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Hybrid marine/lacustrine seas and saline lakes of the world

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Abstract: Water salinity is one of major environmental factors influencing on hydrobionts. According conception of relativity and plurality of barrier salinity zones barrier salinities are relative to the perfection of hydrobionts osmoregulatory capacities and to the water chemical composition. These zones are unequal by their importance. All hydrosphere could be divided into freshwater brackish water, marine and hyperhaline salinity zones and transitional ones between them. Approximate boundaries and corresponding barrier salinities for all of these zones are defined. Revealing barrier salinity zones supposes studying osmoregulatory capacities of hydrobionts and salinity boundaries of their distribution. We distinguish in marine and continental waters four barrier salinities or horohalinicums: α (5 – 8‰), β (22 – 26‰), γ (45 – 50‰) and (0. 5 – 2‰) . In metamorphized continental waters barrier salinities are shifted to higher concentrations. Values of barrier salinities can change following evolution of salinity adaptations and osmoregulation capacities. Maracaibo Lake was occupied by freshwater and freshwater – brackishwater zones. Deepening of the shipping lane increased salt flux and brackish – water zone appeared. It is suggested to distinguish hybrid lentic water bodies in which number there are Baltic Sea, Black Sea, Sea of Azov and Maracaibo Lake. They have Intermixing of marine (saline) and continental (fresh) waters and lost the lacustrine status.

Key words: Salinity   barrier salinities   salinity zones   seas   saline lakes

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1. Introduction

Water salinity is one of the major environmental factors influencing on hydrobionts. On our planet there are many saline lakes not connected to the World Ocean and hybrid lacustrine/marine seas in which salinity is changing smoothly from fresh water to marine and in some cases even to hyperhaline. In the present paper we will discuss some such lakes and hybrid seas.

2. Barrier salinities

According to the Conception of relativity and plurality of water barrier salinity zones [1] zones of barrier salinities are relative, on the one hand, to the degree of hydrobionts osmoregulatory capacities perfection and, on the other hand, to the water chemical composition; there are several zones of barrier salinities (Tab.1, Tab.2, Tab.3, Fig.1, Fig3) and they are unequal by their importance.

Tab.1 Position of barrier salinity zones or horohalinicums

Barrier salinity	Oceanic waters	Caspian Sea	Aral Sea
α-horohalinicum (brackish waters)	5–8‰	7–11‰	8–13‰
β-horohalinicum (polyhaline waters)	22–26‰	26–30‰	27–32‰
γ-horohalinicum (hyperhaline waters)	45–50‰	46–51‰	47–52‰
δ-horohalinicum (fresh waters)	0.5–2‰	0.5–2.5‰	0.5–3‰

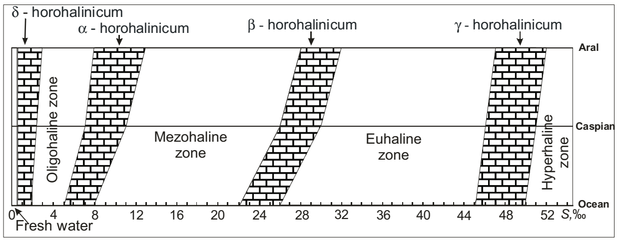

Fig.1 Position of barrier salinity zones or horohalinicums

Revealing barrier salinity zones in the hydrosphere supposes studying osmoregulatory capacities of hydrobionts first of all. It is to reveal types of osmotic relations of internal media with the environment, to find experimentally limits of salinity tolerant ranges, to analyze data on salinity boundaries of hydrobionts distribution in the nature.

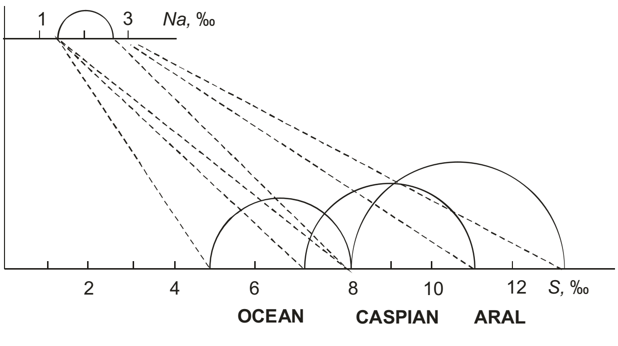

Fig.2 Critical salinity or α-horohalinicum shift to higher concentrations in waters of Caspian and Aral seas as compared with oceanic water

In continental waters positions of barrier salinities can be shifted to higher values because of difference in ion composition when proportion of divalent ions is higher as compared with waters with oceanic ion composition (Fig.2) [2] [3].

