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NOAA FISHERIES

Pacific Islands Fisheries Science Center

Pacific Islands Regional Action Plan

NOAA FISHERIES CLIMATE SCIENCE STRATEGY

by
Jeffrey Polovina and Kurt Dreflak (Chairs), Jason Baker, Scott Bloom, Samantha Brooke, Valerie Chan, Sarah Ellgen, Dawn Golden, Justin Hospital, Kyle Van Houtan, Steve Kolinski, Beth Lumsden, Kim Maison, Michelle Mansker, Tom Oliver, Sylvia Spalding, Phoebe Woodworth-Jefcoats

About this document

The mission of the National Oceanic and Atmospheric Administration (NOAA) is to understand and predict changes in the Earth's environment and to conserve and manage coastal and oceanic marine resources and habitats to help meet our Nation's economic, social, and environmental needs. As a branch of NOAA, the National Marine Fisheries Service (NMFS) conducts or sponsors research and monitoring programs to improve the scientific basis for conservation and management decisions. NMFS strives to make information about the purpose, methods, and results of its scientific studies widely available.

NMFS' Pacific Islands Fisheries Science Center (PIFSC) uses the **NOAA Memorandum NMFS** series to achieve timely dissemination of scientific and technical information that is of high quality but inappropriate for publication in the formal peer-reviewed literature. The contents are of broad scope, including technical workshop proceedings, large data compilations, status reports and reviews, lengthy scientific or statistical monographs, and more. NOAA Technical Memoranda published by the PIFSC, although informal, are subjected to extensive review and editing and reflect sound professional work. Accordingly, they may be referenced in the formal scientific and technical literature.

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U.S. DEPARTMENT OF COMMERCE

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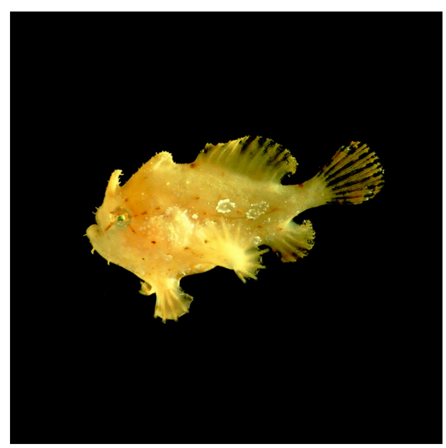
Contents



I. Executive Summary

The physical and chemical responses to climate change in the Pacific Islands region are likely to include a rise in ocean temperatures, reduced nutrients in the euphotic zone, an increase in ocean acidity, a rise in sea level, changes in ocean currents, and changes in weather patterns and extreme weather events (Leong et al. 2014). Many of these changes have already been observed and are projected to intensify further. These changes will have direct, indirect, and cumulative impacts on insular and pelagic ecosystems and the communities that depend upon them. This Pacific Islands Regional Action Plan (RAP) follows the approach presented in the NOAA Fisheries Climate Science Strategy and applies it to the ecosystems and management actions of the Pacific Islands region.

We assessed our current climate science in the region and noted:

i. A major strength is our ability track ecosystem trends and changes based on historical time series and ongoing monitoring programs. These include research surveys and instrumentation covering the coral reef ecosystem, multi-decadal demographic time series of the monk seal population, and multi-decadal time series of catches from the Hawaii-based longline fishery and other fisheries, along with data from periodic socio-economic surveys. Multi-decadal time series of satellite remotely-sensed oceanographic data provide environmental monitoring.

ii. We use physical and biological outputs from dozens of the most advanced earth systems models to project the physical and biological impacts from climate changes in the region and to drive pelagic ecosystem models to project ecosystem and fisheries impacts.

iii. We are proactive in incorporating climate change considerations in many of our regulatory actions and management plans.

iv. Areas we can improve upon include: i) identification and implementation of management strategies that are robust under uncertain projections of climate change impacts, ii) identification of climate-informed reference points for species in managed fisheries, and iii) an increased understanding of many of the processes or mechanisms linking climate change to subtropical ecosystems and human communities.

Our highest priorities for climate information, products, and services are to:

i. Take into account climate impacts on estimates of maximum sustainable yields (msy) for deepwater bottomfishes, striped marlin, bigeye tuna, yellowfin tuna, swordfish, and annual catch limits for coral reef fishes.

ii. Incorporate appropriate climate information in jeopardy and critical habitat determinations, assessment of extinction risk, species vulnerability, listing/de-listing criteria, impact mitigations strategies, environmental analysis for fisheries management actions, recovery plans under the Endangered Species Act (ESA), and take reduction plans under the Marine Mammal Protection Act (MMPA).

iii. Generate climate-informed assessments of impacts to coastal and terrestrial habitats, especially for the low-lying islands found throughout the region, that provide infrastructure for human communities that use the ocean as well as critical pupping and nesting habitat for protected species.

iv. Conduct species vulnerability analyses where appropriate.

v. Evaluate climate driven changes to the structure and energy flows of insular and pelagic food webs with emphasis on impacts to protected and managed species.

Some key actions we can take over the next 5 years include:

i. Maintain and enhance ongoing monitoring programs for insular and pelagic ecosystems, sea turtles, cetaceans, and monk seals and analyze these data to detect climate impacts.

ii. Update surveys of fishing community economics, vulnerability, and resilience.

iii. Develop and incorporate climate indicators and information into Fisheries Ecosystem Status Reports under the Fisheries Ecosystem Plans.

iv. Incorporate climate information into billfish, tuna, and bottomfish stock assessments and coral reef fish annual catch limits.

v. Incorporate climate change information into designations of protected species critical habitat, recovery planning, and National Environmental Policy Act (NEPA) and ESA analyses.

With additional funding we will be able to:

i. Downscale output of earth system models to project impacts at reef and island scales.

ii. Strengthen survey and monitoring programs and analyses of these data to specifically address climate impacts.

iii. Improve economic, habitat, fisheries, and ecosystem models to more fully address climate impacts.

iv. Conduct laboratory experiments to evaluate mechanistic linkages among environmental drivers, genetics, and coral reef physiological responses.

v. Undertake quantitative analyses to identify robust management and harvest strategies and conduct management strategy evaluations under climate change scenarios.

vi. Assess impacts of climate change on coastal human communities, their culture, food security, and economics.

II. Introduction to Climate Impacts in the Region

The Pacific Islands region consists of three federal entities: the Pacific Islands Fisheries Science Center (PIFSC or Science Center), the Pacific Islands Regional Office (PIRO or Regional Office), and the Western Pacific Regional Fishery Management Council (WPRFMC or Council). These agencies have mandates and activities spanning a large geographic area including the North and South Pacific subtropical gyres and the archipelagic waters of Hawaii, American Samoa, Guam, the Commonwealth of the Northern Marianas Islands (CNMI) and the US Pacific Remote Island Areas (PRIAs). Key ecosystems and species of focus include: i) the subtropical pelagic ecosystem, ii) coral reef ecosystems, iii) the deep-water bottomfish complex, iv) the Hawaiian monk seal, and v) a number of species of sea turtles, seabirds, and cetaceans (e.g., whales, dolphins). The region has five fisheries ecosystem plans, one for the subtropical pelagic ecosystem, one for the Pacific Remote Islands Areas (PRIAs), and one for each of the 3 insular archipelagoes (Hawaii, American Samoa, and the Marianas Archipelago).

