PACIFIC ISLANDS FISHERIES SCIENCE CENTER

Summary Report from the First Annual Collaborative Climate Science Workshop 19-21 September 2017 NOAA's Inouye Regional Center Honolulu, Hawaii

Phoebe A. Woodworth-Jefcoats

January 2018

Administrative Report H-18-01

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BACKGROUND

The National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS) has enacted a climate science strategy as part of its proactive approach to better track, forecast, and incorporate information on changing climate conditions into living marine resource management. This strategy is being implemented through customized 5-year Regional Action Plans for climate science (RAPs). These RAPs detail regional climate science needs and specific action items to address them. The drivers and impacts of climate change vary greatly by geographic location. By creating action plans at the regional level, NMFS can tailor its response to meet specific challenges and forge critical partnerships at the local level.

A first step in implementing that Pacific Islands Regional Action Plan for climate science (PIRAP) is to identify what information is needed by resource managers and what scientific research and data are available or being developed. Furthermore, regional staff will need to keep abreast of changes on these fronts. To this end, PIRAP authors decided to convene an internal Annual Collaborative Climate Science Workshop. The first workshop, detailed here, was held in September 2017. It was attended by scientists and advisors from NOAA Fisheries Pacific Islands Regional Office (PIRO) and Pacific Islands Fisheries Science Center (PIFSC), as well as the Western Pacific Regional Fishery Management Council (WPRFMC).

The specific goal of this workshop was to identify climate-related information needs, the science products available or in development that can address these needs, and also the potential existing gaps. The workshop spanned three afternoons, with each afternoon focusing on a specific topic: protected species, coral reefs and insular/bottomfish, and pelagic/highly migratory fish. Each afternoon, participants met in small groups for facilitated discussions to identify climate-related information needs, with each group choosing three "top priority" needs. Participants then reconvened for a plenary exercise to aggregate these "top priority" needs and look for commonalities. Once an aggregated list was generated, participants identified science products that could potentially address individual information needs. Current scientific and/or management limitations were also identified. This report synthesizes and summarizes the information gathered from this workshop.

EMERGENT THEMES

The common thread running throughout the workshop was adaptive capacity. In other words, how is the climate going to change, and what capacity do ecosystems and communities have to adapt to these changes? The information needed to address these questions falls into four broad themes which cut across each day's discussions and information needs. These themes are: Basic Science and Research, Monitoring, Projecting Future Conditions, and Persistent Challenges. There is also considerable overlap between these themes, as illustrated in Fig. 1.

The example of allowable take/catch limits encompasses the overlap between the workshop's themes well (Fig. 2). Considering climate change in setting these limits first requires a better understanding of how species are impacted by their environment. What environmental conditions are species currently facing and where? How sensitive are species to changes in ocean temperature, productivity, and acidification? How sensitive is their prey? These are basic science and research questions for which we currently lack answers in many cases. Long-term monitoring is an essential first step in gathering the data necessary to answer these questions, and then to assess whether and how the environment is changing as well as whether and how species may be responding to such change. Projections of future changes are needed to estimate future impacts. At each of these steps, challenges related to communicating scientific results, the sheer size of the region, and inevitable data gaps must be overcome. Additionally, the information gathered at each of these steps can be used toward additional management questions. For example, it can help inform questions related to changing human dependency on fisheries, trophic cascades, or strategies for effective communication.

Adaptive Capacity

Most of the information needs raised ultimately relate to adaptive capacity, both of the ecosystem and of communities. There were many questions related to species' response to rising temperatures and changing productivity. These ranged from basic questions about physiological limits to more nuanced questions about which life stages might be most vulnerable or how sex ratios or population viabilities might change as temperatures rise. There were also questions about how species will be able to adapt to habitat changes as sea levels rise and the ocean warms.

Looking beyond protected and managed species, there were a number of questions related to social adaptive capacity. How much change in fisheries can fishing communities withstand? For example, how far are fishers able to travel? How much and how easily can change in catch volume or composition be absorbed?

Basic Science and Research

A number of basic science and research questions were identified across the 3 days of the workshop. Some of these questions related to foundational information necessary for stock and vulnerability assessments. These included better understanding of populations segments and stocks as well as species' life history rates and parameters, diet studies, process studies, and an improved understanding of intermediate trophic levels. These types of basic information are needed for a number of both protected and commercially valuable species before we can begin to understand how they might be impacted by climate change and what their potential adaptive capacity might be.

Workshop participants also highlighted the need for further knowledge on restoration science. The importance of traditional knowledge was also raised, along with the need to incorporate traditional knowledge into both climate science and the management of living marine resources.

Monitoring

The need for consistent, high-quality, long-term monitoring was raised throughout the workshop. This is needed as a component of the basic science discussed above, as well as to establish baseline conditions and identify trends. Furthermore, novel approaches to monitoring were encouraged. This need, more so than any others, also involves partnering and data sharing. Partnerships are essential for maintaining time series across the Pacific Islands region. Data sharing is also essential, and given recent federal mandates, is often required.

