学　位　論　文　内　容　の　要　旨/Dissertation Abstract

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学 位 論 文 題 名/Title of Dissertation

Study on a recolonizing population of sea otters (*Enhydra lutris*) in eastern Hokkaido: feeding habits and the effects of a major environmental disturbance upon them

(北海道東部におけるラッコ（*Enhydra lutris*）の再定住個体群に関する研究：食性と大きな環境撹乱の影響)

Sea otters (*Enhydra lutris*) are keystone species throughout most of their range alongside the western coasts of North America and the Eastern coast of Russia, and they exert a disproportionately large influence on the ecosystem to their population numbers or biomass. They are also opportunists and dietary generalists, with a well-documented ability to adjust their diets in response to prey availability changes. Therefore, sea otter feeding behavior is an excellent indicator of the health and lower trophic makeup of a marine ecosystem. After sea otters were extirpated from several regions worldwide due to the fur trade, recolonizations have shown a potential to transform local ecosystems and associated fisheries, altering the availability of benthic invertebrates for predators and extraction by humans. For example, across the western coast of North America, the rapid recolonization of sea otters resulted in conflicts with fisheries that developed during the absence of sea otters. In eastern Hokkaido, sea otters were extirpated before 1900 due to intensive hunting, and the first confirmed sighting of a live individual occurred in 1973, although subsequent sightings have been sporadic. In 2014, a mother and pup were observed for the first time and the population has shown gradual growth. Accordingly, concerns have arisen about potential conflicts between sea otters and fisheries. In fall 2021, a massive red tide event (*Karenia selliformis*) created a major environmental disturbance with wide-ranging impacts, including die-offs of sea urchins, which are valuable fisheries resources, and common prey items for local sea otters. This environmental disturbance provided a unique opportunity to assess how this sea otter population's feeding ecology changed in response. This study aims to indicate how ecosystem health and resource viability may be impacted by this relatively new piece in the ecosystem and potentially coexist going forward.

Sea otter population trend relates to the carrying capacity, and comparison with Alaska situation will provide suggestions for predicting the future in Hokkaido population. Rapidly recolonized sea otter populations across Alaska had demonstrated the capacity to disrupt local ecosystems, often resulting in overexploitation of prey resources, and required dietary and behavioral shifts, such as deeper feeding depths and longer duration. In Chapter 1, feeding dive behaviors in eastern Hokkaido were compared to previous studies in North American populations to assess potential ecosystem impacts and evaluate whether observed behaviors indicate sustained prey availability. To place Hokkaido's sea otter feeding behaviors in the context of other populations, I compiled feeding dive behavior observational data from 2019 to 2023, feeding dive duration and dive depth. The otters in Hokkaido exhibited shallower feeding dives and shorter dive durations than other populations, most similarly resembling the foraging behaviors observed in the first report of Northern Chichagof Island, Alaska, and the outer coast of the Olympic Peninsula, Washington State. These populations existed under many of the same recolonization situations and environmental conditions observed in Hokkaido, including primarily feeding on bivalves, within mixed sediment benthic substrates. However, in the second report of Chichagof Island, otters depleted primary prey items and began foraging for alternative prey at deeper depths. Whereas the absence of significant changes in dive depth, duration, or dietary composition suggests Hokkaido's population had not yet experienced substantial prey

depletion. Shorter feeding dive durations in Hokkaido compared to bivalve-favoring populations in Alaska were most likely a result of shallower feeding depths, and the lack of change in dive depth or prey composition was characteristic of a population with adequate prey availability and no need to forage deeper.

In Chapter 2, I aimed to determine the impacts of a red tide algal bloom of *Karenia selliformis* dinoflagellates on the benthic community of invertebrates and sea otter diets, providing a framework to prepare for future red tide events. The red tide spreading along the eastern coastal side of Hokkaido in the fall of 2021 resulted in widespread mortalities of sea urchins. In this study, SCUBA surveys sampling benthic invertebrates were conducted in 2020, 2022, and 2023 to track impacts on the benthic community. Focal observations of feeding dive behavior of sea otters were conducted from 2020 through 2023. In 2022, the year after the red tide, a significant decrease in benthic sea urchins was observed, resulting in their disappearance from sea otter diets. The benthic bivalve population increased in this year, alongside a doubling of the percentage within diets. In 2023, densities of sea urchins within the benthic environment showed a slight increase, while bivalves displayed a slight decrease. Dietary sea urchin and bivalve percentages immediately returned to pre-red tide levels in 2023, indicating a temporary shift. The lack of impact on bivalves overall or an observed sea otter population decrease also suggests minimal changes in the health of the local population.

In Chapter 3, I aimed to observe how sea otter feeding behaviors changed in response to regularly changing environmental conditions such as seasonal life cycles of marine canopy covering plants which modify the habitat the sea otters live in, or to the stochastic red tide event and its associated sea otter dietary composition shifts. Throughout their range, sea otters are associated with habitats containing dominant canopy-covering marine plants. In the study area, the main composition of the canopy was sargassum and eelgrass, and less kelp. Canopy cover appeared to decline gradually between June 5th and July 8th, and then drastically by September 3rd. Sea otters did not exhibit a change in distance from feeding location to canopy cover across seasons, typical of other sea otter populations in California and Alaska that do not also experience major environmental shifts in temperature or wave condition concurrently, indicating that the otters do not seasonally alter distance and association with canopy covering plants, even as the location and distribution of those canopy plants do change. If this is indeed the case, it may prove a useful tool in predicting sea otter foraging patterns throughout eastern Hokkaido in areas with similar canopy covering communities. The red tide event did not affect feeding dive duration; however, handling time per prey item and number of prey items per dive significantly increased after the red tide. This shift is likely tied to increasing dietary percentages of bivalves and small prey items. Percentages of dives where tool use was present also displayed a decrease after the red tide, which may have been due to the increase in bivalve percentage within the diet and a reduction of sea urchins. These shifts indicate that the dietary changes, in turn, influenced sea otter foraging behaviors.

This thesis indicates that feeding behavior tendencies in eastern Hokkaido were similar to newly recolonizing sea otter populations that forage primarily on bivalves in mixed sediment seafloors across the west coast of North America. I also revealed how this sea otter population displayed resilience to environmental disturbance, temporarily shifting away from sea urchins to a higher reliance on more preferred bivalve prey. Dietary plasticity could benefit the population in the future as the likelihood of environmental disturbances increases due to climate change. However, if more red tides and marine heatwaves occur, there is also the possibility that prey availability is impacted differently. Generally, this research would ideally play a role in informing mediation between the economic needs of vital local fisheries industries and communities of eastern Hokkaido and the emerging interests and health of a growing sea otter population, valuable members of the ecosystem that has long been missing.