EVOLUTION OF COASTAL LAGOONS OF THE SAKHALIN ISLAND

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Lagoons of Sakhalin island is the fifth part of the coast. Two lagoon types predominate in the Sakhalin Island. The first type includes large and medium lagoons located along the edge of seacoast flatlands. This is a "classical" lagoon type. The second type (estuaries) is connected with coast segments in mouths of the rivers. Their development is dominated by alluvial processes. Evolution of lagoons and estuaries the islands of Sakhalin is influenced by increase of global sea level.

Key words: Sakhalin Island, coastal lagoons, barrier-lagoon sedimentary system, marine culture, national park

THE MAIN FEATURES OF LAGOONS

Lagoons are a component of many coastline geomorphologic types: fiords, rias, corals, abrasive accumulative and accumulative flattened coasts. Most lagoons are located along low seacoasts, forming a separate lagoon type of coast [1 – 3]. Lagoon development has been addressed in detail in all major scholarly writings on seacoasts, with main emphasis placed on the formation of sand and pebble barriers separating lagoons from the sea [4-6]. The following specific trend was identified upon a review of relevant literature from the last decades of the past century. Researchers have been showing the greatest interest in relatively small water bodies. Thus, of the 97 explored lagoons, with their area varying from 1 km² to 8,000 km² (average value is 78 km²), the great majority of studies have focused on water bodies with an area of 30–40 km² [7].

The average area of 240 lagoons studied in the Far East of Russia (1–500 km²) is 31.3 km², and the best studied lagoons, Busse on Sakhalin Island and Novgorodskaya in Primorsky Krai, have an area of 43 and 30.7 km2, respectively. One possible explanation for this phenomenon is that medium-size lagoons are the most interesting for analysis of their ecosystems and commercial use. On the other hand, small water bodies do not show individual features of lagoon characteristics due to high impacts of alluvial or eolian input. As for large lagoons, the high wave impact on shores and marine facilities make them less favorable for transportation possibilities and commercial activities.

The lagoons are grouped by size into large (100–500 km²), medium (10–100 km²), small (1–10 km²) and very small (less than 1 km²) ones. The largest of the large lagoons are Baikal and Piltun. In terms of water depth, lagoons are grouped into shallow (less than 1 m deep), medium-depth (1–5 m), deep (5–20 m) and very deep (more than 20 m) ones [8].

Lagoon distribution in terms of their shape is also of interest. The shoreline contour of a water body may be linearly stretched, elongate, rounded, segmental, triangular or rectangular as a result of the evolution of coastal processes. Thus, segmental lagoons are found on the abrasive bay/coast in the northwestern part of the Okhotsk Sea (Ikit Lagoon) and rectangular ones are located on a fiord-type coast (Severnaya Lagoon, Bering Sea). Spit-blocked estuaries are often triangular (Starka Lagoon, Sea of Japan).

According to the degree of isolation from the sea, and to what degree they are influenced by hydrodynamic conditions, and by biological, chemical and other processes taking place inside lagoons, lagoons can be grouped into open lagoons (Tyk), semi-open (Baikal), semi-closed (Nabil), and closed (Ainskaya). There is also a separate group of dismembered lagoons composing lagoon lakes (Rybachye) that have no connection with the sea.

Two lagoon types predominate in the Sakhalin Island. The first type includes large and medium lagoons located along the edge of seacoast flatlands (Pomr, Piltun, Busse, Saroma, *etc.*). This is a "classical" lagoon type. They have a contour stretched along the coast and are connected with the sea by one of two channels. The second type is associated with seacoast segments of river valleys (Bolshoye, Nabil, Niyvo, Ptichya, *etc.*). These lagoons are often stretched perpendicular or at an angle to the coastline general direction. Their development is dominated by alluvial processes. Small water bodies in straits between islands, typical of low elongate peninsulas, make up a separate lagoon type (Terpeniya).

There is complex differentiation of sediment material taking place in lagoons, governed by the direction and velocities of runoff and tidal currents. Bottom sediment is dominated by silts and fine-grain sands. Gravel, pebble material and shell fragments also occur frequently.