The region is subject to climate variability and change on multiple scales. At the inter-annual scale El Niños and La Niñas have significant physical and biological impacts including impacts to temperature, winds, ocean vertical structure, and coral reef bleaching. On the decadal scale the Pacific Decadal Oscillation (PDO) impacts the physical and biological environment. Then on time scales greater than a few decades is the persistent increase in greenhouse gases, referred to here as climate change. The responses from climate change in the region are likely to include a rise in ocean temperatures, increased vertical stratification, reduced nutrients in the euphotic zone, an increase in ocean acidity, a rise in sea level, and changes in ocean currents. Many of these changes have already been observed and are projected to increase further. These changes will directly and indirectly impact insular and pelagic ecosystems and the people and communities that depend upon them.

Recognizing the growing need for information on how to better prepare for and respond to climate-related impacts on the nation's living marine resources and resource-dependent communities, NOAA Fisheries developed a Climate Science Strategy (Link et al. 2015) to provide a national framework designed to be customized and implemented at regional and national levels by NMFS Science Centers, Regional Offices, Programs, and partners. The development of Regional Action Plans (RAPs) addresses the unique combination of ecosystem conditions, climate-related challenges, capabilities, and information needs that will need to be considered to implement the Strategy in each region. The Pacific Islands Regional Action Plan presented here begins by reviewing the region's current or recent climate activities and results, noting strengths, weakness, and opportunities. The second part of the Plan outlines directions for the region's climate activities over the next 5 years following the seven (7) research objectives identified in the NOAA Fisheries Climate Science Strategy.

IIIa. Assessment of Current Climate Work

In this and subsequent sections our climate work is organized by the seven objectives identified in the NOAA Fisheries Climate Science Strategy (Fig.1). We view the objectives as representing a hierarchy in climate work that starts with Objective 7 and progresses in reverse numerical order requiring increasing skill and building on previous objectives ultimately reaching Objective 1. We discuss them in this order.

Objective 7 Build and maintain the science infrastructure needed to fulfill NOAA Fisheries mandates under changing climate conditions.

The number of staff at the Pacific Islands Region dedicated to climate-related research is relatively small consisting of only a couple of staff in the Ecosystem Sciences Division at the Pacific Islands Fisheries Science Center (Science Center) with full time engagement in climate work. However, across the Pacific Islands Regional Office (Regional Office) and Science Center, climate impacts are broadly considered in the mix of inputs in management and research. The Science Center recently added a management strategy evaluation (MSE) position that provides capacity to contribute to climate impact evaluations. While the Regional Office does not have any staff devoted full time to climate issues they use a combination of training and contracts to build their capacity. For example, a number of staff in the Regional Office have taken training courses on incorporating climate change in decision analysis. Regional Office staff include climate change effects in National Environmental Policy Act (NEPA) analyses that support fisheries management actions. They have also issued contracts for climate-related projects ranging from a literature review of the ecological and economic impacts of climate on highly migratory species to the development of stock assessment and fisheries evaluation reports that would include indicators of trends and changes in the ecosystem to inform fisheries management.

Objective 6 Track trends in ecosystems, living marine resources, and resource-dependent human communities and provide early warning of change.

A strength of the Pacific Islands region is its monitoring of ecosystem trends in both the pelagic and insular ecosystems. For coral reef ecosystems, in-situ changes in corals, coral reef fish, and coral reef cryptobiota diversity, density, size structure, and biomass are monitored with regular research cruises across the US Pacific (Figure 2). Further, in-situ instruments at these reefs monitor temperature at 130 sites, carbonate accretion and bioerosion rate in 247 sites, seawater carbonate chemistry in 309 sites, and cryptic (e.g. small invertebrate) biodiversity at 48 sites currently (Fig. 2).

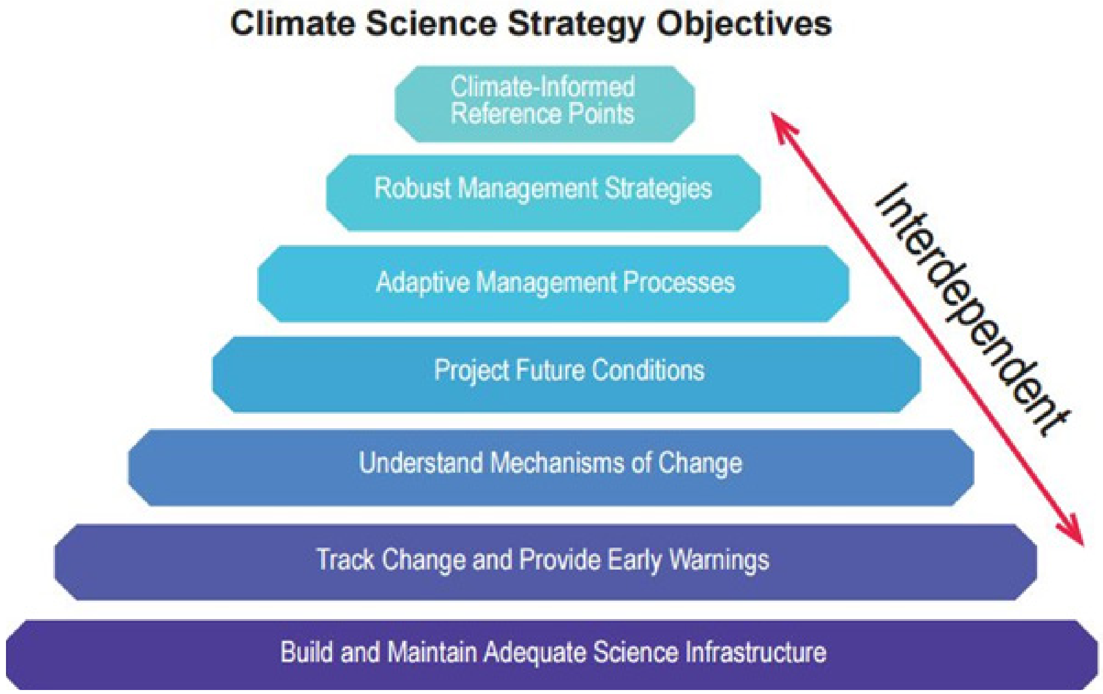


Figure 1. The seven objectives identified in the NOAA Fisheries Climate Science Strategy to be addressed in all regional plans.

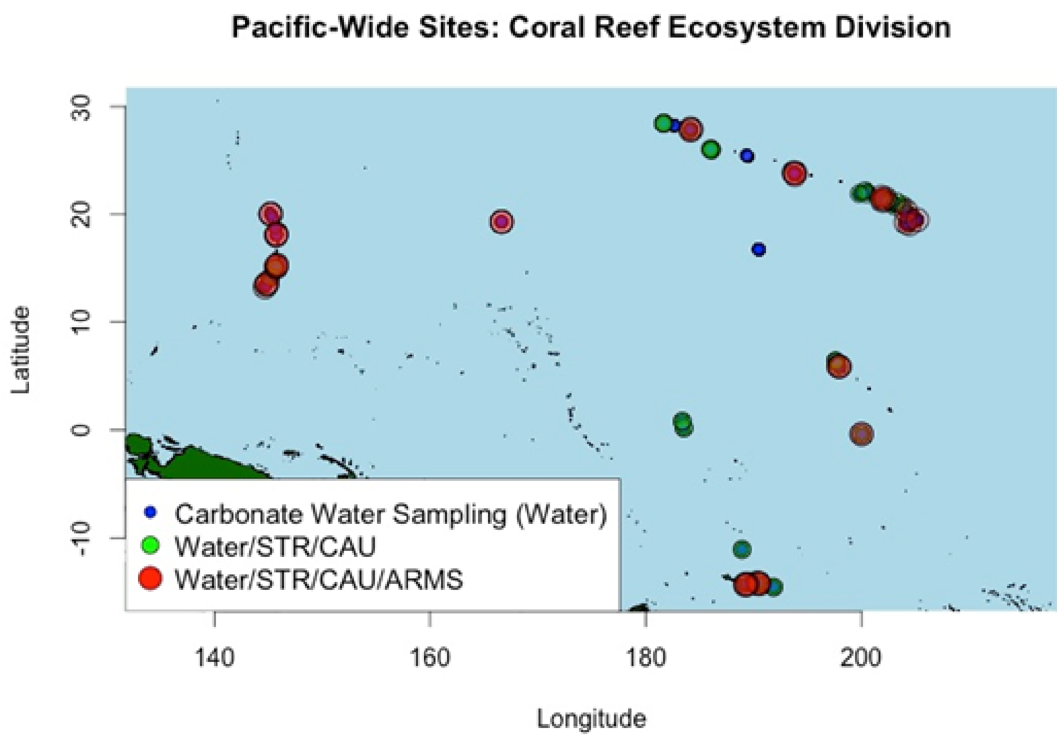


Figure 2. Locations of coral reef ecosystem sampling sites. STR = Sub-surface Temperature Recorders, CAU - Calcification Accretion Units, and ARMS - Autonomous Reef Monitoring Structures.

