The Okhotsk Sea coastal lagoons: Types, evolution and use of resources

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Abstract

As part of the Okhotsk Sea, but separated from it by a depositional feature, lagoons have a particular hydrology and specific conditions for bottom sediment accumulation. Marine organisms in lagoons can be exposed to water temperature and salinity fluctuations of significant range. The Okhotsk Sea lagoons are grouped by size into large (100–500 km^2), medium (10–100 km^2), small (1–10 km^2) and very small (less than 1 km^2) ones. The largest lagoons in terms of area are Baikal, Schastya, Piltun, and Perevolochnaya. Many small lagoons are linked to river estuaries. 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. The evolution of Okhotsk Sea lagoons is associated with the Holocene transgression, during which time they came into existence. As evidenced by well-studied coastal-marine depositions, large sea water bodies, separated by sand banks and morphologically close to modern lagoons, started to form at a higher level in the sub-boreal period. During subsequent sea level fluctuations above the present-day level, the inner shoreline contour of lagoons was reshaping. Today, some lagoons are separated from the sea, partly filled with alluvial-marine, eolian, and biogenic depositions and have turned into lakes. Lagoons are used as harbors for sheltering small fishing and transport vessels. Some lagoons are used for aquaculture farms where fish, seaweeds, and scallops are cultivated. Lagoons are also a convenient recreational resource for developing sports, tourism, health cures and recreation. The best-studied lagoons of the Okhotsk Sea are Nabil, Chayvo, Busse, and Saroma.

A lagoon is part of the sea, separated from it by a bar or spit. It is characterized by a lower salinity and by specific relief formation and sedimentation conditions. 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 (Leontyev, 1961; Leatherman, 1981; Safyanov, 1996). 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 (Zenkovich, 1962; Bird and Schwartz, 1985; Horikawa, 1988, and others).

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 to 8,000 km^2 (average value is 78 km^2), the great majority of studies have focused on water bodies with an area of 30–40 km^2 (Nixon, 1982). The average area of 240 lagoons studied in the Far East of Russia (1–500 km^2) is 31.3 km^2, and the best studied lagoons, Busse on Sakhalin Island and Novgorodskaya in Primorsky Krai, have an area of 43 and 30.7 km^2, 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.

Due to the development of oil and gas offshore resources on the continental shelf of Northeast Sakhalin, a significant range of research in lithology–geomorphology and aquatic biology was carried out in recent years in larger lagoons such as Piltun, Niyvo, Chayvo (121 km^2), and Nabil (181 km^2) (Brovko, 2000; Kafanov *et al.*, 2003).

The Okhotsk Sea lagoons are grouped by size into large (100–500 km^2), medium (10–100 km^2), small (1–10 km^2) and very small (less than 1 km^2) ones. The largest of the large lagoons are Baikal, Piltun, and Perevolochnaya. 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. 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 (Brovko, 1990; Brovko *et al.*, 2002) 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 Okhotsk Sea. 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.

The evolution of Okhotsk Sea lagoons is associated with the Holocene transgression, during which time they came into existence (Brovko *et al.*, 2002; Brovko and Kaplin, 1997). 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.

The Okhotsk Sea 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.

Analysis of the interaction of 17 main production and other activities showed that conflicts could arise in lagoons in 72 cases, 8 of which could have serious environmental consequences. Human-induced impacts on the coast of Sakhalin Island are of a local nature; however, their zone of influence is gradually expanding.

Busse Lagoon, granted an important wild area status in 1977, is the scene of aquaculture operations being conducted by “Sakhalinsky Rybak-2” and “Sakhkor” companies which cultivate sea cucumbers and scallops. Important wild area status was earlier given to other lagoons on Sakhalin Island: Tunaicha, Vavayskiye, Izmenchivoye, and Lunsky.

Other uses of lagoons and lagoon coasts that are coming to the fore are recreational activities. Annual sporting and cultural events in the vicinity of Saroma Lagoon (Hokkaido) have become widely known. Izmenchivoye, Dagi, and Ekhabi lagoons on Sakhalin Island have unique reserves of therapeutic muds. Scientists of the Far East National University and Primorye Branch of 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 (Sutherland and Britton, 1980).

There is a gray whale habitat area extending from Lunskaya Lagoon to Piltun Lagoon in the Okhotsk Sea, which coincides with the offshore oil platform deployment area. Currently, the Korean/Okhotsk Sea whale population slightly exceeds 100 individuals, and there are proposals to organize a federal-level wildlife preserve for their protection. This would contribute to bird protection as well: there are 10,000–12,000 swans and 60,000–80,000 ducks staying in lagoons during autumn and spring migrations. This would also be beneficial for the habitat of Steller's sea eagle, this area's permanent resident listed on the Red Book of protected species.

Chayvo Lagoon in Northeast Sakhalin, which has been a site for semi-stationary observations by the Coast Research Center of Far East National University since 1982, is exposed to heavy human impact. The greatest changes occurred on Chayvo Spit, separating the lagoon from the Okhotsk Sea, during construction of *Yastreb*, an onshore directional drilling rig for the Sakhalin-I Project. It is the industry's largest rig, intended for operations in a highly seismic area. During construction, the spit surface, representing three beach ridge generations, was graded so that all the vegetation cover was removed, which resulted in a higher intensity of eolian processes.

For the lagoon's outer, seaward side facing the Okhotsk Sea, a coastal dynamic forecast was made and stable and retreating coast segments were identified, based on multi-year data (Brovko and Mikishin, 1999). It was in one of those "problem" segments that a basin for small vessels supporting the platform was "cut" into the spit mound and a barge was deployed several times as a temporary berthing facility (as intended by project design), which resulted in a shore-perpendicular "spur dike". Due to highly active lithodynamic processes on the open seacoast, sediment accumulation on one side has resulted in scour on the other side, at a rate of more than 20 m a year. The American method used for shore protection is sand bags placed on the beach in close rows. Unfortunately, this environmentally sound method has proved to be ineffective on the Okhotsk Sea coast.

Keywords: The Okhotsk Sea**,** Sakhalin Island, coastal lagoons, barrier-lagoon sedimentary system, marine culture, national park

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