HUMAN IMPACT ON RIVERS AND FISH IN THE PONTO-CASPIAN BASIN

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ABSTRACT

Fifty years ago up to 650 000 tonnes of fish were captured annually from the rivers of the Ponto-Caspian basin. Among them were valuable sturgeon, bream, carp, pikeperch, sabre fish and catfish. Since then engineering modifications of rivers, such as dams and irrigation systems, direct withdrawal of water and pollution from a variety of sources have had a major impact on the aquatic environment, including fish stocks. At present there are 74 engineering structures in the basin of the Danube that interfere with the free flow: 87 on the Dniester, 650 on the Dnieper, 653 on the Don, 58
on the Kuban, 812 on the Volga, 79 on the Kura, 22 on the Terek and 91 on the Ural. The result has been a degradation of fish stocks and a steep decline in catches especially of the most valuable species such as sturgeon, salmonids and migratory freshwater herring, all of which have lost their spawning grounds. Semi-migratory bream, pikeperch, carp and sabrefish have also been affected. Changes in water regime have altered the areas and the timing of flooding, interfering with the spawning of fish. As the fish reproduction rate declined, the catches declined as well. Great losses of fish are taking place in irrigation pumping stations, with millions of especially young fish ending on irrigated fields. In some rivers pollution further aggravates the situation. In the former countries of the USSR the declining living standards and an increase in unemployment have led to widespread poaching. The degradation of fish stocks has been to some extent reduced by repeated stocking of some rivers with sturgeon and some other young fish produced in hatcheries.

INTRODUCTION

The Ponto-Caspian region covers 3.4 million km², encompassing the basins of the Black, the Azov and the Caspian seas. The major rivers in this region are the Volga, Danube, Dnieper, Dniester, Don, Kuban, Terek and Kura. They, together with many smaller rivers, provide spawning grounds for migratory and semi-migratory fish. Fifty years ago 600 to 650 thousand tonnes of valuable fish were caught in the former Soviet territorial waters of the Ponto-Caspian basin, including about 200 000 tonnes of semi-migratory and migratory sturgeons, herrings, bream, carp, roach, pikeperch and sabrefish.

The life history of these fish is closely linked both with the sea and with rivers. In 1936 the total catch of migratory and semi-migratory fish in the Black-Azov seas basin was 198 000 tonnes (Rass 1965). By 1959, after the completion of dams on the Dnieper, Dnieper, Don and Kuban, catches decreased to about 60 000 tonnes. Sturgeons declined from 6 900 tonnes in 1936 to 1 200 tonnes in 1959 and in the same period pikeperch declined from 74 500 tonnes to 10 800 tonnes, bream from 47 200 tonnes to 5 200 tonnes, herring from 5 700 tonnes to 2 400 tonnes.

This paper discusses the ecological situation of the major rivers of the Ponto-Caspian system following the implementation of large-scale water regulation projects in their basins. Dams and reservoirs, irrigation systems, direct withdrawal of water into transfer canals, pumping of young fish into canals, discharge of waste waters from industry, settlements, agricultural projects, as well as poaching have led to degradation of major fish populations and to a catastrophic decline in fish stocks and catches, especially of the migratory and semi-migratory fish.

In the part of the Ponto-Caspian region that formerly belonged to the USSR there are 2 526 reservoirs with a total volume of 310 km³, including 74 reservoirs with a total volume of 3 km³ on the Danube, 87 with 3.68 km³ volume on the Dniester, 650 with 47.4 km³ on the Dnieper, 653 with 31.4 km³ on the Don, 58 with 4.4 km³ on the Kuban, 812 with 190.4 km³ on the Volga, 22 with 0.8 km³ on the Terek, 79 with 20.4 km³ on the Kura and 91 with 4.9 km³ on the Ural. There are also numerous pumping stations taking water directly from the river channels.

Reservoirs have permanently flooded former spawning grounds of beluga (Huso huso (L.)), Atlantic sturgeon (Acipenser sturio L.), Russian sturgeon (Acipenser gueldenstaedti Brandt), Persian sturgeon (Acipenser persicus Borodin), bastard (spiny) sturgeon (Acipenser nudiventris Lovetzky), starred sturgeon, also called sevruga (Acipenser stellatus Pallas), Black Sea salmon (Salmo trutta labrax), Caspian salmon (Salmo trutta caspius), inconnu (Stenodus leucichthys Guldenstadt), Caspian shad (Alosa caspia Eichwald), black backed shad (Alosa kessleri (Grimm), Black Sea shad (Alosa pontica Eichwald). Spawning grounds of
semi-migratory species such as bream (*Abramis* spp), zander or European pikeperch (*Stizostedion lucioperca* L.), European carp (*Cyprinus carpio* L.), sabrefish (*Pelecus cultratus* L.) and others have remained, but owing to the change in the water regime, the periods and areas of flooding of the spawning grounds have changed, as well as the thermal and sediment regimes. The changes in the hydrological regime have resulted in reduced spawning intensity, which has resulted in lower catches.

Semi-migratory and riverine fish suffer great losses from pumping millions of young fish onto irrigated fields. Pollution affects the reproduction of fish in rivers, estuaries and deltas and in the adjacent sea. Apart from raw or poorly treated sewage, industrial waste waters and return waters from agriculture fields also contribute to the pollution. Even now, when the volume of industrial production has decreased by 30-40 percent in comparison with the year 1991, the maximum admissible concentrations (MAC) of organic matter (oil products, phenols, pesticides, etc.) and heavy metals are exceeded tenfold. The dissolution of the USSR, followed by a decrease in the living standard and increase in unemployment in the catchments of the rivers entering the Azov and the Caspian seas, has led to a widespread poaching of fish. It is estimated that poachers capture at least five times more fish than are declared in official catch statistics. This has led to a decrease in the number of broodstock and a lower rate of recruitment.

To compensate for the losses, numerous fish breeding farms were constructed, with an annual output of 70 million sturgeons and over 2 billion semi-migratory young fish. These measures compensated for the decline in migratory and semi-migratory fish stocks but by no means restored the damage caused by the impact of dams. Fishways were constructed on some dams on the Volga, Don and Kuban rivers to enable the upstream migration of fish. Their efficiency proved to be low, especially for large and slow moving fish such as sturgeons. In general, the situation in the Ponto-Caspian basin rivers is dire and quickly deteriorating. The world should be concerned as more than 90 percent of the world stocks of sturgeon are present in this region.

**MAJOR RIVERS**

There is a strong link between the migratory and semi-migratory fish populations in the Ponto-Caspian basin and the sea.

The Black Sea covers 423 000 km², its mean depth is 1 271 m and its maximum depth 2 245 m. The following major rivers enter the sea: Danube, Dniester, Southern Bug and Dnieper, plus several other smaller rivers.

