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The Caspian Sea

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Introduction

The Caspian Sea is the largest lake on our planet. It is bigger than the Great American lakes and Lake Victoria in Africa (Fig. 1) by surface area. However, it is unique not only because of its size. As distinct from other lakes, the water of the Caspian is not fresh, but brackish. Each liter of Caspian water contains 10-13 grams of salt making this water unsuitable for drinking or irrigation. However, the comparison of of the Caspian water to oceanic water shows that it contains three times less salt than that of the World Ocean.

Why is the Caspian salty, and not fresh? The point is that the Caspian Sea is a remnant of the ancient Thetis Ocean, or more precisely, its gulf - Parathetis. Some 50-60m years ago, Thetis Ocean connected the Atlantic and the Pacific Oceans. Gradually, due to movement of continental platforms, it lost its connection, initially, with the Pacific Ocean, and later with the Atlantic, turning it into an isolated water body. Thus, the salinity of the Caspian can be accounted for its genesis.

So why nowadays is the Caspian three times less salty than the World Ocean? Under the isolation, the salinity of the Parathetis used to fluctuate. In hot and dry climatic phases with little precipitation, the Parathetis would dry up and be divided into separate water bodies with more saline water than in the World Ocean. During cool and humid climatic phases with plenty of rainfalls, water bodies of the Parathetis used to be overflowed and again united becoming less saline. Glacier thawing exerted great influence on fall of water salinity in the Parathetis. A huge amount of thawed, fresh water lowered salt concentration, and for this reason, at present, the Caspian is three times less saline than the World Ocean.

The complicated history of formation of the Caspian Sea influenced its inhabitants. This giant lake can be compared to Australia. In our opinion, this comparison is not an exaggeration and is completely justified. Australia, as well as the Caspian, very early became isolated, and this isolation has ensured survival of many rare animals. Australia is glorified all over the world for its unique marsupial animals, which have managed to live through only because the separation of this continent from the rest of the world, and the evolution there has proceeded with its laws and even slowed down a bit. Therefore, many zoologists compare Australia with a lost world inhabited by living fossils. The same comparison is relevant for the Caspian, which has become famous all over the world for its unique sturgeon fishes. These Caspian fishes, as well as Australian marsupial, also are living fossils. The family of sturgeons already exists 200m years ago in the time of dinosaurs, inhabiting many ancient seas. However, later, in the course of the evolution, because of competition with bony fishes or for other reasons, sturgeons started dying out and survived mostly in the Caspian. Nowadays, more than 90 % of the world stocks of sturgeons live in this lake, which managed to survive only due its particular conditions. It is well known, that except for unique marsupial animals, there are many not less unique inhabitants in Australia, such as duck-billed platypus and echidna. And in the Caspian, besides sturgeons there are many other rare animals, such as, crustaceans and molluscs, which by their antiquity, of course, cannot be compared to dinosaurs, but are quite comparable to mammoths.

Considering the unique biodiversity of the Caspian and its similarity with Australia there are no doubts that this unique lake and its inhabitants should be very carefully dealt with. Besides, the broad public should gain more access to results of Caspian studies and protected measures. Unfortunately, thus far, attention has been paid in scientific, and especially in popular scientific literature to the Caspian, as distinct from Australia. The authors of this report will try to fill this gap.

Evolution of the Caspian

Aggregate basins, located from the valley of the river Rhone in Western Europe up to Central Asia in the Miocene are usually called the Parathetis in Paleontological literature. Traditionally three parts are distinguished: western, Central and East Parathetis. The first relates to the region of the Rhone, the second – the Pannonian or Middle Danube lowland, and the third – the Black and the Caspian Seas (Fig. 2, 3). In terms of modern mobilistic conceptions, this large continental water border formed due to movements of small continental platforms such as Iranian, Anatolian and Rhodopian. According to these notions, the basins of the Southern Caspian and the Black seas are considered as basins with oceanic crust, which enclosed as a result of movements of the above and some smaller other platforms.

The Lower Sarmatian Sea existed in the region of Central and Eastern Parathetis some 15m years ago in the end of the Miocene. It used to occupy a huge area from the Pannonian lowland up to the Aral Sea, and possibly extended further into Central Asia (Fig. 4). Although, the Lower Sarmatian Sea had the salinity of about 20 gr/l, i.e. much lower than that of the World Ocean and comparable to the present Black Sea salinity, the sea was inhabited by normal representatives of marine fauna.

Later, 11.5m years ago Pannonian brackish lake isolated. Endemic fauna, which lives under salinity of 12-15 gr/l, quite quickly formed in this lake.

The Upper Sarmatian Sea with lower salinity of about 6-17 gr/l emerged in another 1,5 million years, approximately 10m years ago. Own endemic brackish fauna, with species composition different from Pannonian Lake also formed here.

Some 8.5m years ago the Upper Sarmatian Sea transformed into the Miotic Sea with slightly lower salinity ranging from 6 to 15 gr/l. Because of lower salinity, the fauna of this sea became more distinct from the fauna of the Upper Sarmatian Sea. However, it is necessary to note that a kind of fauna consisting entirely of endemic species had not formed yet (Neveskaya et al, 1986).

Later, approximately 7m years ago in the end of the Miocene, the Miotic Sea was substituted by Pontic Lake. Extremely rich endemic fauna immediately emerged in this lake. Most probably it had not formed there independently, and was introduced from The Pannonian and Aegean basins (Eberzin, 1949), or only from the Pannonian one (Taktakeshvily, 1977). The salinity of Pontic Lake was close to that of the Meotic Sea, however its fluctuations were less – ranging within 12-15 gr/l. It is necessary to note that only a few representatives of the Meotic fauna survived here. It was probably not linked to changes of salinity since it was not altered. Most probably the competition with invaders from the Pannonian and Aegean basins had played the major role.

Approximately 6m years ago, Pontic Lake divided into the Upper Pontic and Babajan lakes. The first used to occupy the Black Sea or Euxine basin, and the second was in the Southern-Caspian depression. The salinity of Upper Pontic Lake remained at the level of 10-15 gr/l, however in Babajan Lake, due to higher climate aridity, it increased up to 15-30 gr/l.

Some 5 million years ago at the border of the Miocene and Pliocene, Pannonian lake, with emergence of intensive outlet into the Black Sea, and possibly in the Aegean basins, completely freshened from 42 gr/l to fresh water and was settled with rich endemic freshwater fauna. Approximately 1 million years ago Pannonian Lake completely drained and only a small lake Balaton, in which all representatives of endemic freshwater fauna perished, remains on its place.

In the same time, also some 5m years ago, the Upper Pontic Sea transformed into Cimmerian Lake, which had lower salinity of 5-12 gr/l. Later, some 3.5m years ago, Cimmerian Lake was supplanted by Kuyalnits or Egriss Lake with almost the same salinity. Approximately 2m years ago, it was replaced with Guriy Lake with lower salinity of about 5-8 gr/l. Thus, in this case, same as with the Pannonian basin, it was desalting but more smoothly. Because of this, one endemic brackish fauna was slowly supplanted by another, generically connected with it.
Some 5m years ago, or a little bit earlier a hyperhaline lake, Balakhany or so-called productive strata reservoir formed in the Southern Caspian basin (Fig. 5, 6; Tab. 1). Such high salinization, up to 300 gr/l obviously occurred because of heavy water evaporations under conditions of extremely arid climate. Available data on the fauna of the Balakhany reservoir also convincingly testify hypersalinity (Starobogatov, 1970, 1994).

About 3 million years ago the climate dampened and freshwater runoff into Balakhany Lake soared. This led to formation of a huge brackish lake, Akchagyl with the salinity ranging from 5 gr/l to 12 gr/l, with rich endemic fauna of unknown origins (Starobogatov, 1970, 1994).

Akchagyl Lake in the Caspian basin was successively replaced by several water bodies with more or less consistent fauna. Five of these lakes were most important. Absheron Lake with the same salinity as Akchagyl, 5-12 gr/l formed less than 2m years ago. Some 1.7m years ago, Absheron Lake was replaced by Baku Lake, which had the same salinity. Then 400 thousand years ago, Khazar Lake with the same salinity of 5-12 gr/l replaced it. After this, Khazar Lake was substituted by Khvalyn Lake, which had lower salinity ranging from 3 to 8 gr/l, approximately 100 thousand years ago. And finally, New Caspian Lake, which is practically the same reservoir, which we nowadays call the Caspian Sea, formed in the beginning of the Holocene, some 5-7 thousand years ago.

Chaudine Lake appeared in the Black Sea or Euxine basin approximately 900 thousand years ago, and later about 400 thousand years ago, it was supplanted by ancient Euxine Lake. The salinity of these lakes was 5-8 gr/l, i.e. remained same with the former Guriy Lake. About 120 thousand years ago ancient Euxine Lake transformed into the Ashey Sea with higher salinity ranging from 5 to 12gr/l. Later, approximately 80-90 thousand years ago, it was replaced by the Karangat Sea with higher salinity of 15-20 gr/l. Restoration of the connection with the World Ocean resulted in an increase of the salinity. Because of this, marine species started to invade the Black Sea basin, driving endemic brackish Ponto-Caspian fauna closer to regions of estuaries and deltas of rivers with fresher water. However, some 50m years ago, this connection with the World Ocean was lost again, and the Karangat Sea was replaced with heavily desalinated New Euxine Lake, where the survived representatives of Ponto-Caspian fauna flourished. And, at last, on the edge between the Pleistocene and the Holocene, about 11-10 thousand years ago, the connection with the World Ocean was restored again, and the water body, which we nowadays call the Black Sea, appeared.

