3a. 3 Sea ice

The nominated site is located on the Shiretoko Peninsula which juts out into the southern part of the Sea of Okhotsk. Due to topographical and geographical conditions, the Sea of Okhotsk is the most southern (lowest latitude) ocean in the world as a seasonal sea ice area. The coastal waters of the Shiretoko Peninsula support a marine ecosystem that is based on the abundant plankton supplied by sea ice.

3a. 3. 1 Formation of sea ice

Sea ice forms in the coastal waters of the Shiretoko Peninsula but not along the Sea of Japan or the Pacific Ocean at the same latitude. This is due to three unique conditions affecting the Sea of Okhotsk.

The first condition is the double-layered water structure of the Sea of Okhotsk. There is a surface layer and a lower layer with a large difference in salinity. This double-layered structure with different salinity is the primary reason that the Sea of Okhotsk is the southern limit for sea ice.

The Amur, which is the longest river in northeastern Eurasia, drains a large volume of freshwater into the Sea of Okhotsk (approx. 37% of the freshwater supply). The freshwater creates a low salinity surface layer (salinity approx. 32.5‰) at about 50 meters in depth. This surface layer is unique to the Sea of Okhotsk (Aota and Ishikawa, 1991). Therefore, the salinity of the seawater increases significantly at about 50 to 60 meters below the surface. In addition, salt is discharged from sea ice as it forms and, as a result, the salinity of sea ice becomes far lower than seawater. Consequently, the melting of sea ice in spring also contributes to maintain the low salinity of the surface layer (Figure 3-3).

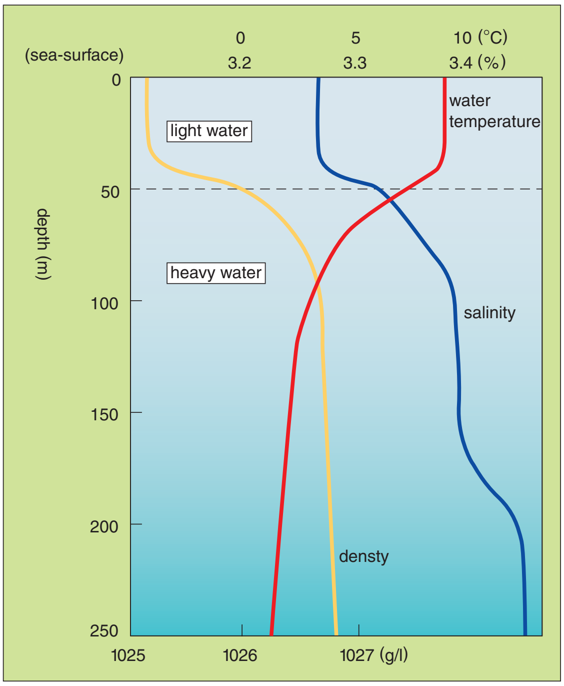


Figure 3-3 The double-layer saline structure of salinity in the sea of Okhotsk (Aota, 1993)

As sea ice forms and develops in winter, the cold brine produced by sea ice descends and creates an intermediate cold water below the surface layer, which is high in salinity and heavy (salinity approx. 33.5‰). In summer, the surface layer is lighter due to the warmer water temperature from solar radiation, and it is difficult to mix the surface layer and the intermediate cold water. Therefore, the temperature of the intermediate cold water is maintained around zero degree even in summer. The presence of this cold layer of seawater is another unique characteristic of the Sea of Okhotsk.

As the ocean surface cools, the surface layer increases in density and descends while the less dense, warmer seawater ascends. This successive circulation of seawater continues and as the whole seawater reaches the freezing temperature (approx. −1.8°C) it begins to freeze. Therefore, the deeper the seawater circulates, the longer it takes for the seawater to reach the freezing temperature, and it requires longer before the seawater begins to freeze.

As described above, at depth of more than 50 meters, there is the intermediate cold water that is denser and higher in salinity than the surface layer in the Sea of Okhotsk. Therefore, even when the cooled surface layer of water increases in density, it does not exceed the density of the intermediate cold water, as its salinity is lower. This creates a barrier and the surface layer only circulates within a depth of 50 meters. Therefore, the surface water is cooled rapidly to the freezing temperature and sea ice is formed (Sakuma, 1994; Aota, 2003).