The Kerch Strait joins the Azov Sea to the Black Sea. It has an area of 37 600 km², mean of depth of 6.8 m and a maximum depth of 13.3 m. That part of the Black Sea with a depth of less than 100 metres accounts for fully one third of the total area of the sea and half of this, including the Karkinitsky Gulf, is situated in its northwestern part and about one third is in the Azov Sea. The Black Sea is stratified into two layers: the upper layer extends to 100-150 m depth and contains plankton, nekton and benthos; below it is a layer saturated with hydrogen sulfide and inhabited only by bacteria.

The upper layer of the Black Sea has two sub-layers, i.e. the surface layer down to 25-50 m and an inner layer, from 50 m to 125-150 m, distinguished by their temperature regimes. The temperature of the surface layer has a wide range from 27°C in the summer to 7-8°C in the winter. In shallow water this variability is even greater: from 30°C in the summer to −1.4°C in the winter. The water of the inner layer has much smaller annual temperature amplitude from 0 to 8.5°C. In a depth of 100-150 m the water temperature stays within the range of 0.1-2°C (Kuksa 1994).
The Black and Azov seawater has lower salinity than the ocean. The salinity of the surface layer in the open part of the Black Sea is 17.4-18.3‰ and at a depth of 50-100 metres is within 18.4-20‰. In the shallow northwestern part of the Black Sea in July-August the salinity is 13-16‰, in the Azov Sea it is 10.5-12‰. From the connection of the Azov Sea with the Black Sea to the head of the Taganrogsky Gulf the salinity decreases from 5 to 1‰. Near the mouths of rivers the salinity is 1‰.

The ichthyofauna of the surface layer of the Black and Azov seas can be divided into three groups:

- **Strictly freshwater fish**, which rarely or never move away from the river mouth: sterlet (*Acipenser ruthenus* L.), pike (*Esox lucius* L.), crucian carp (*Carassius carassius* (L.), tench (*Tinca tinca* (L.), rudd (*Scardinius erythrophthalmus* L.), white bream (*Blicca bjoerkna* (L.) and some others.

- **Fish that propagate in rivers and some feed in seas**: semi-migratory and migratory fish of various origins: pikeperch (*Stizostedion lucioperca* L.), roach/taran, vobla (*Rutilus rutilus* (L.), eastern bream (*Abramis brama* (L.), pontic-sturgeons, migratory herrings, Atlantic salmons;

- **Marine warmwater loving fish of Mediterranean origin**: European anchovy (*Engraulis encrasicholus* (L.)), European sprat (*Sprattus sprattus* (L.), common scad or mackerel/stavrida (*Trachurus trachurus* (L.) and some others.

The existence of this fauna depends greatly on changes in the climate and on the regime of riverflow regime and also on the type of fishery.

**The Danube**

With a catchment area of 817 000 km², a length of 2 860 km and an average annual discharge of 202 km³ the Danube is the second largest river in Europe. The Danube basin is one of the more densely populated regions of Europe: mean population density here exceeds 90 persons km⁻². The Danube River flows through eight countries and is important as a source of hydropower and irrigation water for a million hectares of agricultural land and as a waterway. The Danube has been regulated by large-scale hydraulic structures such as many dams; several canals, including the Danube-Black Sea, Rhine-Main-Danube and Odra-Elbe-Danube; and the irrigation system Danube-Tisa-Danube. The total volume of reservoirs is approximately 80 km³ (Yatsyk, Kovalenko and Lelyavsky 1993). The annual water consumption from the Danube River is estimated at 75-80 km³, of which 27-28 km³ are lost to the system.

A great quantity of untreated or insufficiently treated water, as well as industrial and agricultural waste waters that contain a wide spectrum of poisonous compounds is discharged into Danube along its whole length. Polluted discharges are particularly intense in the middle and lower reaches. The concentrations of dissolved minerals in Danube water has recently increased by a factor of 1.4-1.7, reaching 427 mg L⁻¹, including Ca - 47.8 mg L⁻¹, Mg - 17.5 mg L⁻¹, Na+K - 49.8 mg L⁻¹, HCO₃ - 198 mg L⁻¹, SO₄ - 62 mg L⁻¹ and Cl - 46.5 mg L⁻¹ (Chernyavskaya, Denisova and Babich 1993).

The concentrations of dissolved oxygen range from 5.8 to 11 mg L⁻¹ and the pH along the whole length of the river ranges from 7.5 to 8.6. These narrow ranges of dissolved oxygen and pH indicate that development of phytoplankton in the Danube water is weak and, accordingly, there is a lower intensity of photosynthesis. The reason for this is the high velocity of the current and a high turbidity. Values of COD and BOD range from 7.8 to 20 mg L⁻¹ and from 1.2 to 5.0 mg L⁻¹, respectively. The main organic pollutant is an oil product, which mostly varies within 0.01-0.2 mg L⁻¹, but may reach up to 1 mg L⁻¹ in some areas. Phenols form another large group of organic pollutants and their concentrations range from 0.0 to 0.034 mg L⁻¹. Concentrations of surfactants as a whole do not exceed...
the maximum allowable concentration (MAC), being within a range of 0.05-0.1 mg L⁻¹. The most significant pesticide pollutant of the Danube water is 4,4'-dichlorodiphenyltrichloroethane (DDT) and its metabolite DDE, whose concentrations range from 0.014 to 3.81 mg L⁻¹. High concentrations of DDT (up to 57.4 mg kg⁻¹) have been found in benthic deposits in the mouth of the river (Chernyavskaya et al. 1993).

Concentrations of dissolved and suspended forms of copper and zinc exceed MAC along the entire length of the Danube River. Concentrations of nickel and cadmium are much lower than MAC. The highest concentrations (0.021 µg L⁻¹) of dissolved mercury are found in the waters of the Bulgarian stretch of the Danube. The content of radionuclides of caesium-134 and 137 and strontium-90 in the water from the downstream Galats to the upstream Vienna slowly increases from 5.85 bq m⁻³ to 48.1 bq m⁻³. On the Ukrainian stretch of the Danube we find increasing concentrations of radionuclides of caesium, which is explained by the washing of the radionuclides into the river with rain and snowmelt water.

The phytoplankton of the Danube comprises 529 species of algae. The diatoms and green algae are most broadly represented. Cyanobacteria and Euglena in the Danube are not very diverse and do not reach large populations due to the high turbidity of the water. The zooplankton of the Danube channel is comparatively poor. Mean numbers during the vegetation period do not exceed 7000 ind. m⁻³, reaching 14 000 ind. m⁻³ in the summer, mainly rotifers and copepods. The biomass of summer zooplankton is 162 mg m⁻³. Autumn zooplankton of the Danube channel is extremely poor: no more than 200 ind. m⁻³, with a biomass of only 7 mg m⁻³. Persistent pesticides together with polychlorinated biphenyls are found in all river fish and invertebrate species (Komarovsky, Karasin and Chernina 1993). The levels of pesticide accumulation in organs and tissues of the main groups of fish are within the range of 0.001-0.1 mg kg⁻¹. The accumulation of pesticides in fish indicates that the Danube is polluted by persistent substances that are absorbed into the food chain.