It is especially necessary to mark that only a unilateral exchange of faunas occurred when the Caspian and Euxine basins were connected The Caspian always shared its hydrobionts with the Pont, but not vise versa (Starobogatov, 1994).

The above scheme of development of the Caspian and of previous water bodies for the last 15m years was proposed by Y. I. Starobogatov (1994) based on the study of the evolution of bivalves, particularly dreissenids. Foreign authors (Degens, Paluska, 1979; Jones, Simmons, 1996) proposed similar development schemes. Although this scheme has a number of disputable moments, especially in terms of proposed magnitudes of paleohalinity, nevertheless, in comparison with other development scenarios, it seems to be the most substantiated and probable.

Physical environment of the Caspian

The Caspian Sea – is a lake with no outlets, which is washing shores of the five countries: Azerbaijan, Iran, Turkmenistan, Kazakhstan and Russia (Fig. 7). The length of coastline makes 5580 kms. The level is lower than the M. S. L., it is fluctuates depending on the water balance (Tab. 2). If the balance is positive then the level is rising, if negative – lowering (Fig. 8-10). Because of inconstancy of Caspian levels, its area is also inconstant. The Caspian is meridiannally elongated. According to data published by I. S. Zonn (2000), its length makes 1225 kms. The greatest breadth of the Caspian from the east to the west is 566 kms, at Absheron peninsula its breadth is only 204 kms. The average breadth from the west to the east makes 330 kms. The surface is equal to 436 000 km^2, and volume is about 77000 km^3. The maximum depth of the Caspian is 1025 m, and the average - 184 m.

The area the Caspian Sea is divided into three, approximately equal, parts: Northern, Middle and Southern (Fig. 7). Their volumes they are extremely different.

The Northern Caspian is the most shallow, and its area makes about 29 % of the entire area of the sea, though its volume makes less than 1%. According to I. S. Zonn (2000), the area of the Northern Caspian varies from 92750 up to 126596 km^2, and its average volume makes 900 km^3.

The average depth is 6 meters, maximal depths do not exceed 10m, about 20 % of the area has the depths less than 1 m.

The area of the Middle Caspian makes up about 36 %, and its volume - about 35 % of the sea. According to I. S. Zonn (2000), the area varies from 133560 up to 151626 km^2, and the average volume makes 26400 km^3. The average depth of is about175 m, and the greatest - 790 m.

The Southern Caspian has the largest volume - some 64 % of the total volume, and its area amounts to 35 % of the total area of the sea. It is the deepest part of the sea with the maximum depth reaching 1025 m. According to I. S. Zonn (2000), the area is from 144690 up to 151018 km^2, and the average volume - 48300 km^3. The average depth is 300 m.

Except for the above three areas, the fourth distinguished in the Caspian is a shallow gulf, Kara-Bogaz-Gol (Fig. 11) with maximum depths <10m. Its area is about 15000 km^2 (about 3 % of the total area of the sea). The role of the gulf in the water balance of the Caspian is quite great. This shallow gulf is lower than the level of the sea approximately by 3-4 meters and due to this the sea constantly drains into it. This gulf constantly «drinks» the water of the Caspian, and this water, in turn, quickly evaporates. The gulf is connected with the Middle Caspian by a narrow strait.

The highest level of the Caspian Sea registered during instrumental observations was recorded in 1896 – approximately 25 m below the M. S. L. It is possible to distinguish three periods in the 20th century (Fig. 8): periods of relative stability, periods of water levels fall and periods of water levels rise. The lowest level in the 20th century was recorded in 1977 -29.03 m. However, an extremely fast rise began next year, and in ten years the water reached the elevation of -27.62 m. The Caspian stabilized again in 1995 at the level of -26.61 m, and during subsequent years the level fell by several centimeters each year. Nowadays, the level of the Caspian is slowly decreasing and comes to the altitude of -27.20 m.

As a result of the sea level decrease and increase, the area of the Caspian Sea has changed leading to changes of its outlines. Mainly, it related to the Northern Caspian. In 1930 the area of the sea was 422000 km^2, and in 1970 - only 371000 km^2. Starting from 1978, the area of the sea increased again because of a sea levels rise.

The area of the watershed of the Caspian Sea makes from 3.1 up to 3.5m km^2. It stretches for 2500 kms from the north on the south and for 1000 kms from the west to the east. The area of the Caspian itself makes only 12% of the total area of the watershed (Fig. 12). The water balance of the Caspian is mainly determined by river runoffs and rainfalls (its incoming part), evaporation and water outflow into Kara-Bogaz-Gol (its outgoing part). The ground water runoff into the Caspian is insignificant and this incoming component of the water balance is frequently disregarded. The most important part of the incoming part of the water balance is the river runoff of the Volga, which makes almost 80 % of the total riverine inflow. The incoming part is almost completely counterbalanced with evaporation, of which the discharge into Kara-Bogaz-Gol makes only 5%. More than 130 rivers flow into the Caspian, but only 8 of them (Volga, Terek, Sulak, Samur, Kura, Ural, Atrek, Sefidrud) have a delta.

The major abiotic parameter of the Caspian Sea is its salinity (Fig. 13-15). The average salinity of the Caspian is equal to 12.85 gr/l. Northern, Middle, Southern and the gulf Kara-Bogaz-Gol differ with the salinity of their waters. The lowest concentration of salt is observed in the Northern Caspian. The average salinity of its waters is about 5-10 gr/l. However, in certain areas adjacent to the deltas of the rivers Volga, Ural and Terek, the water salinity is much lower and fluctuates within 2-4 gr/l. In the avant-deltas of these rivers, the water of the Northern Caspian can be considered fresh, since its salinity is less than 0.5 gr/l. In shoals of eastern coast of the Northern Caspian, the water salinity can be a little bit higher than the averages - 5-10 gr/l. Water salinity up to 30 gr/l and even more can be observed in shallow gulfs of the Northern Caspian such as Mertviy Kultuk and Kaidak.

The salinity of the Middle Caspian is 12.7 gr/l. This salinity is reduced only in the region of the delta of the Sulak. As the eastern coast of the Middle Caspian has no river runoff, the amount of rainfalls is very low, and the evaporation is high, so the water salinity in calm weather in surface coastal waters can reach 13.0-13.2 gr/l.

The salinity of the Southern Caspian is 13 gr/l. This salinity is lower in areas, adjacent to the regions of the deltas of the rivers Kura and Sefidrud, and also in the mouth of the river Atrek. The water salinity of 13.2-13.4 gr/l is observed on shoals of the Turkmen coast.

The highest concentration of salt is observed in the gulf Kara-Bogaz-Gol. The evaporation rate from the surface of Kara-Bogaz-Gola amounts to 1500 mm a year, and the rainfalls in this region do not exceed 70 mm per year. For this reason, Kara-Bogaz-Gol is a huge evaporator of the Caspian, and its water is brine – 300-350 gr/l and even higher. It is the only marine saltpan producing mirabilite, halite and astrakhanite. Inflowing water brings some 130-150m tons of salt i.e. 10 times more than the Caspian itself receives. For this reason, the gulf Kara-Bogaz-Gol can be called a natural desalter of the Caspian Sea. Without this gulf, the present salinity of the Caspian would be much higher. A huge amount of mineral substances is accumulated at the bottom of Kara-Bogaz-Gola due to evaporation and natural sedimentation of salts.

Analyzing the areas of the Caspian by their salinity, they can be subdivided into three types: oligo-mesohaline area of the Northern Caspian, meso-polyhaline area of the Middle and Southern Caspian and hyperhaline area of the gulf Kara-Bogaz-Gol.

The average salinity of the Caspian Sea is lower than that of the ocean approximately by a factor of three. However, the salinity of the Caspian waters is not the only difference from waters of the World Ocean, but also the salt composition (Tab. 3). The difference in the ratio of salts of Caspian and oceanic waters has arisen due to the isolation of the Caspian from the World Ocean. As a result, a gradual metamorphosis of Caspian waters under the influence of river runoffs took place. In open parts of the sea, salinity increases with the depth (Fig. 16).
Precipitation is distributed unevenly over the Caspian. In the average the Caspian receives some 100 mm of rainfalls per year. Coastal topography influences the balance of rainfalls over the Caspian.

The temperature regime of the Caspian Sea is rather unusual (Fig. 17). On the one hand, it is characterized by considerable temperature differences in wintertime between its northern and southern areas, and on the other hand, leveling of the temperature regime between the Northern and Southern Caspian in summertime. In general, the Caspian has a sharp continental climate. In the winter only the Northern Caspian freezes, but its open areas were not covered with ice. In summertime, the air temperatures of northern and southern parts of the sea are leveled. The average air temperature in the Northern Caspian is 24-25^{0}C, only by 2-3 degrees higher than in the Southern Caspian.

Water temperature in the Southern Caspian never drops below 13 degrees in wintertime, and in summertime it is usually increases up to 25 and even 30^{0}C. Seasonal oscillations of water temperatures are more considerable in the Middle Caspian. In wintertime, the average temperature of surface waters is only 6^{0}C, and then it increases up to 25^{0}C by the midst of a summer. In the Northern Caspian, seasonal changes of water temperature are maximal. In wintertime it is partially covered with ice, and water temperature is about 0^{0}C and even lower. In the middle of a summer, the average water temperature is 24^{0}C. In calm weather the water temperature in shallow gulfs could reach 35^{0}C. Similar and even higher summer water temperatures (up to 40^{0}C) are observed at eastern shoals of the gulf Kara-Bogaz-Gol. Constant temperature is maintained at depths of the Caspian Sea both in winter and summer (Fig. 18).