Tab.2 Percentage of areas of different barrier salinity zones (horohalinicums) in hybrid marine/lacustrine seas and saline lakes

	Horohalinicums			
	α	β	γ	δ
Baltic Sea	62%	4%	< 0.01%	6%
Black Sea	0.02%	< 0.01%	< 0.01%	0.2%
Sea of Azov	7%	1%	1%	< 2%
Caspian Sea	13%	< 0.01%	< 0.01%	5%
Aral Sea (before 1960)	88%	< 0.01%	< 0.01%	до 1%
Modern Aral Sea (Small Aral)	1%	–	–	< 0.1%

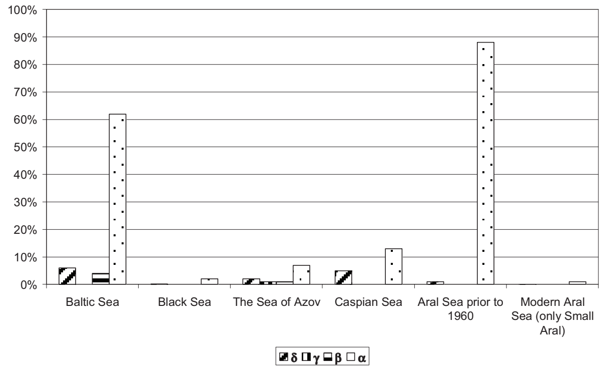

Fig.3 Percentage of areas of different barrier salinity zones (horohalinicums) in hybrid marine/lacustrine seas and saline lakes

Tab.3 Percentage of total areas all barrier salinity zones (horohalinicums) in hybrid marine/lacustrine seas and saline lakes

Sea/lake	Total
Baltic Sea	72%
Black Sea	< 1%
Sea of Azov	11%
Caspian Sea	18%
Aral Sea (before 1960)	89%
Modern Aral Sea (Small Aral)	1%

Position and width of barrier salinities ranges cannot depend on water physicochemical properties only. Values of barrier salinities can change following evolution of salinity adaptations and osmoregulation capacities of aquatic plants and animals.

3. Salinity zones

All hydrosphere of our planet could be conditionally divided into freshwater brackish water, marine and hyperhaline zones. Between these four basic zones there are transitional zones.

Following main principles of conception of relativity and plurality of salinity barrier zones [1] the following approximate ranges of all basic and transitional salinity zones were suggested for oceanic, Caspian and Aral waters (Tab.4, Fig.4).

Tab.4 Ranges of salinity zones

Zones	Ocean	Caspian	Aral
Basic freshwater	0-2‰	0-2.5‰	0-3‰
Transitional freshwater-brackishwater	2-5‰	2.5-7‰	3-8‰
Basic brackishwater	5-8‰	7-11‰	8-13‰
Transitional brackishwater-marine	8-26‰	11-28‰	13-29‰
Basic marine	26-40‰	28-41‰	29-42‰
Transitional marine-hyperhaline	40-50‰	41-50.5‰	42-51‰
Basic hyperhaline	> 50‰	> 50.5‰	> 51‰

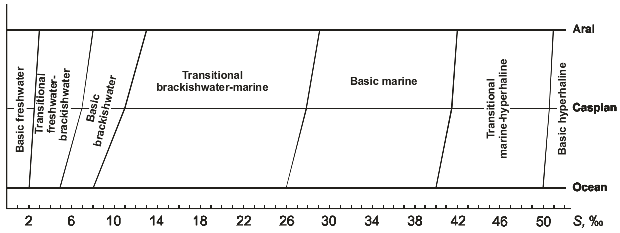

Fig.4 Ranges of salinity zones

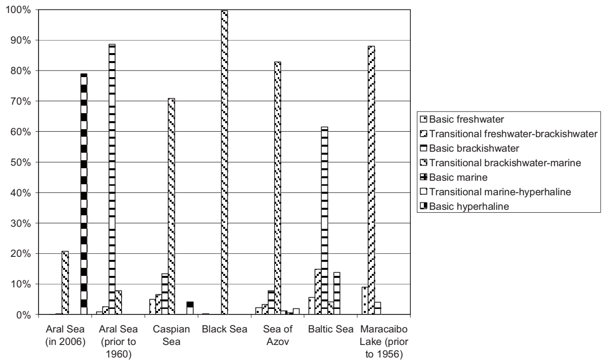

Fig.5 Percentage of areas of different salinity zones in hybrid marine/lacustrine seas and saline lakes

Marine zone occupies more than 95% of the hydrosphere surface. Freshwater zone occupies less than 3%. Brackish water and hyperhaline zones occupy about 0.5% each. Transitional zones are occupying less than 0.5% each.

Portions of all salinity zones in the considered hybrid marine/lacustrine seas and saline lakes are shown on Fig.5.

