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Sea of Azov: A brief review of the environment and fishery

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The Sea of Azov, bounded by Ukraine and Russia, is a unique brackish waterbody from many points of view despite its small size. Low water salinity, shallow waters, high summer temperatures, large riverine inputs of organic matter and minerals, and other factors lead to its very high biological productivity. The article reviews specific features of the Sea of Azov fish fauna and fisheries providing some historical and modern statistical data. An updated check-list of native and non-indigenous fish taxa permanently or occasionally inhabiting the Sea of Azov is included.

Keywords: Eurasia, fish community, check-list, fisheries, conservation

Introduction

Overview of the basin

The Sea of Azov is bounded in the west by Ukraine and in the east by Russia. It is an internal sea with passage to the Atlantic Ocean going through the Black, Marmara, and Mediterranean Seas and is connected to the Black Sea by the Strait of Kerch (Figure 1), which at its narrowest has a width of 4 kilometres. The Sea of Azov is the shallowest sea in the world with an average depth of 7 m and maximum depth of 14 m; in the bays, the average depth is about 1 m. The sea bottom is also relatively flat with the depth gradually increasing from the coast to the centre. It may be considered both as peripheral waterbody of the Black Sea and a vast brackish estuary ("liman") of the River Don; i.e. the mixing zone of fluvial and Black Sea waters (Zenkevich, 1963; Dobrovolsky and Zalogin, 1982; Goptarev et al., 1991). The Sea of Azov is a unique brackish waterbody from many points of view despite its small size. Low salinity is the main reason for low diversity of flora and fauna in comparison with the Mediterranean, Caspian and Black Seas. Concurrently, shallow water, high summer temperature, large input of organic and minerals with river influx, and some other factors lead to very high biological productivity. In fact, the entire Sea of Azov area, with few exceptions, represents an extended feeding ground, for both adult fish species and their juveniles. The deltas of rivers entering the Sea of Azov, primarily large rivers such as the Don and the Kuban, serve as spawning grounds for a number of anadromous and seminandromous fish species. Fish production was up to 85 kg ha^{-1}. Valuable commercial fishes – Sturgeons, Shads, Vimba *Vimba vimba* (Linnaeus, 1758), Azov Shemaya *Alburnus leobergi* Freyhof et Kottelat, 2007,

Aquatic Ecosystem Health & Management, 18(2):184–194, 2015. Copyright © 2015 AEHMS. ISSN: 1463-4988 print / 1539-4077 online
DOI: 10.1080/14634988.2015.1039428

UA-56

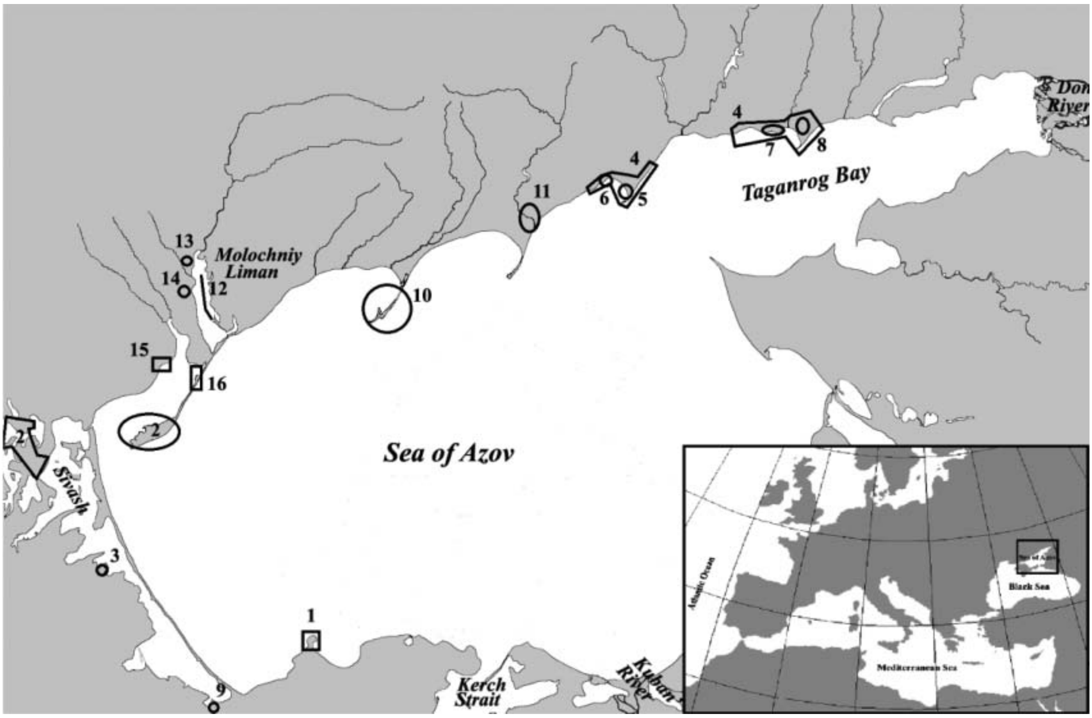

Figure 1. Map of the Sea of Azov and national-level entities of Ukrainian Nature Conservation Fund located at the Sea of Azov and its coastal zone (based on data from Leonenko et al., 2003): Kazantip Nature Reserve (1), Azov-Sivash National Nature Park (2), regional landscape parks, Kalinovsky (3) and Maeotida (4), and 12 special reserves ("zakaznik") (5–16).