The second condition is that the Sea of Okhotsk is surrounded by lands and there is little exchange of seawater with the open sea. The Sea of Okhotsk is surrounded by the Eurasian Continent, Kamchatka Peninsula, the Kuril Islands, Hokkaido and Sakhalin. Exchange of seawater is mainly through several channels between the Kuril Islands with the Pacific Ocean and the inflow of the Soya warm current (a branch current of the Tsushima warm current) through the Soya Strait. As a result, the Sea of Okhotsk is relatively closed off with little exchange of seawater with the open sea (Aota and Ishikawa, 1991). The low level of exchange contributes in maintaining the double-layered structure of different salinity.

Sea ice of the Sea of Okhotsk photo by Ministry of the Environment

The third condition is the distribution of atmospheric pressure in the area. In winter, a high pressure system develops in the west over Siberia while a low pressure system develops in the east over the Sea of Okhotsk. This weather pattern causes cold air from Siberia to blow into the area and it is very effective in chilling the seawater. These conditions result in the rare phenomenon of the waters around the Shiretoko Peninsula freezing even though they are located at the relatively low latitude of 44° N.

As described above, the nominated site is a prime example representing the unique mechanism of sea ice formation in the Sea of Okhotsk.

3a. 3. 2 Development of sea ice

Nine percent (32×10^6 km^2) of the global sea surface (361×10^6 km^2) is covered with ice in winter. Of this ice-covered area, 56 percent is located in the southern hemisphere and 44 percent is located in the northern hemisphere. Some of these areas are covered in ice all year around (perennial sea ice area) while others are covered only for a certain period of the year (seasonal sea ice area). The seasonal sea ice area accounts for 70 percent (22.5×10^6 km^2; 15.5×10^6 km^2 in the southern hemisphere, 7×10^6 km^2 in the northern hemisphere) of the total sea ice area (Takahashi and Shirasawa, 2002).

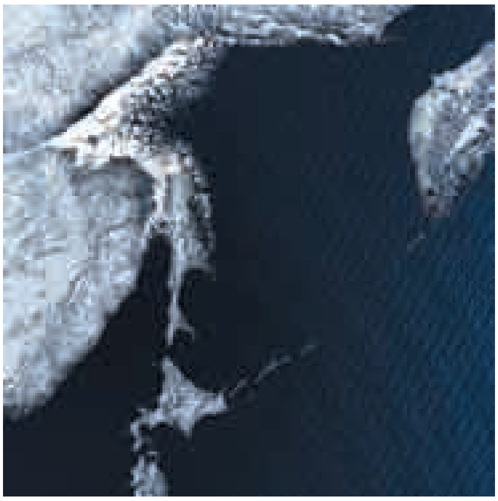
The coastal water of the Shiretoko Peninsula is the lowest latitude of seasonal sea ice area in the world. In fact, it is at the border between the cold zone (arctic zone) and the warm zone (temperate zone) and temperatures would normally be quite inadequate for the formation of sea ice. The unique feature of the Shiretoko Peninsula can be recognized by comparing its latitude (44° N) with the famous wine region of Bordeaux (44° 50' N) and the canal-filled city of Venice, Italy (45° 30' N). The Shiretoko Peninsula is situated south of these two locations.

In the northwestern part of Sea of Okhotsk, sea ice begins to form along the eastern coast of Siberia, and at the mouth of the Amur River, from early November. Due to the effects of the northwestern seasonal winds and sea currents (e.g. East Sakhalin Current), the sea ice area expands southwards along the western part of the Sea of Okhotsk and reaches the coast of Hokkaido in mid-January. By this time, the coastal waters of northern Hokkaido have also dropped to freezing point and the sea ice formed along the coastline combined with the sea ice from the north creates an expansive ice field. The area covered by sea ice reaches its maximum size in mid to late March, covering approximately 80 percent of the Sea of Okhotsk (Aota, 1993).

The sea ice begins to melt from the end of March, with the ice edge slowly receding northward along the same course of its expansion, but in reverse. All of the ice disappears by the end of June and there is no permanent ice left until the next winter (Figure 3-4).

3a. 4 The marine ecosystem under the sea ice around Shiretoko

The coastal water of the Shiretoko Peninsula is located in the lowest latitude among sea ice area in the world. The physical changes brought upon by sea ice and the resulting dynamic food chain supports a rich marine ecosystem.