**The Dniester**

The Dniester is a semi-mountainous river that flows through the territory of the Ukraine and Moldova. The catchment area is 72 100 km² and the length of the river 1 352 km. The Dniester has its beginning on the slopes of the Carpathians, at an altitude of about 900 metres and eventually enters the Black Sea. In the upper part the river (up to the town of Galich) has the character of a mountain river. Downstream of Galich the current becomes quieter but the valley continues to be narrow and deep. Below the town of Mogiliv-Podolsky the valley widens. Below the city of Tiraspol the Dniester enters lowlands and the valley is between 8 and 16 km wide. The predominant source of water is snowmelt and rain. The average annual discharge is estimated to be 10.1 km³, or 320 m³ s⁻¹. In the winter, ice-jams form along the river.

Of the 87 reservoirs in the basin of the Dniester, two are considered here: the Dniestr reservoir, situated above the town of Mogiliv-Podolsky, is 678 km from the mouth of the river and the Dubossary reservoir, near the town of Dubossary, 351 km from the mouth. Both are multiple use reservoirs including irrigation, water supply, hydroelectric production, fisheries and recreation.

Development of industry and intensification of agriculture, especially by using mineral fertilizers and pesticides, has led to an increase in the concentration of some chemicals in the river water. For example, concentrations of DDT in water of the Dubossary reservoir range within 0.15-0.61 µg L⁻¹, DDD, 0.51-0.62 µg L⁻¹, DDE, 0.50-0.58 µg L⁻¹, etc. Below the Dubossary reservoir the quality of water becomes better due to self-purification, with a concentration of DDT of 0.26 µg L⁻¹, DDD, 0.42 µg L⁻¹ and DDE, 0.22 µg L⁻¹. The concentration of the total dissolved solids of the Dniester water has also changed. Fifty years ago,
in the period of snowmelt floods, it was 230-300 mg L\(^{-1}\) while at present it is 300-350 mg L\(^{-1}\). In the summer-autumn period and during the winter low flows the concentration has increased from 440-600 mg L\(^{-1}\) to 500-700 mg L\(^{-1}\). The chemical composition of water is dominated by calcium carbonates/bicarbonates (Gorbatenky, Byzgu and Kunichan 1986).

**The Dnieper**

The catchment area of the Dnieper covers 504 000 km\(^2\) and the river is 2 200 km long making it one of the largest rivers of Europe. The river originates on the Valdai Heights and flows through Russia (485 km), Belarus (595 km) and for 115 km forms the border between Belarus and the Ukraine. Then it flows for 1 005 km through the Ukraine. The Dnieper can be divided into three reaches:

- The Upper Dnieper, from the source to the city of Kiev, with a length of 1 375 km. In this reach the main tributaries are the Berezina, Sozh, Prpyyat and Desna and prior to the construction of dams their water quality determined the Dnieper River chemical composition.

- The Middle Dnieper, which runs for 570 km from Kiev to Zaporozhye. It receives the following major tributaries: the Ross, Sula, Psel, Vorskla, Orel and Samara rivers.

- The Lower Dnieper runs for 340 km, from Zaporozhye to the mouth of the river.

The upper river lies in the forest zone, the middle one in the forest-steppe and steppe zones and the lower river in the steppe zone. In the upper reach, from the source to Dorogobuzh, the river flows between low-lying banks covered by forest; below the city of Mogilyov, it flows through a hilly terrain: the valley here is narrow and without floodplain. Between Mogilyov and Kiev the valley of the river widens, with a floodplain 14 km wide and covered with meadows and bushes. The middle and lower Dnieper (from the mouth of the Prypyat to Kakhovka) has a chain of reservoirs: Kiev, Kaneyv, Kremenchug, Dneprodzerzhinsk, Dneprov (formerly Zaporozho) and Kakhov. Only below the city of Dneprodzerzhinsk does a small stretch of natural channel remain. There are some 650 reservoirs in the Dnieper basin. They have a total volume of 47.4 km\(^3\) and a water area of 8 147.6 km\(^2\).

The main source of water in the Dnieper is snowmelt. The average annual water discharge at the mouth of the river is 53 km\(^3\) or 1 681 m\(^3\) s\(^{-1}\). The spring snowmelt floods generate 60-70 percent of the annual flow. In summer there are periods of low flow and in autumn there are short floods caused by heavy rain. From Kakhovka to the mouth the channel of the river is meandering and the Dnieper divides into branches and arms, which end in the Dnieper-Bug estuary. The Dnieper-Bug estuary enters a Black Sea gulf near the shores of the Ukraine. The gulf juts 55 km into the land, has a width of 7.4-16.7 km and a depth of 5.5 m. The water in the gulf has a salinity of 2-4.5‰ and freezes in winter.

The presence of the cascade of reservoirs has changed the Dnieper’s hydrological and hydrochemical regime. In addition, the river has been polluted by radioactive elements resulting from the Chernobyl reactor catastrophe. Flow regulation has resulted in an increase in nitrite and phosphate concentrations. Ammonium concentrations have increased in the middle and lower Dnieper but did not change in the upper Dnieper. The concentration of iron considerably decreased due to its sedimentation in reservoirs and accumulation in bottom deposits (Denisova, Timchenko and Nahshina 1989). The regulation of the Dnieper has led to periods of intensive development of phytoplankton, especially of cyanobacteria, which cause water blooms in the reservoirs.

Survey of radioactive caesium 137 in the bottom deposits of reservoirs in the Dnieper cascade gives the following concentrations: in Kiev 2.5 cu km\(^2\), Kaneyv - 0.7 cu km\(^2\), Kremenchug - 0.25 cu km\(^2\), Dneprodzerzhinsk - 0.4 cu km\(^2\), Dneprov - 0.1 cu km\(^2\).
km², Kakhov - 0.1 cu km² (Izrael, Vakulovsky and Vetrov 1990). Bream, white bream, roach and pikeperch from Kiev reservoir showed the following concentrations of heavy metals: lead in muscular tissue exceeding MAC by a factor of 40, in fins and scales by a factor of 10-12, in gills by a factor of 2 and in gonads by a factor of 4-5. Elevated concentrations of cadmium are found in tissues of bream, exceeding MAC by a factor of 1.5-6 (Savchenko 1997).