Pike-Perch *Sander lucioperca* (Linnaeus, 1758), and Black Sea Roach (taran') *Rutilus rutilus heckelii* (Nordmann, 1840) – played an important role in fisheries. For instance, sturgeon catches in mid-19th Century amounted to 15,000 tonnes (Matishov, 2003; Matishov et al., 2005).

This high biological productivity is the main reason for the considerable scientific attention paid to the sea from early times. The history of hydrobiological research in the basin of the Sea of Azov was reviewed by Aldakimova and Zakutskiy (1985). Regrettably, the current state of the unique ecosystem of the Sea of Azov may be characterized as degraded. The Sea of Azov, previously among the most productive seas of the world, has almost completely lost its commercial importance within the last 150 years, due to numerous reasons. Some of the decline is the result from the impact of natural factors but much of it is due to various human activities. Nevertheless, further degradation of the Sea of Azov ecosystem and its bioresources might be halted and even restored to a moderately sustainable level, given stricter regulation of economic activities.

The goal of the article is to review specific features of the Sea of Azov fish fauna with regard to taxonomic content, modern state of fish communities, and fisheries.

Review of the Sea of Azov freshwater fauna and freshwater fishery

Fishes have always been an important product of the Sea of Azov. A total of 120 species and subspecies from 39 families have been reported (Appendix 1, available in the online supplementary material). This inventory lists all fish species registered exclusively in the sea area (excluding other waterbodies in the basin) by various researchers in various years, including single occurrences.

According to their origin, there are freshwater species, Pontic-Caspian relicts, Atlantic-Mediterranean migrants, and several non-indigenous species introduced in recent time. From a taxonomic point of view, the most diverse families are the Cyprinidae and Gobiidae (20.9 and 17.4%, respectively), which together make up a third of the overall fish species diversity.

In relation to salinity, the fish fauna of the Sea of Azov includes representatives of all ecological groups: anadromous, semi-anadromous, freshwater, brackish water and marine species (following Kessler [1877] who developed his classification specifically for the brackish seas – Caspian, Black and Azov – of the Russian Empire). Freshwater species (Bleak *Alburnus alburnus* (Linnaeus, 1758), Pike *Esox lucius* Linnaeus, 1758, Perch *Perca fluviatilis* (Linnaeus, 1758), and Asp *Aspius aspius* (Linnaeus, 1758)), are few, as a rule; they occur locally in the most desalinated areas at river inflows. However, since the mid-1980s, an increase in the number of Prussian Carp *Carassius gibelio* (Bloch, 1782) has been recorded in the coastal waters of the Taganrog Bay. Thus, during the period 1983–2000, its contribution in Taganrog Bay catches increased from 1.7 to 30.5–41.5%. Concurrently, distribution of this species in the Sea of Azov expanded as well (Abramenko, 2000, 2003).

Certain primary-freshwater species (e.g. Bream *Abramis brama* (Linnaeus, 1758), wild Common Carp *Cyprinus carpio* (Linnaeus, 1758), and Pike-Perch), under conditions of the Sea of Azov, exhibit the behavioural pattern of semi-anadromous fish by reproducing in the lower reaches of rivers and desalinated estuaries, and feeding in the sea.

Anadromous fishes of the Sea of Azov represent its primary wealth. This refers, above all, to sturgeons (family Acipenseridae), which are the most valuable representatives of the fish fauna of the Sea of Azov. However, currently they are excluded from fishery, since a ban on commercial sturgeon fishing was introduced in 2000. At present, their fishing may be executed exclusively for artificial reproduction and research purposes. Sturgeon stocks in the Sea of Azov were severely depleted in the late 20th Century, and the threat of sturgeon overfishing emerged as early as in the first half of the 20th Century. To avoid the fisheries crisis, artificial hatchery reproduction developed effectively in 1960s–1980s. More than 40 million sturgeon fingerlings were released annually into the sea. So, by early 1980s a new commercial sturgeon stock (13–17 million individuals, commercial reserve – up to 8 tonnes) was formed in the Sea of Azov, mainly through hatchery activities. Similar stock abundance was observed in 1950s–1960s, through natural sturgeon reproduction. However, by 1998, their number had declined drastically to 4 million individuals (Matishov et al., 2005). Withdrawing the majority of sturgeon spawners destroyed the system of artificial reproduction created during the Soviet era. Sturgeon fishes are under special concern of CITES – Convention on International Trade in Endangered Species of Wild Flora and Fauna (1973, Ukraine entered in 1999); sturgeons of the Sea of Azov basin are listed in Appendix 1, available in the online supplementary material. Other valuable commercial anadromous fish species include Vimba, Black Sea-Azov Shad *Alosa immaculata* Bennett, 1835, and Azov Shemaya.