4. Hybrid seas and saline lakes

4.1 Aral Sea

In the first half of the 20th century, the Aral Sea was a single terminal water body of two rivers in the arid zone. The main part of its water area was brackish (Fig.6) with specific aboriginal brackish water ecosystems. Since 1960s, decrease of level and salinization of the Aral Sea have begun. Due to the structure of its depression the Aral Sea began to split into several residual water bodies. In 1988–1989, when level decreased by 13 m, the Aral Sea was divided into 2 polyhaline terminal lakes with marine ecosystems – the Large and Small Aral (Fig.7). In the fauna, only widely euryhaline species remained due to water salinization and introduction of exotic species. Piscifauna consisted of introduced species of marine origin. In spring 1990, level of the Small Aral increased and a water flow to the Large Aral appeared. The threat appeared of moving the Syrdarya River mouth to the Large Aral. In August 1992 a dike was built in the Berg's Strait. Salinity growth in the Small Aral stopped; the salinity began to decrease what was favorable to the fauna. Conditions of transitional brackishwater-marine salinity zone were formed. In April 1999, the dike was destroyed by a storm. Construction of new solid dike started in 2004 and was finished in autumn 2005. After Aral Sea division, salinization and level fall in the Large Aral became faster. The Large Aral was divided into the Western Aral, Eastern Aral and Tschebas Bay (Fig8). Salinity in the eastern basin is growing faster than in the western one. In the late 1990s, the Large Aral became hyperhaline with specific fauna. Some invertebrate species inhabiting saline water bodies in the Aral Sea region moved into the Large Aral by natural way. Among them, the brine shrimp (*Artemia parthenogenetica*) became predominating in zooplankton [4],[5].

As you could see, original brackish-water ecosystem of the Aral Sea nearly totally has gone due to salinization. The only hybrid marine/lacustrine sea that could be compared with Aral Sea is Baltic Sea. In our unique Baltic brackish-water ecosystems cover up to 60%. In the Aral Sea they covered up to 90%.

In the case of Aral Sea redirection of riverine waters for irrigation purposes allowed to increase harvesting of cotton and rice. Unfortunately salinization of irrigated lands didn't allow having sustainable agriculture in this area [6].