In the Northern Caspian there is no water stratification by temperatures due to its shallowness. Similar homeothermia is observed in the shallow gulf of Kara-Bogaz-Gol. Thus, each of the four areas of the Caspian has its own certain features of the temperature regime.
There is a system of horizontal and vertical movements of water masses in the Caspian, as well as in any other water body. Surface currents in the Middle and Southern Caspian will form a rotating circulation. In the Northern Caspian the current regime is determined by river runoffs and prevailing winds. Here surges can flood a coastal strand up to 30 kms broad in lowland area.

The Caspian is a storm sea. From November to March the choppiness of the sea reaches force 6. The quietest period is the end of the spring and the first half of the summer. A maximum force of choppiness was registered at western coast of the Middle Caspian. Vertical movements of the Caspian waters are as well expressed as horizontal. Due to this the deep waters of the Caspian don’t have a dead zone (oxygen deficiency causing deaths of hydrobionts) and are extremely rich with dissolved oxygen (Fig. 19).

Three main forms are clearly distinguished in the relief of the bottom of the Caspian: shelf, continental slope, and bed of deep-water depressions. The shelf stretches from the coastline up to depths of about 100 m. The continental slope begins from the depth of 100 m and stretches in the Middle Caspian up to the depth of 500-600 m, and in the Southern up to the depth of 700-750 m. Two deep-water depressions are distinguished in the Caspian Sea. In the Middle Caspian, this is the Derbent depression with the maximum depth of 790 m, and in the Southern – the southern Caspian depression with the maximum depth of 1025 m.

The shores of the Caspian are mainly made of Quaternary deposits. The shore of the Northern Caspian is low-lying and gently sloping, and is often heavily rugged. In the Middle Caspian, the western coast is mountainous and the eastern is elevated. In the Southern Caspian, the shore is mountainous and rugged.

The waters of the Caspian Sea are characterized by high transparency (Fig. 20, 21). The most transparent are the open waters of the Southern Caspian. In the Middle Caspian the transparency of open waters is a little bit lower. In the Northern Caspian, because of the large inflow river drifts, the transparency is very low and is usual less than 1 m, and only at a great distance from the deltas the transparency increases up to 7-8 m.

The trophic level and primary production of the Caspian Sea is low. The majority of nutrients brought in the Caspian with waters of the tributaries and, first of all, the Volga. Initially, nutrients used to come into the Caspian mainly in late spring or early summer. However, when the rivers became regulated (mainly the Volga), numerous dams detain and include in circulation of river reservoirs a part of nutrients (dissolved and suspended), which leads to a sharp decrease in the amount of phosphorus and silicon coming into the Caspian. Huge extents of the deltas are covered with macrophyte thickets. These macrophytes detain nutrients running into the Caspian.

Levels of nutrients in the Caspian Sea are low, even in the Northern Caspian, which is the most productive and richest part of the sea. Eutrophic conditions are observed only in some regions adjacent to the delta of the Volga. Levels of nutrients in the Middle and Southern Caspian are very low. In these parts the nutrients arrive at the expense of an internal recirculation and with small runoff of rivers flowing into the Middle Caspian and the Southern Caspian and also with rains. Thus, it is incorrect to name the Caspian a rich lake with high productiveness. The Caspian Sea is a poor lake in terms of production; only the Northern Caspian is not so poor.

Main species groups of the Caspian

The Caspian Sea is the largest lake in the world. Based on this one can assume that it has the highest biodiversity. It is logical to assume that the greater the area of a lake, the more plant and animal organisms live in it. In our opinion this correlation with the area is rather indirect. Certainly, the greater the area of a water body, the higher probability that it will contain more species of hydrobionts. However, there is no doubt that, in this case, the defining parameters are the age of a lake, its biotope diversity, biotic and abiotic conditions, and the availability of necessary and balanced amount of matters and energy.

An important feature of the Caspian is the extreme diversity of biotopes, biotic and abiotic conditions (Zenkevich, 1963). First of all, water salinity in different parts of this lake is quite different (Kosarev, Tuzhilkin, 1995).

The vertical stratification of water salinity in the modern Caspian is poorly expressed. Good intermixing of waters is observed in this lake, which causes the bottom waters to be rich in oxygen. However, earlier, when the level of the Caspian was much higher than now, and there was strong vertical salinity stratification, the oxygen was practically absent at the bottom (Kosarev and Tuzhilkin, 1995; Dumont, 1998). That is why, presently, there is poor life at the depths of more than 100m. There is no abyssal fauna and flora in this lake. It is possible to assume that this ancient natural ecological catastrophe heavily reduced modern diversity of the Caspian fauna and flora.

Except for strong differences in salinity of different parts of the Caspian, the temperature parameters are also extremely diverse and it also contributes to its biodiversification. Latitudinal stratification of surface water temperatures allows both cold water, and warm water hydrobionts to live in this lake. Besides, there is strong vertical temperature stratification in the Caspian. After the zone of a temperature jump, the water temperature remains low even during the hottest summer months. Seasonally independent thermostatic cold water conditions are actually observed in deep water parts of this lake. The presence of deep cold water in the Caspian allows populating its upper horizons even with arctic organisms (Zenkevich, 1963; Kosarev, Yablonskaya, 1996). As well as in case of varying salinity, the diversity of temperature conditions of the Caspian increases its biodiversity.

Production characteristics of various areas of the Caspian are also quite different and, as well in the cases of salinity and temperature, which results in the magnification of biodiversity of this lake. M. A. Salmanov (1987) presented the most complete information on production processes in recent years. The ratio between the total production of phytoplankton and bacterioplankton makes 1:0.45. Gross production of primary organic matter (OM) of phytoplankton for the period of 1964-1984 reached 143.4m tons of carbon. In the same time, in northern, middle and southern parts of the Caspian formed, accordingly, 19.9, 44.4 and 35.77 % of organic matter. It is necessary to note a very high producing capacity of the Northern Caspian, as it makes 0.5 % of the total volume of the sea, and produces about 20 % of organic matter. Undoubtedly that the mineral elements arriving with river runoffs serve as a basis for biological production. The areas of the Caspian adjoining to river estuaries are always characterized by increased producing capacity due to organic matter brought by rivers. The entire Northern Caspian is considerably more productive, than the Middle and Southern Caspian (Karpevich, 1975).

The modern fauna and flora of the present Caspian Sea consists of the four main components: 1 – of Caspian origins; 2 – of arctic origins; 3 – of Atlantic and Mediterranean origins; 4 – of freshwater origins (Derzhavin, 1912; Knipovich, 1938; Berg, 1928; Zenkevich, 1963). In Zenkevich's opinion (1963), the fauna and flora of the Caspian Sea usually could not compete with invaders and often such invaded fauna and flora destroyed native species.
The biodiversity of the Caspian Sea is 2.5 times poorer, than that of the Black Sea (Tab. 4), or 5 times poorer, than that of the Barents Sea (Zenkevich, 1963). The main reason of this is probably its variable salinity. For the present freshwater fauna and flora, the water salinity is too high, and for the present marine species - low. Thus, the modern Caspian Sea is a real paradise for brackish water species originating both from marine, and from continental water bodies (Birstein, 1939; Mordukhai-Boltovskoy, 1979).

Fishes and crustaceans have the greatest diversity in the Caspian (Fig. 22; Tab. 5). They come to 2/3 or 63 % of the total number of species. These organisms, due to very good osmoregulatory abilities, can live in a very broad range of salinity: from fresh water up to brackish, and even in more salty water, than oceanic (Zenkevich, 1963). Thus, the modern biodiversity of the Caspian Sea simply reflects a complicated history of paleo-Caspian transgressions and regressions, desalinisation and salinization.

The first good report on fauna and flora of the Caspian Sea was published in 1963 by Zenkevich. According to this data, 718 species inhabit the Caspian: 62 species of protozoa, 397 -

invertebrates, 79 - vertebrates (totally 476 species of free-living Metazoa) and 170 species of parasitic organisms. Of these species, some 46 % are endemics of the Caspian Sea, 66 % inhabit also in adjacent southern seas, and 4.4 % are of Atlantic and Mediterranean origins and 3 % - of arctic origins.

315 species and subspecies are registered in the zooplankton of the Caspian Sea (Kasymov, 1987, 1994); of these 135 species refer to infusorians (Agamaliyev, 1983; Bagirov, 1975). The main part of zooplankton is species of Caspian origins. The species composition of zooplankton of the Northern Caspian amounts to about 200 species. Infusoria are represented most diversely (more than 70 species). Rotatoria (> 50), Cladocera (> 30) and Copepoda (> 20) are less diversely represented (Kasymov, 1997).

Four main zoogeographic groups of animals are distinguished in this fauna of the Caspian Sea - freshwater, arctic, Mediterranean-Atlantic and autochthonous. This fauna is mostly eurythermal and euryhaline

The most typical feature of the benthic fauna is the predominance of autochthonous Caspian species, which often are endemic for the Caspian and are grouped into endemic genera or sub-genera.