THE DON

The Don flows through Russia (73 percent) and the Ukraine (27 percent). It has a catchment of 422 000 km² and a length of 1 967 km. The Don is one of the main sources of fresh water in the basin of the Azov Sea. It starts on eastern slopes of highlands near the town of New-Moscow and flows into the Taganrogsky Gulf of the Azov Sea. In its upper reaches the river is confined to a narrow valley, where the main tributaries are: the Nepryadva, Krasivaya Mecha, Seyim and Voronezh. In its middle course (before the town Kalach-on-the Don) the valley broadens, with a wide floodplain reaching 6 km in places. The middle course ends in Tsimlyansk reservoir, which has a maximum depth of 36 m. From the dam to the mouth of the river, the Don flows in a wide valley (20-30 km) with a large floodplain and in some areas the river is 20 m deep. Below the city Rostov-on-the Don the Don makes a delta which covers an area of 340 km². Before the construction of the Tsimlyansk reservoir and the Volga-Don navigable canal the annual average discharge in the mouth of the Don was 29.5 km³ and the annual average flow rate was 935 m³ s⁻¹; following damming the average annual flow was reduced to 160 m³ s⁻¹. Tsimlyansk dam was closed in 1953. It has a multiple use, including hydropower generation, water supply for settlements and industries, irrigation, navigation and fishery. When full the reservoir contains 23.9 km³ of water, which is 9 percent more than its average annual flow rate in this section (22.3 km³). The reservoir is 360 km long.

Over the years there has been considerable increase in the total dissolved solids in the Don water. Concentrations of sulphates have increased 2.6-2.8 times, chlorine and magnesium 2 times, sodium and potassium 2.3-3.1 times and the total dissolved solids (TDS) concentration has increased 1.6 times in recent years. In the Taganrogsky Gulf, which has an important fishery especially for migratory and semi-migratory fish, TDS have increased 4.6 times, largely due to increases in chlorine (6 times), sulphates (2.8 times) and sodium (5 times).

In the spring, at the beginning of the summer and in late autumn the phytoplankton of Tsimlyansk reservoir is dominated by diatoms (Stephanodiscus, Cyclotella, Melosira and Asterionella), in some years reaching a biomass of 45 g m⁻³. From June to October the phytoplankton consists mainly of cyanobacteria, which may cause an intensive bloom. Abundant zooplankton feeds on the rich phytoplankton and bacterioplankton. Of the 169 species of zooplankton, the most common are 13 species of rotifers, 8 species of cladocerans and 8 species of copepods. Two species of Polychaeta, (Hypania invalida and Hypania kowalewskyi), and two of Mysidacea, (Mesomysis intermedia and Mesomysis kowalewskyi), have been introduced in Tsimlyansk reservoir with the objective of enriching the food base of bream, pikeperch and other fish. The largest biomass of benthos is reached from October to May, ranging from 4 to 10 g m⁻² (Pirozhnikov 1972). An average biomass of phytoplankton of 15 g m⁻² is present in the summer to autumn period. The average biomass of zooplankton is 10 g m⁻². The average biomass of zoobenthos in different parts of the reservoir ranges from 0.8 g m⁻² to 26 g m⁻² (Isaev and Karpova 1989).

The State Water Committee of Russia provided the following information on discharges of wastewater from point sources into the Don for the year 2001: oil products – 260 tonnes; suspended matter – 25 610 tonnes; sulphates – 302 790 tonnes; chlorides – 179
510 tonnes; total phosphorus – 1 284 tonnes; nitrogen – 842 tonnes; phenols – 220 tonnes; ammonia – 3 228 tonnes; nitrates – 7 747 tonnes; nitrites – 284 tonnes; pesticides – 4 tonnes; surfactants – 116 tonnes; greases and oils – 1 008 tonnes; iron – 540 tonnes; copper – 9.3 tonnes; zinc – 18.2 tonnes; nickel – 0.92 tonnes; chromium – 3.5 tonnes; aluminum – 8.7 tonnes; lead – 0.72 tonnes; hydrogen sulphide – 6.85 tonnes; magnesium – 16 444 tonnes; manganese – 3.32 tonnes; fluorine – 112 tonnes; calcium – 28 tonnes; silicon – 2.82 tonnes.

The Don River has 75 species and subspecies of fish, including lampreys, sturgeons (beluga, sterlet, Russian sturgeon, starred sturgeon), herrings (Caspialosa brashnikovi Borodin, Caspialosa kessleri pontica Eichwald, Caspialosa caspia tanaica Grimm, Clupeonella delicatula Nordmann, Clupeonella delicatula caspia Svetov), pike, carp, loaches (Gobitis taenia (L.), Misgurnus fossilis (L.), Noemacheilus barbatulus (L.), N. merga (Krynicki), catfishes, burbots, zanders, silverside, gobies and channel catfish (North American catfish). Channel catfish has been introduced from North America.

The Kuban

The Kuban is formed by the confluence of the Ullukan and Uchkulan rivers, which rise on the slopes of Mt. Elbrus. The length of the Kuban River is 870 km, the catchment area 57 900 km². The average annual discharge at its mouth is 12.8 km³. From the source to the town of Nevinnomysk the Kuban River flows in a deep and narrow canyon with steep slopes and rapids. A dam for supplying water to the Nevinnomysk canals has been constructed near Nevinnomysk. In the middle stretch the river flows in a wide valley with terraced slopes and rapids. A dam for supplying water to the Nevinnomysk canal has been constructed near Nevinnomysk. In the middle stretch the river flows in a deep and narrow canyon with steep slopes and rapids. A dam for supplying water to the Nevinnomysk canals has been constructed near Nevinnomysk. In the middle stretch the river flows in a wide valley with terraced slopes. Below the mouth of the river, the valley broadens and the river floodplain reaches a width of 20 km, to narrow to 3-4 km towards the river mouth. Between the mouths of the Laba River and Afips River there are the Adygeyskie wetlands (300 km²), while the Zakubanske wetlands (800 km²) are situated below the Afips River. The Protoka branches off 16 km upstream from the sea and as a result the delta of the Kuban River covers an area of some 4 300 km². The characteristic feature of the Kuban delta is the exceptional developments of estuaries, which cover 1 200 km², have a volume of 1.1 km³ and a mean depth of 0.9 meter. These estuaries have an important role for the Kuban ichthyofauna, as they serve as both spawning and breeding grounds.

Over 3 km³ of water is withdrawn from the Kuban River and discharged into the Nevinnomysky canal (constructed in 1948) and the Big Stavropolsky canal (constructed in 1967), which form part of the Kuban-Egorlyksky and the Kuban-Kalaussky irrigation systems. Krasnodar is the largest reservoir on the Kuban River, constructed in 1975 to develop irrigation and fisheries and for flood prevention in the Lower Kuban. Krasnodar dam has a catchment of 45 900 km². The full capacity of the reservoir is 2.4 km³ and the useful capacity 2.16 km³. The length of the reservoir is 46 km, the mean depth 5.5 m and the maximum depth 20 m. The Krasnodar dam has a fish lift for the transfer of migratory and semi-migratory fish from downstream to upstream. The Kuban River has a long period of floods, from May to August, fed predominantly by snowmelt. In the upper stretch of the river snowmelt and ice-melt water provides 49 percent of annual flow, while near the city of Krasnodar the snowmelt supplies 34 percent of the annual flow, with rain and groundwater providing 66 percent of the annual flow. The flow of the Kuban River has changed greatly as a result of its regulation and due to the irrevocable withdrawal of water for transfer to other basins for irrigation. During the period of fish reproduction in May-August the water volume passing through the river near the town of Kropotkin has been reduced from 3.5 km³ to 2 km³. As a result about 50 percent of the spawning grounds have been lost and the rest have been flooded by Krasnodar reservoir.

