Marine Ecosystems Climate Risk Team Project Abstracts

Title: Projecting changes to habitat suitability and connectivity for predators and prey in California sanctuaries

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Introduction to the problem: Climate change is causing the unprecedented redistribution of living marine resources, impacting ecosystem function and people living in marine-dependent communities. These impacts have been observed in the California Current - a diverse and productive ecosystem that provides important habitat for many marine species, services for millions of people, and home to four California National Marine Sanctuaries (NMS).
Rationale: It is unclear how iconic species in the California Current will respond to future climate
variability and change, and the subsequent impacts on the capacity of NMS to meet their mission to conserve, protect, and enhance biodiversity, ecological integrity and cultural legacy.
Brief summary of the work: We propose to use existing downscaled climate projections to examine predator and prey species distributions across the U.S. West Coast and their connectivity among California marine sanctuaries in response to long-term climate change and climate events such as marine heatwaves (MHWs). This project has several objectives: 1) Project species distributions under long-term climate change; 2) Quantify species historical and future responses to long-term warming, deoxygenation, and MHW; 3) Develop time-series indicators of species responses for use by sanctuary managers and stakeholders; 4) Develop sanctuary-specific products to aid NMS in achieving science needs and management planning. We will use a series of case study species, including 11 predator species (e.g. marine mammals, seabirds, finfish, and leatherback sea turtles), and 4 prey species (e.g. anchovy, krill, and gelatinous zooplankton).
Broader impacts: The research will provide time-series indicators of species responses to climate change, which will be of considerable benefit to California NMS, NOAA/NMFS, and the broader scientific community and public. An improved understanding of how species will be affected by climate change will support sustainable resource management and functional NMS.

Relevance to the competition and NOAA's long-term climate research goals: This project directly addresses the main objectives in Type 1C in the call for proposals, in that it will use downscaled climate projections to evaluate the ability of NMS to meet their mission. This work responds to the NMS Climate Change Science Priorities Workshop Report, which most researchers on this proposal participated in, as well as the Climate Change Vulnerability Assessment for the North-central California Coast and Ocean (Hutto et al. 2015). Projections of climate impacts on marine species will inform sustainable management of U.S. sanctuaries in a changing climate, addressing NOAA's Long-term Climate Goal of Healthy Oceans and Climate Adaptation and Mitigation, as outlined in NOAA's Next-Generation Strategic Plan. This project will establish collaborations between NMFS, NMS and academic partners to support increased production, delivery and use of climate-related information, as called for in NOAA's Fisheries Climate Science Strategy (NCSS; Link et al. 2015).

Title: Modeling climate-driven anchovy and krill variability along the U.S. West Coast in support of National Marine Sanctuaries

Lead PI: Jerome Fiechter (University of California, Santa Cruz)
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Abstract

In the California Current, northern anchovy and krill are a primary source of forage for myriad marine mammals and seabirds, and support deepwater pelagic and benthic ecosystems via vertical flux of material. Anchovy populations in the region were low throughout much of the 2000s, resulting in widespread mass strandings of seabirds, unusual mortality events of sea lions, and shifts in whale distributions. Beginning in 2014, however, anchovy populations surged and returned to historically high levels by 2016. Despite years of research, the mechanisms that first caused anchovy to decline and then rebound are opaque. By integrating existing field/satellite observations, species-specific diet information, and state-of-the-art modeling techniques, our proposed research will evaluate the broader ocean/climate drivers controlling anchovy population dynamics along the West Coast of the U.S. (including the Channel Islands, Monterey Bay, Cordell Bank, and Greater Farallones National Marine Sanctuaries) and explore the co-variability of anchovy and krill (another key forage species) in relation to coastal upwelling.

Our integrated observational and modeling approach will provide information that better prepares west coast National Marine Sanctuaries (as individual entities and as an integrated network) for assessing and communicating past, present, and future impacts (positive and negative) associated with the surge and wane of anchovies within their boundaries. Furthermore, predictions of anchovy abundance and distribution will benefit Condition Reports and Vulnerability Assessments by providing better characterization of historical and future essential habitat of krill, anchovy, and their predators, in a manner that is consistent across the network of California Sanctuaries. Through regular consultation with an advisory board of Sanctuary representatives, we will develop products that can help National Marine Sanctuaries and other management entities mitigate climate impacts resulting in distributional shifts of key marine species and potential increased overlap of these species with human activities.