Projecting Future Conditions

The need for robust projections of future conditions reaches into nearly every question raised at the workshop. These projections are needed for a host of variables (productivity, temperature, acidity, sea level, etc.) to determine things like habitat shifts, risk to critical infrastructure, and stock movement. They're also needed at scales that are currently challenging: fine spatiotemporal scales and in dynamic coastal environments. Projections of future conditions are needed for scenario planning and population assessments.

Along the lines of projecting future conditions, a number of workshop participants identified the need for scenario planning. For example, there are situations where managers need robust alternative future scenarios to evaluate proposed management actions. Scenario planning is also needed to determine the impact that a proposed management action might have on the future climate.

Persistent Challenges

Several persistent challenges were identified. One challenge that was raised each day was that of effective communication between stakeholders, managers, and scientists. Scientists are often not particularly skillful in communicating their work to non-scientists, including managers and stakeholders. Additionally, there is also a lack of effective communication in the opposite direction. This is important because managing living marine resources in a changing environment will inevitably involve tradeoffs. Deciding how to balance these tradeoffs depends, in part, on understanding how stakeholders value different resources. For example, if changing ocean conditions result in increased interactions between fisheries and protected species, the value the public places on fisheries will have to be weighed against that which it places on protected species. A similar tradeoff could result as rising sea levels create a choice between preserving either infrastructure or critical habitat. Effective communication between all parties will be crucial in these situations. Furthermore, effective communication has the potential to increase trust between scientists, managers, and stakeholders, which could lead to benefits such as higher-quality fishery-dependent data and improved regulatory compliance.

Another persistent challenge was the transboundary nature of many living marine resources in the Pacific Islands region. Many organisms routinely move between State, Federal, and international waters. While this has obvious management challenges, it also leads to challenges in monitoring species to gain basic information about their life history, diet, and adaptive capacity.

Finally, and perhaps not unexpectedly, the challenge of limited resources was raised. The Pacific Islands region has few, if any, staff working full-time on climate science. Furthermore, the region is both vast and far from the continental United States. The region's size makes monitoring both expensive and time consuming. And the region's remoteness can make collaborating with the broader scientific community challenging.

Additional challenges identified included those related to the legal challenges associated with the uncertainty inherent in climate change, the long-term commitments necessary for effective monitoring, historical and international data gaps, and constraints imposed by management structures.

SYNERGIES AND GAPS

Pairing existing in-house science products with climate-related information needs illustrated both synergies and gaps. Furthermore, a number of science products were identified as being able to meet multiple information needs, often spanning two or three of the daily workshop topics (Fig. 1). The current scientific and management limitations that participants raised further illustrated gaps.

Synergies

The workshop identified over three times as many unique science products as it did information needs. At the same time, several science products were identified as being able to meet multiple needs. This is encouraging and suggests that a considerable amount of information already exists that can be brought to bear on current resource management.

The topic that appears to have the most potential synergies is the impact of climate on bottomfish and the bottomfish fishery (Table 1). Multiple bottomfish monitoring data sets were identified (fishery-dependent and -independent), as well as time series of environmental conditions and preliminary research on this topic. Additionally, an Atlantis model that is in development will be applicable to this topic.

Taking the opposite perspective on potential synergies – individual products that can address multiple information needs – there are several examples. The Main Hawaiian Islands Atlantis model that's in development was identified as being able to address quite a number of information needs. Data hosted by the OceanWatch program was also identified as having many potential applications. Likewise, a range of coral reef environment time series were identified throughout the workshop. Finally, several socioeconomic monitoring products were identified as applicable to information needs raised for each of the workshop's daily topics.

Gaps

Only one information need was raised for which no science products were identified. This was the sensitivity of prey and target species (e.g., calcareous plankton, larval fish) to ocean acidification. While there is work being conducted at PIFSC to understand the impacts of ocean acidification on coral reef and benthic communities, no work is being done for pelagic organisms. Given that the region's most valuable commercial fishery is the pelagic longline tuna fishery, this is a significant information void. That said, it is worth noting that very little research has been done on this topic by the broader scientific community. If the right collaborators can be identified, this is a topic ripe for investigation.

Additional gaps were identified by the current scientific and management limitations that participants raised in response to information needs. Most of these tied back to the basic science and research needs discussed above. For example, a number of participants highlighted the lack of baseline population information. A lack of clear mechanistic understanding about the impact of environmental change on species across their life histories was also consistently highlighted.

SUMMARY AND NEXT STEPS

The first Annual Collaborative Climate Science Workshop brought together participants from a range of scientific, management, and community backgrounds, thereby allowing scientists and managers to become more familiar with each other's work. The workshop's exercises highlighted pressing climate-related information needs that can help direct the region's climate science. Additionally, more than 80 unique science products with points of contact were identified and are available to all workshop participants and local NMFS leadership. This list should not only help managers access the information they're seeking, but it should also lead to collaboration between scientists and to wider application of existing data.