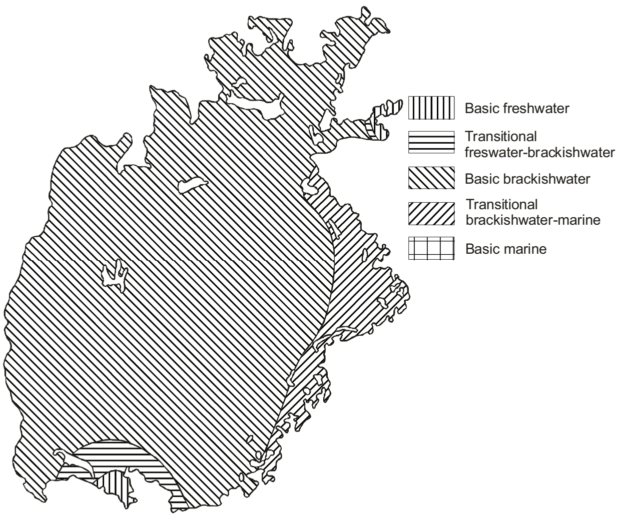

Fig.6 Salinity zones of the Aral Sea in 1960

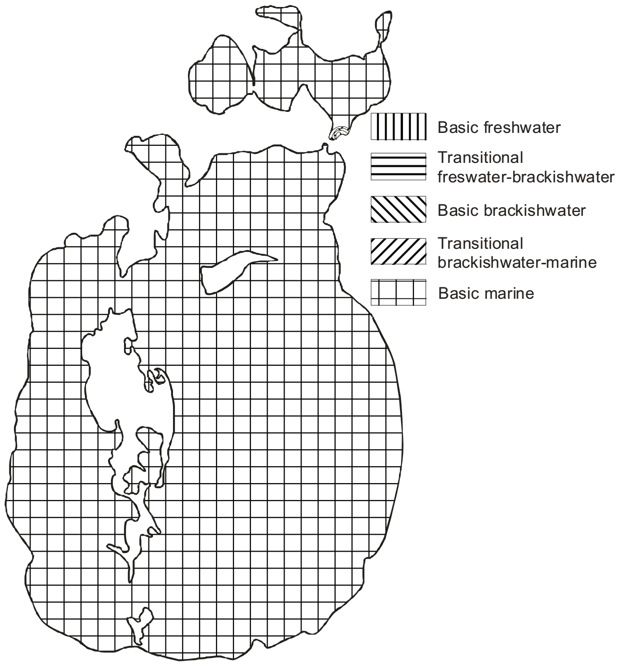

Fig.7 Salinity zones of the Aral Sea in 1989

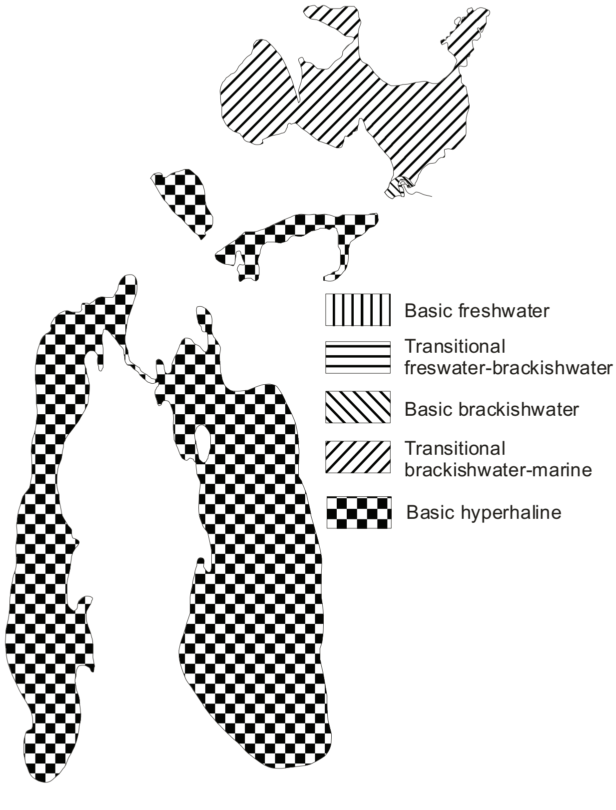

Fig.8 Salinity zones of the Aral Sea in 2006

Desiccation of the Aral Sea has wrought severe consequences. Greatly reduced river flows ended the spring floods that sustained wetlands with freshwater and enriched sediment. Fish species in the lakes dropped from 32 to six because of rising salinity and loss of spawning and feeding grounds. Commercial fisheries were lost. Shipping on the Aral also ceased because the water receded many kilometers from the major ports. Groundwater levels dropped with falling lake levels, intensifying desertification. The climate also changed up to 100 kilometers beyond the original shoreline: today summers are hotter, winters are colder, humidity is lower (so rainfall is less), the growing season is shorter and drought is more common [6].

The receding sea has exposed and dried 54000 km^2 of seabed, which is choked with salt and in some places laced with pesticides and other agricultural chemicals deposited by runoff from area farming. Strong windstorms blow salt, dust and contaminants as far as 500 km. Airborne sodium bicarbonate, sodium chloride and sodium sulfate kill or retard the growth of natural vegetation and crops [6].

4.2 Baltic Sea

Baltic Sea is young and in glacial time it was a cold lake. Baltic Sea retains many features of lake until now. It is semi-closed, shallow, brackish water body having smooth salinity gradient and unique fauna and flora. Biodiversity of Baltic Sea is relatively low while it is unique.

Riverine waters are giving considerable contribution practically to the whole water areas of the Baltic Sea.

In the Baltic Sea there are oligohaline and mesohaline water areas, and each of them has its own specific flora and fauna. The most freshened areas there are Gulf of Finland and Gulf of Bothnia. Central water area of Baltic Sea has pronounced mesohaline character. Only in Kattegat and Sound can polyhaline conditions be found.

Biodiversity of this young sea was formed in the postglacial time and is highly heterogeneous by its composition. It consists of three main components: marine, freshwater and brackishwater (*sensu stricta*). The first group is the main part of Baltic Sea biota. It includes relicts if previous geological times and immigrants from remote marine water bodies. The second group includes large number of Baltic Sea inhabitants, which come together with freshwater inflow. The third group is represented by large number of species and is divided into 2 subgroups:

1. ancient brackishwater arctic relicts (pseudorelicts-immigrants) formed in the glacial time in freshened areas of arctic basin that migrated into the Baltic Sea in postglacial time from the North-East and East possibly via fresh waters;
2. Brackishwater forms originated from freshwater ones.

In the Baltic Sea it is possible to distinguish all 4 basic and 3 intermediate zones (Fig. 9).

The basic zones are: freshwater, brackish water, marine and hyperhaline. The intermediate zones are: transitional between freshwater and brackish water, transitional between brackish water and marine, transitional between marine and hyperhaline. From the position of earlier published conception of relativity and plurality of barrier salinity zones [1] the following bounds of these zones for Baltic Sea were defined.

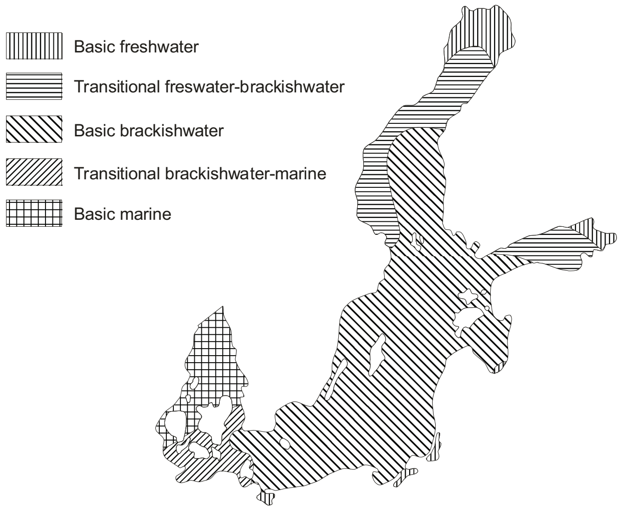

Fig.9 Salinity zones of the Baltic Sea

Freshwater zone in the Baltic Sea occupies mouths of inflowing rivers and also waste adjoining areas of shallow gulfs. Absence of pronounced high and low tides in the Baltic Sea contributes to stable existence of δ-horohalinicum (0.5–2‰). This barrier salinity divides freshwater ecosystems from brackish water. δ-horohalinicum is well distinguished in the eastern part of the Gulf of Finland and the Northern part of the Gulf of Bothnia. It is to note Vistula and Curonian lagoons which are divided by this barrier salinity into fresh and brackish water zones. In the South-Eastern area of the Gulf of Riga being constantly influenced by riverine water inflow δ-horohalinicum zone is well distinguished also.