The Sea of Azov is one of the oldest fishery basins. The first information about fishing in the region comes from the 7th–6th Centuries BC – the time of settlement of the Hellenic colonies on coasts of the Black Sea and Sea of Azov (called Maiotis Liman by Greeks, and Palus Maeotis later by Romans) (Marti, 1941). The history of commercial exploitation of the Sea of Azov is particularly demonstrative as predatory use of natural resources in this plentiful waterbody. This applies both to the contemporary history characterized by a high development of scientific and technological progress, and past years – the second half of the 19th Century. Without detailed discussion of that period, we just refer to the quotation from Knipovich (1932, p. 368) devoted to the characteristics of the Sea of Azov fisheries in the second half of 19th–early 20th Century: "The fishery records in the Sea of Azov may serve as an impressive warning against over-intensified fishing plans and, at the same time, as a good illustration of the natural resources' limitations in fishing areas. By the beginning of World War I, the once-rich, highly productive fishery at this sea was brought to the deep depression by unsustainable fishing. Reduction and partial temporary suspension of fishing during external and civil wars sufficed for the sharp improvement in the situation, fish abundance increased greatly and certain species that had previously lost their fishery importance re-entered commercial fishery items. Increased fishing, along with some obviously rapacious fishing methods and insufficient protection of rich fish resources recurred to a rapid abrupt decline in the number of certain commercial fish." In general, these comments are also relevant to the next historical period. Prior to the year 1952, rivers of the Sea of Azov basin were characterized by the natural flow regime, while anthropogenic impact at that time was relatively insignificant. During that period, the largest catches were recorded as well (Figure 2). For example, between 1930 and 1952 (excluding the WWII years, 1942 and 1943), the average annual catches were at the level of approximately 200,000 tons. The maximum catch was recorded in 1936 – 275,000 tonnes; notably, the proportion of the most valuable anadromous, semi-anadromous, and freshwater species in the catch amounted to 59%.

Disruption of the natural riverine flow that had started with River Don regulation in 1952, later caused a decrease of the Sea of Azov's productivity and led to the decline of fish stocks and, consequently, catches, especially those of primary freshwater species (Figure 2). Comparison of the catches for the period of 1980s vs. the maximum catch in 1936 shows that they declined by a factor of 5−12 for anadromous fishes and by a factor 15−33 – for semi-anadromous species (e.g. Pike-Perch, Bream and Black Sea Roach). Since the late 1980s, due to the mass development of invasive Comb Jelly *Mnemiopsis leidyi* (Agassiz, 1865), a sharp drop in marine pelagic fish stocks (Anchovy *Engraulis encrasicolus maeoticus* (Pusanov, 1926), and Tyulka *Clupeonella cultriventris* (Nordmann, 1840)) has occurred resulting in a sharp drop in marine fish catches through the next decade (Figure 2).

Thus, by the end of the 19th Century, the catches (involving all ecological fish groups) decreased in this waterbody. During 1991−2000, the total annual catch ranged from 16.6 to 40 thousand tons, the average annual value was equal to 27.3 thousand tons; i.e. a tenth of the catch level in 1936. Currently, fish catches in the Sea of Azov have risen slightly, compared the values of 1990s, to the level of 45−50 thousand tons per year. This is mainly related to the increasing stocks of traditional commercially important fishery item – Azov gobies; their fishing resumed after a nearly 20-year suspension; another contributing factor was a relatively stable commercial stock of introduced Redlip Mullet *Chelon haematocheilus* (Temminck and Schlegel, 1845).