The second group consists of generative-freshwater species, which invaded the Caspian during its desalinization and adapted to live in brackish water. This fauna is rather poor (Kasymov, 1987, 1994). The third group consists of arctic species, which invaded the Caspian from northern seas in later glacial period, about 10-12 thousand years ago and nowadays are widespread in northern seas. The fourth group is made of Mediterranean species, which invaded the Caspian from Azov-Black Sea basin independently or were introduced by people (Agamaliyev, 1983; Kasymov, 1987, 1994).

The main part of benthic organisms lives on or in the sea bottom (epi- and endobenthos). These are usual representatives of periphyton (fouling) and planktobenthos. In regards to salinity, 4 ecological groups are distinguished in the benthos of the Caspian Sea:

1. Freshwater forms, spreading within estuaries with the salinity of 0-2 gr/l.
2. Coastal and brackish forms, including freshwater by genesis invertebrates and representatives of autochthonous Caspian fauna. These forms live mainly under the salinity ranging from 0-2 up to 7 gr/l, some of them are euryhaline and can live in a broad range of salinity and depths (Romanova, 1958, 1959).
3. Brackish forms, living under salinity from 3-5 to 10-11 gr/l.
4. Marine forms - invertebrates of Mediterranean origins and halophylic forms of relict Caspian faunal complex. Mass development of marine forms is observed under the salinity of above 8-10 gr/l.

An increase of Caspian levels and desalinization of its waters have made changes into a qualitative composition and quantitative parameters of hydrobionts. In all regions of the sea, the significance of organisms of freshwater and brackish water complexes has increased. Replacement of halophylic organisms happened in benthos of the Northern Caspian, and in the

Middle and Southern Caspian, the greatest development of benthic invertebrates was observed during the spell of an increased discharge of the Volga.

The distinctive feature of the Caspian ichthyofauna is its high endemism, observed from the category of a genus up to the level of a subspecies. Early separation of the Caspian Sea from the World Ocean has ensured a high level of endemism of its ichthyofauna. According to Kazancheyev (1981), the number of endemics at the level of a genus make 8.2 %, species - 43.6 %, subspecies - 100%. In general, the Caspian is inhabited by 4 endemic genera, 31 endemic species and 45 endemic subspecies (Kazancheyev, 1981). The active speciation processes in the Caspian Sea are largely related to special hydrological conditions in geological past and present. Repeated transgressions of the sea, its salinization and desalinization promoted formation of new species and subspecies and as well as various biological and ecological forms and races.

One of the endemic species of fauna is the Caspian Seal (*Phoca caspica* Gmelin), the smallest existing varieties of seals and the nearest relative of northern earless seals *P. puso*, endemic and the only mammal in the fauna of the Caspian Sea (Badamshin, 1966, 1969).
Many present marine animals like Scyphozoa, Anthozoa, Ctenophora, Gordiacea, Gastrotricha, Kinorhyncha, Sipunculida, Phoronidea, Loricata, Scaphopoda, Tanaidacea, Pantopoda, Tardigrada, Asteroidea, Ophiuroidea, Echinoidea, Holothurioidea, Chaetognatha, Ascidiacea, Appendicularia and Acrania are not known in the Caspian. But some of these organisms, which are capable of osmoregulation and which are the most euryhaline, can invade into the Caspian. There are a lot of freshwater and brackish water species ranging in estuaries of Caspian tributaries.

Zenkevich (1963) included approximately 450 species in his list of free-living Metazoa in 1963, Chesunov (1978) included approximately 550 species in 1978, and Kasymov (1987) included approximately 950 species in 1987. It is possible to imagine that the real number of free-living Metazoa is approximately 1500 or even 2000 species. Speciation in the Caspian Sea has created a general high-level endemism (approximately 42-46 %). In our opinion, deep-water oxygen depletions during transgressions of the ancient Caspian sharply reduced the number of Caspian endemics. Only in the Caspian, some groups of animals, which were subject to significant adaptive radiation, had a level endemism close to 100%.

Threats to the biodiversity of the Caspian

Introduction (chronic and acute impact)

Environmental problems of the Caspian Sea are multiple and various in their origin. On one hand, they are caused by the commercial use of the sea; on the other hand, human activity impacts coastal areas, including input from rivers in the Caspian. As the Caspian is an inland water body, anthropogenic (man-caused) impacts on catchment area (about 3.5 million km^2) accumulate here. Anthropogenic impact on the Caspian ecosystem occurs concurrently with various natural endogenous and exogenous processes. It is primarily sea level changes, periodical seismic activity, surges and retreats, mud volcanoes and neo-tectonics. Special features of the Caspian include constant alterations of its area, volume, and configuration of the coastline and water column structure. Anthropogenic activity, as well as a natural impact, can have a chronic (long term) or acute (short term) effect. Regulation of Caspian rivers discharge is an example of a long-term anthropogenic impact. Man-built dams have reduced water input into the Caspian. It took a few years to fill huge water reservoirs; during this period the Caspian lacked a high amount of river fresh water. The recent rise of the level of the Caspian is an example of a long-term natural impact. It rose by 2.2 m during the period from 1997 till 1995. This natural impact on the Caspian lasted for about two years. An accident at an oil tanker can be an example of a short-term anthropogenic impact. This type of accident results in an oil spill and has a severe negative impact on a localized area. However, natural purification processes will counteract the oil spill in a short period of time. An earthquake causes a short-term natural impact on the Caspian. A few seconds of seabed movement can result in high waves, collapse of coastline and even the formation of new bays. Meanwhile, natural processes will soon erase the consequences of the earthquake.

Rivers regulation

Regulation of rivers that flow into the Caspian is one of the most significant anthropogenic impacts on the biodiversity of the water body. In the early 1930's, many reservoirs were built on the Caspian rivers for the purposes of hydroelectric power industry. At present the Volga is surrounded by a chain of huge man made lakes or reservoirs (Fig. 23). The capacity of the water bodies is over 180 km^3. Every year 8-10 km^3 of water are lost from evaporation, which is approximately 3% of the annual flow of the Volga (Zonn, 2000). Besides, man-made channels were built to link the Volga and then the Caspian with other rivers and with other seas via the rivers. At present the Volga links the Caspian with the oceans of the world. This great river is connected with the Baltic Sea via the Volga-Baltic waterway; with the White Sea via the North Dvina system and the Belomor-Baltic channel; with the Azov and Black Seas via the Volga-Don channel; with the Moscva River via the Moscow channel. Water from the Caspian rivers is used for irrigation, which also reduces the annual flow. Water used for irrigation of fields is a loss to the Caspian. At present the Caspian lacks about 12% of river input. During the period of water reservoir infill water loss was even higher. In 1942-45 total loss was 113 km^3 or more than 8 km^3 per year. In 1956-69, during the construction and operation of large hydrotechnical facilities on rivers, the Caspian lost 350 cubic kilometers of river water, or over 25 km^3 per year. According to the State Institute of Hydrology, the annual loss of river input in 1956-1990 ranged from 30 to 50 km^3. In 1942-1990 about 1100 km^3 of river water was used for economy purposes, including 600 km^3 water intake from The Volga (Bortnik et al, 1997). It was calculated that in 1930-40 water management caused 2-3 cm decrease of sea level, while in late 1970's – early 1980's the annual decrease reached 10-12 cm. It can be concluded that, if not for the river regulation (water intake), the level of the Caspian would have been at least 1-1.5 m above the present level (Georgievsky, Shikhlomanov, 1994). Regulation of river flow has both chronic and acute impact. Chronic impact can be described as a shoaling of river deltas. For instance, lack of river input reduced the area of delta vegetation, caused loss of reeds, cat's tail, and bushes. Loss of vegetation resulted in loss of aquatic and coastal fauna. However, not only deltas suffered the consequences of river regulation. Many anadromous and semi-migratory species were deprived of their natural spawning grounds. As river deltas became shallower, fish could not migrate to rivers for spawning. Those individuals that managed to get to the rivers, encountered the problem of hydropower plants. The impact of dam construction on sturgeon and salmon was the most severe. The species cannot overcome obstacles such as dams even with fish ways and fish lifts. The loss of natural spawning grounds resulted in almost complete loss of the Caspian salmon population; as for the sturgeon, it is bred in fish hatcheries. As per 'The Volga revival…', published in 1996, the annual loss of sturgeon due to hydropower plant activity is over 10,000 tonnes per year. State report 'Status of environment of the Russian Federation in 1994-95' contains data about the construction of dams at the Volga that resulted in the reduction of spawning grounds from 3-4 thousand hectares to 0.4 thousand hectares which is 12% of the previous grounds in the delta and food plain of the Volga and the Akhtuba. The same report highlights the loss of natural spawning grounds of beluga, Caspian inconnu, and anadromous herring. The only available natural spawning grounds are located on the Ural and the Iranian rivers where no dams were built.

Accidental discharges of hydropower plants have an acute (short term) impact on the Caspian. The discharges occur in spring when reservoirs are flooded with snow water and accumulation of high amount of water is a threat to dams. To prevent this, engineers discharge a high amount of water in a jet stream. The man made floods damage bottom and coastal ecosystems and make difficult it for spring spawning migrations. On the other hand, engineers can minimize river input downstream from the dam during low-flow periods. They keep the sea level high in the reservoirs to provide continuous work for water turbines, so the riverbed downstream from the dam almost dries up. This is particularly dangerous for shallow river arms and flood plains. A chain of dry flood plains can be seen along the Caspian rivers during dry years. This tragic picture is a reminder of the tragedy of the Aral Sea which lost half of its water reserve after the input of rivers Amu-Daria and Syr-Daria had been regulated. The tragedy re-occurs in flood plains of the Caspian rivers. Fortunately, dry years are not typical for the Caspian, and such tragedies are uncommon. However, just one dry water system is enough to make unrecoverable damage to the biodiversity of the environment.