Area of the Baltic Sea occupied by freshwater zone is not large – only 6% of the total area. They are only small areas where fresh riverine waters are mixing with saline Baltic Sea waters. Salinity varies here from fresh water up to 2‰. However many freshwater plants and animals are living only here and never are found in the Baltic Sea proper. In Baltic freshwater ecosystems there are about 1200 species of fishes, free-living invertebrates and plants (without bacteria, protozoans and tiny metazoans). These water areas are shallow, maximal depths don't exceed several tens of meters. Special distinguishing of freshwater zones and ecosystems is important for forming universal conception of Baltic Sea biodiversity. δ- horohalinicum is restricting zone for freshwater organisms invading Baltic Sea.

Brackish-water zone and α-horohalinicum occupy the Baltic Sea proper, Bothnian Sea, Archipelago Sea and the Gulf of Riga. This boundary zone occupies the largest part of the sea area, about 62% of the total Baltic Sea. Salinity here varies between 5-8‰ and many scientists considered these salinities as the normal salinity of the Baltic Sea. In the Baltic Sea α-horohalinicum is occupied by brackish water ecosystems which are the most poor in the species number. In them there are about 700 species of fishes, free-living invertebrates and plants (without bacteria, protozoans and tiny metazoans). Some of them are descendants of inhabitants of glacial lake existed on the place of modern sea in the ice age. Zone of α-horohalinicum occupies the deepest part of the Baltic Sea where depths are up to 500 m.

β-horohalinicum (22–26‰) is located in the West of Baltic Sea and the Eastern water area of Danish Straits strongly influenced by inflow of full-saline waters from the North Sea. Salinity here varies from 22‰ up to 26‰. While the area is only about 4% of the total Baltic Sea area, number of species of fishes, free-living invertebrates and plants (without bacteria, protozoans and tiny metazoans) found here is about 3000.

γ-horohalinicum (45–50‰) is not directly found in the Baltic Sea. This zone in fact is outside of the sea or at its bounds. γ-horohalinicum can be found in rock pools or on salted shoals named "salt marshes". Hyperhaline ecosystems can be named seasonal ecosystems, which are formed in summer time when evaporation is highest. γ-horohalinicum divides inhabitants of full saline Baltic Sea waters from inhabitants of hyperhaline waters where maximal number of plant and animal species including unicellular ones don't exceed 100.

In the case of Baltic Sea the main threat is eutrophication. This subject is excellently covered in the Baltic Sea Action Plan. We hope that environmental mistakes made agricultural business around Aral Sea will not be repeated in the area around Baltic Sea [7].

4.3 The Sea of Azov

The Sea of Azov is semi-closed, shallow, saline water body as well as the Baltic Sea having smooth salinity gradient. By Kerch strait it is connecter with the Black Sea. Only two large rivers, Don and Kuban, are flowing to the Sea of Azov. In the Sea of Azov it is possible to distinguish all 4 basic and 3 intermediate salinity zones with the same bounds as in the Baltic Sea [8].

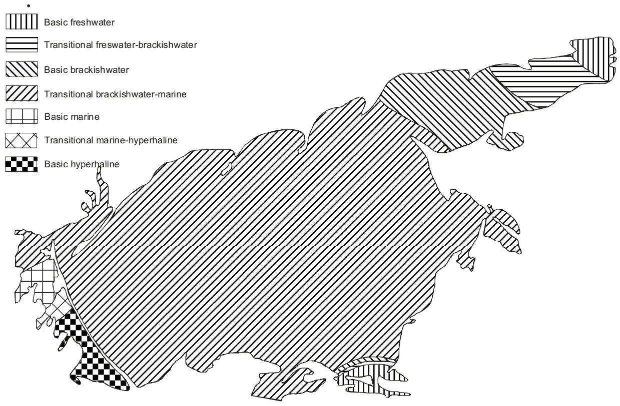

Fig.10 Salinity zones of the Sea of Azov

Freshwater zone in the Sea of Azov occupies water areas at the mouths of Don and Kuban rivers. Absence of pronounced high and low tides in the Sea of Azov contributes to stable existence of δ-horohalinicum. Tis barrier salinity zone is well distinguished in the eastern part of the Taganrog Gulf and the mouth of Kuban River. Brackish-water zone and α-horohalinicum occupy the Sea of Azov western part of Taganrog Gulf. The most part of of the Sea of Azov water area is occupied by transitional brackishwater-marine salinity zone (Fig.10).