In the case of protected species, the Science Center maintains long term monitoring for both green turtles in Hawaii and the Hawaiian monk seal. In particular, the monitoring of monk seal demographics from Kure through the main Hawaiian Islands represents the most detailed (i.e., age- and site-specific survival rates), longest term, and greatest spatial extent biotic time series for any marine species in the Central Pacific. These data have been collected to support the recovery of the species but have also proven valuable in detecting climate-related ecosystem changes (Baker et al. 2012). Continuing to monitor these populations during anticipated future climate change will help elucidate trends in the ecosystem, including how new oceanographic regimes affect a top predator in the system (Baker and Thompson 2007, Baker et al. 2007, 2012). Science Center monitoring of cetacean stocks throughout the Pacific Islands region using both vessel based and moored acoustic techniques can be used to detect changes in distribution, species assemblages, and density in relation to climate variables. A time series of ecosystem indicators for the West Hawaii marine ecosystem has been developed and maintained as part of our Integrated Ecosystem Assessment (IEA) program (http://www.pifsc.noaa.gov/kona_iea/). The region's pelagic ecosystem is monitored with catch data for over two-dozen species from the Hawaii-based and American Samoa-based longline fisheries recorded with logbooks and observer data administered through the Regional Office. These time series span more than two decades and have been key in describing trends in ecosystem size structure and species composition (Polovina and Woodworth-Jefcoats 2013). Along with fishery-dependent reporting and surveys on other pelagic and insular fisheries, these data also serve as input for ecosystem modeling and as a baseline for assessing future climate impacts. In addition to the catch data, there are economic data for the Hawaii longline fishery (trip costs, fish prices, etc.) and other regional fisheries that have been used in socio-economic models to project socio-economic impacts of management actions.

Changes in the ocean environment are monitored with satellite remotely-sensed oceanographic data and data collected from research cruises. Time series of two to three decades with basin-wide coverage are available from satellite remotely-sensed oceanographic data for many oceanographic variables. For example a remotely-sensed time series of surface chlorophyll has documented an expansion of the most oligotrophic waters in the ocean's subtropical gyre (Polovina et al. 2008). Oceanographic cruises to the subtropical frontal zone have described the temporal and spatial phytoplankton community structure in this region (Howell et al. 2015). All these data sets (oceanographic, coral reef, and pelagic) provide key indicators to track and provide an early warning of ecosystem and oceanographic changes in the US Pacific. A challenge in the pelagic ecosystem is monitoring the micronekton. However, a recently initiated study of the diets of lancetfish, from stomachs collected by the longline observers, appears to provide a broad sample of the micronekton community.

Science Center social scientists have developed methods to derive and assess social indicators of fishing community vulnerability and resilience in Hawaii with considerations for natural hazards risk and climate change (Kotowicz and Beavers in review). The indicators are developed at the Census County Division (CCD) scale and couple US Census data with local fisheries data to allow for trends and changes in community resiliency and vulnerability from climate impacts to be assessed over time. Recent survey-based research across the region has begun to document baseline attitudes and perspectives towards climate change impacts, including: (i) noncommercial fishers' baseline perceptions of current fishery conditions and the perceived threat that climate change and ocean acidification pose on Hawaii's marine environment (Madge et al. in press) and (ii) Guam general public perspectives towards vulnerability and preparedness to natural hazards, awareness of natural hazard risk, and recent climate change trends on Guam (Kotowicz and Biggs, pers. comm.). Future replications of these survey efforts will afford analysis of trends in community awareness and resiliency towards climate change impacts.

Objective 5 Identify the mechanisms of climate impacts on ecosystems, living marine resources, and resource-dependent human communities.

One focus of national and international research is understanding the mechanisms of how various physical and biological changes due to climate change will impact ecosystems at all trophic levels (Drinkwater et al. 2010, Otterson et al. 2010, Doney et al. 2012, Nye et al. 2013, McClure et al. 2013, Halley et al. In Review). The Pacific Islands region requires additional research in all ecosystems but some mechanisms are starting to be elucidated. For example, in corals, patterns in accretion and bioerosion show correlations to both aragonite saturation state and nutrient levels (N). Sites with higher N showed higher than expected accretion given the aragonite saturation levels, but also showed significantly higher bioerosion rates (Decarlo et al. 2015). Further, using correlative general additive models and a large set of survey sites spanning gradients in both fishing pressure and coral reef ecosystem productivity, it has been shown that anthropogenic impacts of local fishing interact with baseline regional productivity to generate observed patterns of reef fish biomass. This quantitative model produced quantitative hypotheses about both the potential limits on un-fished biomass in a given region and a means to estimate the existing impacts of fishing pressure (Williams et al. 2015, MacNeil et al. 2015). By forcing this model with output from climate models it can be used to forecast climate impacts on reef ecosystems.

Rising sea level will likely result in a range of impacts in coastal areas. It will affect human communities and the facilities used in recreational and commercial fishing as well as terrestrial habitats for protected species. Key pupping and nesting habitat for sea birds, sea turtles, and monk seals in the low atolls of the Northwestern Hawaiian Islands may be lost (Baker et al. 2006, Reynolds et al. 2012).

In the Northwestern Hawaiian Islands, monk seal pup survival varies in response to the position of an oceanic front linked to climate variation (Antonelis et al. 2003, Baker et al. 2012). Climate change has the potential to impact the reproductive output of marine turtles. For instance, physiologically-based models suggest increased temperatures at foraging sites can lead to delayed remigration intervals (Neeman et al. 2015), while increases in sand temperature on nesting beaches can skew hatchling sex-ratios leading to female dominance (Fuller et al. 2013). Studies of future climate change scenarios suggest increasing temperature regimes will overrun the resilience of turtle populations conferred from temperature-dependent sex determination (Santidrián Tomillo et al. 2015).

Additionally, marine turtles nesting at low lying atolls (Baker et al. 2007) and in fringe habitat where little beach or surface is available before jutting cliff sides will be increasingly vulnerable to sea level rise and storm surges. Changing ocean temperatures and increases in rainfall or storm surges could potentially skew temperature dependent hatchling sex ratios or lead to increased nest inundations. Lastly, the numbers of loggerhead sea turtles both in the Atlantic and Pacific appear to vary in response to decadal oceanic conditions (Van Houtan and Halley 2011, Ascani et al. 2016).

Going forward, a challenge will be to understand climate impacts at all trophic levels. Plankton surveys for the pelagic ecosystem or reef surveys for the coral ecosystem will be useful in detecting changes at the base of the ecosystems. At the top of the food web, socio-economic data, fisheries data, stock assessments, and reef ecosystem surveys can provide insights into changes at the top of the food web. Elucidating changes in the middle of the pelagic ecosystem is particularly challenging but trawl surveys and fish diet studies may be helpful. For coral reef ecosystems, the region's live animal facility is available to conduct research on the links between changing ocean chemistry and/or temperature and the biological processes of key species but funding to conduct the work is currently limiting.