State of freshwater fish science in the country

Current state of knowledge of freshwater fishes

Information on the ecosystem dynamics, habitat conditions, fish biology, and reproduction in the Sea of Azov that has been accumulated for several decades, may be considered as one of the most comprehensive and detailed datasets about the

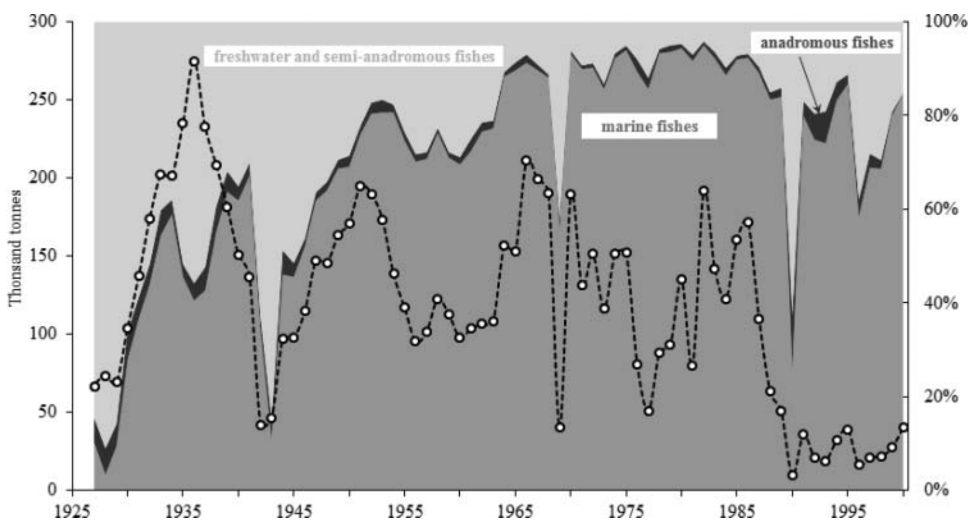

Figure 2. Dynamics of fish catches, thousand tons; 1927–2000 official statistics data (dashed line, left axis) and percentage in total catch (right axis) of fishes of different ecological groups.

UA-56

fishing industry of the former USSR. A specialized research institution, the Azov Fisheries Research Institute (AzNIIRKh) (Rostov-on-Don, Russian Federation), has been operating in the Sea of Azov basin for more than 75 years. In the period when the Ukraine became an independent state, one of the AzNIIRKh subdivisions provided the basis for the establishment of a state enterprise, the Azov Centre of YugNIRO, now Institute of Fisheries and Marine Ecology. The primary research institution of Ukraine, which is directly involved in fisheries issues on the Sea of Azov (and the Black Sea), is the Southern Scientific Research Institute of Marine Fisheries and Oceanography (YugNIRO) located in the city of Kerch. Certain issues are also within the scope of research interests of other research institutions, the National Academy of Sciences, and some of Ukraine's higher educational institutions.

The fish fauna composition and its recent transformation have been discussed in a few recent publications (Volovik and Chikhachev, 1998; Chkihachev, 2001). The most recent identification guides of the Sea of Azov fishes are those by Diripasko et al. (2001, 2011).

Fishery gear used in the Sea of Azov

The following major types of fishing gears are used in the Sea of Azov basin: mobile nets, fixed nets, and traps. Additionally, various gears are used for harvesting shellfishes and seaweeds. Mobile nets gears include seine nets, various trawls, dredges and their combined varieties.

A small beach seine net, "volokusha," represents a net screen fastened to the guard ropes (lines) at top and foot; the head line is equipped with floats, the lead line bears weight (plumbs). It consists of two equal-length wings of equal height and a codend, "kutok," stitched between the wings (an optional feature). The main types of mobile net gears used in the open sea are surrounding net (purse seine) and lampara. Purse seines were used for commercial harvesting of almost all pelagic fish (especially gobies, Tyulka, and Anchovy) that form aggregations; the mesh size is commonly 6.5 mm and the length of the floating top line is commonly 500 m or more. However, this only applies to earlier years, before late 1980s when stocks of these fish species were sustained at a very high level. These species had formed dense aggregations in the open sea and the timing and routes of wintering migrations of these species were well-known. However, anchovy and sprat stocks decreased sharply after the expansion of Comb Jelly into the Sea of Azov. Currently, commercial fishery concentrations of these species are insignificant, migration terms and routes differ considerably between the years and, therefore, the contribution of purse net fishing has dropped to less than 20% in the total catch value for these fishes.

A variety of a long surrounding net with a large mesh (up to 30 mm) were also used for catching Redlip Mullet in years of its great abundance. The lampara net is a surrounding net with the leadline much shorter than the floatline, two lateral wings and a central codend to retain the catch. In the Sea of Azov, a local variety of the lampara is 150 m long or less. The lampara nets provided up to 80% of Redlip Mullet total catches.

Regarding the commercial Goby fishing, close-meshed 6.5 mm purse seine and lampara are less effective, and more than 70% of the total Goby catch is obtained using so-called Goby dredges (manual, aided, and mechanized). Goby dredge lacks any metal frame and can be classified as a net gear close to seine net but used for catching fish from the bottom or over the bottom (almost exclusively Gobies). The Goby dredge is designed as a small seine 45−50 m long and having a codend and two wings but the bottom leadline bears thick ropes considerably exceeding the wings' length are attached to dredge wings. While hauling, these ropes touch the bottom and, as a result of traction, scare fish away and, thus, stimulate their directed movement towards the net section of the fishing gear, whereupon fish "slides" in the codend. Dredges are hauled ashore or on board of the vessel.