The impact of water turbines on aquatic life deserves a special mention. Entrained fish and invertebrates die or become badly damaged. Thus, every hydropower plant makes significant damage to the biological diversity of the aquatic community

Caspian rivers carry a high amount of pollutants from catchment areas produced by both industrial and agricultural anthropogenic impact. This can result in the Caspian becoming severely polluted. Fortunately, only a small proportion of diluted and suspended pollutants reach the sea, as water reservoirs serve as man made sumps or purifiers. Pollutants accumulate in bottom sediments of these huge man made lakes. If it were not for the reservoirs on the rivers, we would not be able to maintain the present the biodiversity of Caspian deltas and adjacent areas. This proves that the interface between the negative and positive anthropogenic impact is delicately balanced.

Water reservoirs on the Caspian rivers hold not only pollutants but also nutrients. The retention of chemicals that are vitally important for plant life cannot be considered as positive. Disruption of nutrient input into the Caspian significantly reduces the trophic potential of deltas and adjacent areas of the Caspian Sea and has a negative impact on its productivity and biodiversity.

Over-fishing and illegal fishing

The biodiversity is of high commercial significance. Biological resources of the Caspian (mainly fish resources) are estimated as 5-6 billion USD per year (Glukhovtsev, 1997). The high cost of fish resources threatens the biodiversity of the most important commercial species.
The annual catch in the Caspian (without sprat) reduced from 283 thousand tonnes in 1951-55 to 81 thousand tonnes in 1990-95. However, reduced catches of the majority of species in the Caspian cannot be related to the reduction of resources and can be a result of an economic recession in the fishing industry. There is no real threat to the majority of commercial species.

However, fishing along with other factors (rivers regulation, pollution) resulted in the complete loss of some species of fish and Cyclostomata. In the 1920-40's typical commercial species were Caspian lamprey, Volga shad, Caspian trout, and Caspian inconnu. The total catch of these species was about 80 thousand tonnes. At present the species are included in the Red Book of Republic of Kazakhstan, Russian Federation and other Caspian states.

About 90% of world sturgeon reserves are concentrated in the Caspian, so the Sea can be considered a global genetic fund for the species. At present there is a real threat to the survival of the species. Nowadays the catch of sturgeon in the Caspian has reduced from 25,000 tonnes per year to 1,000 tonnes. Before 1962 when fishing of sturgeon was legal, commercial fishing made a significant damage to the population, as many juvenile fish were caught. In late 1970's over-fishing reached 30%.

At present fishing and criminal fishing – poaching – is the main threat to the biodiversity of sturgeon. After the Soviet Union collapsed, Fishing Regulations were not observed, fish control authorities disintegrated, marine fishing of sturgeon resumed.

Russian specialists believe that illegal fishing increases official catch by a factor of 11, i.e. by a factor of 8 offshore and three times in rivers. Fishing control authorities are not sufficiently equipped to be able to prevent poaching. The situation is complicated with what is commonly known as 'common poaching' when mass unemployment forced people who were previously law abiding to break the law.

The poaching problem is most severe along the Azerbaijan, Dagestan and Kalmykiya coasts. The situation in other sectors is not much better. Though the official legal catch of sturgeon in Turkmenistan is 20 tonnes per year for scientific purposes, approximate calculation based on amount of fish in Ashkabad markets gives a figure of at least 300 tonnes. significant damage to the Turkmenian population of sturgeon is made by international poachers (Iranian and Azeri vessels). At present only border guard vessels restrain this factor.

Poaching is a serious problem that must be resolved with joint efforts of the Caspian states.
The problem of over-fishing affects other species. Thus, in Iran over-fishing of Caspian trout, bream, zander, along with the damage of their habitats and spawning grounds, resulted in complete loss of these species. Zander disappeared due to massive catches in Azerbaijan and Turkmenistan.

Catches of other species are far from scientific methods and regulations, so it is not a threat and will not be a threat in the near future. Over-fishing is less dangerous for species with a short life cycle. Even if the abundance of the species reduces, it recovers within a few years under the right conditions. To recover the reserves of sturgeon with its long life cycle will take at least 30-50 years.

Caspian Sea level changes

Caspian Sea level changes are one of the most important natural impacts on the biodiversity of this huge water body (Fir. 24, 25) (Dumont, 1995). The impact can be both chronic (long-term) and acute (short-term). A long-term impact is historical natural sea level fluctuations, which can be attributed to changes of climate and river discharge into the Caspian. Acute (short-term impact) is seasonal or wind-induced changes of level. It is known that the seasonal changes of level of the North Caspian can reach almost 0.5 m, while under the influence of surges it can rise for 1.5-2 m. At the west of the North Caspian surges cause inundation of the coastline up to 30 km onshore, while retreats cause exposure of 10 km of the seabed.

Let's review chronic (long-term) impact of sea level changes on the biodiversity of the Caspian. In the 20th century the sea level has been decreasing from the late 1920's - early 1930's till 1970's. The level of the Caspian decreased by almost 3 m. Such a significant change had a negative impact on its flora and fauna. Shallow waters of the North Caspian and deltas of Caspian rivers suffered the most. Shallow bays such as Kaidak and Mertviy Kultuk dried, the populations of the bays died. The river delta areas reduced significantly. When the sea level lowered, the exposed seabed formed new islands. Existing islands formed peninsulas or merged with the land. An example of the formation of new islands on the Caspian is Zemchuzny Island that appeared late in 20's. In 1978 it was 6 km long, 0.5-1 km wide. At the beginning of the 20th century only vast shallow waters existed in place of the island. Island Cheleken at the west coast of the South Caspian is a good example of peninsula formation. In early 30-s it merged into the coast and lost the status of an island.

It is obvious, that a continuous decrease of the Caspian Sea level has a negative impact on aquatic life and a positive impact on onshore organisms. Plant and animal life soon cover recently formed islands and turns them into an important component of onshore ecosystems. The above-mentioned island, Zemchuzny, is now a nesting area for waterfowl. There are also seal-rookeries of the Caspian seal on the island.

Loss of island status almost always has a negative impact on inhabitants of former island because the territory becomes more available for predators and people. This leads to reduction of the biodiversity of the island. When Cheleken Island turned into a peninsula, wolves, jackals, foxes and stray dogs could easily reach the island not only via ice but also directly via dry seabed. The amount of birds and mammals on the island significantly reduced. People also visited Cheleken after it lost island status more often, and used it not only for hunting but also for cattle pastures, reed cutting etc.

Lowering of the Caspian Sea level created problems for navigation. Almost all the deltas of the Caspian rivers became so shallow that dredging had to be undertaken. Grabs, suction dredges and hydraulic jets contributed to damaging the delta's ecosystems. This activity cannot be considered a short-term impact as the equipment is used throughout the year, except for the winter period when there is no navigation. Although anthropogenic activity had a negative impact on the biodiversity of the Caspian, it was also of some benefit. Dredging resulted in formation of man made islands, which were occupied by animal and plant life. Conditions of the islands were the most favorable for water fowl. For instance, the extensive Volga-Caspian channel that connects The Volga delta with the navigable part of the North Caspian, is surrounded with man made islands occupied with active wild life. This channel looks like a «road» to the sea where road fencing is replaced with beautiful islands full of various animal and plant life. Such man made «roads» to the sea are typical not only for The Volga but also for other navigable rivers that flow into the North Caspian.

The above example shows that changes in the level of the Caspian Sea can have a non-direct impact on biodiversity, via human activity. Sea level changes affect human interests, and response actions can make more damage to the environment than the change itself. Construction of a dam at the head of the Kara Bogaz Gol Bay serves as an example. The Bay was blocked with a dyke in 1980. At the time over 10 km^3 of water was discharged from the Caspian into the Bay, and the scientists believed that construction of the dyke would prevent the sea level decreasing to a certain extent. The result of this action was that the Bay dried within a three-year period (1981-83) and turned into a huge salt desert. Only a few percent of the previously significant original surface of the Bay was/is now covered with water. It is obvious that the drying of the Bay resulted in the death of its inhabitants such as salt-loving Crustaceans, algae and bacteria. Some of the largest species served as a food-base for flamingo, so their loss caused starvation for the beautiful birds. As with the flamingoes, humans also suffered from the construction of the dyke at Kara Bogaz Gol. Nauplii (cysts) of salt-loving Crustacean *Artemia salina* were used for fisheries and aquarium fish breeding as a food source for juvenile fish. As this type of food is highly required all over the world, there was a branch of industry to prepare the cysts for sale. When *Artemia salina* disappeared, this branch of the industry collapsed. Minerals production that was historically typical for the area also suffered the consequences of the Kara Bogaz Gol tragedy. According to L. A. Zenkevich (1963), the waters of the Bay contained about 18 billion tonnes of mineral salts including 9.3 billion ton of sodium chloride, 5.3 billion ton of magnesium sulfate, 2.8 billion tonnes of magnesium chloride. In winter, when the water temperature in Kara Bogaz Gol decreased, about 8 billion tonnes of mirabilite settled in sediments of the Bay. People use these minerals, and production of the minerals was commercially important.. Therefore the failure of mineral production at Kara Bogaz Gol due to the drying of the Bay had a significant impact on the economy of this Caspian region.