Our proposed research also addresses broader research priorities established by the NOAA OAR Climate Program Office. The project provides a roadmap for developing a state-of-the-art climate-to-fish modeling framework informed by cutting edge observations (e.g., eDNA) and capable of producing historical solutions and regional climate projections at spatial scales relevant to management agencies. As such, our proposed research advances current capabilities of producing end-to-end (from science to decision making) information streams that will help implement short and long-term management strategies to protect and conserve coastal marine resources in the face of climate change.

Title: Pulse of the planet: A climate data decision-support dashboard for National Marine Sanctuary management and participatory adaptation planning

Lead PI: Kelly Dunning (Auburn University)
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Co-Is: Melissa Moulton, Frederic Castruccio (NCAR)

Rationale: Planning in national marine sanctuaries (NMS) requires understanding climate-driven changes. Just like NMS managers, many stakeholder groups with livelihoods dependent on NMS are making high-stakes decisions on how they will adapt to climate change. Decisions are often made without sufficient access to climate data to guide those decisions; with climate scientists producing data products in siloes, rarely engaging stakeholders to learn about desired products and formats. We propose to address this challenge by engaging NMS managers and stakeholders in a co-design process to develop an interactive “ocean climate dashboard” tool that improves access to critical climate-related information. We address two research questions: How

resilient are NMS governance systems to climate change?; and how can we use information from climate model ensembles and projections to increase their resilience?

Project Summary: Our project includes six objectives. 1) Research: An interdisciplinary, comparative case study of two systems of multi-stakeholder governance, the Florida Keys NMS and Flower Garden Banks NMS, analyzing their governance and resilience to climate-related hazards. 2) Stakeholder co-design workshops: this project is participatory, shaped by stakeholders. Participation will occur within two workshops per case site. 3) A climate model data tool: The Ocean Climate Dashboard is tailored to specific NMS manager needs and is easily interpreted by decision-makers, stakeholders, and the public. 4) A quantitative, social science survey of NMS stakeholders with livelihoods based on the sanctuary on the capacity to respond and adapt to climate threats. 5) Diversity and inclusion activities: funding two undergraduate researchers selected from Minorities in Agriculture, Natural Resources, and Related Sciences to engage in undergraduate research. 6) Outreach including a website, white paper, and student blogs.

Relevance to the Competition: Our project meets several needs identified in the Science for Sanctuaries Workshop Report 2021, including "increased integration of natural and social sciences [for] incorporating multiple disciplines and perspectives into science." The work proposed here grew out of our conversations with NOAA partners at the Flower Garden Banks NMS and addresses Type 1 proposal topics C, D, and E. Specifically, we are assessing and presenting information from CMIP model projections on space and time scales relevant to NMS (C), studying sanctuary-adjacent communities including impacts to culture, tourism, natural resource use, and public health (D), and investigating Sanctuary-relevant climate adaptation or management frameworks (E). By developing a stakeholder-informed climate dashboard to provide information for all NMS, we will improve access to information to allow greater inclusion of climate factors in sanctuary planning and management, with particular focus on two sites to pilot our interdisciplinary approach.

Relevance to NOAA climate research goals: to learn how to enhance the resiliency of NMS to climate threats, contribute to effective multi-stakeholder management at NMS, build the community necessary for actionable science at sanctuary scale, generate a co-design research prototype process to provide climate information that is effective for NMS management that can be replicated in other NMS sites, and ensure meaningful engagement with stakeholders.

Title: Variability of subsurface water masses in the Olympic Coast National Marine Sanctuary

Lead PI: Melanie Fewings (Oregon State University)
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Collaborators: Jenny Waddell, Katie Wrubel (OCNMS), Joe Schumacker (Dept. of Fisheries), Tommy Moore (Northwest Indian Fisheries Commission), Charles Seaton (Columbia River Inter-Tribal Fish Commission), Kym Jacobson (NOAA Northwest Fisheries Science Center) Jennifer Fisher, Maria Kavanaugh (Oregon State University)

Introduction to the Problem: The Olympic Coast National Marine Sanctuary (OCNMS) off Washington State is embedded in the northern California Current system (NCC), which is affected by major climate fluctuations, including marine heat waves, El Niño, changes in timing of spring transition to upwelling, seasonal hypoxia, and ocean acidification. The Sanctuary's 2020 Condition Report (Waddell, et al. in preparation) identifies understanding subsurface physical oceanographic conditions in OCNMS as a key data gap. The Newport Line off Oregon presently represents the entire NCC for some aspects of California Current Integrated Ecosystem Assessment (CCIEA) Ecosystem Status reports. There is a need to assess under what conditions subsurface water properties in OCNMS are related to water properties off Newport.