Trawls in general are not used in commercial fisheries but small trawls are in use for research and experimental fishing.

Fixed nets are mostly represented by gillnets that may consist in single, double, or triple netting (trammel net). So-called "porezhovye" nets used in the Sea of Azov have double or triple netting, the main wall being a usual gillnet while one or two additional walls are of a larger-sized mesh. So-called "frame" nets, also known as "tied-down gill nets," are gill nets stitched from the headrope to the footrope by additional lines keeping meshes from sagging. These nets are subject to strict limitations due to the frequent by-catch of banned species. Currently, in the Sea of Azov, frame nets are used primarily to fishing Azov Flounder, "kalkan."

A net gear of a category intermediate between gillnet and trap is "karavka" – a small stationary gillnet forming a top-open net trap with constantly fixed walls and one or several guide-way tow wings. The trap part consists of the "garth" and one or several entrapments with the system of inlets. The karavaka's height is commonly less than 3 m, it is fixed with its footrope at the bottom and the headrope over the water surface, and has a single guide-way wing adjacent to the shore or to the rift. Fish aggregate in the catching chamber without being either gilled or enmeshed. The karavka may be set both from the shore, and in the open water, either single, or in few units; it is mostly used for catching Tyulka. The most vivid example of the 6.5 mm mesh karavka's efficiency in the Sea of Azov is its use for Tyulka fishing at the northern coast of the Sea of Azov and, particularly, in the Taganrog Bay, the destination of spring spawning migration of Tyulka. Karavkas contributed up to 90% of the total Ukrainian Tyulka catch in the Sea of Azov.

For catching gobies, the fyke nets (venter) with 16–18 mm mesh are used. They are fixed on the bottom and, in the Sea of Azov, have only one long wing guiding the fish towards the entrance of the netting bag. Fyke nets are operated in coastal zone in shallow waters in places of Goby migrations.

Traps are rather expensive in construction costs, installation and maintenance, but they are commonly considered as having the low negative environmental impact as caught juveniles or undersized species can be released alive in particular by selection of specific mesh size in the trap.

Current status of freshwater habitats

River flows, atmospheric precipitation, and evaporation play key roles in the water balance of the Sea of Azov (Goptarev et al., 1991). Distinct water masses are formed as a result of interaction between Black Sea waters that come via the Kerch Strait and river flows coming mainly from the Don River and the River Kuban.

Salinity defines the condition and dynamics of the Azov ecosystem. Salinity changes due to climatic and anthropogenic factors. The arid climate around the Sea of Azov causes significant evaporation. Over the long-term, the average salinity in the Sea and atmospheric humidity in the entire basin show a strong negative correlation (Bronffman et al, 1979). Periods with high salinity were rather short and are interspersed with long-time periods of lower salinity (Figure 3). The present state of the Sea of Azov ecosystem has been formed under the influence of climate processes

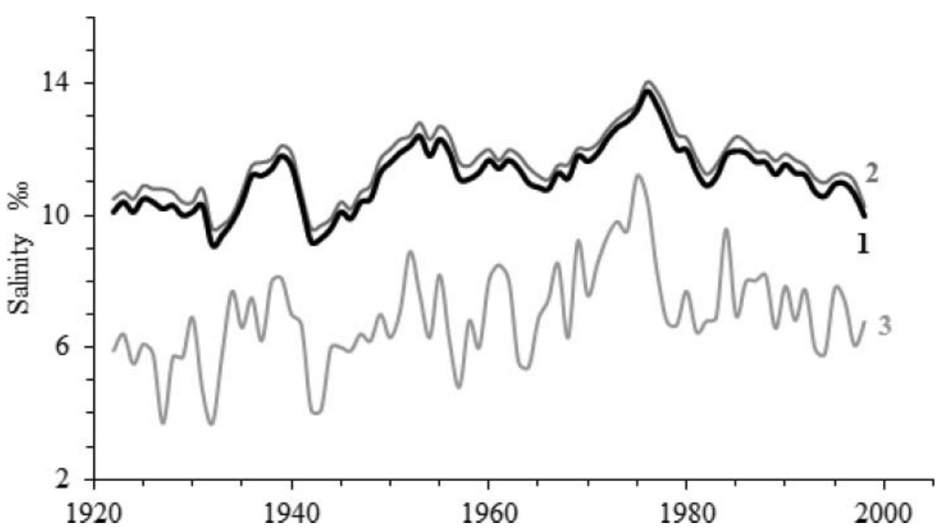

Figure 3. Long-term fluctuations of the salinity of the Sea of Azov (from Garkopa, 2000): 1: average for entire Sea of Azov; 2: Sea of Azov proper (main part, without the Taganrog Bay); 3: Taganrog Bay.

beginning in the 1980s with freshening as a result. Now, the salinity has decreased to 10−11‰, which corresponds to the concentration of the rivers flowing into the Azov basin. Damming of the main rivers has also contributed to the changes in the salinity equilibrium in the Sea of Azov. The damming began 50 years ago and some consequences are still being seen at the present time.