MORPHOLOGY AND EVOLUTION OF LAGOON

Morphology and dynamics of individual topographic forms can have common or local differences. Morphological system of the Sakhalin lagoon shore includes a number of elements, which reflect the morphology and genesis of the landscape, as well as the character of coast-forming processes. It is most obvious in the northeast of the island. They include the following: accumulative underwater coastal slope, bars and bay bars, accumulative plains of lagoon seabed, lagoon and sea terraces, lagoon straits and abrasive ridges between the lagoons.

Accumulative underwater coastal slope is a slightly wavy tilted plain with submerged coastal sand-and-gravel bars. The upper part of the slope has a series of underwater bars, influences by the joint effect of the waves, tidal and wavy alongshore currents. Recurrent surveys show that the bar tend to shift towards the shore. Narrow gravel and pebble deposits lie along the shoreline. Large and average-grain sands cover the slopes and crests of underwater bars.

Bars and bay bars separate lagoons from the Sea of Okhotsk and consist of accumulative formations of various morphological type and size. The surfaces of bars – major formations 20-30 meters long and 6-8 meters wide – have multiple generations of offshore bars cutting each other at different angles. This location of bars shows multiple transformations of the shoreline.

The Piltun Laguna is separated from the Sea of Okhotsk by a very complex bar. Its body includes the original residual hill, which used to be an island in the time of maximal development of the Holocene transgression; later it was connected to the shore by accumulative formations.

Smaller lagoons – Urkt, Ekhabi, Keutu and others are separated by bay bars with one wide bar up to 3 meters high. Lagoon muds in the horizon section also exposed on the underwater coastal slope under the poor layer of modern sand, gravel and pebble sediments, witness about the shifts of bay bars towards the shore and advancing of sea sediments onto the lagoon sediments.

Accumulative plains of the lagoon seabed consist of sub-horizontal and slightly tilted surfaces of three levels. The upper level is occupied by the tidal foreshores almost along the whole coastline. Slightly tilted accumulative plains of the middle level occupy up to 50% of the

lagoon seabed area. Central parts of the lagoon seabed (lower level) are taken by the sub-horizontal accumulative plains at the depths of 2-4 meters. They consist of fine aleuritic and clayed silts.

Lagoon and sea terraces of the middle-late Holocene are widely spread on the shores and line up the internal shores of lagoons. The estuaries of major rivers – Paromai, Piltun, Evai and others have well-developed terraces with flat horizontal swampy surface and cryosolic torfhuegels. The majority of terrace coasts are subjected to coastal erosion and rarely gradually transfer into beaches or sand-muddy tide field areas.

Lagoon straits are the most dynamic forms; by the time of existence, they are divided into two types: permanent and seasonal. Permanent straits are the straits of major lagoons with bigger areas of transverse currents – Piltun, Kleye, Anuchin, and Aslanbekov. Their sizes and expected outlines allow judging about the predominant direction of sediment transport. Thus, the Strait of Aslanbekov is actively shifting towards the north; and the Strait of Piltun – to the south.

The evolution of Sakhalin lagoons is associated with the Holocene transgression, during which time they came into existence [9]. As evidenced by well studied coastal-marine depositions, large seawater bodies, separated by sand banks and morphologically close to modern lagoons, started to form at higher sea level in the sub-boreal period. During subsequent sea level fluctuations above the modern level, the inner shoreline contour of lagoons was reshaping. Some water bodies are already at the post-lagoon stage, being partly or fully filled with alluvial, marine, eolian, or biogenic depositions.

HUMAN ACTIVITY

Anthropogenic effect in the Sakhalin lagoon shore involves anthropogenic violation of the natural landscape and disruption of the natural chemical composition of river and lagoon waters, which cause negative changes in the structure of highly efficient biocenosis of closed shallow waters. This effect is mostly related to the development of sand open mines for construction purposes on the bay bars and surf zones. In recent years, over 20 authorized and unauthorized open sand mines have been operating on the Sakhalin shores; half of them on the lagoon bay bars. In some cases, insufficiency of sediments in the coastal area results in a more intensive abrasion.