Other salinity zones and horohalinicums can be found in the Sea of Azov only in its shallow bay Sivash. In this bay there is pronounced salinity gradient and in the top there are hyperhaline conditions (Fig.10).

4.4 Caspian Sea

The Caspian Sea is the largest closed water body on the Earth located between Europe and Asia Though the Caspian Sea is continental water body, it has oceanic origin: it is the rest of Paratethys – a gulf of ancient ocean Tethys. It is possible to explain salinity of waters by its origin from this ancient ocean. About 6 million years ago the Pontic Lake was divided into Upper Pontic Lake, occupied the Black Sea hollow, and completely isolated Babadjan Lake occupied only South-Caspian hollow. Since this tine Caspian Sea exists as isolated basin. In the subsequent time Caspian Sea has gone through a number of transgressions and the regressions, accompanied by significant decrease or increase in its salinity, and about 5–7 thousand years ago modern Caspian Sea was formed [9].

Caspian Sea occupies large by area and deep continental depression, its modern level is varying about mark -27 – -28 m a.s.l. [11] [12] [13]. By features of morphological structure of hollow and physical-geographical conditions Caspian Sea is divided to the Northern, Middle and Southern Caspian Sea and isolated gulf Kara Bogaz Gol [14] [15]. From these parts Caspian Sea *sensu stricta* are Middle and Southern, the Northern actually is extensive estuary of rivers running into it.

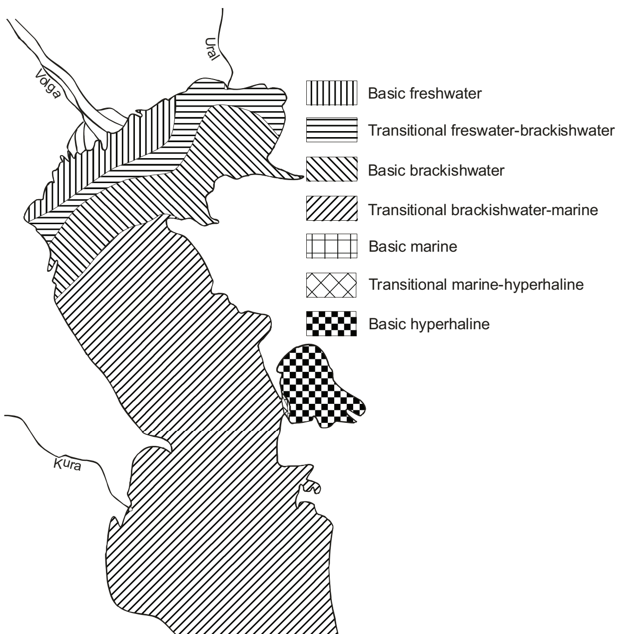

Fig.11 Salinity zones of the Caspian Sea

The maximal depth of the Caspian Sea is 1025 m. Average depth is 208 m. Northern part of Caspian Sea is shallow, its maximal depth does not exceed 25 m, and average depth is 4 m [15] [16].

At the east coast there is connected with the main water area by narrow strait (5.5–11 km long) with shallow hyperhaline gulf-lagoon Kara Bogas Gol, which level is by some meters below the level of Caspian Sea. To the gulf there is constant drain, and water in it quickly evaporates. In 1980, in order to slow down Caspian Sea level fall, the gulf has been separated with dam and for three years has dried up almost completely, having turned to huge saline desert. Closing of drain to Kara Bogaz Gol has led to serious negative consequences. Salt began to be carried by winds, salinizating environment and ground; chemistry of gulf was broken. In 1984 the water-carrying construction for restoration and preservations of surface brines, for weakening negative influence on environment and restoration of extraction of mineral salts has been constructed. In 1992, because the Caspian Sea level has begun to increase, the dam has been liquidated. By present time the gulf was completely restored.

Into the Caspian Sea130 rivers run. Catchment area is about 3.5 million km^2. The water balance of the Caspian Sea is defined mainly by river drain and precipitations, evaporation and outflow of water to Kara Bogaz Gol. Main importance in income part of water balance has Volga River giving almost of 80% of riverine waters inflow. Income part is almost completely counterbalanced by evaporation, the drain to Kara Bogaz Gol makes only 5% [15].