Rationale: There is a wealth of underutilized data available from OCNMS moorings deployed at 10 locations from 2000-present, and complementary public data from moorings deployed by NANOOS and OOI Endurance Array in nearby waters off Washington and Oregon. In our previous work, we have developed a toolbox of time series and spatial analysis methods for Newport Line shipboard and mooring data; we are poised to apply these tools to study the OCNMS and surrounding waters and compare the results to Newport.

Summary of Work to be Completed: We will focus on six variables: water temperature, salinity, density, spiciness, velocity, and dissolved oxygen concentration, and produce updated climatologies and anomalies for these six variables using the data from the full OCNMS mooring record 2000-present. We will make accessible the data from 2000-2005 and CTD data that have not been examined. To complement these OCNMS data, we will use the NEMO complex, including the Ćhá?ba mooring, and OOI Endurance Array moorings off Olympic Coast and other publicly available data off Washington and Oregon. We will determine dates of hydrographic spring and fall transition based on position of the 7°C and 8°C isotherms in OCNMS and develop a new index of pycnocline depth. Finally, we will determine when, and under what conditions, water properties in OCNMS are similar to the Newport Line.

Broader Impacts and Relevance:
Broader Impacts: NOAA has treaty trust obligations to four Washington Coastal Treaty Tribes with treaty-protected rights to marine resources on the Olympic Coast. We will work

closely with tribal resource management partners (see Letters of Support).
Relevance to the Competition: We will leverage underutilized data sets to enable more effective monitoring of subsurface conditions at OCNMS, including anomalies due to climate impacts, by producing authoritative seasonal climatologies and new long-term indices of subsurface anomalies. These curated, value-added data sets will inform OCNMS Condition Reports, new OCNMS Ocean Acidification Sentinel Site efforts and Climate Vulnerability work.

Relevance to NOAA's Long-Term Climate Research Goals: Our anomalies and indices will improve monitoring and assessment efforts in the NCC and can be incorporated in reports issued by the Pacific Fishery Management Council, Northwest Indian Fisheries Commission (Tommy Moore, Marine Conditions Bulletin), and MERHAB (Harmful Algal Bloom Bulletin); and the CCIEA Ecosystem Status Reports, which presently rely on data off Oregon to represent observed subsurface conditions off Washington between times of NOAA annual surveys. Our assessment of when conditions in OCNMS are similar to the Newport Line will inform conversations at NOAA about whether to implement a new sampling line off the Olympic Coast.

Title: Climate Change Indicators Across the National Marine Sanctuaries System

Lead PI: Frank Muller-Karger (University of South Florida)
Co-PIs: J. Dorton (Southeast Coastal Ocean Observing System), C. Simoniello (Gulf of Mexico Coastal ocean Observing System), J. Killborn, R. Zarger (USF)
Collaborators: A. Bruckner (Florida Keys National marine Sancuary), C. Kelble (AOML), J. Trinanes (NESDIS), W. Klabjor (ONMS, NCEI, NMFS Knauss Fellow), M. Johnston (Flower Garden Banks National Marine Sanctuary)

Abstract
Changes in climate have led to changes in physical and biogeochemical characteristics of the Earth's system that affect marine life and ecosystem services. This Type 2 proposal (team lead role) seeks to co-develop operational applications for the National Marine Sanctuary System (NMSS) based on historical and ongoing physical and biogeochemical datasets along with results from the Coupled Model Intercomparison Project (CMIP6) and other model forecasts (Topics A and C). Each Sanctuary and Monument needs to address the general question: "Have recent, accelerated changes in climate altered water conditions and how are they changing?" (Question 8 on Water/Climate Change of the NMSS Condition Report guidelines). Answers are relevant to other Condition Report questions, on eutrophication, foundation species, and ecosystem services. We propose to characterize the frequency, timing, intensity, and synergistic

