1 Overview and Abstract

The western Antarctic Peninsula (WAP) is one of the most rapidly warming regions on Earth [1], and climate change in the region is affecting seabird populations through changes in sea ice, snow cover, and prey availability [2, 3, 4, 5]. Gentoo penguins (*Pygoscelis papua*) are increasing in abundance and expanding southward even as Adélie (*Pygoscelis adeliae*) and chinstrap (*Pygoscelis antarctica*) penguins decline precipitously. The three *Pygoscelis* species of penguins differ across several dimensions, including in diet, breeding phenology, and their tolerance of sea ice; these traits have been cited as important factors influencing their contrasting population trends [4, 6]. While recent studies have documented significant changes in biological productivity associated with rapid regional climate change on the WAP [7], there is insufficient data on demographic rates across the latitudinal range of the WAP to build a robust mechanistic population model that can explain both breeding distribution (occupancy of potential sites) and the environmental dynamics underlying population abundance for all three *Pygoscelis* species. Long-term observations allowing the joint estimation of reproduction, survivorship, and skipped breeding across the full range of core and edge habitat will be essential to understanding how each *Pygoscelis* species balances these life-history trade-offs, and will allow for mechanistic (not merely correlative) predictions of future population. The effects of climate change in this region appear to be accelerating [8, 9], and continued data collection over the next ten years is critical to understanding how future change will influence population persistence of the three *Pygoscelis* species penguins.

Tracking individual penguins through time using mark-recapture of flipper-banded penguins is the gold standard for understanding how environmental conditions influence demographic rates [10], but the acquisition of these data has been hampered by the logistical challenges and emerging ethical concerns involved in flipper banding penguins [11, 12, 13, 14]. As a result, relatively little is known about spatial variation in demographic rates (e.g., breeding success, survival), spatial variation in demographic stochasticity, or the role that stochasticity may play in the population dynamics of Antarctic seabirds. While it has long been assumed that estimating demographic rates such as survival required the tracking of marked animals over time, advances in age-structured Bayesian state-space modeling allow for the extraction of these data from point counts alone if the time series are sufficiently long to permit parameter estimation [15]. Preliminary analyses by Lynch and Bugallo suggest that demographic rates can be estimated even if several age-stages are unavailable for census, though parameter estimation requires sophisticated methods for Bayesian inference that must be developed. Developing these methods will allow us to infer demographic rates without the disturbance inherent to flipper banding individuals, and will radically expand our understanding of why penguin populations are changing around the continent. Moreover, the class of state-space model represented by this application is an interesting and broad class of problem for which novel inference approaches are required and thus this pilot study would open new opportunities for funding in the area of advanced Bayesian inference.

While the proximate interest in pursuing this project lies with its application to Antarctic penguins, the estimation of demographic rates using so-called mark-recapture methods (i.e. marking or banding an individual and tracking it through time to assess reproductive effort and survival) is one of the most important tools in the field of conservation and wildlife biology. As such, our proposed methodology to obtain comparable information using counts of unmarked individuals, which is cheaper and has less impact on the animals under study, would be an important development for the discipline with implications extending far beyond the case study under consideration.