine (Republic of Crimea, city of Sevastopol, Odes'ka, Mykolaevs'ka and Khersons'ka regions); methodologically, the study is limited by the scarcity of data, novelty of the approach and limited time and space available for reporting. Results obtained shall be treated as tentative and further research is obviously needed.

Main damage indicators

1. Reduced commercial values of the water bodies (fisheries and other water bodies products)
2. Reduced biodiversity of the water bodies
3. Increased costs of drinking water treatment
4. Clean-up costs of waterways (dredging, weed-cutting);
5. Reduced recreational and amenity value of water bodies for water sports, (bathing, boating, windsurfing, canoeing), angling, and general amenity (picnics, walking, aesthetics);
6. Net economic losses for commercial aquaculture, and shellfisheries
7. Negative ecological effects on biota (arising from changed nutrient status, pH, and oxygen content of water), resulting in both changed species composition and loss of key or sensitive species
8. Costs of control of legislation compliance arising because of negative impacts of nutrient enrichment

Assessment of the indicators

1. Reduced commercial values of the water bodies (fisheries and other water bodies products)

Reducing of commercial value has been taking place during recent 30 years with the increasing of antropogenic pressure on the Dnipro basin and Ukrainian share of the Black Sea basin. This process takes place with increased efficiency, and eutrophication plays significant role in it. Impact of the eutrophication has a seasonal character and may be, by our estimation, assigned a range of 5 – 7% of total loss. Considering that fishering does not take place during winter time, seasonal coefficient of impact of eutrophication on commercial values of water bodies may be estimated as 0,96875.

Then the annual damage will be estimated as: $\mathbf{D_1 = F\ Kd(1 - Ke)}$,

Where:

D_1 – damage from the decrease of the commercial values of water bodies;

F – value of the fisheries catch (annual, mln of UH)

Kd – coefficient of fishering catch decrease caused by the totality of all factors, equal 0,22 (2000);

Ke – seasonal coefficient equal to 0,96875.

Fisheries catch for the Southern part of Ukraine studied here are shown in the Table below (data from 2002, if not otherwise indicated)

Region	Fish catch in the inner water bodies (freshwater, incl rivers), t	Fishering zone of Ukraine in the Black Sea, t	Seafood and other sea products, t	Average costs of wholesale trade (basing on the average wholesale cost of 1t of fish caught by the resident of Ukraine as 4,480 UH), mln UH
Republic of Crimea	676.0	21,658	57.0	97.02784
Sevastopol	23.3	44,239.0	39,256.0	198.29072
Odes'ka	3,336.0	1,135.0	39.0	5.0848
Mykolaevs'ka	563.0	1,217.0	-	5.45216
Khersons'ka	1,996.0	3,002.0	5.0	13.44896
Total				319.20448

Thus, annual damage **D_1 constitutes 2,1945 mln UH**.

2. Decrease of biodiversity of the water bodies.

Economic value of decrease of biodiversity has been assessed on the basis of provisions of the Cabinet of Ministries of Ukraine and taking into account the experts studies(>>). Decrease of one species assessed on the basis of the average number of the individuals, or, if the above is not possible, on the basis of the average costs of maintaining one species preservance which is 20 mln USD (Reimers approach, 1994). Eutrophication has a seasonal character, and for the assessment of the negative impact on biodiversity average impact coefficient has been estimated as 0,97. 18 most valuable specie whose habitats lie in the study regions has been selected out of protected fish specie in Ukraine *(Eudontomyzon mariae Berg, Acipenser nudiventris Lovetzky, Huso huso ponticus Salnikov et Malatski, Umbra krameri Walbaum,Vimba vimba tenella, Barbus barbus borysthenicus Dybowski, Chalcalburnus chalcoides mento, Gobio uranoscopus, Barbus tauricus Kessler, Hippocampus guttulatus microstephanus Slastenenko, Lucioperca marina, Gymnocephalus schraetser, Zingel zingel, Zingel streber streber, Callionymus belenus Risso, Acipenser ruthenus Linnaeus, Umbrina cirrosa, Trigla lucerna Linnaeus).*

Basing on the described approach, $\mathbf{D_2}$ **= 57,24 mln UH**[1].

3. Costs of drinking water treatment.

Costs of drinking water treatment are assessed on the basis of the average cost of water to the consumer in the municipal sector and the volume of water consumption in the regions affected by eutrophication.

Experimental studies show that eutrophication damage is meaningful for the Southern part of Ukraine during 4 months in the year. Using same approach as when calculating the increase in costs for fisheries, the value of the coefficient is assessed as 0,945.