There has been a gradual increase in sulphates, magnesium, chlorine, potassium and sodium. Despite an increase in the water flow in the early 1980s, the
concentration of TDS remained unchanged; this is explained by increased discharges of return waters from irrigated fields. The following shows the concentrations of pollutants entering the river with wastewater from point sources in 2001: oil products – 130 tonnes; suspended matter – 26 000 tonnes; sulphates – 37 250 tonnes; chlorides – 22 530 tonnes; total phosphorus – 467 tonnes; total nitrogen – 1 455 tonnes; ammonium – 495 tonnes; phenols – 130 kg; pesticides - 3.83 tonnes; surfactants – 11 tonnes; grease and oil – 287 tonnes; iron – 80 tonnes; copper – 1.35 tonnes; zinc – 2.23 tonnes; nickel – 580 kg; chromium – 2.27 tonnes; magnesium – 952 tonnes; nitrite – 72 tonnes; fluorine – 8.5 tonnes; and tannin – 315 tonnes.

Phyto- and zooplankton in the Kuban River are very poor due to high turbidity, which in terms of suspended solids reaches 200 g m⁻² in the Upper Kuban and 650-700 g m⁻² in the Lower Kuban. While the bottom fauna of the Kuban River is poor; the life in the branches of the delta is much richer.

The ichthyofauna of the Kuban River changes greatly from the river source to its mouth. The uppermost stretches of the river are inhabited only by trout, which prefer clean and cold water. Some 18 species of fish are found in the middle stretch of the river, in its unregulated part. Most of them are barbel (*Barbus barbus* (L.)), bleak (*Alburnus alburnus* (L.)), chub, rifle minnow (*Alburnoides bipunctatus* Bloch), gudgeon (*Gobio gobio* (L.)), Donets ruffe (*Gymnocephalus acerinus* Guldenstadt), white bream, Colchian undermouth (*Chondrostoma colchian* Kessler), asp, sabrefish and catfish. A small number of lake or river fish (carp, bream, roach, rudd) and migratory fish (starred sturgeon, vimba, Caspian shemaya) have been reported. After the confluence with the Belaya River into the Kuban 25 additional species have been recorded, including Russian sturgeon and the Black Sea shad. Nearer the mouth the ichthyofauna of the channel part of the Kuban River is enriched by many estuarine and sea species.

Before the regulation the river had 39 species of fish, including the sturgeons beluga and sterlet and in recent years grass carps and silver carps have been introduced. Krasnodar reservoir has functioned as a sedimentary basin and this has made the downstream river channel suitable for gobies, smalemouth buffalo, Black Sea roach, flat needlefish and some other fish, which were previously unable to live there because of the high turbidity.

**THE CASPIAN SEA, THE VOLGA AND URAL RIVERS**

The Caspian is the largest endorheic brackish lake on earth. About 15 000 years ago it was part of a large sea that was joined with the ocean. The Caspian Sea is situated in arid and semi-arid zones and its shores are shared by Russia, Kazakhstan, Turkmenistan, Iran and Azerbaijan. The sea covers 435 000 km², the mean depth is 183 m and maximum depth 1,025 m. A number of rivers enter the sea, among them the Volga, Ural, Kura, Terek, Samur, Sulak, Seifdrud.

The northern part of the sea is shallow (up to 10 m) and in winter it freezes for 2-3 months. The water temperature reaches 30 °C in this part in summer. In the middle and the southern parts of the sea the winter temperature does not fall below 5.9 °C. Salinity in the northern part of the Caspian ranges from 5‰ (1‰ near the river mouth) to 12.6‰, which are similar values to those in the Azov Sea. The salinity of the middle and the southern parts of the Caspian Sea is 12.6-12.9‰, which is lower than in the open waters of the Black Sea.

The fish fauna of the Caspian Sea includes 75 species and 17 subspecies; there are 47 species and subspecies that prefer brackish water and 13 migratory and 26 semi-migratory species. There are only 6 strictly marine species, half of them being introduced quite recently. Also recently the Caspian fishery was affected by a sharp drop in the water level between 1936 and 1977, followed by a rapid rise and by the construction
of many large dams on the major inflowing rivers, the Volga, Ural, Terek and Kura.

**THE VOLGA**

The Volga basin constitutes the largest part of the Caspian Sea catchment. With an area of 1360 000 km², length of 3531 km and average annual flow of 245 km³, the Volga is the largest river in Europe. Its tributaries, the Kama and the Oka rivers, greatly influence the water regime of the mainstem Volga. There is a cascade of large reservoirs on the Volga: the Ivankovo, Uglich, Rybinsk, Gorkov, Cheboksary, Kuybyshev, Saratov and Volgograd reservoirs. In addition, three large reservoirs, the Kamsk, Votkinsk and Nizhnekamsk, have been constructed on the main tributary of the Volga River, the Kama River. Altogether, in the Volga basin there are 812 reservoirs with a total volume of 190.5 km³ and a water area of 27 239 km². The majority of these reservoirs, both large and small, were constructed to supply water to industry and cities as well as for irrigation.

Below the Volgograd dam (the lowest in the cascade) the Volga valley cuts into the lowlands for more than 400 km, as the river continues towards the Caspian Sea. Above the city of Volgograd the Akhtyuba branch of the river separates from the Volga, following it in parallel. The area between the Volga and the Akhtyuba is called the Volgo-Akhtyubinsk floodplain. The width of the floodplain ranges from 12 km to 40 km. The floodplain is crossed by many arms and canals as well as having many shallow floodplain lakes, locally called “ilmens.”

The width of the Volga channel between Volgograd and the river delta ranges from 0.6 to 2.2 km, with depths from 2.5 m to 35 m in pools. As it approaches the Caspian Sea, the Volgo-Akhtyubinsk floodplain becomes wider and forms a delta. The delta of the Volga River is one of the largest deltas in the world, covering 24 292 km².

Concentrations of most of the dissolved anions and cations, as well as nitrogen and phosphorus, increase downstream. The highest concentrations of phosphorus were recorded in Ivankov and Cheboksary reservoirs. The concentration of the total nitrogen increases from 1.28 to 1.77 mg L⁻¹. Organic matter concentrations are lower in the middle and lower reservoirs, in spite of a higher primary production as compared with that in the upper reservoirs. This is related to the higher water temperature in the middle and lower reservoirs and to a faster rate of decomposition of the organic matter. The morphometric and hydrographic characteristics of the Volga reservoirs are presented in Table 1.