It is clear that construction of the dyke in the head of the Kara Bogaz Gol Bay had a negative impact on both the biodiversity and economical activity of the area. In 1992 the dyke was totally destroyed, and within 9 years the Bay became partially rehabilitated. A population of *A. salina* in the Bay rehabilitated. Therefore flamingo returned to Kara Bogaz Gol. Production of cysts of *Artemia salina* also re-commenced. After Turkmenistan claimed its independence in the middle of 1990's, a Turkmen-Belgian company specializing in producing cysts of *Artemia salina* was founded in the area. The Company is operating successfully and profitably (Atamuradov, 1999). Production of mineral at Kara Bogaz Gol is also successful again. Not only is the surface and the volume of the Bay restored but also its biodiversity.

Chronic (long-term) impact of sea level rise is xerophytization of coastal plants and desertification of coastal areas.

Let's discuss a chronic (long-term) impact of the sea level rise on the biodiversity of the Caspian. In the 20th century, the sea level has been rising from 1978 until approximately 1996. The total rise was about 2.5 m. This had a negative impact both on the biodiversity and economical activity. Sudden level rise damaged industrial, agricultural facilities and inhabited buildings located at the coast. A lot of pollutants were discharged into the sea, which reduced populations and even resulted in localized death of animal and plant communities. First of all, flooding of oil production and transportation facilities had a damaging effect on the biodiversity. Many were surrounded by localized oil spills that polluted seawater after the rise occurred. The west coast of the North Caspian suffered the most where many economical facilities were flooded (Atirau and Mangistau areas of Kazakhstan). In the Atirau area the coastline moved 70 km onshore. About 1 million hectare of land was flooded, most of it was previously used for agricultural purposes. According to Ozturk and other authors (Ozturk et al., 1999), total economy damage was about 150,000,000 USD. Oil and gas fields were most threatened. The Tajigali, Pribereznoe, Pustinnoe, Morskoe, Terenozek, Ugo-Zapadnoe fields and others were flooded. There is a possibility that the Kalamkas and Karazanbas fields in Buzachy district of Mangistau area will be flooded. These fields provide 50% of the oil for the area. The Arman, Zalgistob and Severny Buzachy fields located in the same area were completely flooded. Many wells were drilled during a few decades of oil production in these areas. The exact number of the wells is not known. According to I. S. Zonn (2000) there is enough oil in any operating, suspended or abandoned well to cause a local ecocatastrophe, to destroy spawning grounds of fish, nesting grounds of birds and seal-rookeries of Caspian seals. Onshore well equipment was not covered with underseal so it would get corroded under water. Oil equipment can be cut with ice movement in winter and spring resulting in oil spills. Cement plugs of suspended onshore wells would be destroyed under water also resulting in oil spills. We believe that the pollution of the North Caspian from flooded suspended onshore wells would be several times higher than the pollution from the existing wells. Therefore previous oil fields are a bigger threat to the sea than the present ones.

A continuous sea level rise made significant damage to plant life in deltas of the Caspian rivers. Trees cannot be constantly flooded, so dead forests can be found in all river deltas. Fast sea level rise for more than 2 m within less than 20 years had a negative impact on m any plant communities; some of them were lost due to flooding. Animal communities also disappeared with the loss island. However, we believe this was not such a tragedy as other representatives of the species managed to survive on non-flooded islands.

The positive impacts of long-term sea level rise are the improvement of spawning ground conditions, increased spawning ground areas, and reinforced water exchange between different sections of the sea, extension fresh water of buffer zone and increase of potential productivity in the North Caspian.

Consider the short-term (acute) impact of level changes on biodiversity of the Caspian. As mentioned above, these are seasonal fluctuations or surges and retreats. As a rule, short-term sea level changes do not have any significant impact on biodiversity of the Caspian but slightly decrease abundance of individual species of onshore animals and do not affect the abundance of plant life. Of course seasonal fluctuations or surges can cause death to some animals or even people but the percentage is insignificant. Temporary flooded onshore plants do not suffer such consequences and easily recover. Impact of seasonal decreases of sea level or retreats is also minimal. As a rule, only some fish die on the exposed seabed, whole invertebrates and plants easily survive the unfavorable conditions. The most tolerant to surges and retreats and seasonal fluctuations of sea level is the reed *Phragmites australis*. This plant is wide spread in Caspian deltas. They form communities that can be found up to 20-30 km offshore and at 2-2.5 m depth.

It can be concluded that sea level rise does not allow endemic Caspian aquatic life to spread to the north due to desalination of the Caspian. When sea level reduces, its salinity increases and the abundance of true Caspian endemics increases.

Pollution

Pollution is a significant threat to the biodiversity of the Caspian. The sources of pollution are industrial, agricultural and accidental discharges and sewage. The main flow of pollution comes from Volga. The Volga input contains discharges from other sources that did not accumulate in reservoirs and its delta. The Volga discharges are comparable with oil field and industrial discharge from the Baku and Sumgait facilities and with the Kura discharge. In Turkmenistan the main pollution comes from the Turkmenbashi oil refinery and from the Cheleken oil fields. The input of Kazakhstan into the pollution is not so significant. Pollutants mainly come from flooded oil fields and with the Ural river discharge.

The highest level of pollution was observed in late 1980's. Later input of pollutants into the sea reduced due to economic crisis, reduction of industrial capacity and abandonment of plants.

The most typical toxicants in the Caspian are petroleum hydrocarbons, heavy metals, phenol, surfactants, and chloral-organic pesticides. Oil pollution is the most dangerous one. Interaction of aquatic life with petroleum hydrocarbons causes various physiological, biochemical and morphological changes in organisms. In some cases the changes can be reversible, otherwise they cause chronic pathological effects that result in death of fish.

Oil pollution of the North Caspian ranges from 1 to 6 MPC. The largest input in oil pollution was made by oil production that commenced in late 1940's at Apsheron peninsula, and later – at Cheleken peninsula. In 1980's exploration of the Kalamkas, Karajambas and Tengiz fields commenced in the north coastal waters of Kazakhstan. As the fields are located in shallow waters and protected with dams that were constructed with light soils, they regularly get washed out and carry pollutants from the fields to the sea. The sources of oil pollution of the Caspian are primarily offshore wells during the drilling and production phases. (oil outflow on the surface of the sea) formed in 27 wells during the exploration of Oily Rocks gryphons. Some of the gryphons' activity lasted from a few days to 2 years. The amount of oil coming out of the gryphons was about 100-500 tonnes per day (Mailyan, 1966).

The following events can also result in oil pollution of the sea: underground and underwater maintenance of operating wells, accidental pipeline breaking, cleaning of effluent of oil refineries. Until recent developments, air surveys carried out by GOIN to control oil pollution in the surface layers, regularly registered large drifting oil spills (hundreds and thousands of square kilometers).

Though oil toxicity (A. Nelson-Smith, 1977) is considered less dangerous for aquatic life than the toxicity of heavy metals, pesticides and some other organic pollutants, its impact on marine life must not be underestimated. Recent data from continuous experiments and the most sensitive indicators confirm that even low oil concentrations (below MPC) have a toxic effect. Toxic impact on fish is identifiable even at relatively low concentrations (0.0.1-0.1 mg/l). This impact does not cause the death of fish but the deterioration of their physiological condition, feeding, reproduction and other life processes. Higher oil concentrations (up to 15 MPC) have a significant impact on fish. This and higher concentrations of crude oil and its derivatives reduce the growth and development rate, fertility, reproduction capacity (Abbasov et al, 1991; Kasymov et al, 1992). Fertility of females of every next generation decreases a few times. If in the first generation it reduces for 10%, in the second and third it reduces for 25-30% respectively. Reduction of reduce growth and development rate, fertility, reproduction capacity is caused not only by direct impact of oil on gonads but also by significant deterioration of physical conditions of the fish. Besides, it impacts immune system, first of all, leucocytes. That increases possibility of infecting fish with various diseases and induces cancerous growth; oil has carcinogenic compounds. There is information in literature about teratogenic effect (growth of cells unusual for the organism) and new growth in organism of sturgeon (Romanov, Altufiev, 1990).

Many scientists outline negative impact of drilling muds and stratal water on fish. Long-term impact of the above compounds causes quantitative changes in basic blood elements, the rise of mortality rate of fish larvae, and reduction of activity and orientation (Gorbunov, 1989; Isuyev, Gabibov, 1989).

The second common toxicants are heavy metals. The most dangerous for biocenosis elements are lead, cadmium, zinc, and copper. Trace metals that accumulate in liver and gonads induce changes of the organs, and depress immune functions of organism. The highest concentrations of trace metals are typical for predators: catfish, zander.

In 1990's concentrations of copper and zinc increased compared to early 1980's, and exceeded maximum permissible concentrations 5 times. In contrast, average concentrations of lead that ranged from 1.2 to 5.7 MPC previously in 1994-96, were at MPC level.

Concentration of copper in fish tissue ranged from 0.12 to 2 MPC; the highest concentrations were found in liver and gonads of sturgeon and Stellate sturgeon. High concentrations of cadmium were found in the same organs. Zinc content in tissue of sturgeon ranged from 6.0 mg/kg to 70 mg/kg of wet weight.