The level of Caspian Sea is changeable. Up to 1917 relative stability was observed. Since 1917, a level began to fall, from -25.82 m a.s.l. to 1925 it has lowered up to -26.26 m. To 1930 it has raised a little up to 26.06 m a.s.l. Then slow downturn of level has begun, and from 1933 it became fast. In 1941 level has reached -27.88 m a.s.l. Also it was again stabilized at -27.96 m a.s.l. In 1949 falling of level has renewed and continued up to 1977 having reached mark -29.03 m a.s.l. From 1978 fast rise of level has begun. In 1995 at mark -26.61 m a.s.l. level was stabilized, but further it began to decrease slowly, having lowered to 2002 up to -27.15 m a.s.l. [17] [18]. Changes of river drain and visible evaporation are considered as the principal cause of Caspian Sea level changes, and also geological, climatic and anthropogenous factors [17] [11] [12]. Fast rise of Caspian Sea level has caused significant damage to economy. In the zone of flooding there were significant territories. Plenty of polluting substances has got to the sea. Special harm to biodiversity was brought with flooding coastal objects of oil excavation and transportation. On the other hand, rise of the level has improved conditions fishes pasturing, area spawning grounds has increased, and freshened buffer zone has expanded and promoted increase of potential productivity of the Northern Caspian Sea.

Average salinity of Caspian Sea waters is 12.7-12.8‰, maximal (not including gulf Kara Bogaz Gol) at the east coast is up to 13.2‰, minimal in the northwest – 1-2‰. The Caspian Sea water is rather poor with ions of sodium and chlorine and is richer with ions of calcium, magnesium and sulfates owing to old isolation from the World Ocean, and metamorphization under influence of riverine drain [15] [19].

The lowest concentration of salts is observed in Northern Caspian Sea – on the average 5-10‰. Near to deltas of Volga, Ural and Terek, salinity is up to 2-4‰. Directly in avandeltas of these rivers salinity is less than 0.5‰. In shallow water areas of east coast of Northern Caspian Sea water salinity be above the average. In shallow gulfs water salinity can reach 30‰ and higher. Salinity of Middle Caspian Sea is 12.7‰. Salinity of Southern Caspian Sea is 13‰ [16] [20].

The highest salinity is in gulf Kara Bogaz Gol. It is the huge evaporator, and salinity of its waters is 300-350‰ and more. The Caspian Sea water brings in the gulf huge amount of salts. Kara Bogaz Gol plays a role of a desalter. At the bottom of gulf owing to evaporation and natural sedimentation the huge amount of salts is being accumulated [15] [19].

In the Caspian Sea there are all 4 basic and 3 intermediate salinity zones and all barrier salinities having specific for existing here salt composition bounds (Fig.11). Freshwater zone in the Caspian Sea occupies vast water area at the delta of Volga River in the Northern Caspian and small water areas at the mouths of other large rivers. In this part of the sea salinity gradient exists and there are transitional freshwater-brackishwater and basic brackish-water salinity zones. The Middle and Southern Caspian Sea belong to transitional brackishwater-marine salinity zone. Marine and transitional marine-hyperhaline salinity zones exist in the short salinity gradient existing in the gulf Kara Bogaz Gol at the entrance to it. The rest of water area of this gulf is hyperhaline zone.

Biodiversity of Caspian Sea is by 2.5 times poorer than biodiversity of Black Sea or by 5 times is poorer than in Barents Sea [20]. For true fresh-water fauna and flora salinity is too high, and for true marine species it is low. By origin modern fauna is mainly of Neogene age. The recent biodiversity of Caspian Sea reflects complex history of Paleocaspian transgressions and regressions and connected with their freshening and salinization. In Caspian Sea there are living more than 500 species of plants and 854 species of fishes and animals, various by origin. Speciation in the Caspian Sea has created the general high level of endemism (approximately 42-46%).

In XX century invaders has got into Caspian Sea from other seas as intentionally or in passing as a result of deliberate acclimatization of economic valuable species of fishes, and casually: with ballast waters or from biofoulings on the bottoms of vessels. It creates a problem of such invasive species which are capable to break seriously biological balance which has developed in the ecosystem of water body [10] [21] [22] [23]. Fish stocks of Caspian Sea are estimated very highly.

Now ecological state of Caspian Sea is in very complex condition. The rivers bring to Caspian Sea pollution from the huge catchment is subjected to strong anthropogenous influence. Isolation makes ecosystem of Caspian Sea as closed lake especially vulnerable to various kinds of pollutants, remaining in its boundaries. Thus, Caspian Sea accumulates in itself all harmful substances coming into it. Such pollutants as oil hydrocarbons are in the lead. In some water areas, first of all in the places of extraction and transportation of oil, pollution can be catastrophic. Despite of catastrophic local pollution, waters of Caspian Sea as a whole are polluted while poorly, owing to high speed of processes of autopurification [10]. Because of absence of the uniform agreement on protection of the sea among the near-Caspian countries, catastrophic growth of poaching takes place. Injurious catching of sturgeons has led to impossibility to provide fish-breeding factories with necessary number of spawners necessary for artificial reproduction of sturgeon fishes, now unable to support their number. Now existence of sturgeon fishes in Caspian Sea is under threat [10].