As a result of flow regulation the water regime of the lower Volga has been altered. Prior to this there were spring snowmelt floods (April-June), which represented 57 percent of the annual flow, summer-autumn low-flow period (July-November), representing 29 percent of the annual flow and winter low-flow period, with 14 percent of the annual flow. Now the river behaves as follows: spring snowmelt flood (38 percent), summer-autumn low flow (34 percent) and winter low flow (28 percent). The annual pattern of peaks and lows of water level in the lower Volga has changed, with the water level mainly determined by discharges through the Volgograd hydroelectric power station. The water level rises sharply and reaches the maximum level in spring. This level lasts 36 days instead of the previous 59 days. This is followed by a sharp fall in water level in summer.

River flow regulation has resulted in a decrease in suspended loads in the lower Volga, as the sediments are being deposited in reservoirs. Prior to dam construction the suspended sediment transport was 19.3 million tonnes, but currently it is 8 million tonnes only (Tarasov and Beschetnova 1987). All ion concentrations have increased (Table 2).

Chlorine concentration increased by 80 percent and sulphates by 22 percent; although carbonates hardly changed, calcium increased by 8 percent, magnesium by 20 percent, the sum of potassium and sodium...
by 63 percent and total dissolved solids by 16 percent. The annual range of the concentration of the individual ions narrowed. The maximum concentrations are presently reached during the period of snowmelt floods rather than during the summer or winter periods as it was before the flow regulation. As a result of the construction of reservoirs, phosphorus concentrations have decreased by a factor of approximately 2 in the lower Volga. The dissolved oxygen concentrations are higher and there are no more sudden mortalities of aquatic organisms due to the low dissolved oxygen concentrations. The Volga River remains severely polluted. In 2001 the river received the following quantities of pollutants: oil products – 2 370 tonnes; suspended matter – 164 540 tonnes; sulphates – 736 460 tonnes; chlorides – 1 863 070 tonnes; total phosphorus – 10 877 tonnes; total nitrogen – 10 765 tonnes; ammonium – 38 611 tonnes; phenols – 11 tonnes; nitrates – 22 656 tonnes; nitrites – 3 789 tonnes; surfactants – 947 tonnes; greases and oils – 4 425 tonnes; iron – 2 431 tonnes; copper – 45 tonnes; zinc – 142 tonnes; nickel – 43 tonnes; chromium – 32.2 tonnes; mercury – 20 tonnes; aluminum – 987 tonnes; acetone – 1.47 tonnes; vanadium – 16.5 tonnes; benzene – 690 kg; hydroxenon – 140 kg; dichloroethane – 7.8 tonnes; tin – 5.1 tonnes; lead – 13 tonnes; hydrogen sulphide – 41.5 tonnes; carbon bisulphide – 1.05 tonnes; antimony – 590 kg; cadmium – 2.8 tonnes; cobalt – 3.3 tonnes; magnesium – 11,209 tonnes; manganese – 163 tonnes; methanol – 190 tonnes; arsenic – 760 kg; turpentine – 3.0 tonnes; tannin – 9 718 tonnes; and fluorine – 552 tonnes. It is important to note that many pollutants (pesticides, oil products, mineral fertilizers, etc.) enter rivers with the surface flow.

**The Ural**

The Ural is shared between Russia and Kazakhstan. The river has its beginning in the southern Ural Mountains at an elevation of 640 m. The catchment area is 231 000 km² and the length 2 428 km. The Ural River enters the Caspian Sea next to the town of Atyrau (Kazakhstan) through a delta that has two arms,

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Average annual flow km³</th>
<th>Water surface area km²</th>
<th>Shallows, depth less than 2 m %</th>
<th>Maximum depth of reservoir m</th>
<th>Mean depth of reservoir M</th>
<th>Maximum depth of reservoir M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ivankovo</td>
<td>9.65</td>
<td>327</td>
<td>47</td>
<td>1.12</td>
<td>0.81</td>
<td>4.0</td>
</tr>
<tr>
<td>Uglich</td>
<td>13.6</td>
<td>249</td>
<td>36</td>
<td>1.24</td>
<td>0.81</td>
<td>5.5</td>
</tr>
<tr>
<td>Rybinsk</td>
<td>35.2</td>
<td>4 550</td>
<td>21</td>
<td>25.42</td>
<td>16.67</td>
<td>6.0</td>
</tr>
<tr>
<td>Gorkov</td>
<td>52.5</td>
<td>1 591</td>
<td>23</td>
<td>8.81</td>
<td>2.78</td>
<td>6.4</td>
</tr>
<tr>
<td>Cheboksary</td>
<td>112</td>
<td>2 274</td>
<td>-</td>
<td>13.85</td>
<td>5.7</td>
<td>6.1</td>
</tr>
<tr>
<td>Kuybyshev</td>
<td>239.7</td>
<td>6 450</td>
<td>16.5</td>
<td>58.0</td>
<td>34.6</td>
<td>9.4</td>
</tr>
<tr>
<td>Saratov</td>
<td>247</td>
<td>1 831</td>
<td>18.5</td>
<td>12.86</td>
<td>1.75</td>
<td>7.0</td>
</tr>
<tr>
<td>Volgograd</td>
<td>251</td>
<td>3 117</td>
<td>37</td>
<td>31.45</td>
<td>8.25</td>
<td>10.1</td>
</tr>
</tbody>
</table>

**Table 1: Morphometric and hydrographic characteristics of the Volga reservoirs**

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Average annual flow km³</th>
<th>Water surface area km²</th>
<th>Shallows, depth less than 2 m %</th>
<th>Maximum volume of reservoir km³</th>
<th>Useful volume of reservoir km³</th>
<th>Mean depth of reservoir M</th>
<th>Maximum depth of reservoir M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ivankovo</td>
<td>9.65</td>
<td>327</td>
<td>47</td>
<td>1.12</td>
<td>0.81</td>
<td>4.0</td>
<td>14</td>
</tr>
<tr>
<td>Uglich</td>
<td>13.6</td>
<td>249</td>
<td>36</td>
<td>1.24</td>
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<td>Gorkov</td>
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<td>1 591</td>
<td>23</td>
<td>8.81</td>
<td>2.78</td>
<td>6.4</td>
<td>22.0</td>
</tr>
<tr>
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<td>112</td>
<td>2 274</td>
<td>-</td>
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<td>Volgograd</td>
<td>251</td>
<td>3 117</td>
<td>37</td>
<td>31.45</td>
<td>8.25</td>
<td>10.1</td>
<td>37</td>
</tr>
</tbody>
</table>

**Table 2: Chemical composition of the Volga River water before and after the regulation of the Lower Volga (Tarasov & Beschetnova 1989)**

