Project Title: Influence of North Pacific Ocean climate and northern fur seal pup dispersal and survivorship $50.5K

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Overview: Management of pinniped species under NOAA's purview requires an understanding of how variability in the earth's climate influences demography of pelagic marine mammals. In turn, this requires an understanding of how the physical manifestations of climate – such as weather systems, ocean eddies and currents, and sea level pressure patterns – influence individual animals or groups of individuals, requiring NOAA scientists to analyze and interpret both animal behavior and the underlying physical mechanisms that may correlate with this behavior. This challenge is particularly formidable for the northern fur seal (NFS) Eastern Pacific Stock due to its seasonal occupancy of the Bering Sea in the summer months and wide range throughout the North Pacific Ocean during the winter months. Addressing this challenge through continued study of the key physical, biological, or anthropogenic factors influencing demography during each segment of the Eastern Pacific Stock annual cycle is an important priority at MML.

The NFS Eastern Pacific Stock has declined in two distinct periods since 1956, separated by a period of relative population stability. The initial phase of the decline is mainly (~70%) explained by a targeted harvest of adult females [1], though the failure of the population to recover following the cessation of this harvest, and its further decline from 2000 onward, are unexplained. Population models of the Eastern Pacific Stock indicate that one of the most important factors influencing its stability and growth is the recruitment of females to reproductive age [1-3]. This recruitment is heavily influenced by the survivorship of pups during their initial migration, which begins when they are weaned at age 4 months and for most individuals lasts until return to the breeding islands at 24 months of age. Survivorship during this early migration is very low relative to that of adults, and exhibits large variations between cohorts. These variations are partially explained by pup growth prior to weaning, but with large residuals that are thought to be caused by oceanographic and atmospheric conditions during pup dispersal and overwintering [3]**. The central goal of this study is to identify physical environmental factors that affect winter dispersal and survivorship of pups, independent of pup condition.** By combining these with physical and biological factors known to influence summer growth, it is then hoped to explore the degree to which these factors together act as a "bottleneck" on Eastern Pacific Stock abundance at long time scales by influencing the recruitment of reproductive females. Investigation of linkages between the physical climate and pup survivorship may potentially provide a more comprehensive view of factors impacting fur seal demography and improve projections of Eastern Pacific Stock abundance within a changing North Pacific Ocean and Bering Sea.

In furtherance of the above goals, MML currently collaborates with physical oceanographer Dr. Noel Pelland, in cooperation with the Joint Institute for the Study of the Atmosphere and Ocean

at the University of Washington (JISAO). Dr. Pelland fills a critical gap in our current knowledge of fur seal ecology through his training in the observation and theory of underlying physical mechanisms, and his ability to apply this to the study of ecological processes and behaviors of upper trophic organisms – specifically northern fur seals and Steller sea lions. By collaborating with JISAO in this endeavor, MML hopes to answer fundamental questions about the influence of climate on the demography of a top marine predator. This request seeks funding to continue collaborative research with Dr. Pelland and JISAO into 2017.

Research Description: The current goal of our research is to combine the ecological knowledge of MML researchers with the physical expertise of Dr. Pelland to identify processes that affect northern fur seal demography to explain the Pribilof Islands pup production decline. This effort includes both aspects of the Eastern Pacific Stock annual cycle – the overwintering period in the North Pacific Ocean and the summer breeding season in the Bering Sea – and is composed of three distinct elements, investigating 1) summer growth, 2) spatial dispersal of pups during the first migration, and 3) effects of dispersal direction and other factors on migratory survivorship. Regarding the first of these, Dr. Pelland has collaborated significantly with Dr. Jeremy Sterling of the Alaska Ecosystems Program (AEP) on a comprehensive study of Bering Sea basin and shelf environmental conditions, attendant female foraging behavior, and pup growth rates during four growing seasons of contrasting oceanography, atmospheric phenomena, and walleye pollock stock structure. Dr. Pelland has assisted with spatial analyses of pollock survey and oceanographic data, statistical classification of dive behavior, and identification of basin eddy fields and their interannual variability. These collaborative efforts have revealed a strong correlation between diving behavior and the age structure of pollock on the Bering Sea shelf, and between basin oceanographic conditions, foraging, and pup growth. Dr. Pelland's analyses have also helped to quantify the variability in range and duration of attendant female foraging trips, and the influence of surface winds on these quantities, with results implying that late-season storms may substantially alter the vertical and/or horizontal distribution of available NFS prey in the Bering Sea ecosystem, through their influence on upper-ocean physical properties. Thus, work towards the first of these points will be to continue Dr. Pelland's collaboration on this study and for him to assist in its publication.