Objective 4 Identify future states of marine, coastal, and freshwater ecosystems, living marine resources, and resource-dependent human communities in a changing climate.

There has been considerable focus in the region on evaluating and projecting impacts from climate change often based on various modeling approaches. For example, the Regional Office's Marine National Monuments Program (Monument) has issued a grant to create a geographically explicit model of climate change impacts and the rate of climate change for various functional and ecological components of the reef ecosystem in the Monument areas. This impact model will address climate threats,

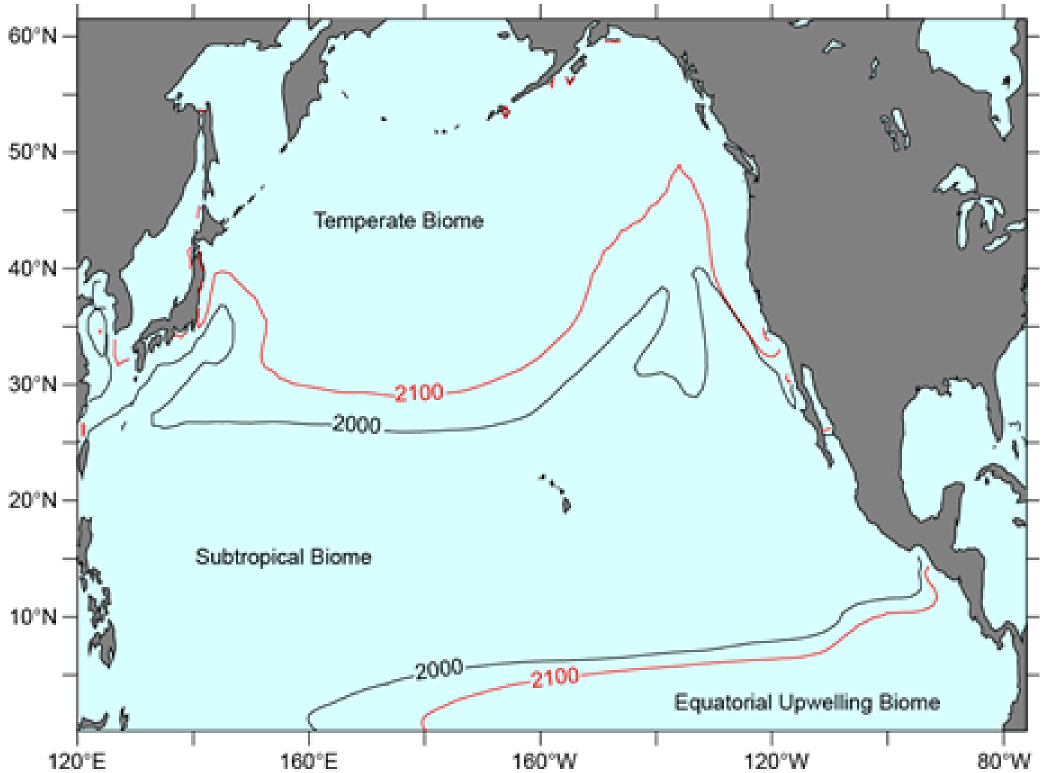


Figure 3. Boundaries of the temperate, subtropical, and equatorial upwelling biomes in 2000 and projected for 2100 showing an expansion of the subtropical biome (Polovina et al. 2011).

biotic vulnerability, and adaptive capacity. The impact models will be built using the existing global-scale human impact models (Halpern et al. 2007, Selkoe et al. 2008), those from the Papahanaumokuakea Marine National Monument (MNM) (Selkoe et al. 2008), as well as new MNM-specific data that will be aggregated from reports, publications, surveys of experts (scientists, managers and local practitioners), and outreach to local stakeholders. Additional products include Management Prioritization Analysis and Data Prioritization Analysis that will help guide action plans focused on mitigating climate impacts and gathering new data to inform management of the MNMs.

In the pelagic ecosystem the physical and biological output of an earth system model over the 21st century has been analyzed to describe broad oceanographic changes such as a projected expansion of the subtropical biome and the contraction of temperate and equatorial upwelling biomes in response to climate change (Fig. 3, Polovina et al. 2011). Additionally, phytoplankton density time series output from an earth system model have been used to force species-based and size-based ecosystem models to project ecosystem and fisheries changes (Woodworth-Jefcoats et al. 2013, Howell et al. 2013). These efforts are now being extended with the output from 11 earth system models. In the coral reef ecosystem, climate model sea surface temperature is being downscaled to assess bleaching impacts on coral reefs of the Hawaii Archipelago. Work to assess impacts from ocean acidification is anticipated both with basin-wide monitoring, tank studies, and models. Going forward there is an opportunity to use socio-economic models to extend these impacts to fishing and recreational uses and evaluate the social and economic impacts of climate change.

Sea level rise potentially poses a great risk to terrestrial habitats for monk seals, green turtles, millions of seabirds, and a host of endemic terrestrial species in the Northwestern Hawaiian Islands (NWHI) and other low islands across the region. High-resolution elevation maps are now available for most of the low-lying NWHI. Some simple inundation models demonstrate that sea level rise anticipated this century is likely to have significant impacts on several islands, with some likely to disappear entirely (Baker et al. 2006) while other models suggest that low-lying atoll islands may either remain stable or increase in area (Webb and Kench 2010, Dickinson 2009). Going forward, more sophisticated, dynamic models incorporating elevation, bathymetry, substrate, sea level, wind, and wave action could achieve more robust predictions of shoreline evolution including erosion and accretion. Such models could also assist resource managers in exploring potential mitigation measures (Reynolds et al. 2012). Likewise future work on the vulnerability of insular and pelagic species to climate change will aid researchers and managers.

The long term Hawaiian monk seal demographic dataset coupled with information on fish abundance and distribution, commercial bottomfish fishing, and oceanography and climate patterns from across the Hawaiian archipelago, present a basis for developing complex ecosystem models that will help address questions such as how fishing activity and monk seals influence marine resources and each other. These models could also predict how these relationships may alter under climate change. PIFSC scientists will explore the potential to construct multi-faceted ecosystem models (Ecopath with Ecosim as an initial framework, perhaps eventually building into an Atlantis ecosystem model) in which climate and oceanographic features are incorporated as system drivers. Changes in temperature or ocean currents will drive primary productivity and prey availability throughout the modeled food web. Historical time series data will be important in parameterizing models to account for the impact that changing conditions exert on the ecosystem. Once parameterized, models can be used to estimate impacts of a range of future scenarios (such as those predicted by IPCC models).

Based on large-scale cetacean surveys carried out in the Hawaiian EEZ, as well as in waters surrounding Palmyra Atoll and the eastern tropical Pacific, remotely-sensed habitat-based models of cetacean density have been developed (Forney et al. 2015). The models now exist in a framework that allows prediction of cetacean density based on remotely-sensed data from periods outside the original data collection, and could provide a method for predicting future cetacean distribution and density under alternative climate scenarios. Further, telemetry data currently being collected can be used to characterize habitat use and thus help predict future distribution. Currently, PIFSC is providing satellite telemetry tags to partner researchers at Cascadia Research for deployment on short-finned pilot whales to evaluate changes in distribution and movements in response to the ongoing El Niño.