Anthropogenic impact of the Tunaicha Laguna has increased dramatically over the recent decade. Forests were logged in many water-intake areas; it will undoubtedly result in the decrease of the water transparency and increase in the rate of sediment accumulation due to the increased particles content in the inflowing streams. Additionally, in the mid-1970s, a bridge was constructed across the estuarine part of the Krasnoarmeisk tribute near the settlement of Okhotskoye. Much of the tribute was filled with ground leading to dramatic shallowing of the estuarine zone and complete blockage of seawater entry into the lake. Lake water was a little desalinated. Open sand mines are developed on the bay-bar, which separates the Laguna from the sea.

Biocenosis is very diverse in the Busse Laguna. The Ahnfeltia seaweed is the most valuable; it is in a satisfactory condition. Its resources were seriously depleted in the 1920-60s. Since Ahnfeltia takes a long time to grow, reproduces only in a vegetative way and is vulnerable to changes in the environmental conditions, an intensive and uncontrolled production of it inevitable results in a dramatic reduction of its amount. Currently, the fields of Ahnfeltia are slowly recovering.

Scientists of the Far East Federal University and Russian Geographic Society have launched a proposal to establish the Tunaichinsky National Park in the Sakhalin southeast, including Tunaicha, Busse, Izmenchivoye and other lagoons. This project could greatly benefit from Japan's experience in establishing their national parks, where beautiful coast, spa resorts and cultured pearl farms can all be found within a relatively small territory of the park [10].

Changes in the chemical composition of waters, regardless of the contamination source, lead to the irreversible structural changes in the structure of seabed biocenosis. Meanwhile, lagoons possess the highest biological productivity and are the most favorable water areas for farming in comparison with straits, open bays and gulfs.

The Sakhalin lagoons have great commercial importance in terms of marine civil and transport construction, development of mineral deposits, production of building materials, fishing and aquaculture, and recreation. Many lagoons are convenient harbors protected against storms. This makes them suitable for the organization of transport facilities and cargo reloading bases, for the construction of sheltered ports for small vessel, and for the erection of wharves and other civil structures, particularly in oil and gas production areas. Usually, these facilities are localized in specific areas and do not involve the whole lagoon; however, the environmental and geomorphological monitoring would have to be conducted in all cases.

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REFERENCES

1. E. C. F. Bird, *Encyclopedia of the World's Coastal Landforms*, Vol.1. Dordrecht: Springer, 2010. 485 pp.
2. M. L. Schwartz, *Encyclopedia of coastal science*. Springer, 2005. 263 pp.
3. V.P. Zenkovich, *Principles of the Science of the Sea-shore Development*. Moscow: Publishing House of the USSR Academy of Sciences, 1962. 710 pp. (in Russian).
4. S.P. Leatherman, "Barrier beach development. A perspective of the problem", *Shore & Beach* , 1981, No. 49, pp. 3–9.
5. Li Congxian, Chen Gang. "Postglacial transgression and regression and barrier-lagoon sedimentary system", *Acta oceanol. Sin*. 1986, Vol.5. 1, pp. 82-89.
6. G.F. Oertel, "The barrier island system", *J. Marine Geology*. V. 63, 1985, pp. 1-18.
7. S.W. Nixon, Nutrient dynamics, primary production and fisheries fields of lagoons. *Oceanol. Acta*, 1982, No. 4, pp. 357–371.
8. P.F. Brovko, *Coastal lagoons development*, Vladivostok: Far East National University, 1990. 148 pp. (in Russian).
9. P.F. Brovko "The Okhotsk Sea coastal lagoons: Types, evolution and use of resources", *PICES Scientific Report*, 2008, No. 36 pp. 191-193
10. M. Sutherland, and D. Britton, *National Parks* of *Japan*. Tokyo: Kodanka International Ltd., 1980, 148 pp.