Regarding the second and third of these elements, Dr. Pelland is also working with Dr. Devin Johnson of AEP in using existing satellite telemetry data to statistically model the effects of winds and ocean currents on the migratory movements of pups and adult female NFS. We intend to proceed by using the modeled effects of these physical variables, in addition to atmospheric reanalyses, to test the hypothesis that interannual variations in surface wind fields can significantly alter the spatial dispersal patterns of naïve, newly-weaned pups and the conditions experienced by these pups along migratory pathways. All of the above information will then be examined in the context of existing (1950-1970) and ongoing studies of NFS vital rates (2009-2017) to attempt to formulate bulk climate indices that have skill in predicting juvenile survivorship.

Anticipated Outcomes and Deliverables: Early results indicate that the movements of pups are influenced by the wind to a much greater degree than adults, and that this effect could influence the migratory trajectory of individual pups by hundreds of kilometers over the course of a single winter season. These are strongly suggestive that wind effects can lead to differential dispersal

between cohorts. We anticipate one publication whose central goal is to model this effect using results from collaboration with Dr. Johnson. A second publication will address the application of large-scale climate indices to juvenile survivorship and NFS Eastern Pacific Stock abundance.

Research and Management Utility: Dr. Pelland's publications and ongoing efforts are essential for current management needs and the needs detailed in the Conservation Action Outline of the Conservation Plan for the Eastern Pacific Stock of Northern Fur Seals. Understanding factors responsible for past Eastern Pacific Stock declines is of vital importance to 1) identifying future natural and anthropogenic threats to a depleted marine mammal population, and 2) providing guidance on potential management actions that could increase the likelihood of future population growth and recovery to previously observed levels. In addition, the research described here may have important implications for NOAA fishery managers and the North Pacific Fisheries Management Council. As described above, evidence from several studies during the summer months – including ongoing collaborations between Dr. Pelland and AEP – indicate that walleye pollock stock structure and abundance, in addition to Bering Sea climate states and mesoscale physical processes, plays a key role in affecting pup growth.

Performance Indicators:

1. Stage 1 of this project involves assisting Dr. Sterling with manuscript preparation and publication in his study of summer foraging ecology of attendant female northern fur seals in the Bering Sea.

2. Stage 2 involves movement and dispersal modeling of NFS Eastern Pacific Stock pups.

    a. Collaboration with Dr. Johnson on a publication describing statistical modeling of effects of wind and surface currents on pup, adult female movement.

    b. Analysis of variability between individuals in the influence of these variables; effects of sex, age, size, year, etc.

    c. Using distribution of modeled behavioral effects, and reanalysis wind fields (potentially also mean surface currents), draw random individuals and simulate their dispersal movement. Repeat to obtain estimate of cohort dispersal range vs. time in each year.

3. Stage 3 involves analysis of juvenile survivorship vs. environmental variables.

    a. Mean atmospheric patterns in years of anomalously high, low survivorship.

    b. Dispersal effects: wind influence on fraction of pups migrating to profitable habitat.

    c. Rate of wind energy input to surface ocean (mean, maximum, number of storms during early dispersal period).

    d. Heat loss to surface ocean, heat loss in final weeks prior to weaning.

e. If good correlation found between observed survivorship and a reasonable choice of predictors, attempt population modeling using these predictors to estimate juvenile survivorship over duration of Eastern Pacific Stock population decline.