The Council is in the process of revising its five Fishery Ecosystem Plans to strengthen their ecosystem information, including climate change. The draft plans are under NOAA internal review. The archipelagic and pelagic annual reports of these plans will include monitoring of climate related variables, climate change impact indicators, and reference points. The key facet of the annual Ecosystem Status Report is the data integration of the ecosystem parameters (including climate related variables) with the fishery-dependent data to explain the trends in each of the fisheries being monitored. Community workshops will ensure that the data and reference points align with local needs and reflect local values. Lastly, as part of the West Hawaii Integrated Ecosystem Assessment (IEA), a suite of indicators including climate variables have been developed (Gove et al. In Press).

Objective 3 Design adaptive decision processes that can incorporate and respond to changing climate conditions.

The PIRO Monument Office develops and implements management plans for the four Marine National Monuments in the Pacific. Management plans are designed to be adaptive approaches to managing these protected ecosystems in changing climates. For the Papahanaumokuakea MNM, a draft Climate Change Action Plan is in review. This extensive document identifies strategies for addressing climate change in several areas and has the following five goals: i) implement multidisciplinary research and monitoring efforts to understand variation in resilience and climate change impacts across the Hawaiian Archipelago under differing climate change scenarios, ii) implement appropriate adaptive actions before ecosystem integrity and social values are compromised, iii) contribute toward regional and national efforts to raise awareness about climate change and change behavior through strategic partnering and engagement in policy, education, and outreach, iv) serve as an international example in the context of climate change for collaborative management of natural, cultural, and historic resources that hold universal and indigenous significance, and v) account for climate change in operations and logistical planning. For the Marianas Trench Marine National Monument activities from the draft plan include: i) identifying management options to maintain ecological integrity for species and systems considered vulnerable to climate change, ii) conducting a vulnerability assessment to understand potential climate change scenarios, iii) locating areas within the Marianas Marine National Monument that demonstrate potential for climate change resilience, and iv) convening a working group to identify key climate change research questions. Though it will be a challenge to implement these management approaches, the development of effective evaluation tools is a key step in the process.

In the case of Hawaiian monk seals, adaptive management approaches being considered include translocation and captive care/rehabilitation. The conservation benefits of these activities could be maximized if variation in juvenile seal survival could be better predicted spatially and temporally. Previous studies identified a link between the latitude of a major oceanographic front and subsequent monk seal survival in a portion of the NWHI (Baker et al. 2007). If this relationship was better characterized and drivers of productivity in other portions of the seal's range could be identified, they could be incorporated into translocation and captive care plans (Baker et al. 2007, 2011, 2012, 2013). This may best be achieved by future downscaling of earth system models, including biological variables, to the Hawaiian Archipelago.

Objective 2 Identify robust strategies for managing living marine resources under changing climate conditions.

The Center is beginning to perform some management strategy evaluations (MSE) using outputs from earth systems models and ecosystem models to project the state of resources of interest under various management actions and levels of climate change. For example, an Atlantis ecosystem model of the Guam coral reef ecosystem was coupled with output from a climate model to explore the impacts on coral biomass of several management scenarios in the presence of bleaching and ocean acidification (Weijerman et al. 2016). The model predicted that management actions could slow but not prevent a collapse in coral biomass over the next few decades assuming a business-as-usual greenhouse gas emissions scenario (Fig. 4, Weijerman et al. 2016).

Objective 1 Identify appropriate, climate-informed reference points for managing marine resources.

Most of the work incorporating climate information into reference points to date has focused on the pelagic ecosystem and addressed impacts at the broader ecosystem level. Impacts to ecosystem trophic structure, biomass, and fishery catch for the Hawaii-based longline fishery have been projected with two very different ecosystem models (size-based and species-based) coupled to the phytoplankton outputs from earth system models (Fig. 5, Howell et al. 2013, Woodworth-Jefcoats et al. 2013, Woodworth-Jefcoats et al. 2015).

In summary, while few staff are engaged full time in climate work, the Pacific Islands region actively incorporates climate themes in its research and management. A major strength of the region is its ability to track ecosystem trends and changes based on historical and ongoing monitoring, including research surveys and instrumentation covering the coral reef ecosystem, multi-decadal demographic time series of the monk seal population, and multi-decadal time series of catches from the Hawaii-based longline fishery and other fisheries, along with data from periodic socio-economic surveys. Multi-decadal time series of satellite remotely-sensed oceanographic data provide environmental monitoring. The region also has a significant effort using physical and biological outputs from dozens of the most advanced earth systems models to project the physical and biological impacts from climate changes in the region and to drive pelagic ecosystem models to project ecosystem and fisheries impacts. The region is proactive in incorporating climate change considerations in many of its regulatory actions and management

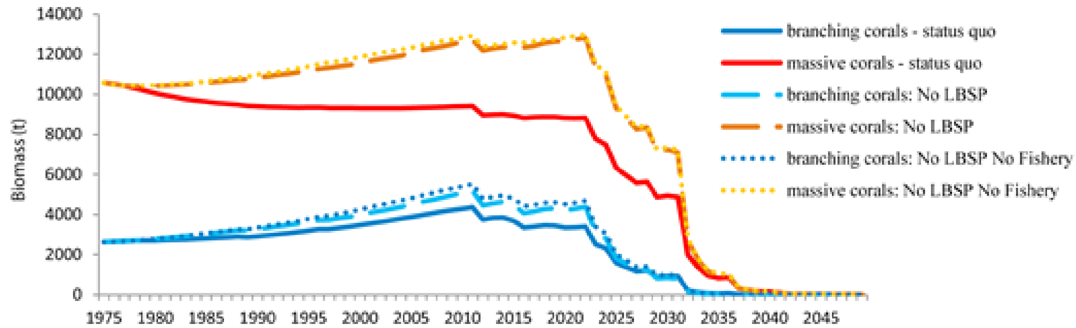


Figure 4. Biomass trajectories of massive corals and branching corals under four management approaches simulating the effects of predicted climate change (ocean acidification and ocean warming) under the IPCC AR5 RCP 8.5 emission scenarios. The scenarios were i) status quo, ii) no land-based sources of pollution (LBSP), and iii) no fishing and no LBSP scenario (Weijerman et al. 2016).

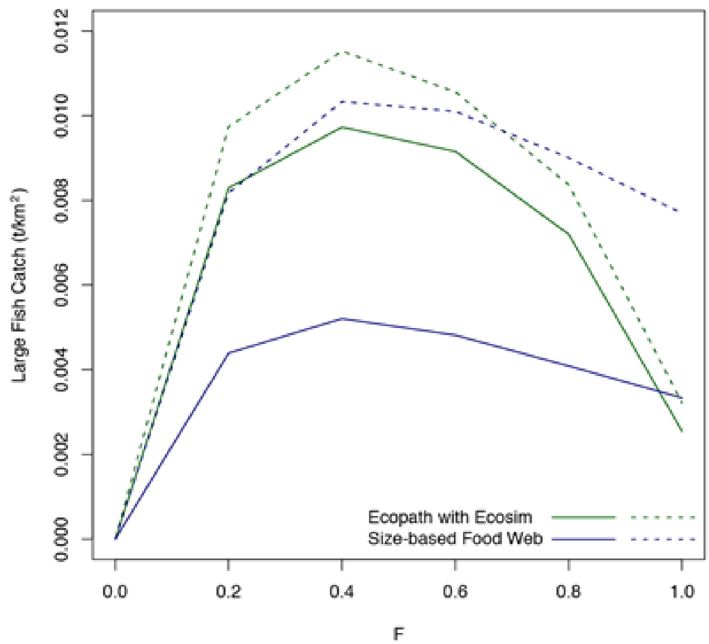


Figure 5. Multispecies yield curves and multispecies MSY for large pelagic fishes in the subtropical ecosystem from two ecosystem models without (dashed lines) and with (solid lines) climate change (derived from Woodworth-Jefcoats et al. 2015).

plans. Areas for improvement include identification and implementation of management strategies that are robust under climate change, identification of climate-informed reference points for species in managed fisheries, and an increased understanding of many of the processes or mechanisms linking climate change to subtropical ecosystems. Some challenges for the Pacific Islands region are its vast size, diverse ecosystems, and the remote nature of the areas managed. Little infrastructure is available outside the Honolulu office to support climate related studies or to monitor changes over time. Such work is, therefore, resource and time intensive and, in the Pacific, dependent on building partnerships with other institutions and organizations to pool already limited resources.