In 1994-96 mercury concentrations in muscle tissue of sturgeon slightly increased. Thus, in 1993 the average value was 0.048 mg/kg, in 1994-96 they ranged from 0.10-0.19 mg/ kg of wet weight.

Pollution level varies in different sections of the sea.

The Volga water is described as 'medium polluted' with transition to 'very' and 'highly polluted'. Ecosystem is generally described as affected by anthropogenic pollution with elements of environmental regress.

General toxicity of water at the same level of pollution varies highly and depends on ecosystem condition (hydrochemistry, eutrophication etc.). Toxicity of water of Volga delta assessed by means of biotesting and general toxicity range varied from low toxic to high toxic depending on the time of year and part of delta. Biotesting was being carried out during 127 days (April-September). At spawning grounds toxic affect of water on juvenile fish increased with no relation to its quality in the river. Besides, it had general toxic and genotoxic and embryotoxic effects.

Anthropogenic pollution of the Volga delta makes regular damage to commercial resources of the Volga and the Caspian. Preliminary estimate of damage made by toxicosis to fisheries of Volga-Caspian area gives a figure of 8,000 of semi-migratory and fresh water fish. 13.7-89.3% of Caspian roach, bream, carp, silver bream, blue bream, perch and zander in delta of the Volga had symptoms of toxic poisoning prior to spawning.

Water of the Middle and South Caspian is described as medium-polluted or polluted. As a result, the biodiversity of benthic fauna reduced by a factor of 3 to 10. In the Sumgait area and Baku Bay the abundance of Crustacean and molluscs reduced. The same happened at Kura delta. The environmental situation in the Baku Bay is catastrophic. The seabed is covered with domestic waste, oil products, heavy metals and organic compounds; no seabed benthic fauna is present. Complex assessment of environmental situation in the Azerbaijan sector of the Caspian identifies water of the sector as polluted to high polluted by microbiological and hydrochemical indicators.

During last 6 years concentration of oil products in coastal waters of the Krasnovodsky Bay tend to reduce; concentration of phenol reduced from 7 to 1.5 MPC. However, this is a result not of a technology update, but of the cancellation of drilling operations and general activity reduction.

In Turkmenistan sector of the Caspian the most polluted areas are coastal waters of the Krasnovodsky Bay and Cheleken peninsula, where average annual concentration is 2-4 MPC. The pollution is mainly related to Turkmenbashi oil refinery and transfer terminal, marine transport, and operation of oil wells.

Previously high level of pollution was recorded also in Ogurchinski and Kuuli Cape.
Increase of anthropogenic stress in the ecosystem of the Caspian (pollution with pesticides, oil products, heavy metals) had primarily impacted sturgeon. It caused a disease of sturgeon not recorded previously which is gepatoxic hypoxia, the symptom of which is exfoliation of muscle tissue.

Chloral-organic pesticides that were widely used in agriculture, health protection and other activity in 1960-80, had a major impact on pathology of fish. As per Russian specialists, during this period the most massive affection of sturgeon occurred. Almost all forms of metabolism were upset including protein, carbohydrate, lipid and mineral metabolisms. In kidneys albumen dystrophy, chronic nephritis were found; in liver – albumen and fat dystrophy, necrobiosis of hepatocytes, cirrhosis. Pathology of spleen and muscle tissue was recorded (The Caspian Sea, 1996; Belyaeva et al, 1998).

Functional errors in work of various systems and organs upset reproductive capacity of sturgeon. The errors included growth of hermaphrodites, growths in gonads, ovocestice, and the deterioration of gamete capsules. At the end of the 1980's 44-51% of spawning population of sturgeon had upset reproductive function (Belyaeva et al, 1998).

Study of physiological and biological condition of sturgeon in 1990's revealed some decrease of pathologies compared to the level of 1960-70's. However, there was no return to relatively normal conditions. The toxicosis has become chronic with periods of improvement and acute condition. During the period of improvement the amount of fish with significant functional and morphological pathologies reduced. Some of the studied physiological, biochemical and morphofunctional parameters tend to improve, even to return to relatively normal condition. The period of 1994-96 can be described as a 'phase of unstable functioning of physiological systems'.

At present, changes in organism of sturgeon have not become irreversible. There is information that confirms rehabilitation of one of the systems of immune function (antioxidant) of sturgeon. This is the basis for rehabilitation of other functions and systems of organism.
A significant toxic impact was made on seals. Recently recorded pathology of the Caspian seals is a very complicated combined process that is classified as cumulative politoxicosis caused primarily by pollution. Heavy metals mainly accumulated in liver and hypodermic fat (Khuraskin et al, 1994).

Studies of 1994-95 showed that compare to 1993 toxicological indicators reduced. Content of toxicants in tissue of adult seals did not actually change which is due to very slow degradation of DDT. Unlike in 1993, none of the samples contained heptachlor and aldrin. Heavy metals are second important toxicological stress index. Content of mercury in tissue of adult species was reduced by a factor of 5.8 compared to 1992 when the content of lead was reduced by a factor of 11.5. Accumulation of heavy metals in pups compare to previous years also has trend to reduce. Thus, average concentrations of lead (in liver) reduced from 3.1 to 0.5 mg/kg, concentrations of cadmium – from 1.3 to 0.14 mg/kg of wet weight, concentration of mercury did not change significantly.

The surveys confirmed a hypothesis of Japanese environmentalist S. Tanabe (1986) that original disbalance of pups occurs during pre- and postnatal periods of development as pups get it with mother's milk. The most clear negative connection of female and the pup is recorded during transfer of chloro-organic pesticides. Insignificant transfer of heavy metal occurs through milking.

In general, it can be concluded that pollution is not a leading factor in formation of main biological productivity of the Caspian. At the same time, this factor is determining for localized areas where pollution is continuous, like polluted areas in the south oil fields. Ecological situation along the west coast of the Middle and South Caspian is unfavorable, ecological situation in Baku Bay is critical.

Development of processes of eutrophication and pollution in fresh and saline waters causes reduction of fish reproduction. As estimated by specialists, the catch of semi-migratory fish in Volga-Caspian region (Caspian roach, bream, zander) would reduce for 60% due to three factors: regulation of rivers discharge, pollution and eutrophication of waters.

Therefore, in spite of a certain negative impact of pollution on condition of ecosystems, its effect is limited with the level of population, as it deteriorates the quality of the environmental and level of possible reproduction and abundance but does not affect the biological diversity itself. Probably these factors affect the biodiversity at genetic level but not at species level. This is the most realistic assessment confirmed by the practice.

Impact of introduced species on the Caspian

The impact of introduced species on the biological diversity of the Caspian Sea falls into two groups: chronic (long term) or acute (short term) impact. Acute impact is identified during first years after the introduction of the new species into the Caspian. Its positive or negative impact is highlighted most clearly during these years. Later the ecosystem adapts to the introduced species, and its positive or negative effect weakens while its impact on the biodiversity becomes chronic (long-term).

All present resident species in the Caspian can be described as introduced. The only difference is the time of introduction. Some of the species were introduced so long ago that now can be considered 100% resident species.

Aquatic organisms of the Caspian can be divided into four groups. The first group is the most ancient introduced species. A scientific name for them is indigenous. Their ancestors lived 20,000,000-30,000,000 years ago and were the descendants of the ParaThetis inhabitants. As the ParaThetis was a huge northern bay of the ancient ocean Thetis, all aquatic life was introduced from Thetis. Thus, Caspian indigenous species are the descendants of ancient introduced organisms from the presently non-existing Thetis. Therefore indigenous Caspian species are called 'living fossils'.

The second group is Arctic introduced species. A detailed list of the species is given in Section 3.4.5. A scientific name of the species is glacious relicts. The ancestors of the species were introduced into the Caspian 1,000,000-1,500,000 years ago during the period of melting of a huge ice sheet that covered almost all Europe, Arctic and coastal areas of the Baltic and the White Seas. The northern species reached the Caspian with melted waters. There are several opinions about the way the species reached the Caspian that were reviewed in previous Sections. We would like to review one more way proposed by Grosswald (Grosswald, 1980) and Dawson (Dawson, 1992) (Figure 26). The scientists believe that a superflood occurred during the late Valdai period. The level of the ancient Caspian rose by 2-3 m above the level of the oceans of the world (Lamb, 1977), and its waters run through the Azov-Black Sea basin. Waters of a large ice lake that existed in the West Siberian Plain run into Aral basin and from Aral into the ancient Caspian.

The third group includes introduced species from the Black and Mediterranean Seas. Their scientific name is ‘Atlantic introduced species’. The most ancient of the species were introduced into the Caspian 50,000 years ago during Khvalyn period. The ancient Caspian was then connected with Azov-Black Sea basin through the Manych channel. Seven species were introduced into the Caspian in a natural way including *Zostera nana*, *Cardium edule*, *Fabricia sabella*, *Atherina mochon pontica*, *Syngnathus nigrolineatus*, *Pomatoschistus caucasicus*, *Bowerbankia imbricata* (Zenkevich, 1963). Some scientists (Fedorov, 1958; Fedorovich, 1987; Starobogatov, 1994) deny natural introduction of the species into the Caspian, as they believe that strong current in the Manych channel had always been directed away from the Caspian. If this point of view is correct, 50,000 years ago a first anthropogenic impact on the biodiversity of the Caspian was recorded.