The most intensive development of the agro-industrial complex in the former USSR occurred in the region at the same time. As a result, the Sea of Azov has received strong anthropogenic impacts through air, soil and surface water pollution, and through direct pollution of the sea waters. With the economic depression in 1990s in the newly independent states Ukraine and Russia, following the collapse of the USSR, the pollution levels in the Azov basin decreased significantly, but some negative impacts are still present.

The most significant factor that altered the balance of the ecosystem at the end of the 20th Century was the biological pollution due to the invasion of Comb Jelly, *Mnemiopsis leidyi*. The first introduction in the Black Sea occurred in the beginning of 1980s, possibly with ballast waters. By 1989, there was a large bloom with a biomass reaching up to a million tons (Vinogradov et al., 1989, 1992). In the Sea of Azov, *Mnemiopsis* was first found near the Kerch Strait and in the southern and eastern parts of the Sea in August 1989 (Mirzoyan et al., 2000). From that time, the ctenophore annually penetrates into the Sea of Azov from the Black Sea at the end of spring or in early summer, is distributed around the Sea and forms a temporary "Azov population."

Ctenophore population development is very intensive like an algal bloom, and the total biomass can reach up to 30 million tonnes wet weight (Mirzoyan et al., 2000). These blooms have a significant influence on the whole ecosystem of the Sea of Azov especially fishery resources, as the Comb Jelly become the main food competitor of the abundant pelagic fishes such as Tyulka and Black Sea Anchovy.

Oxygen depletion in the bottom water layers of the Sea of Azov is also a major ecosystem problem. It occurs during summer due to the absence of wind and the stratification of the water column by the density gradient effects of temperature and salinity. Hypoxia in the bottom water layers is accompanied with the death of benthic fauna. Gobies are impacted more than other fishes.

Survey of freshwater fishes management

Legislative and regulatory treatment of fish, habitat and fisheries

The first legislation acts were created and developed in the 19th Century and later became the basis for creating fishing legislation for the Sea of Azov during the Soviet era. After the collapse of the Soviet Union (1991), the Sea of Azov becomes a sea of two states – Ukraine and the Russian Federation. Each country developed a unique national fishery legislation. Coordination on the use of aquatic bio-resources in the Sea of Azov by Ukraine and Russia is coordinated by a specially created organization, the Ukraine-Russia Commission on Fishery in the Sea of Azov. The Commission's work was initiated in accordance with an international agreement concluded in 1993 between the State Committee of Fisheries and Fishing Industry of the Ukraine and Federal Fisheries Committee of the Russian Federation. The main Commission tasks are:

- Annual estimation of total limits of catch (Total Allowable Catches – TAC) (currently, the Commission estimates TAC for the following fish species: Russian Sturgeon, Stellate Sturgeon (Sevruga), Great Sturgeon (Beluga), Pike-Perch, Redlip Mullet, Gobies, Azov Turbot, Black Sea Anchovy, Black Sea Tyulka, Shads, Bream, and Black Sea Roach);
- Split TAC into national quotas for Ukraine and the Russian Federation;
- Coordination of changes and additions to the base international rules on commercial fishing in the Sea of Azov, which are used by both countries in creation of their national fishery legislation and regulations;
- Joint planning of both countries efforts to the restore the fishery resources in the Azov basin;
- Coordination of fishery-inspection activities of both countries.

Taking account of the decisions of Ukraine-Russia Commission on fisheries in the Sea of Azov, Ukraine developed the basic legislation guiding fishing in the Sea of Azov, "Temporary Rules of Commercial Fishery in the Sea of Azov Basin" (State Committee of Fisheries of Ukraine, 2000). Yearly supplements and amendments to the Rules are introduced as "The Fishing Regime in the Sea of Azov" for each year. The regime may: (i) provide for temporary bans or restrictions on certain types of commercial fishing; (ii) set fishing procedures for the works that have already been agreed by Azov riparian countries yet unregulated by the Rules; (iii) clarify certain standards of the rules.