IIIb. Assessment of Priority Climate Data and Information

I. **Future climate scenario projections for the region.** Future climate scenarios are most commonly, but not exclusively, the output of earth systems models consisting of a suite of physical and in many cases low trophic biological variables. The spatial scale of these models is currently approximately 1° with monthly to yearly temporal resolution which is adequate for the pelagic ecosystem and long-term projections, but downscaled model output will likely be required for the insular ecosystem, including deepwater bottomfishes, and the coral reef ecosystems and phenological applications. These climate scenarios will support the work in Objectives 1,2,3,4.

II. **Development of models of managed and protected species, their habitats, and key ecosystems including human communities that can incorporate output from climate scenarios to project impacts.** These models serve as the link between the climate scenarios including outputs of the climate or earth system models, and impacts to the species and habitats of management focus. These models are wide ranging and include socio-economic models to assess economic, social, and cultural impacts to human populations, fish and protected species population models that estimate maximum sustainable yield (MSY) or extinction risk, ecosystems models that estimate multispecies MSY, shoreline habitat models that project changes in terrestrial habitat in response to sea level rise, and animal movement models as well as more qualitative climate vulnerability models. The key requirement is to develop approaches to incorporate climate scenarios and/or data into these models. A challenge that is not well addressed by models is the identification of the occurrence of invasive species in response to climate change unless the invasive species are anticipated in advance and incorporated into the models. These models will address Objectives 1,2,3,4,5.

III. **Information on the mechanisms of how climate impacts the key species, habitats, and ecosystems of interest.** A limitation in our ability to project climate impacts for key species and habitats is our lack of understanding of the mechanisms resulting in the impacts. This information can come from field studies, comparative studies, and laboratory studies. Advancing our understanding of the mechanisms linking climate to the changes in key populations and habitats will result in improved models to support work identified in needs I and II. This information will address Objectives 1,2,3,4,5.

IV. **Information on specific robust management and harvest strategies and approaches to identifying robust management strategies under climate change that address multiple user objectives.** One need is to learn more about robust management and harvest strategies, including traditional approaches and experiences in other applications or regions, to identify possible approaches for the Pacific Islands region. There is a need to conduct management strategy evaluations (MSEs) to quantitatively evaluate strategies under a suite of climate scenarios and multiple user priorities. Lastly the need exists to develop a management strategy and coordination between adjacent Council regions and between the Council and State/Territorial agencies to address shifts in management unit species distribution and change in fisheries dynamics due to climate change impacts. This information will address Objectives 2,3.

V. **Strengthen monitoring and reporting of climate trends and ecosystems responses.** The need is to document how physical, biological, and human dimension indices have been changing. This requires physical and biological monitoring programs for fisheries, protected species, human communities, and ecosystems of high priority that support timely reporting of key indicators. The region is just beginning to develop trends and status reports or ecosystems considerations chapters that consist of time series of climate and ecosystem (including human dimensions) data to augment single species stock assessments. This will involve collaborations between, physical, biological, and social scientists. This information will address Objective 6.

VI. **Staff and training for the needs identified previously and computer infrastructure for the considerable computing these tasks require.** The need is for both additional staff as well as training for current staff in order to fulfill the previously identified needs. Additionally, improved computer infrastructure is necessary to conduct the modeling and analysis activities addressed above. For example, the region currently lacks the expertise and computing resources necessary to either downscale current climate and earth system model output or develop new modeling strategies. These resources will address Objectives 1,2,3,4,5,6,7.

Highest priority areas for climate information, products, and services:

i. In support of fisheries management of deepwater bottomfishes, coral reef fishes, striped marlin, bigeye tuna, yellowfin tuna, and swordfish. Specifically, climate-informed Maximum Sustainable Yield (MSY) and annual catch limits (ACLs) for most insular species with deepwater bottomfishes and coral reef fishes having the highest priority.

ii. In support of assessments of habitats and populations of endangered and threatened species in order to make jeopardy and critical habitat determinations, assess extinction risk, evaluate listing/de-listing criteria, develop impact mitigations strategies, to provide context for environmental analysis for fisheries management actions, and develop and inform realistic recovery plans under the Endangered Species Act (ESA) and take reduction plans under the Marine Mammal Protection Act (MMPA).

iii. In support of assessments of impacts to coastal habitats, especially for the low-lying islands found throughout the region, that provide infrastructure for human communities that use the ocean as well as critical pupping and nesting habitat for protected species.

iv. Conduct species vulnerability studies.

v. To evaluate climate driven changes to the structure and energy flows of insular and pelagic food webs with emphasis on impacts to protected and managed species.

vi. Assess impacts of climate change on coastal human communities, their culture, food security, and economics for various fisheries.

IV. The Action Plan

Actions listed by objective and summarized in Table 1.

Objective 7 Build and maintain the science infrastructure needed to fulfill NOAA Fisheries mandates under changing climate conditions.

- Convene an annual internal workshop to exchange climate change results and information needs among staff at PIRO (P), Science Center (S), and Council (C) (P/S/C) (FY17-21).
- Participate in the Marine Mammal Distribution Shifts Workshop and communicate results to relevant staff (S/P) (FY 17).
- Participate in the Protected Species Climate Vulnerability Workshop and communicate results to relevant staff (S/P) (FY 17).
- Participate in ICES-PICES international working group on climate change impacts on fish and fisheries (S/P) (FY 17).
- Regularly publish climate and ecosystem research (S/P/C) (FY17-21).
- Conduct community-based workshops to exchange information including climate change information (C) (FY 17).
- Assemble information on traditional knowledge as it pertains to climate change (C) (FY 17).
- Build local capacity through training programs to support development of climate-informed community-based socioeconomic monitoring programs (S) (FY17-21).

Objective 6 Track trends in ecosystems, living marine resources, and resource-dependent human communities and provide early warning of change.

- Develop and track appropriate climate indices for inclusion in the Council's annual reports (S/C) (FY17-21).
- Continue monk seal survey and monitoring of demographic rates in the Hawaiian Archipelago and continue research linking these rates with climate and oceanographic variables (S) (FY17-21).
- Continue ongoing monitoring of Hawaiian green sea turtles in the NWHI including (i) monitoring index site nesting abundance at East Island, French Frigate Shoals, (ii) expansion of demographic rate measurements (e.g., number, frequency and size of clutches, hatching success, and emergence rates), (iii) assessment of remigration intervals for individual nesters through mark-recapture methods, (iv) assessment of nesting activity at non-index nesting sites throughout the NWHI (S/P) (FY17-21).
- Continue and expand both spatially and temporally the temperature logging efforts for green turtle nests in the NWHI and hawksbill nests in the MHI (S) (FY17-21).
- Continue collecting long-term autonomous acoustic data from several locations in the central and western Pacific for assessment of cetacean occurrence and seasonality (S) (FY17-21).

- Continue vessel-based visual and acoustic surveys of cetacean distribution, abundance and stock structure within US Pacific Islands EEZs (S) (FY17-21).
- Maintain and if possible expand coral reef ecosystem monitoring (NCRMP) (S) (FY17-21).
- Update suite of social indicators of fishing community vulnerability and resilience in Hawaii using more recent data. Explore potential for expanding social indicators to U.S.-affiliated island areas of the Western Pacific (S) (FY 17).
- Update suite of social indicators of fishing community vulnerability and resilience every 5 years as new American Community Survey data become available (S) (FY17-21).
- Conduct regular survey (every 5 years) of fisher attitudes and preferences of current ecosystem health and monitor trends in perceptions of climate change impacts (S) (FY17-21).
- Perform analysis with a suite of our monitoring time series to identify statistically significant declines or increases that are coherent with climate indices (S) (FY17-21).