organization of Essential Ocean Variables (EOVs) that may affect biology and ecosystem processes throughout the NMSS. The approach will be to co-develop synthesis products based on historical time series of environmental observations, including indicators, and sets of user tools that are consistent and have the same user interface throughout the NMSS. Products will be developed jointly and transitioned to operations working with the Integrated Ocean Observing System including the Marine Biodiversity Observation Network (IOOS, MBON), the NOAA Science Council's Ecosystems Indicator Working Group (National Marine Ecosystem Status or NAMES), the NOAA Climate Program, regional Integrated Ecosystem Assessment (IEA) programs, and others as appropriate. The products will be based on instrumented records of precipitation, frequency and intensity of storms, wind intensity and direction, river discharge, nutrient and sediment load (turbidity), water and air temperature, ocean acidification parameters, harmful algal blooms, sea level, waves, and other data spanning the past several decades to 100 years as available. These will be coupled with novel synoptic water quality indices from satellite data (~1999 - present) at regional to global-scales. The three-dimensional variability of the state of the ocean will be examined using time series of numerical model results (CMIP NASA ECCO, NOAA Global RTOFS). The approach will quantify the mean, trend, and variability of EOVs relevant to the biology and ecology of the Sanctuaries and synthesize information to help understand local changes in the context of larger scales and a changing climate. The project includes a transdisciplinary model of climate change education and research that will guide NMSS in planning, management, and outreach. Outcomes will provide information to update Sanctuary Condition Reports more dynamically than possible today. The effort addresses NOAA's fundamental priorities of science, service, and stewardship. The team is diverse in gender, includes members from under-represented groups, and is interdisciplinary.

Title: Vulnerability of the Stellwagen Bank National Marine Sanctuary to climate-driven zooplankton changes in the Gulf of Maine

Lead PI: Jacob Kritzer (NERACOOS)
PIs: Jeffrey Runge (UMaine/ISMN), Rubao Ji, Joel Llopiz (WHOI), Jacqueline Motyka (NERACOOS)
Federal Co-PIs: Benjamin Haskell, David Wiley, Tammy Silva (SBNMS)

Introduction to the problem and rationale: Stellwagen Bank National Marine Sanctuary (SBNMS) is one of the most productive areas in the Gulf of Maine (GoM). The foundation of this productivity is the planktonic copepod, Calanus finmarchicus (hereafter Calanus), the primary prey of forage species such as krill, herring, and sand lance that in turn support other

economically and ecologically important species, including Atlantic cod, bluefin tuna, great shearwaters, and humpback whales. Prevailing ocean currents in the region indicate that SBNMS depends on other areas of the GoM for its Calanus supply.

Since 2010, observations conducted by NOAA and the Marine Biodiversity Observation Network (MBON) consistently show Calanus abundance at 30-60% of historical means in late summer and winter. The decline is driven by a shift of environmental conditions including warming and circulation-induced changes of water masses entering the GoM. Statistical models predict that this trend will continue over the next several decades associated with rising water temperatures. It is increasingly likely that changing oceanographic conditions will cause the next tipping point in the western GoM, resulting in a Calanus population crash. SBNMS depends on supply of Calanus from the western GoM, so this shift has important implications for the health of the Sanctuary. This project will utilize regional observing infrastructure and modeling capabilities to develop forecasting tools for key SBNMS productivity variables. The results will provide critical information in support of core Sanctuary goals, including climate adaptation, policy development, stakeholder education and engagement, and new research and monitoring.

Brief Summary of Work to be Completed: We will review existing information and data sets on drivers of Calanus abundance and interactions among Calanus and sand lance. Using a coupled physical-biological model, we will determine the role of Wilkinson Basin as a source and the Maine Coastal Current as a vector for supply of Calanus to SBNMS, including the capability of upstream data to predict SBNMS oceanographic and Calanus conditions, spatial synchrony of population variability at different time scales, and climate-driven oceanographic drivers that mediate these relationships. We will model the interactions between Calanus and sand lance to determine the extent to which Calanus forecasts provide forecasts of the forage base in SBNMS.