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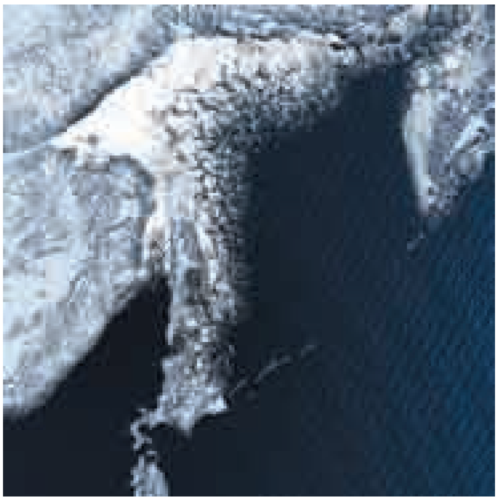

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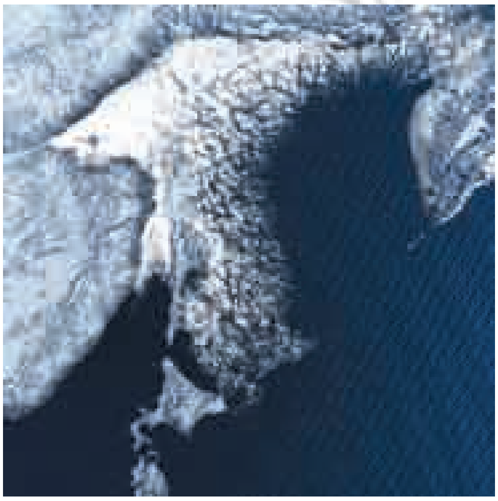

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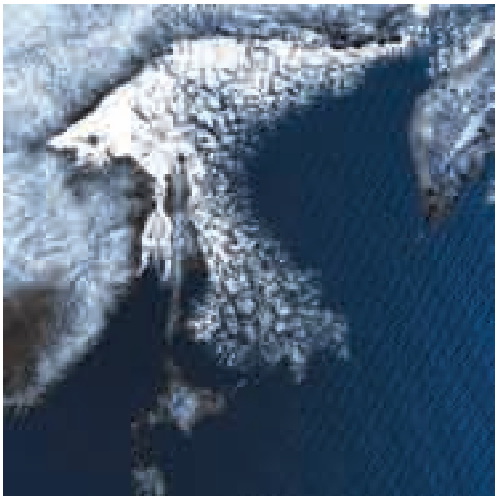

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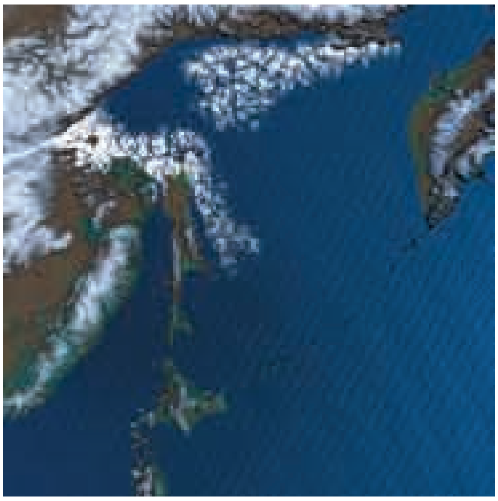

May 1986

Figure 3-4 Seasonal distribution of sea ice in the Sea of Okhotsk (1985-1986) (Kurasawa, 2001)

Sea ice photo by KURASAWA Eiichi

The base of the marine food chain is phytoplankton which consists mainly of diatoms. Blooms of phytoplankton develop on the nutrients supplied by sea ice. The phytoplankton become a source of food for krill and zooplankton such as small shrimp, and then, they become food for small fish, benthos including sea urchins and sea squirts on the ocean floor, crustacean and shellfish. These animals in turn become food sources for large migratory fish, marine mammals such as seals and sea lions and birds such as Steller's sea eagles and white-tailed eagles. In addition, salmon and trout that swim upstream to spawn become food for the brown bear, red fox and Blakiston's fish-owl.

The formation of sea ice plays an integral role in the proliferation of phytoplankton which is the primary producer in the marine ecosystem. Similar to terrestrial plants, phytoplankton need nutritive salts such as silicate, phosphate and nitrate in addition to sunlight for photosynthesis. Usually, the concentration of these nutritive salts is lower in the surface layer and higher in the deeper layers of the sea. In lower latitudes, the strong sunlight promotes active photosynthesis in the surface layer of the sea. Therefore, the nutritive salts are depleted due to the consumption by phytoplankton. Furthermore, the surface layer is warmed by sunlight which reduces its density. As a result, there is little circulation with the lower layers. Consequently, the nutritive salts stored in the lower layer are not circulated up to the surface layer and the lack of nutrients restricts the proliferation of phytoplankton.

