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Shift in trophic role of northern fur seals in the northwestern Pacific Ocean

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Ecological characteristics of northern fur seals

Northern fur seals (*Callorhinus ursinus*, NFS) are the most abundant otariid species with recent population estimates reaching approximately 1.2 million (Angliss and Lodge, 2004). NFS are widely distributed in the subarctic zone of the North Pacific Ocean, with the northwestern Pacific Ocean (particularly the area off the Tohoku region of Japan) providing a major wintering and foraging area for NFS. Approximately 100,000 of fur seals, primarily adult females and juveniles, migrate to this area where they remain from the winter to early spring. Thus, NFS are important apex predators in the area, which corresponds to one of the most productive fishing grounds in the world due to mixing of the Kuroshio and Oyashio currents.

"Miho Collection"; long-term time series data and sample collection

Under the auspices of the North Pacific Fur Seal Commission, the National Research Institute of Far Seas Fisheries (NRIFSF) previously conducted a long-term investigation of NFS breeding and ecology in the Tohoku and Hokkaido regions. From the 1960s to the 1980s, the study accumulated extensive time series data, samples, and biological information, including stomach content data, and gonad and canine teeth specimens. The NFS data and sample archive was named the "Miho Collection" after the scenic spot "Miho no Matsubara", which located near the NRIFSF laboratory. The Miho Collection has provided valuable information on the ecology of NFS and on the variability of marine ecosystems generally.

Relationship between NFS diet and prey environment

Previously, studies on NFS diet were conducted based on snapshots of their prey preference observed by short-term sampling (e.g., Wada, 1971, Antonelis *et al*., 1997, Kiyota et al., 1999), or on a much more general picture obtained by pooling long-term diet data (e.g., Kajimura, 1985, Perez and Bigg, 1986, Gudmundson *et al*., 2006, Zeppelin and Ream, 2006). However, very few studies have focused on the long-term changes in NFS diet in the northwestern Pacific Ocean.

We therefore analyzed decadal changes in NFS diet using the "Miho Collection" (Yonezaki et al., 2008). The stomach contents data revealed that dominant prey species consisted of Japanese sardine (*Sardinops melanostictus*), chub mackerel (*Scomber japonicus*), walleye pollock (*Theragra chalcogramma*), myctophid fishes, sparkling enope squid (*Watasenia scintillans*), and oceanic squids. Compared with NFS populations in the northeastern Pacific Ocean, one of the characteristic features of NFS food preference in the northwestern Pacific Ocean is the high proportion of myctophids and sparkling enope squid. In the 1980s, an increase in the percentage wet weight of Japanese sardine in the NFS diet corresponded with a marked increase in commercial harvests of this species. Similarly, an increase in the percentage wet weight of chub mackerel in the NFS diet also corresponded to an increase in the commercial harvests of this species between the 1970s and 1980s. Long-term shifts in ocean climate have caused marked changes in pelagic fish communities (Kawasaki, 1983, Yatsu *et al*., 2003), and the decadal-scale NFS diet data revealed shifts in the prevalence of Japanese sardine and chub mackerel. Specifically, preference for these fish species was

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reflected by a decadal alternation in the dominance of these fishes within the pelagic waters of the Tohoku region (Yonezaki *et al*., 2008).

Stable isotope ratios (i.e. indicators of the trophic level position of various marine organisms) of NFS gonad samples from the Tohoku region revealed historical changes in the food environment. The ^{15}N ratios of adult female NFS gonad tissue showed a marked decrease from high mean values in 1969, 1970 and 1971 (i.e. "Mackerel regime") to low means in 1987 and 1988 (i.e. "Sardine regime"). Analysis of stomach content data indicated that this decline in ^{15}N ratios (1.5 ‰) was related to the explosive increase in Japanese sardine populations in the 1980s. Since Japanese sardine consume phytoplankton and occupy a lower trophic level compared to other prey species, intensive feeding on Japanese sardines may have decreased the trophic level of NFS in the region.

Trophic role of NFS in the subarctic ecosystem of the northwestern Pacific

These results suggest that NFS are important apex predators in the Tohoku region that feed upon a variety of prey species by changing their diet in response to shifts in the distribution and abundance of prey species. The changes in the ^{15}N ratios of NFS gonads may be indicative of a decrease in the length of the food chain from primary production to the top predators in oceanic ecosystems, and/or the utilization of food resources from different systems.

In future studies, we will attempt to clarify whether the shifts observed in the trophic level of NFS due to changes in the food environment could impact on their productivity and population dynamics using the information on their fecundity and fetal weight from the "Miho Collection".

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