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博士（環境科学）

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学 位 論 文 題 名/Title of Dissertation

Studies on habitat use of ringed seals (*Pusa hispida*)
in glacial fjords, northwestern Greenland

（グリーンランド北西部の氷河フィヨルドにおける
ワモンアザラシの生息地利用に関する研究）

Climate change is altering abiotic and biotic factors across the globe, leading to widespread changes in species distribution and habitat use. For example, in the Arctic, the melting of glacial fjords is affecting the marine environment and ecosystems. Glacial fjords and surrounding waters are important habitats for marine mammals because subglacial discharge from the glacier during the open-water period creates biologically productive areas. Marine mammals are top predators in Arctic marine ecosystems and an important resource for local people. Therefore, the impacts of climate change on marine mammals are likely to be even greater due to the interrelationship with ecosystems and society. In order to predict what effects will be felt in the future, it is necessary to understand the relative importance and interactions of abiotic and biotic factors influencing habitat use.

Ringed seals *Pusa hispida* are keystone circumpolar Arctic endemic species and are important to the subsistence economy of the local community. They primarily inhabit coastal areas, including glacial fjords, where land-fast ice forms during winter. In the open-water period, ringed seals concentrate close to tidewater glacier fronts, where abundant prey species are expected to be found. Ringed seals feed opportunistically on sympagic, pelagic and semi-demersal fish and invertebrates. To understand why ringed seals concentrate near tidewater glacier fronts, it is necessary to investigate effects of abiotic and biotic factors on their habitat use in glacial fjords. However, few studies have investigated the distribution of biotic resources, including prey species and sympatric species, to assess their habitat use in glacial fjords. This is because glacial fjords are closed off by large icebergs and sea ice throughout most of the year, and surveys from large research vessels inside the fjord system are difficult to conduct.

Recent advances in survey and analytical methods allow us to obtain more detailed information on marine ecosystem, such as environmental DNA (eDNA) metabarcoding and biologging methods. By combining these approaches, it is possible to investigate various aspects of marine ecosystems in glacial fjords. The objective of this study was to characterize abiotic and biotic factors influencing habitat use of ringed seals in the Thule area, northwestern Greenland, by combining multiple approaches.

In Chapter 2, abiotic and biotic factors influencing the habitat use of ringed seals were investigated using visual surveys and stable isotope (SI) analysis during the open-water period in the Thule area. Visual surveys provide snapshot data on abiotic features related to distribution, including distance to tidewater glacier fronts. SI analysis provides a dietary record integrated over time and was used to assess the dietary niche overlap of sympatric species. From the visual survey, ringed seals and two other species of seals were observed: bearded seals (*Erignathus barbatus*) and harp seals (*Pagophilus groenlandicus*). Ringed and harp seals were found closer to tidewater glacier fronts, whereas bearded seals were found farther from glaciers, in relatively shallower waters. SI indicated that ringed and harp seals mainly fed on pelagic species, including polar cod (*Boreogadus saida*), whereas bearded seals mainly fed on benthic species. The SI niche size of ringed seals was greater than harp seals, and overlap in SI niche of ringed and harp seals was higher than that of bearded seals. SI supported that physical habitat features of each species of seals were associated with foraging. Ringed and harp seals used closer to tidewater glacier front areas to feed on pelagic prey species, whereas bearded seals used shallower waters to feed on benthic prey species.

In Chapter 3, the distribution of the fish community, including the prey species of ringed seals, during summer in the Thule area, northwestern Greenland, was investigated using eDNA metabarcoding analysis. Water samples were collected from each depth at each site. Extracted eDNA was amplified and sequenced using MiFish, a universal primer for fish. The obtained sequences were processed using Claident, and fish species were determined by QCAuto. As a result, eDNA detected 11 genera within 12 families including prey fish species of ringed seals, such as polar cod, sculpins (Cottidae), and snailfish (Liparis). Polar cod were widely distributed throughout the glacial fjord, with relatively higher abundance closer to tidewater glaciers and at depths below 150 m. Sculpins and snailfish were also found in areas closer to tidewater glaciers. These results suggest that tidewater glaciers created biologically productive areas where the prey species of ringed seals were concentrated.

In Chapter 4, to understand the seasonal habitat use of ringed seals in relation to the oceanographic environment, CTD-Satellite Relay Data Loggers which record oceanographic data (depth, temperature, and salinity) and transmit via Argos system were deployed on four seals in Inglefield Bredning. All seals spent most of their time in front of tidewater glaciers during the open-water period. Two seals that continued to transmit after beginning of the ice cover period moved out of glacial fjords due to the formation of land-fast ice and stayed in the shallower water depth area, where sea ice was relatively thin and sparse during the ice-covered period. Additionally, the oceanographic data indicated that ringed seals mainly dove to depths associated with the habitat of polar cod. These findings suggest a strong association between ringed seals and tidewater glaciers during the open-water period, likely linked to the prey species availability.

In conclusion, the habitat use of ringed seals was closely associated with ice and prey species distribution. These abiotic and biotic resources were impacted by climate changes, with shifts in prey distribution under changing climate conditions potentially leading to increased interspecific competition. Continuous monitoring is essential for detection changes in abiotic and biotic features induced by climate change, and eDNA metabarcoding and biologging were highlighted as valuable tools for monitoring marine environment and ecosystems inside glacial fjords. The present study provides fundamental insights into the habitat use of ringed seals in glacial fjords, and offers essential baseline data for predicting the impacts of future climate change on marine ecosystems.