Broader impacts, relevance to the competition, and NOAA's long-term goals: This project advances understanding of ways in which changes in biodiversity affect the functioning of marine ecosystems and the services they provide. Through development of a useful forecasting tool, it will be a model of how interdisciplinary, integrated scientific research that leverages existing and new knowledge and data can enhance a marine sanctuary's ability to plan and respond to climate variability and change. A collaboration of academic and research scientists with NOAA personnel, the project represents a partnership that builds end-to-end pipelines of information flow from scientists to decision-makers.

Title: Climate Change Impacts on Reef Fish Spawning Aggregations, Larval Dispersal, and Settlement in Southeastern U.S. National Marine Sanctuaries and Surrounding Areas

Lead PI: Rebecca Asch (East Carolina University)
Co-PI: Cheryl Harrison (Louisiana State University)

Introduction to the problem: Historically, marine sanctuaries have not often been sited with climate change impacts in mind. Climate change can have negative impacts on fishes that use sanctuaries for spawning or larval settlement. The capacity to project future changes to marine ecosystems will allow us to better manage fisheries, since marine sanctuaries could otherwise become less effective in their conservation goals as climate change shifts species distribution. Among reef fishes, such as the Nassau Grouper and Cubera Snapper, climate change is projected to have significant impacts on spawning aggregation sites. For Nassau Grouper, preliminary work by our team shows that some protected areas may behave as thermal refuges for spawning, while other regions may be abandoned as conditions exceed thermal tolerances. We propose to model changes in the distribution, phenology, and metapopulation structure of fish spawning aggregations (FSAs) under climate change scenarios to assess the occurrence of climate refugia and source and sink populations within marine sanctuaries.

Rationale: Fishes that reproduce via FSAs are among the most vulnerable to threats from overfishing and climate change. Having a limited number of spawning sites increases their sensitivity to changes at their spawning grounds. Marine reserves have proven to be one of the most effective ways of conserving FSAs. However, we do not know if current reserves will support FSAs in the future, because most models of species distribution shifts do not consider the more limited habitats used during spawning. Species that form FSAs are important for dive-based ecotourism and can support ecosystem services since the concentrated food resources at FSAs are associated with migrations by large migratory predators and mega-planktivores. Nassau Grouper and Cubera Snapper will be used as target species due to abundant range-wide data on historical and current FSAs. Additionally, this project will provide insights into climate impacts on multiple species since many groupers and snappers spawn at multi-species FSAs.

Summary of work to be completed: A multi-model approach using CMIP6 climate models will be used to assess oceanic changes at sanctuaries under the SSP2-4.5 and SSP5-8.5 climate scenarios. Conditions from these models will be used to determine the suitability of spawning habitat via the Non-Parametric Probabilistic Ecological Niche (NPPEN) model. Spawning habitat suitability will be determined for the Gray's Reef, Florida Keys, and Flower Garden Banks National Marine Sanctuaries. While Gray's Reef does not currently provide habitat for these species, it may support habitat in the future due to species range shifts. We plan to explore how use of artificial reefs and other hard substrates as spawning habitat might influence projections of range shifts. Also, we will examine how source-sink dynamics of larval dispersal may change due to climate effects on ocean circulation and changes in species distribution, phenology, and fishing pressure. The Connectivity Modeling System particle tracking model will be coupled with the high-resolution GFDL CM2.6 model to study larval dispersal and identify source or sink populations based on changing conditions inside and outside of sanctuaries. We have been in contact with researchers and managers at the National Marine Sanctuaries Office,

NMFS, NCCOS, Grouper Moon Project, and Reef Environmental Education Foundation about serving on a project advisory panel to ensure relevance for sanctuary managers.

Relevance to the competition: This proposal contributes to focus area C of this competition since it will use CMIP6 models to: 1) understand the impacts of climate extremes on successful reef fish life history completion, 2) conduct model-based experiments to investigate alternative designs for no-take areas, and 3) identify climate refugia for FSAs and assess the climate sensitivity of source populations for larval dispersal. Overall, sanctuaries are designed to protect pristine environments and their species, as reflected in their management plans. Specifically, sanctuary management plans call for assessments of "impacts of climate change on resources" (GRNMS, 2014), "documenting the status of ecologically and economically important species" (FKNMS, 2007) and investigating "the reproductive ecology of marine organisms" (FGBNMS, 2012). This project would directly address these sanctuary management goals providing a powerful tool for identifying climate refugia, addressing future no-take designations, and adjusting seasonal fishing closures to reflect changes in spawning phenology.