

## **A clear separation of foraging areas between two neighboring colonies of Adélie Penguins observed in a year of extensive sea ice cover**

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Intra-specific competition would be an essential factor affecting the foraging distribution of animals. Breeding seabirds may face intense intra-specific competition for food near their colonies. Especially when the foraging areas of multiple colonies overlap each other, theoretical models predict that neighboring colonies may segregate their foraging areas. Previous studies on seabird species reported different levels of inter-colony segregations, ranging from a clear separation to extensive overlap. Such variety in the level of inter-colony segregations has been attributed to density-dependent competition, with varying population size, distance between colonies, and prey densities. However, relatively little is known about how changes in the behavior of individual seabirds drive the varying degrees of inter-colony foraging segregations. In this study, we examined the foraging movements of Adélie penguins *Pygoscelis adeliae* from two neighboring (2 km apart) colonies by using bird-borne GPS loggers in two years of drastically different sea ice conditions. In the austral summer of 2018/2019, the sea around the colonies was extensively covered by fast sea ice (“fast ice” year). On the other hand, in 2016/2017, the sea around the colonies was almost open, with sparse pack ice (“open sea” year). The foraging sites of penguins showed contrasting distributions between two years, associated with annual changes in sea ice conditions: they were restricted to small cracks on the ice in the fast ice year, but widely dispersed over the sea in the open sea year. Even though we found much smaller foraging ranges in the fast ice year than in the open sea year, the two colonies were still within each other’s maximum foraging ranges. Therefore, there could be an overlap between two colonies, if penguins use the surrounding area uniformly. Nevertheless, the foraging areas of two colonies showed a clear separation (utilization distribution overlap index (UDOI) = 0.001) in the fast ice year, which was contrasting to the extensively overlap (UDOI = 0.89) in the open sea year. The movement directions of penguins to foraging destinations showed notable concentrations to several specific directions in the fast ice year, a pattern not observed in the open sea year. Based on these results, we discuss how changes in the foraging movements of individual penguins in response to sea ice conditions might drive the varying degrees of foraging segregation between the neighboring colonies of Adélie penguins.