<table>
<thead>
<tr>
<th>Period</th>
<th>Cl Mg L⁻¹</th>
<th>SO₄ Mg L⁻¹</th>
<th>HCO₃ Mg L⁻¹</th>
<th>Ca³ Mg L⁻¹</th>
<th>Mg Mg L⁻¹</th>
<th>Na⁺K Mg L⁻¹</th>
<th>Σ ions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>19.8</td>
<td>49.8</td>
<td>122.4</td>
<td>47</td>
<td>9.0</td>
<td>13.3</td>
<td>261</td>
</tr>
<tr>
<td>After</td>
<td>35.8</td>
<td>60.7</td>
<td>122.9</td>
<td>51.1</td>
<td>10.8</td>
<td>21.7</td>
<td>303</td>
</tr>
</tbody>
</table>
the Yaitsky and the Golden. The delta covers 700 km². In its upper reaches the Ural River is a mountain river with a turbulent current. It then flows into the Yaitsky swamp which it leaves as a quiet river flowing through a valley that slowly broadens to 5 km. Below the town of Verkhneuralsk the Ural is a lowland river with a wide floodplain, covered by meadows and floodplain lakes. Two reservoirs, situated far upstream (1 810 km and more from the river mouth), do not have a major influence on the hydroecological regime of the river.

However, numerous pumping stations situated along the length of the river withdraw about 40 percent of its annual flow. The main source of water for the Ural River is snowmelt. The spring snowmelt floods the lower Ural River from the end of March to the beginning of June. These are followed by small rain floods, after which the flow stabilises for the rest of the year. In the snowmelt flood the river floodplain is over 10 km wide in its middle course, in the delta less then 10 km wide.

In the upper course the water level fluctuates by 3-4 m, in the middle and lower course by 9-10 m and in delta by 3 m. The average annual flow near the city of Orenburg is 104 m³ s⁻¹ and near the settlement of Kushum 400 m³ s⁻¹. Concentrations of the TDS range from 400 to 690 mg L⁻¹. Concentrations of microelements and organic matter do not exceed the maximum admissible concentrations.

The fish fauna of the Ural consists of 60 species and is very similar to that of the Volga, but the Ural has bastard sturgeon, which are absent from the Volga. One should point out that the Ural is the only river flowing into the Caspian Sea in which the natural hydrological regime has been preserved over a large stretch of the river, in this case for 1 810 km, where the first upstream dam is situated.

HUMAN IMPACTS ON FISH STOCKS

The recent intensive fishing of the Black Sea has had serious impact on fish stocks and other marine biota resources. There has been a sharp drop in mackerel and bonito catches, the Black sea scad seems to have emigrated out of the Black Sea and dolphins have suffered from a variety of diseases. Planktonic *Mnemiopsis* (Ctenophora) was introduced into the Black Sea from the Atlantic Ocean and in autumn 1989 its biomass reached 1 billion tonnes. As a consequence *Mnemiopsis* reduced the biomass of plankton available to fish by 3 to 5 times as well as feeding on fish fry.

Human activities have led to a decline in the stocks of sturgeons and semi-migratory fish, both of which have declined. The decline in predatory fish has resulted in an increase in the stocks of small fish with a short life cycle, such as European anchovy (*E. encrasicolus* (L.)), European sprat (*S. sprattus* (L.)) and small mackerel.

The construction of reservoirs has led to changes in the ichthyofauna of the Dniester River. As spawning grounds of migratory and semi-migratory fish became inaccessible, species with these habits disappeared from most of the river. Rheophilous fish disappeared from the reservoirs. The numbers of lookups (*Culter* spp), white-eye (*Abramis sapa* (Pallas)) and river perch (*Perca fluviatilis* L.) have increased sharply and they now account for 15-17 percent of the total catch. Presently 85 species of fish live in the lower Dniester and the Dniester Gulf, the most numerous of which are carp (*Cyprinus carpio* (L.), gobies (Gobiidae) and perches (Percidae)). The most commonly fished species are bream, carp, pikeperch, roach, sabrefish, pike and white bream. They represent 1,030 tonnes of the total mean annual catch of 1 180 tonnes (Greze, Polikarpov and Romanenko 1987). Since 1978 the annual catch of the exotic silver carp (*Hypophthalmichthys molitrix* (Valenciennes) and grass carp (*Ctenopharyngodon idella* (Valenciennes) is 30 to 60 tonnes.
A comparison of fish catches in the Dnieper River before and after the construction of the Kakhov dam shows that:

- Before the dam construction. The average annual total catch was 5 000 tonnes. Of this the migratory beluga, Russian sturgeon, starred sturgeon and herrings represented 161 tonnes (3.3 percent of the total catch); semi-migratory species roach-taran \((\text{Rutilus rutilus} \, (\text{L.})\), bream, vimba, sabrefish, carp and pikeperch represented 1 816 tonnes (36.8 percent); freshwater fish pike, rudd \((\text{Scardinius erythrophthalmus} \, (\text{L.})\), asp \((\text{Aspius aspius} \, (\text{L.})\), crucian carp, catfish, river perch, gobiies and other species 1 268 tonnes (25.7 percent); and kilka \((\text{Clupeonella cultiventris} \, (\text{Nordmann})\) 1 687 tonnes (34.2 percent).

- After the dam construction. The average annual total catch was 6 980 tonnes. Of this migratory fish represented 31 tonnes (0.4 percent); semi-migratory fish 796 tonnes (11.4 percent); freshwater fish 608 tonnes (8.7 percent); and kilka 5 545 tonnes (79.5 percent). One can see that the catches of migratory, semi-migratory and freshwater fish have declined dramatically, although the total catches increased by 40 percent for kilka, a fish of little value. Sturgeons, sabrefish, asp and gobiies have lost fishery importance (Greze et al. 1989). The total annual catch from all Dnieper reservoirs ranges from 16 000 to 21 000 tonnes.

Until recently the Azov Sea was one of the richest bodies of water in the world. In the mid-1930s over 300 000 tonnes of fish were caught there annually, which equals a yield of 85 kg ha\(^{-1}\). Anadromous fish dominated, having very favourable spawning grounds covering some 600 000 ha (Volovik 2001).

Rapid changes in the sea ecosystem started in the 1950s, when not only the major affluent rivers (the Don and Kuban) but also their tributaries and other small rivers were dammed. The development of industry, intensification of agriculture and growth of municipal economies led to a discharge of great quantities of pollutants into the rivers and the Azov and Black seas. In those days there were few restrictions to prevent this. Pollution, regulation of water flow in rivers, invasion of \textit{Mnemiopsis} and overfishing resulted in decline in fish catches from 200 000 tonnes to 15 000 tonnes by the end of the twentieth century.