Objective 5 Identify the mechanisms of climate impacts on ecosystems, living marine resources, and resource-dependent human communities.

- Build correlative models of climate drivers of coral reef ecosystem spatial temporal patterns (S) (FY17-21).
- Examine spatial changes in the Hawaii-based longline fishery catch and effort relative to changes in climate indices including ocean temperature and productivity (S) (FY17).
- Develop and run Ecopath/Ecosim model to evaluate impacts of fishing and climate change on monk seal population in Hawaiian Archipelago (S) (FY17-18).
- Initiate laboratory and field experiments to evaluate mechanistic linkages among environmental drivers, genetics, and coral reef physiological responses and resilience (S) (FY17).
- Conduct a review to assess effects of how climate and other factors impact protected species and influence their interactions with fisheries (C) (FY18).
- Develop robust models to estimate and predict trip costs within the Hawaii and American Samoa longline fisheries to allow for assessing potential costs of future climate scenarios (S) (FY17).
- Develop economic models of fisher participation and drivers of spatial location choice in Hawaii longline fishery to assess behavioral responses and predict impacts from climate change (S) (FY17).

Objective 4 Identify future states of marine, coastal, and freshwater ecosystems, living marine resources, and resource-dependent human communities in a changing climate.

- Describe projected oceanographic impacts of climate change from 11 earth system models (S) (FY 17).
- Conduct fish species vulnerability assessments (S) (FY17).
- Project climate change impacts on pelagic fishery yields and ecosystem size and trophic structure projected with output from 11 earth system models used in 2 ecosystem models to develop climate informed estimates of multispecies maximum sustainable yield and ecosystem reference points (S) (FY17).
- Project climate change impacts on the spatial distribution of pelagic fishes in the central North Pacific and coral reef fishes in the Coral Triangle using spatially explicit ecosystem models and output from earth system models (S) (FY20).

Objective 3 Design adaptive decision processes that can incorporate and respond to changing climate conditions.

- Incorporate climate change information to inform management designations of protected species critical habitat and recovery planning (P) (FY17-21).

Objective 2 Identify robust strategies for managing living marine resources under changing climate conditions.

- Conduct management strategy evaluations and regulatory reviews to identify strategies that are robust under climate change scenarios for various fisheries and management actions (P/C) (FY17-21).

- Incorporate climate change information in NEPA and ESA analyses (P/C) (FY17-21).
- Incorporate climate change information into Fishery Ecosystem Plans when updated and analysis of actions that fall under plans (P/C) (FY17-21).
- Incorporate climate change information into MNM management plans when updated and analysis of actions that fall under plans (P/C) (FY17-21).

Objective 1 Identify appropriate, climate-informed reference points for managing marine resources.

- Incorporate climate data into the billfish stock assessment (S) (FY17).
- Incorporate climate information into the bottomfish stock assessment (S) (FY18).
- Begin incorporating climate impacts in coral reef fish annual catch limits (ACLs) (S/C) (FY18).

Actions with additional resources:

Objective 7 Build and maintain the science infrastructure needed to fulfill NOAA Fisheries mandates under changing climate conditions.

The current action plan assumes very modest growth in staff and training to support our climate activities under the current budget scenario. **Additional resources** in growth of staff (1-3/yr) to focus on climate work and staff training, as well as computer infrastructure, are needed to address the additional work outlined in this section (S/P/C). This addresses need VI in section IIIb.

Objective 6 Track trends in ecosystems, living marine resources, and resource-dependent human communities.

This objective is addressed in our current action plan with ongoing monitoring for monk seals, cetaceans, sea turtles, coral reefs and reef fishes, and fisheries data. We will also be developing and evaluating climate indicators and contributing climate indices and information to the Fisheries Ecosystem Plan annual Ecosystem Status Reports. **Additional resources** in both ship time and staff are needed to strengthen our survey and monitoring programs to specifically identify climate impacts across all trophic levels and to improve the scope and timeliness of analyses from these programs. Additional funds are needed to use new sampling tools and methods and broaden the scope of partners. This addresses need V in section IIIb.

Objective 5 Identify the mechanisms of climate impacts on ecosystems, living marine resources, and resource-dependent human communities.

We will address this objective with some laboratory experiments to evaluate mechanistic linkages between environmental drivers, genetics, and coral reef physiological responses. **Additional staff** is needed to build sophisticated models of the impacts of sea level rise on low islands (S). Further work is needed that employs rigorous statistical analysis to identify mechanisms of how climate impacts key species, habitat, and ecosystems by using the spatial and temporal variation in our various monitoring programs (corals, monk seal, turtles, longline observer, and logbook) data together with climate variables (S). Development of physiologically-based models to understand impacts of resource availability on the reproductive output (e.g., of sea turtles) through delayed sexual maturity or remigration intervals (S). Develop robust models to estimate and predict trip costs within the Hawaii and American Samoa insular fisheries to allow for assessing potential costs of future climate scenarios (S). Develop economic models of fisher participation and drivers of spatial location choice in Hawaii insular fisheries to assess behavioral responses and predict impacts from climate change (S). This work addresses need III in section IIIb.

Objective 4 Identify future states of marine, coastal, and freshwater ecosystems, living marine resources, and resource-dependent human communities in a changing climate.

We will address this objective with the analyses of the physical and biological output from 11 earth system models, however for insular and phenological applications these outputs will need to be spatially downscaled. We will also address this objective by incorporating output from climate models in ecosystem models, several fisheries models, and coral reef ACLs. However, this work falls short in fully addressing all our needs to project climate impacts with models. Thus **additional staff** will be needed to support dynamic or statistical downscaling of earth system model output for insular and phenological applications and makes these results available to the local communities (S). Resources will be needed to support development of models that incorporate climate data for human community, stock assessment, and protected species needs. Currently our models do not have adequate spatial resolution so support is needed to advance in this area, especially to develop human community response models, spatial ecosystem models, and critical habitat models (S). If data gaps can be addressed and support for personnel is available, the Ecopath/Ecosim model developed in FY16/17 may be expanded to an Atlantis ecosystem model with a monk seal component. This work addresses needs I and II in section IIIb.

Objective 3 Design adaptive decision processes that can incorporate and respond to changing climate conditions.

Our action plan addresses this objective by providing climate information to managers via Ecosystem Status Reports, indicators, etc. **Additional resources** in staff are needed to research and evaluate approaches to adaptive decision processes beyond our region. This work will address need IV in section IIIb.

Objective 2 Identify robust strategies for managing living marine resources under changing climate conditions.

Our action plan addresses this objective by incorporating climate information in various mandated management actions and Fishery Ecosystem Plans annual reports. **Additional resources** are needed to undertake more quantitative analyses to identify and evaluate robust management and harvest strategies, and conduct management strategy evaluations under climate change (S/P/C). This work addresses need IV in section IIIb.

Objective 1 Identify appropriate, climate-informed reference points for managing marine resources.

Our action plan addresses incorporating climate information in two stock assessments and beginning to address climate impacts in coral reef fishery ACLs. **Additional resources** are needed to extend this work to more stock assessments and more quantitatively address climate impacts in coral reef fishery ACLs. This work addresses needs IV and V in section IIIb.

V. Metrics

Science quality and quantity:

1. Number of peer-review publications produced that address climate change and climate impacts.
2. Completion of species climate vulnerabilities studies.