Then economic damage caused by eutrophication via increased costs of drinking water are: (Table)

Region	Drinking water treatment costs, mln UH per month	Annual eutrophication damage, mln UH
Republic of Crimea	9.17	2.0174
Sevastopol	1.74	0.3828
Odes'ka	11.11	2.4442
Mykolaevs'ka	5.66	1.2452
Khersons'ka	5.23	1.1506

Total for the region **D3 = 7.2402 mln UH**

4. Clean-up costs of waterways (dredging, weed-cutting);

Costs are assessed basing on the data of the enterprises involved in the clean-up works of the water bodies and waterways. Majority of such work is carried out in Ukraine by the "Ukrrechflot" company. Assessment is calculated as: $\mathbf{D_4 = Mc \times Me \times Ke_4}$

where

D_4 – Increased costs for waterways clean-up caused by eutrophication

Mc – maintenance costs for clean up, mln UH per month

Me – number of months when the eutrophication is maximum.

Ke_4 – eutrophication coefficient, equal to 0,945.

Expert assessment of the maintenance costs is 50 thousand UH per month, i.e.

$\mathbf{D_4}$ **= 0,2 mln UH**.

5. Reduced recreational and amenity value of water bodies for water sports, (bathing, boating, windsurfing, canoeing), angling, and general amenity (picnics, walking, aesthetics)

This indicator is difficult to calculate, since the majority of such changes in the priorities of the tourists are not reflected by the statistics. However, several studies of recreational industry show the dependence of decreasing of the visits of the water body and eutrophication. We assume that the majority of economic damage is born by the small private business serving the tourists. Literature shows that the income may decreases up to 10-15% during algae bloom (>>>). Then assessment of the damage D_5 is calculated as: $\mathbf{D_5 = I \times Me \times Ke_5}$

Where

D_5 –decrease in economic value of the water body caused by eutrophication

I – average monthly income from small business serving tourists, expert assessment, thousand UH per month

Me – number of months when the eutrophication is maximum.

Ke_5 – eutrophication coefficient, equal to 0,15.

Annual income from small business serving tourists is shown in the Table below (mln UH, 2002)

Region	Declared income	Official expert data of the Ministry of economy on non-declared income
Republic of Crimea	1,4	2,24
City of Sevastopol	0,69	1,104
Odes'ka	2,628	4,2
Mykolaevs'ka	0,6	0,96
Khersons'ka	0,1	0,16
Total		8,664
Total accounting for 4 months of maximum eutrophication		2,89

[1] Damage is quite significant; however it represents "monetary value" approach towards biodiversity decrease that does not have "reverse dynamics" in the future regardless any financial and organizational efforts of the humans.

Hence the decrease in economic value of the water body caused by eutrophication is: **D_5 = 0,43 mln UH**.

6. Net economic losses for commercial aquaculture and shellfisheries

Losses for commercial aquaculture are directly connected with the changes of habitats. Shellfish yield has dropped 7 times compared to the 1970 level. Aquaculture and shellfisheries are scattered and non-organised in the Ukrainian part of the Black Sea basin; therefore, statistic adapt are scare and our assessment s based on the experts judgment. Eutrophication impact on the decrease of aquaculture income is assessed as 8-12%. Decrease of the area of traditional aquaculture is assessed according to the national standard (>>>>>, >>>>) as 17,000 per ha. Therefore eutrophication impact on aquaculture and shellfisheries may be assessed as: **D_6 = Aa x U x Ke_6;**

where

D_6 – loss of aquaculture and shellfisheries income caused by aquaculture,

Aa - average area of the territory used for the aquaculture, ha

U – damage standard, UH per ha

Ke_6 – eutrophication coefficient equal to 0,12.

Area of the territory used for aquaculture is approximately equal to the shelf of the Black Sea, appr. 14,164.5 km^2.

Therefore, D_6 – income loss from commercial aquaculture caused by eutrophication is **D_6 = 0,29 mln UH**.

7. Negative ecological effects on biota (arising from changed nutrient status, pH, and oxygen content of water), resulting in both changed species composition and loss of key or sensitive species

It is quite complicated to assign monetary values to the negative impacts on biota, and they are actually reflected in the results of the economic activities (decrease in fisheries, biodiversity, commercial aquaculture). We suggest to assess negative consequences to the biota by analysis of environmental protection costs on the regional level and by defining the weight of the costs for preservation of the water bodies biodiversity, with the consideration of the eutrophication relative value. Expert assessment suggests that for the protected areas in Ukraine impact of eutrophication on decreased biodiversity of the water bodies is 30-45% (….. 2002).