The most serious situation is in the Caspian Sea, where the sturgeon population was once the most numerous and diverse in the world and a large number of semi-migratory fish also inhabited the sea. In the 1980s the annual catch of sturgeons reached 25 000-30 000 tonnes and production of black caviar was 2 000 tonnes. In the 1960s sturgeon hatcheries were constructed which annually released from 60 000 000 to 100 000 000 sturgeon fingerlings. However, a serious decline in sturgeon catches started from the end of the 1980s (Table 3). A similar decline took place with other species of fish, except kilka (Table 4).

The stocks of sturgeon in the Caspian Sea have declined by a factor of 5, but the stock of starred sturgeon has declined by a factor of 8.5 and the semi-migratory fish catches have decreased by a factor of 11. The dire state of the sturgeons is explained by many factors, but the most important one is the loss of spawning areas. In the Volga 85 percent of the spawning areas were lost, those of beluga completely disappeared, those of Russian sturgeon were reduced by 60 percent and of starred sturgeon by 40 percent (Nikonorov, Maltsev and Morgunov 2001). There are no important spawning grounds of sturgeons left downstream of the Volgograd reservoir, for they have been subjected to sharp fluctuations in water level resulting from the operation of the Volgograd hydroelectric power station. The fluctuations cause mass destruction of sturgeon eggs. In 30 percent of female sturgeons, oocytes have been found to be resorbed.
There are also unfavourable conditions in the Ural-Caspian and Kura-Caspian regions. The irrevocable water consumption from the Ural River takes away 50-60 percent of the annual flow and 90 percent of larvae and young sturgeon perish and do not reach the sea. The fishing pressure leaves only 20 percent of the broodstock to reach their spawning grounds. The falling of the level of the Caspian Sea from the 1930s to 1977 had a great influence on the reproduction of semi-migratory fish, as the salinity in their feeding grounds in the northern Caspian increased. Since then, however, the situation has improved as a result of a rise in the Caspian sea water level by almost 2 m..

An effort to stock reservoirs with broodstock with the hope that this would restore fish stocks did not work. Between 1989 and 2000 fish catches from the main reservoirs of the Volga cascade continued their decline. In Kuybyshev reservoir catches fell 1.91 fold, in Saratov reservoir 3.43 fold and in Volgograd reservoir 5.13 fold (Sechin, et al. 2002).

The increased water consumption and growth of ecologically harmful industries in the Volga basin further worsened the quality of water. The data regarding point sources of pollution mentioned earlier reveal only the tip of the pollution “iceberg,” for there are many diffused sources, especially of pesticides, nitrogen, phosphorus, oil products and phenols, which increase the pollution of the river. The toxic substances entering the Caspian Sea disturb the structure and function of the ecosystem. In 1984 a myopathy, a degenerative disease of muscles, attacked Volga-Caspian sturgeons. Other serious changes were also discovered in the diseased fish: disruption of ionic homeostasis, distrophy and necrosis of the liver, changes in kidneys and sexual glands and disruption of gametogenesis and gonadogenesis. DDT and other pesticides were found to persist in the tissues and organs of such fish. Cadmium, nickel, mercury, lead, copper and other heavy metals have been found in fish livers (Kuksa 1994).

Table 3: Numbers (millions) and catches (tonnes) of sturgeons in the Caspian Sea (Lukyanenko 2002)

<table>
<thead>
<tr>
<th>Catches</th>
<th>1968</th>
<th>1987</th>
<th>1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sturgeons (all)</td>
<td>228</td>
<td>101</td>
<td>42.2</td>
</tr>
<tr>
<td>Beluga</td>
<td>-</td>
<td>14</td>
<td>7.6</td>
</tr>
<tr>
<td>Russian sturgeon</td>
<td>129</td>
<td>45</td>
<td>23</td>
</tr>
<tr>
<td>Starred sturgeon</td>
<td>99</td>
<td>42</td>
<td>11.6</td>
</tr>
<tr>
<td>Sturgeons (all) (t)</td>
<td>22000</td>
<td>21000</td>
<td>2000</td>
</tr>
</tbody>
</table>

Despite a recent increase in the Volga River flow rate and thus an improved self-purification, in the sea and especially in the coastal zone pollution levels remain very high. Due to an increase in the level of the Caspian Sea and increased freshwater input the conditions for semi-migratory fish have improved. But these changes have by no means benefited the sturgeons.

Table 4: Fish catches (tonnes) in the rivers of the Caspian Sea

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-migratory</td>
<td>24100</td>
<td>16500</td>
<td>20100</td>
<td>112400</td>
<td>44300</td>
<td>20000</td>
<td>22800</td>
</tr>
<tr>
<td>Freshwater</td>
<td>62000</td>
<td>25800</td>
<td>34000</td>
<td>32100</td>
<td>42800</td>
<td>27000</td>
<td>20000</td>
</tr>
<tr>
<td>Kilka</td>
<td>81800</td>
<td>136500</td>
<td>56100</td>
<td>54900</td>
<td>18000</td>
<td>12000</td>
<td>4600</td>
</tr>
<tr>
<td>Vobla (roach)</td>
<td>-</td>
<td>-</td>
<td>53000</td>
<td>16900</td>
<td>9400</td>
<td>5000</td>
<td>3600</td>
</tr>
<tr>
<td>Salmon</td>
<td>900</td>
<td>1100</td>
<td>400</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Kilka</td>
<td>6900</td>
<td>8900</td>
<td>21600</td>
<td>176000</td>
<td>423200</td>
<td>315400</td>
<td>150547</td>
</tr>
</tbody>
</table>
Many experts believe that sturgeons could disappear from the Caspian Sea basin during the twenty-first century.

**RECOMMENDATIONS**

It is recommended that:

- The impact of selected factors influencing migratory and semi-migratory fish be studied. These impacts include: hydraulic engineering constructions; pollution; introduction of harmful exotic species that are dangerous for the ecosystem (e.g. *Mnemiopsis*);

- Hatchery-produced young sturgeons be stocked in the Volgo-Caspian, the Azov and Black Sea (Altukhov and Evsyukov 2002);

- The effectiveness of artificial spawning grounds be evaluated;

- That discharge of waste water into rivers from both point and diffusion sources be gradually decreased and eventually stopped;

- Rice production in the deltas of the rivers Volga, Kuban, Terek and several others should be stopped and the deltas used only for fisheries;

- The volume of water transferred from the Kuban River into the basins of other rivers through Nevinnomyisky and Bolshoy Stavropolsky canals be reduced;

- Tsimlyansk reservoir be stocked in the period of spring snowmelt flood when spawning grounds for migratory and semi-migratory fish are available;

- Volgograd, Saratov and Kuybyshev dams be removed to save the Caspian Sea sturgeon;

- Two International Commissions be established, one for studies of the Black-Azov Seas and their catchments, the other for studies of the Caspian Sea with its catchment. The programmes of these Commissions would have as a major objective achieving a long-term improvement of the environment in both watersheds, including the above proposals.
REFERENCES