4.5 Lake Balkhash

Lake Balkhash is a terminal lake in eastern Kazakhstan, located in the desert. Its area varies with its water level and is 17000–22000 km^2. The lake extends east-west by 588–614 km, and is from 9–19 km wide in its eastern section and 74 km in the western section. In the 1960s maximum depth was 27 m. River Ili flowing to the western section contributes about 80% of total annual inflow. Other some rivers are flowing to the eastern part. The two section of Lake Balkhash are relatively independent and connected by narrow and shallow strait of Uzun-Aral, a narrow and shallow channel. Because of lake's division into two sections of unequal size, with most inflow into the western one, salinity in west Balkhash is very low (1.1‰) whereas in the east Balkhash it is higher (4.3‰ or more). Mineralized waters of Lake Balkhash differ by ionic composition from marine water likewise in the Caspian Sea and Aral [24].

West Balkhash is occupied by freshwater salinity zone. East Balkhash belongs to transitional freshwater-brackishwater salinity zone (Fig.12). They are divided by δ-horohalinicum.

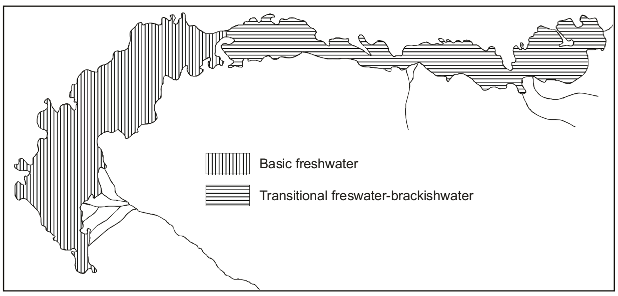

Fig.12 Salinity zones of Balkhash Lake

In the western part of Balkhash lake freshwater and euryhaline hydrobionts predominate, but in the eastern Balkhash freshwater organisms disappear [24].

We did not test inhabitants of this lake. Our suggestions are based on our data on the inhabitants of Aral Sea. We have applied the same approach to determination of salinity ranges. However, considering works by N. Khusainova and A. Karpevich it is not excluded that these ranges in this lake could be shifted to higher salinities than in Aral.

In 1967 an extension of irrigated areas began and in 1960 the Kapchagay Reservoir on Ili River began to fill. Water withdrawal increased what caused decrease in the Lake Balkhash level and some sanity increse. Continued level fall can lead to the complete degradation of the basin ecosystem as has happened in the Aral Sea basin [25] [26].

Accepted recommendations enabled some improvement in the position of the lake so far as its biota was concerned, but river pollution continues and salinization proceeds.

4.6 Lake Maracaibo

The Maracaibo System is located in northwestern Venezuela. It consists of Lake Maracaibo and a natural channel composed of Maracaibo Strait and Tablazo Bay connecting the lake with the Gulf of Venezuela. Length of Lake Maracaibo from the north to the south is150 km, the greatest width reaches 120 km. Surface area is 12000 km^2. Lake Maracaibo has average depth of 26 m, and maximum depth of 34 m. To Lake Maracaibo there are flowing 30 rivers. The only outflow is via Maracaibo Strait. It is 40 km long and has average width of 7.7 km. Here there is salinity gradient. Shallow (mean depth 3 m) Tablazo Bay connects Maracaibo Strait and the Gulf of Venezuela. Its connection to the Gulf of Venezuela is restricted to two small openings between islands [27] [28] [29] [30].

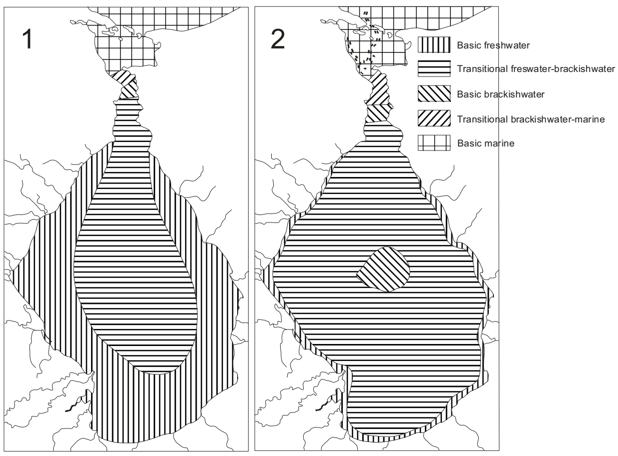

Fig.13 Salinity zones of Lake Maracaibo

In 1956 this natural channel has been deepened by 14 m deep, 100 km long, dredged, wide shipping lane, which has increased intrusion of sea water from Gulf of Venezuela into Lake Maracaibo. Prior to 1956 diluted seawater entered Lake Maracaibo during the dry season, while during the wet season the restriction of Tablazo Bay and Zapara Mouth was sufficient to prevent the influx of diluted seawater into the lake [27] [28]. Salinity in Lake Maracaibo was low and in the lake only basic freshwater and transitional freshwater-brackishwater zones were presented (Fig.13A). So, only δ-horohalinicum can be found

After 1956 the results of the inflow of saline water from the Gulf of Venezuela are persistent salinity stratification in Lake Maracaibo [27], total salinity growth and appearance of brackishwater salinity zone (Fig.13B) and α-horohalinicum.

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