Linkages with biodiversity conservation, aquatic and terrestrial ecosystem management, sustainable development, ecosystem health

One of the most effective ways to conserve biological communities and diversity is the establishment of protected areas. Within Ukrainian borders at the Sea of Azov and its coastal zone 16 operational national-level conservation units have been established under Nature Conservation Fund (Figure 1): one National Nature Park, two regional Landscape Parks, and 12 special reserves ("zakaznik") of different classes (landscape, hydrology, forestry, botanical, ornithological, zoological). Currently, they cover in total about 87,000 hectares. Recently, in February 2010, the President of Ukraine signed an order to establish a new national nature park in the northern Sea of Azov area that will include 35,500 hectares of waters of the Molochnyy and Utlyukskiy limans. The Azov and Black Sea littoral areas of the Ukrainian coastal zone are located in the Azov-Black Sea Ecological Corridor targeted under the international WB-GEF "Azov Black Sea Corridor Biodiversity Conservation" Project, 2002–2006.

Under the current legislation, rare and endangered animal and plant species are recorded in the Red Data Book of Ukraine. The current species list of the Sea of Azov ichthyofauna registered in Red Data Book of Ukraine and IUCN Red List includes 20 species (Table 1).

Examples of specific success stories regarding freshwater fishes

In the 20^{th} Century, particularly, in the second half, there were widespread efforts to raise fish productivity of the waterbodies through various fisheries management activities. Among such interventions in the Sea of Azov, the most extensive ones were hatchery fry production of valuable fish species and introduction (acclimatization) activities. For example, by the year 1985, fourteen hatcheries for industrial production of the Sea of Azov fish juveniles (e.g. Sturgeon species, Pike-Perch, Bream, Black Sea Roach, Vimba, Shemaya) were functioning; they produced and released into the sea more than 4.2 billion fish fingerlings (Zaydiner and Popova, 1990).

In different years, the following fish species were introduced into the Sea of Azov: Striped Bass (*Morone saxatilis* (Walbaum, 1792)), Kutum (*Rutilus kutum* (Kamensky, 1901)), Pacific Redfin (*Tribolodon brandtii* (Dybowski, 1872)), Chinese carps (*Ctenopharyngodon idella* (Valenciennes, 1844)), *Hypophthalmichthys molitrix* (Valenciennes, 1844)), Redlip Mullet, and others. These introductions did not produce tangible results and the only introduced species that became well established is Redlip Mullet (Dem'yanenko and Diripasko, 2003). Redlip Mullet introduction was initiated in 1978. Activities for stocking and release were carried out at Molochnyi Liman where an experimental facility had been constructed. Instead of the direct method, a phased acclimatization method (captive broodstock formation and production of hatchery-bred progeny) was applied. Following production of the first hatchery generation in 1984, fish translocation from the Sea of Japan ceased and the fingerlings of local origin were used for stocking purposes (Sabodash and Semenenko, 1998). By the end of 1980s, the entire project had been completed with the formation of a self-reproducing population in the Sea of Azov. Redlip Mullet spread into the Black Sea, and appeared in the Mediterranean Sea. Beginning in 1992, it was included in the commercial species list of Azov-Black Sea basin. Its contribution to fishery yield gradually increased and now Redlip Mullet is among the major fishery items accounting for 15–20% of annual catches in the Sea of Azov (Figure 4).

A very revealing failure in protection and management of fish resources is shown by the current situation with the Sea of Azov Sturgeon species. Prior to the early 1990s, the stock status of the Russian Sturgeon and Stellate Sturgeon was assessed as "healthy." The stock abundances were supported by effective large-scale reproduction at sturgeon hatcheries. After the collapse of the Soviet Union, followed by protracted economic crises in both Ukraine and the Russian Federation, stocking of Sturgeon fingerlings into the sea declined sharply. At the same time, illegal fishing developed as a result of adverse socio-economic conditions among the local people. Thus, the total numbers of Russian and Stellate Sturgeons were

Table 1. A list of fishes of the Sea of Azov registered in Red Data Book of Ukraine for 2009.