Budget:

Base Salary	**Monthly**	**Year 1**	**Total**
	4,725	**28,350**	**$28,350**
Total Salaries:			**$28,350**
Fringe Benefits			
Professional rate of 30.5%		**8,647**	**$8,647**
Total Salaries & Fringe Benefits:			**$36,997**
Travel Domestic – (Alaska Marine Science Symposium)			
Airfare		**450**	**$450**
Perdiem		**200**	**$200**
Lodging		**600**	**$600**
Registration		**100**	**$100**
Total Domestic Travel		**1,350**	**$1,350**
Total Direct Costs			**$38,347**
Indirect Cost rate of 26.0%		**9,970**	**$9,970**
Total Direct and Indirect Costs		**48,317**	**$48,317**
Publication Costs		**2,183**	**$2,183**
Total		**50,500**	**$50,500**

Budget Justification: No additional data collection is required for the goals described here. The budget includes 6 months of salary to fund collaborative research with a postdoctoral-level physical oceanographer, Dr. Noel Pelland, in addition to travel to a single conference and publication costs. While a student at the University of Washington, Dr. Pelland collaborated with AEP, Dr. Nick Bond of JISAO, and Dr. Mary-Anne Lea of the University of Tasmania to examine factors affecting northern fur seal migration patterns in the California Current Ecosystem. To accomplish this, he combined remotely sensed data and five years of autonomous ocean profiling data (Seaglider) with northern fur seal tracking and diving data. This investigation resulted in a manuscript titled, "Fortuitous Encounters between Seagliders and Adult Female Northern Fur Seals (*Callorhinus ursinus*) off the Washington (USA) Coast: Upper ocean Variability and Links to Top Predator Behavior" [4]. In addition, Dr. Pelland co-authored a manuscript with Dr. Sterling [5] and the results from both of these manuscripts has led to a renewed focus to identify processes influencing overwinter survival of newly weaned northern fur seal pups. While his current focus is and has been on the northern fur seal overwintering period, Dr. Pelland has also been instrumental in developing analytical tools to identify key summer processes that affect adult fur seal foraging behaviors, coauthored two AFSC Quarterly Reports [6,7], is coauthoring a manuscript with Dr. Lea, and is assisting Dr. Michelle Lander with her adult female Steller sea lion analyses.

Collaborators/University Partners: This project will rely on close collaboration with the University of Washington (Dr. Bond, JISAO).

Total Requested Funds: $50,500

References:

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2. Chapman DG (1961) Population dynamics of the Alaska fur seal herd. Transactions of the Twenty-Sixth North American Wildlife and Natural Resources Conference 26: 356-369.
3. Lander RH (1979) Role of land and ocean mortality in yield of male Alaskan fur seal, *Callorhinus ursinus*. Fishery Bulletin 77: 311-314.
4. Pelland NA, Sterling JT, Lea MA, Bond NA, Ream RR, et al. (2014) Fortuitous Encounters between Seagliders and Adult Female Northern Fur Seals (Callorhinus ursinus) off the Washington (USA) Coast: Upper Ocean Variability and Links to Top Predator Behavior. Plos One 9.
5. Sterling JT, Springer AM, Iverson SJ, Pelland NA, Johnson DS, et al. (2014) The sun, moon, wind, and biological imperative -- shaping contrasting wintertime migration and foraging strategies of adult male and female northern fur seals. PLoS One 9(4): e93068.
6. Melin SR, Sterling JT, Ream RR, Towell RG, Zeppelin TK, et al. (2012) A tale of two stocks: Studies of northern fur seals breeding at the northern and southern extent of the range. AFSC Quarterly Report Feature (April-May-June 2012) 11 p.
7. Sterling JT (2011) Using Traditional Knowledge and Archived Documents to Aid Research and Conservation Goals for the Northern Fur Seal AFSC Quarterly Report (July-August-September) 3 p.