Therefore, calculation will be: **$D_7 = Z_b$ x B_b x Ke_7;**

where

D_7 – monetary value of the negative impact on the biota caused by eutrophication

Z_b – consolidated financing of environmental protection and biodiversity maintenance measures for the region, thousands UH

B_b – share of the financing spent for the biodiversity maintenance in the water bodies

Ke_7 – coefficient of the relative eutrophication weight equal to 0,45.

Financing of the environmental protection measures in the studies regions are (mln UH, 2002):

Region	Z_b	B_b (%)	$B_{b\text{, mln UH}}$
Republic of Crimea	61,1933	0,18	0,11
City of Sevastopol	15,0258	0,18	0,027
Odes'ka	59,54	0,16	0,095
Mykolaevs'ka	63,909	0,18	0,116
Khersons'ka	25,5067	0,17	0,045
Total	225,1748	0,17	0,393

Therefore, considering relative eutrophication weight, monetary value of the negative impacts of eutrophication on biota may be assessed as **D_7 = 17,22 mln UH**.

8. Costs of control of legislation compliance arising because of negative impacts of nutrient enrichment

Costs of control of legislation compliance arising have never before studies individually and are not reported in the official statistics. According to the assessment of the officers of the Main Ecological Inspection of the Ministry of Environment of Ukraine, they constitute not more then 10% in seasonal form (where the season is the whole eutrophication cycle, namely from March to October, 8 months) Therefore, calculation is: **$D_8 = 8 (L_{env}/12 – (L_{env}$ x $Ke_8)/12) = 2/3 (L_{env} – L_{env}$ x Ke_8),**

where,

D_8– costs of control of legislation compliance arising because of negative impacts of nutrient enrichment, thousand UH per year

L_{env} – consolidated financing of the measures on monitoring of compliance with environmental legislation, by region, thousand UH per year

Ke_8 – coefficient of the eutrophication weight equal to 0,9.

Consolidated financing of the measures on monitoring of compliance with environmental legislation, by region, thousand UH per year is shown in the Table below.

Region	L_{env}
Republic of Crimea	3,055
City of Sevastopol	0,75
Odes'ka	2,95
Mykolaevs'ka	3,15
Khersons'ka	1,28
Total	11,185

Therefore, costs of control of legislation compliance arising because of negative impacts of nutrient enrichment are **D_8 = 0,75 mln UH**.

Total eutrophication economic damage for the 5 studied regions is 85.647 mln UH (1 USD = 5,31 UH) per year. Considering that income part of the consolidated budget of the funds of Environmental protection of Ukraine (including state Fund and regional and local Funds) is about 43 mln UH, the figure is significant and clearly indicates the necessity of tackling eutrophication problem on the regional, country and international level.

Annex V Classification tables for eutrophication levels of marine and fresh waters

Status	TRIX [x)]	g $Cm^{-2}yr^{-1}$ [xx)]
Oligo	< 4	< 100
Mezo	4 – 5	100 – 300
Eutro	5 – 6	301 – 500
Hyper	> 6	> 500

x) Erika Magaletti, 2000
Vollenweider et al., 1998
Italian Legislation (Dlg.152/99)
xx) Nixon, 1995

Trophic Index

TRIX = (Log [Chl"a"]*[D%O]*[PT]*[DIN]* + 1.5) / 1.2

Where Chl"a" in µg/L, D%O deviation, in absolute value, of dissolved Oxygen from 100% saturation, PT = Total Phosporus in µg/L, DIN = Dissolved Inorganic Nitrogen in µg/L

Table of eutrophication levels classification

	Chl "a" µg/l	N_{tot} mg/l	P_{tot} mg/l															
	OECD	FN	RSA	SW	UA	Ave	OECD	FN	RSA	SW	UA	AVE	OECD	FN	RSA	SW	UA	Ave
Oligo	<2,5	1-3	-	-	<2,0		-	-	-	0,30-0,45	>0,3		0,010	0,010	-	0,007-0,015	>0,015	
Mezo	2,5 – 8,0	3-8	-	-	3-8		-	-	-	0,45-0,75	0,3 –0,7		0,010 –0,03	0,010-0,020	-	0,015-0,025	0,015-0,050	
Eutro	8,0 –25,0	8-40	10-30	-	8-40		-	-	-	0,75-1,5	0,7-1,5		0,03 –0,10	0,020-0,10	-	0,025-0,050	0,050-0,15	
Poly	-	-		-	40-100		-	-	-	-	1,5-5,0			-	-	-	0,15-0,50	
Hyper	>25,0	40-100	30 - 100	-	>100		-	-	-	>1,5	>5,0		>0,10	0,10 –1,0	-	-	>0,50	

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