Species, subspecies	Category in Red Data Book of Ukraine (Akimov, 2009)	IUCN category (IUCN, 2009)
Acipenser nudiventris (Lovetsky, 1828)	Extirpated	Endangered A1acde+2d (Black Sea stock)
Acipenser ruthenus (Linnaeus, 1758)	Endangered (“vanishing”)	Vulnerable A1c+2d
Acipenser gueldenstaedtii (Brandt et Ratzeburg, 1833)	Vulnerable	Endangered A2d
Acipenser stellatus (Pallas, 1771)	Vulnerable	Endangered A2d
Huso huso (Linnaeus, 1758)	Endangered (“vanishing”)	Endangered A2d
Alburnus leobergi (Freyhof et Kottelat, 2007)	Vulnerable	Least Concern
Rutilus frisii (Nordmann, 1840)	Endangered (“vanishing”)	Least Concern
Salmo labrax (Pallas, 1814)	Endangered (“vanishing”)	Least Concern
Lota lota (Linnaeus, 1758)	Endangered (“vanishing”)	Least Concern
Syngnathus variegatus (Pallas, 1814)	Vulnerable	[Not Evaluated]
Syngnathus tenuirostris (Rathke, 1837)	Vulnerable	[Not Evaluated]
Hippocampus guttulatus microstephanus (Slastenenko, 1936)	Vulnerable	[Not Evaluated]
Chelidonichthys lucernus (Linnaeus, 1758)	Rare	[Not Evaluated]
Dicentrarchus labrax (Linnaeus, 1758)	Data Deficient	Least Concern
Diplodus puntazzo (Cetti, 1777)	Data Deficient	[Not Evaluated]
Sciaena umbra (Linnaeus, 1758)	Rare	[Not Evaluated]
Umbrina cirrosa (Linnaeus, 1758)	Rare	[Not Evaluated]
Benthophiloides brauneri (Beling et Iljin, 1927)	Rare	Data Deficient
Benthophilus stellatus (Sauvage, 1874)	Rare	Least Concern
Gymnocephalus acerina (Gueldenstaedt, 1774)	Endangered (“vanishing”)	Least Concern

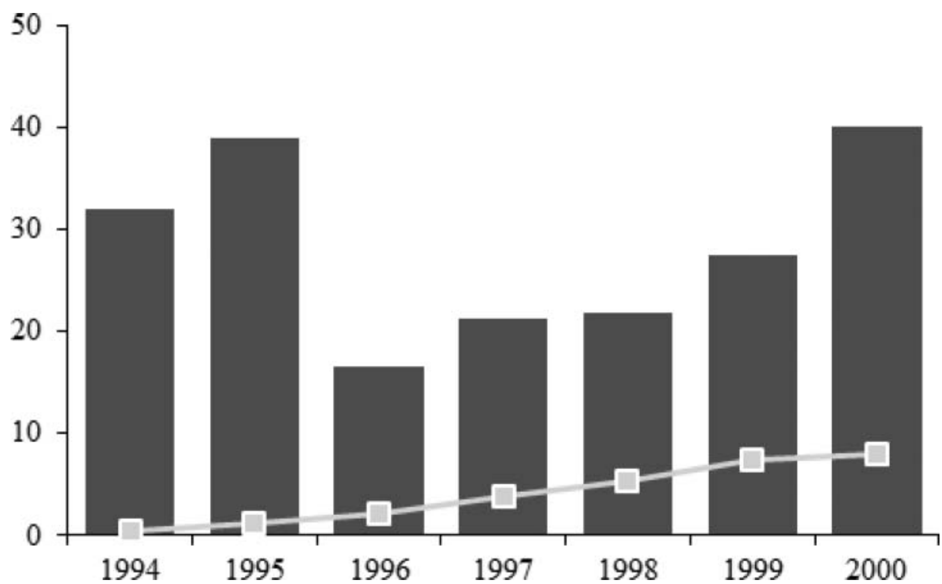

Figure 4. Redlip Mullet catch (initial stage of commercial exploitation) against the background of annual total commercial fish catch in the Sea of Azov (official statistics data, thousand tons) 1994–2000: rectangular: total catch; dots: redlip catch.

UA-56

reduced by a factor of 4 through the period 1994−2001 (Rekov, 2002). A ban on sturgeon fishing was introduced in 2000; fishing for them is permitted only for reproduction and research purposes. However, this action did not stabilize the populations as their numbers kept declining. At present, a deficit in ripe sturgeon adults ready to spawn already exists and the situation still becoming more acute.

Conclusions

The current status and feasible opportunities of the Sea of Azov are largely determined by the environmental situation that, in turn, is due to a complex set of natural and anthropogenic factors. Only a small fraction of factors can be altered through the efforts of the fishery industry itself. Changes in the majority of the other factors realistically, requires the active participation of the other users of the ecosystem at different institutional levels, from the regional to the international. Moreover, environmental aspects of the Azov fisheries development will need to be considered throughout its hydrographic network including smaller waterbodies.

Given the current situation in the Sea of Azov basin, the following major issues may be indicated for development of fisheries:

- Interstate settlement of problems related to reducing anthropogenic loads on aquatic resources and biota.
- Pursuit of active environmental policy aimed at rehabilitation of hydrological ecosystems (structures, regimes, and functions).
- Solution to problems related to the protection of biological resources, and the reproduction and sustainable use of fish stocks.
- Reconstruction and introduction of updated equipment and technology throughout the fishing industry.
- Rehabilitation of fish stocks to levels reflecting the ecosystem's capacity and intensive development of various aquaculture opportunities.
- Education of highly qualified experts and further development of fisheries science in Ukraine.

Supplemental material

Supplemental data for this article can be accessed on the publisher's website.

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UA-56

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UA-56