However, from autumn onwards in sea ice areas, there is an active circulation of water due to the cooling of the surface layer. In addition, the brine descends with the development of sea ice, which further promotes circulation of the nutritive salts of the lower layer to the


Ice algae photo by SUZUKI Yoshifusa

surface. In other words, the circulation of deep seawater causes the nutrients to be used at the surface layer in the ice sea area. In addition, it is not totally dark under the sea ice and there is sufficient light for photosynthesis. Therefore, the sea ice is not a negative factor for the growth of phytoplankton. The layer of water just under the sea ice is a perfect habitat for phytoplankton as there are high amounts of nutritive salts, sufficient levels of sunlight, a stable temperature around minus 1.8 degrees Celsius and an adequate level of air capsules containing oxygen and carbon dioxide (Takahashi and Shirasawa. 2002; Aota, 1993).

Phytoplankton (called “ice algae”) consist mainly of diatoms which grow within and on the bottom surface of the sea ice. The ice algae rapidly multiply in early spring when the ice starts to melt (spring bloom) (Matsumoto *et al*., 2002; Shirasawa *et al*., 2002). Primary production levels are low when the sea is covered with ice. However, the food supply becomes abundant with the bloom of ice algae. In addition, as the ice melts along the ice edge, a type of phytoplankton different from ice algae begins to multiply rapidly with the increase of sunlight and the organic matter supplied by the melting ice. These primary production activities occur earlier in seasonal sea ice areas compared with sea which is never covered by ice (Takahashi, 2002). In fact, there are reports that the standing stock of phytoplankton in the coastal water of Hokkaido in the Sea of Okhotsk are more than ten times higher than that of the Pacific Ocean side (which is not covered with sea ice) (Furuhashi, 1980). Accordingly, the sea ice nurtures phytoplankton which in turn feed the zooplankton, supporting a food chain that extends to higher level consumers such as large fish, marine mammals and terrestrial wildlife.


Larga seal *Phoca largha* photo by TAZAWA Michihiro

Primary production activity by organisms such as phytoplankton occur earlier in the waters around Shiretoko Peninsula than in any other place in the Sea of Okhotsk, the melting and breakdown of ice also occurs earlier here than in the rest of the Sea of Okhotsk. This period of high-level primary production coincides with the shoals of fish fry and the weaning of seal pups that need a good quality and abundant food source. As a result, the plankton plays an important role in the life cycle of marine wildlife. For example, fry of walleye pollack and chum salmon as well as pups of the larga seal all feed upon the zooplankton that proliferate with the melting of sea ice. In addition, salmon fry that swim downstream into the ocean have been observed to follow the abundant levels of phytoplankton and zooplankton along the ice edge to higher latitude areas as they feed and grow on this food source (Takahashi, 2002). The coastal waters of the Shiretoko Peninsula are an important starting point of the food chain for the integrated ecosystem that consists of the ecosystems of sea, river and land.

As described above, the coastal waters of the Shiretoko Peninsula support an abundant food source for high-level producers and promote a diverse biota by producing a high level of food compared to the surrounding ocean which is not covered with ice. Furthermore, this rich food source is supplied at the right time. The nominated site is an outstanding example representing this mechanism.

Description

3a. 5 Plants

The majority of the vegetation covering the Shiretoko Peninsula, including the nominated site, is in virgin condition. While the altitude changes is only some 1,600 meters from the coast to the mountain peaks, alpine plants such as Japanese stone pine *Pinus pumila* and other alpine plant communities are developed at relatively low altitudes, and diverse vegetation is distributed vertically at the site. In addition, the flora contains both northern and southern species and therefore, it is rich in species diversity.

3a. 5. 1 Vegetation communities

With regard to horizontal distribution of the forest vegetation in the low altitude areas of the Shiretoko Peninsula, it is a Pan-Mixed Forest Zone according to Tatewaki (1958) and consists of a mosaic of three types of forests:

1. The cool temperate deciduous broad-leaved forest with species such as Japanese oak *Quercus mongolica* var. *grosseserrata,* painted maple *Acer mono* and Japanese linden *Tilia japonica*,
2. The subarctic evergreen coniferous forest with species such as Sakhalin fir *Abies sachalinensis*, Yezo spruce *Picea jezoensis* and Sakhalin spruce *Picea glehnii*, and
3. The mixed forest which is a combination of the above cool temperate deciduous broad-leaved forest and subarctic evergreen coniferous forest.

The forest belongs to the “Manchu-Japanese mixed forest” biogeographic province of Udvardy which covers nearly all of Hokkaido excluding Kuromatsunai lowland zone and areas south of this zone, as well as southern parts of the Far East including southern Kuril Islands,