In the 20th century the amount of the introduced species from the Black and the Mediterranean Seas suddenly increased. All the cases of introduction were related to anthropogenic activity. In the 1920’s 4 species were accidentally introduced into the Caspian: algae *Rhizosolenia calcar-avis*, bivalve *Mytilaster lineatus*, and two species of shrimps: *Leander squilla* and *L. adspersus*. There is no reliable information about the way the species were introduced. Scientists suggest that merchants, who transported their small wooden boats on carts from the Azov Sea to the Caspian, may have introduced them. The four species could have been introduced with Azov water that remained in the boats, or in cages with living fish. During the first years following introduction the abundance of the species was quite high; they suppressed the Caspian species. For instance, in 1936 the biomass of algae *Rhizosolenia calcar-avis* was several millions tonnes which was about 65% of the total plankton biomass. Following the ‘biological wave’, the abundance of the species reduced; an acute phase of impact on the biodiversity of the Caspian turned into a chronic one. A short raise of abundance and further reduction was recorded for bivalve *Mytilaster lineatus*, and the two species of shrimps. Later people deliberately introduced five more species into the Caspian. These included two species of mullet (*Mugil auratus, M. saliens*) (*Mugil auratus, M saliens*), one species of flounder (*Pleuronectes flesus luscus*), one species of Polychaeta (*Nereis diversicolor*) and one species of bivalves (*Abra ovata*). All the species adapted to the conditions of the Sea, and after a first abrupt raise of abundance stabilized and became a part of the ecosystem of the Caspian. In the middle of the 20th century, after the Volga-Don channel has been built, a new group of species was introduced into the Caspian. Some of them were introduced in ballast water of vessels, others were attached to the bottom of vessels. The following species were introduced with ballast waters: plankton Crustacean (*Pleopis polyphemoides*), jelly fish (*Blackfordia virginica*), four species of algae (*Ceramium diaphanum*, *C. tenuissimum*, *Ectocarpus confervoides* f. *fluviatilis*, *Polysiphonia variegata*) and crab (*Rhithropanopeus harrisi*). The following species were introduced with biofouling: sea acorns (*Balanus impovisus* и *B. eburneus*) and one species of pearlwort (*Membranipora crustulenta*). Only barnacles had a raise of abundance, it was not so obvious for other introduced species. Introduction of Atlantic species into the Caspian through the Volga-Don channel continues. A full list of recent introduced species is given in Section 3.4.2 where main groups of species of the Caspian were listed. We would like to mention only two plankton species (*Copepoda aquaedulcis*, *Acartia clausi*) and Ctenophore (*Mnemiopsis leidyi*), that were introduced into the Caspian with ballast waters at the end of the 20th century. The first two species can be an example of a positive introduction as they are used as a food base by plankton-feeding fish and increase the value of the Caspian zooplankton. As for the Ctenophore, this species is an example of a negative impact on the biodiversity of the Caspian (Ivanov et al, 2000). The species eats out zooplankton and causes starvation for the plankton-feeding fish. There is an opinion that the Ctenophore can cause complete loss of Caspian population of sprat (Aladin, Plotnikov, 2000). If this happens, the Caspian seal and largest sturgeon beluga will also be lost.

The fourth group includes species introduced from fresh waters. As the above-mentioned species, they were introduced into the Caspian long ago, so they can be divided into ancient and recent species. The most ancient introduced species are Caspian Gastropods that were originated from fresh waters of Pliocene. They could have been introduced into the ancient Caspian approximately 2,000,000-5,000,000 years ago when it was the most desalinated. This could explain the relation of the species to Baikal molluscs. It is also possible that Caspian Polychaeta (*Manayunkia caspia*) was also introduced into the Caspian from fresh waters of Pliocene several million years ago. Caspian Carp was originated from the more recent introduced species. It was probably introduced into the Caspian during recent post-ice transgression, when the Sea received a lot of water from the rivers. Fresh water species could have been introduced during Khazar transgression (400,000 ears ago), or during Khvalyn transgression (50,000 year ago) or New Caspian transgression (5,000 years ago). There is no doubt that introduction of fresh water species into the Caspian continues nowadays. However, it is difficult to register the species so no attention is paid to them. This conclusion can be confirmed by works of Yu. S. Chuikov (1994). He found many new microscopical fresh water species in the Volga delta and the adjacent coastal waters of the North Caspian. The species included Rotifera, Cladocera and Copepoda Crustaceans. There were no previous surveys of the fresh water species introduced into the Caspian.

The distribution of the above four main groups of the Caspian species varies with the different sections of the Caspian (Fig. 27). Thus, 75% of species in the Middle and South Caspian are Caspian indigenous organisms, 20% are fresh water species, 3% are Atlantic introduced species, and 2% are Arctic species. A proportion of the species in the North Caspian is different. Fresh water species dominate here. The proportion of them is 60%: Caspian indigenous species are 36%, Atlantic species are 4%, and Arctic species – less than 1%.

No above-mentioned species can be found in the Kara Bogaz Gol Bay. Only salt-loving species (halophyles) inhabit the area. They represent another group of introduced species in the Caspian that originated from cosmopolitan forms of arid areas. All salt-loving organisms have a resting stage that can survive drying, freezing and other unfavorable conditions (Makrushin, 1985). The resting stage can be delitescence eggs, spores, seeds and cysts. They develop in saline water. The resting stages are small and can be carried with wind and migrating birds. Some cysts remain viable during tens and hundreds years. Thus, when in early 1980's the Kara Bogaz Gol Bay dried, resting phase of salt-loving organisms remained on its exposed seabed and revived after the Bay was refilled with salt water. We would like to point out that the dry Kara Bogaz Gol Bay was a source of many dust storms. The storms carried the cysts all over the world. This is the reason why all salt-loving organisms are considered cosmopolitan. Therefore, many of the salt-loving organisms that inhabit the Kara Bogaz Gol Bay are similar to the species from slat lakes of America, Europe, Asia, Africa and Australia. It is also worth mentioning that these forms are the most ancient inhabitants of the Earth that did not really change during several hundred million years. Some scientists (Clegg et al., 1997; Lee, 2001) believe that resting stages of some halophyles can travel between planets in meteorites, remaining vital.

Consider a role of introduced species in the ecosystem of the Caspian and their impact on its biodiversity. We believe that to dramatize the impact of introduction is not right. As highlighted above, the present community of the Caspian contains mainly introduced species that form its rich biodiversity. However, the Caspian is not open to any exotic species that get into it. There is no doubt that such introduced species as Ctenophore needs to be neutralized. The surveyors of the Caspian should have balanced and differentiated approach to the problem of introduced species in the Caspian.

There is no doubt that the most ancient introduced species in the Caspian should be protected against any negative impact, including the impact of new introduced species. The Caspian indigenous flora and fauna are the main value of this continental water body. These living fossils are of high biological, ecological, genetic and commercial importance. Some surveyors believe (Dumont, 1998; Zonn, 2000; Aladin, Plotnikov, 2000) that biological resources of the Caspian are more valuable than its oil and gas resources. We would like to outline that the most valuable fish is Caspian indigenous sturgeon that is the descendant of inhabitants of the ancient ocean Thetis.

We are positive about aimed introduction of species into the Caspian. Introduction of Polychaeta *Nereis* and bivalve *Abra* were done as recommended by the scientists (Karpevich, 1975). It significantly increased value of the Caspian benthos as a food base. Adaptation of mullet and flounder was also successful. There can be more perspective-introduced species in the area. However, search for the species should be based on scientific studies; any haste must be avoided. The opinion to reject any introduction of the species into the Caspian is not correct. Due to specifics of its formation, this great lake has free econiches that can be filled by people. New aimed introductions in the Caspian should not put us off. However, successful ecosystem management of this water body is possible only on the basis of long-term and well-financed surveys.

A range of accidental introductions appeared to be commercially useful. Many microscopic Crustaceans increased the value of the Caspian plankton as a food base, shrimps increased the value of benthos. A high amount of accidental introduction did not have any significant impact on the biodiversity of the water body. However, some of them such as balanus and bivalve *Mytilaster* had a certain negative impact from people's point of view. The abovementioned organisms cannot be used as food for fish because of their thick shells; they are typical representatives of non-food benthos. Besides, the introduced species can inhabit bottoms of vessels, port piles and offshore oilrigs. They hamper movement of the vessels and gradually corrode port and oil structures.

As a conclusion, we would like to outline that it is necessary to develop a set of measures to protect the biodiversity of the Caspian and its ecosystem against the most recent introduced Ctenophore species. This is probably the most dangerous introduced species in the Caspian Sea. We have already mentioned that the species (*Mnemiopsis leidyi*) eats zooplankton and causes starvation for other plankton-feeding species. In 1980's it was introduced onto the Black sea and made an unrecoverable damage to its fish reserves (Ctenophore…, 2000). By late 1980's the total weight of the Ctenophore was about billion tonnes. This highly productive organism ate not only zooplankton but also caviar and small larvae. Later the Ctenophore was introduced to the Azov sea via the Kerch channel where also made unrecoverable damage to the commercial fishing. At present it is in the Caspian, and we should prevent the tragedy of the Black and Azov Seas. We propose to commence a continuous monitoring of the species distribution in the Caspian. We need to find natural predator of the Ctenophore and after a range of laboratory and natural condition tests introduce it into the Caspian. We also believe that it is necessary to have a strict control of ballast water to avoid any accidental introduction.

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