Supporting fisheries and protected species management:

1. Number of Ecosystem Status Reports that incorporate climate information and/or indices.
2. Number of stock assessments and ACLs that are climate-informed.
3. Number of NEPA and ESA analyses that are climate-informed.
4. Number of protected species recovery plan and critical habitat designation analyses that incorporate climate information.

Strengthening climate science infrastructure:

1. Number of long-term monitoring time series or assessments maintained and distributed.
2. Full-time equivalent (FTE) time (part time plus full time) devoted to climate science.
3. Number of climate workshops or conferences attended or convened.

TABLE 1– ***RAP ACTION ITEM TABLE***

Action Name (short title)	Funding Scenario (Level or Increase)	Time Frame (years)	Action Description (short description of who, what, key products and expected outcomes)	POC (name)	Partners	Other Objectives Addressed (1 – 7)
Objective 1 – Climate Informed Reference Points						
Climate informed bill-fish MSY	Level	2017	Incorporate climate data into the billfish stock assessment	Boggs	NMFS, Council	
Climate informed bot-tomfish MSY	Level	2018	Incorporate climate information into the bottomfish stock assessment	Boggs	NMFS, Council	
Climate informed coral reef ACLs	Level	2018	Begin incorporating climate impacts in coral reef fish annual catch limits	Brainard	NMFS, Council, University	
Climate informed references points for fisheries and protected species	Increase	2017-2021	More fully address climate impacts on fishery and protected species reference points	various	NMFS, Council, University	
Objective 2 – Robust Management Strategies						
Fisheries MSEs	Increase	2017-2021	Conduct management strategy evaluations for selected fisheries to identify strategies that are robust under climate change scenarios for various fisheries and management actions	Boggs	NMFS, University	
Objective 3 – Adaptive Management Processes						
Identify adaptive man-agement	Level	2017-2021	Identify adaptive decision process that work well in other regions to respond to climate impacts and evalu-ate them for the PI region.	Dreflak	NMFS, Council	
Objective 4 – Project Future Conditions						
Projected climate change impacts in open ocean	Level	2017	Describe projected oceanographic impacts from cli-mate change from 11 earth system models	Polovina	NMFS	

Coral reef assessment	Level	2017	Conduct coral reef climate vulnerability assessments	Brainard	NMFS, University	
Insular and pelagic fishes assessment	Level	2017-2021	Conduct assessments of vulnerability of insular and pelagic fishes to climate change	Kobayashi	NMFS, Council, University	
Projected pelagic ecosystem impacts from climate change	Level	2018	Project climate change impacts on pelagic fishery yields and ecosystem size and trophic structure projected with output from 11 earth system models used in 2 ecosystem models to develop climate informed estimates of multispecies maximum sustainable yield and ecosystem reference points	Polovina	NMFS	
Projected coral reef fishes impacts from climate change	Increase	2021	Project climate change impacts coral reef fishes in the Coral Triangle using spatially explicit ecosystem models and output from earth system models	Brainard	NMFS, University	
Downscale climate model output	Increase	2018-2021	Perform dynamic or statistical downscaling of earth system model output for insular and phenological applications and makes these results available to the local communities	various	NMFS, Council, University	
Ecosystem model improvement	Increase	2018-2021	Develop and apply models that incorporate climate data for human community, habitats, stock assessments, and protected species needs including models with spatial resolution	various	NMFS, Council, University	
Objective 5 – Understand the Mechanisms of Change						
Coral reef lab studies	Level	2017	Initiate laboratory experiments to evaluate mechanistic linkages between environmental drivers, genetics, and coral reef physiological responses and resilience	Brainard	NMFS, University	
Coral reef ecosystem field studies	Level	2017-2021	Building correlative models of climate drivers of coral reef ecosystem spatial temporal patterns	Brainard	NMFS, University	
Pelagic ecosystem analyses	Level	2017-2021	Examine spatial changes in the Hawaii-based longline fishery catch and effort relative to changes in climate indices including ocean temperature and productivity	Polovina	NMFS, University	
Monk seal modeling	Level	2017-2018	Develop and run Ecopath/Ecosim model to evaluate impacts of fishing and climate change on monk seal population in Hawaiian Archipelago	Littnan	NMFS, University	

Economic longline fishery models	Level	2017	Develop robust models to estimate and predict trip costs within the Hawaii and American Samoa longline fisheries to allow for assessing potential costs of future climate scenarios	Hospital	NMFS, University	
Modeling response of longline fishers to climate change	Level	2017	Develop economic models of fisher participation and drivers of spatial location choice in Hawaii longline fishery to assess behavioral responses and predict impacts from climate change	Hospital	NMFS, University	
Climate impacts on protected species interactions	Level	2018	Conduct a review to assess effects of how climate and other factors impact protected species and influence their interactions with fisheries	Simonds	Council	
Model sea level rise impacts	Increase	2019-2021	Build sophisticated models of the impacts of sea level rise on low islands	various	NMFS, University	
Advanced statistical analyses of monitoring programs to detect climate impacts	Increase	2017-2021	Employs rigorous statistical analysis to identify mechanism of how climate impacts key species, habitat, and ecosystems by using the spatial and temporal variation in our various monitoring programs (corals, monk seal, turtles, longline observer and logbook) data together with climate variables	various	NMFS, University	
Develop physiological and energetics models	Increase	2017-2021	Development of physiologically-based models to understand impacts of climate change on fishes and protected species	various	NMFS, University	
Model fishers economics and behaviors in response to climate change	Increase	2018-2021	Develop economic and behavioral models to predict impacts from climate change on fisheries	Hospital	NMFS, University	
Objective 6 – Track Change and Provide Early warnings						
Continue monk seal surveys and monitor-ing	Level	2017-2021	Collect monk seal demographic rate data and link these rates to climate and oceanographic variables	Littnan	NMFS, University	5
Continue ongoing monitoring of Hawaii green sea turtles in NWHI	Level	2017-2021	Collect sea turtle demographic rate data and link these rates to climate and oceanographic variables	Jones	NMFS, University	5

Continue collecting passive acoustic data on cetaceans in the central and western Pacific	Level	2017-2021	Collect long-term autonomous data from several locations to assess cetacean occurrence and seasonality.	Oleson	NMFS, University	5
Contribute climate indices to Council's annual reports	Level	2017-2021	Develop and track appropriate climate indices for inclusion in the Council's annual reports	various	NMFS, Council, University	
Coral reef ecosystem monitoring	Level	2017-2021	Maintain coral reef ecosystem monitoring	Brainard	NMFS, University	
Monitor social indicators	Level	2017-2021	Update suite of social indicators of fishing community vulnerability and resilience in Hawaii and US affiliated Pacific Islands	Hospital	NMFS, Council, University	
Fishers survey	Level	2017-2021	Conduct regular survey (every 5 years) of fisher attitudes and preferences of current ecosystem health and monitor trends in perceptions of climate change impacts	Hospital	NMFS, Council, University	
Climate focused monitoring	Increase	2017-2021	Expand monitoring to more directly assess climate impacts on ecosystems, key species, and habitats with additional effort, new tools, and additional analyses.	various	NMFS, Council, University	
Objective 7 – Science Infrastructure to Deliver Actionable Information						
Build staff capacity	Level	2017-2021	Staff participation in various local, national, and international trainings, workshops, working groups, and conferences.	various	NMFS	
Allocate existing staff	Level	2017-2021	Support climate work by allocating existing staff with appropriate skills	various	NMFS	
Hire new staff to address climate work	Increase	2017-2021	Add 1-3 staff/yr to fully address climate work needs	various	NMFS	
Increase ship time for monitoring	Increase	2017-2021	Add additional days at sea of ship time to expand monitoring of climate impacts on key ecosystems, species, and habitats	various	NMFS	

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