Addressing some of the persistent challenges and gaps identified through this workshop is a logical next step. While the most-commonly stated need was for improved future projections, accomplishing this is likely beyond the expertise of regional staff (though it is an area of active research by other NOAA entities and collaborators). However, another highly ranked need was for better understanding of mechanistic relationships between the environment and species' life history, diet, abundance, and range. This information is essential for climate-informed management strategies. It is also an area where quite a number of science products and preliminary studies were identified. Focusing resources on this area of research could have a large and positive impact on the region’s ability to incorporate changing climate conditions into living marine resource management.

It is hoped that the information generated at the first Annual Collaborative Climate Science Workshop can help inform regional NMFS planning and priorities as they relate to climate science and the management of living marine resources in a changing environment. It’s clear from this workshop that a tremendous amount of information and motivation exists. The challenge now is to continuing moving forward and to identify the activities that can provide the most broadly-applicable information.

See you next year!

The second Annual Collaborative Climate Science Workshop will be held in September 2018. If you’d like to help plan the workshop or provide feedback on this year’s workshop, please contact:

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WCPFC: Sylvia.Spalding@wpcouncil.org

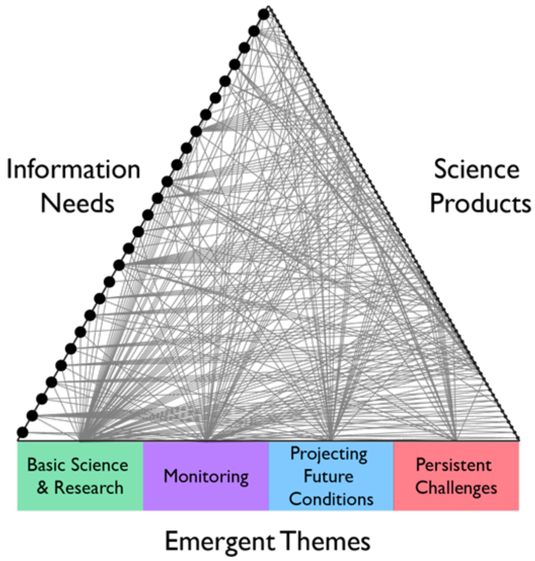

Figure 1 Conceptual diagram illustrating the considerable overlap between the workshop's emergent themes (base), information needs raised (left side), and science products available to meet these needs (right side). Each node on the left side represents an information need listed in Table 1. Each node on the right side represents a unique science product identified (Table 1). Lines connect needs with respective science products, and connect both with the applicable emergent theme(s).

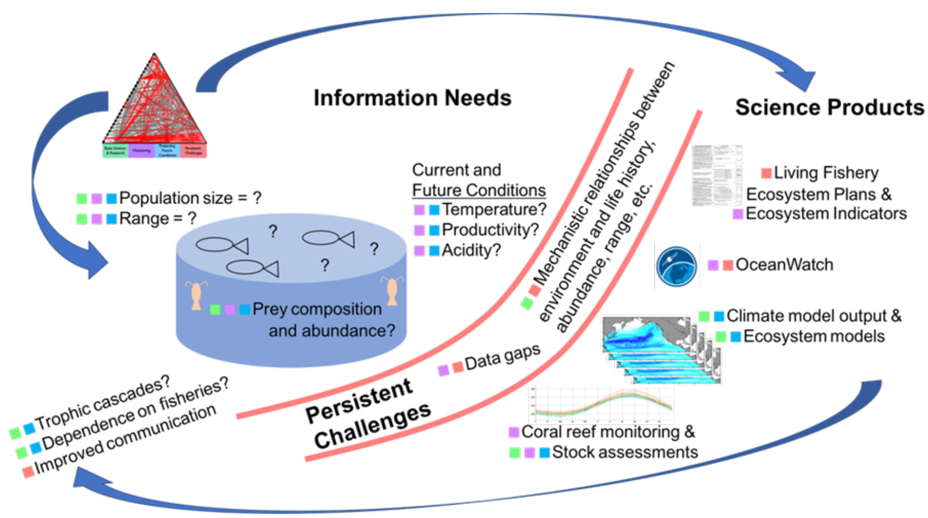

Figure 2 Schematic diagram illustrating the information needed for climate-informed allowable takes/catch limits, the challenges in providing this information, the science products currently available to meet these information needs, and the utility of these products in addressing additional information needs. These pathways are indicated in red in the scaled version of Fig. 1 in the upper left. Colored squares indicate the themes that emerged during the workshop: ■ Basic science and research, ■ Monitoring, ■ Projecting future conditions, and ■ Persistent challenges.

Table 1 Consolidated "Top Priority" information needs, available science products, and current limitations. Common threads are identified at the top of each color block, with individual needs bulleted below. Applicable science products and points of contact follow. Limitations are noted by italics. Information needs are listed in rank order by the number of science products identified to meet each need. All acronyms are defined in Appendix 1.

<table>
<tr><td colspan="2">Need for fine-scale information on current and future climate
• Improved spatial maps that capture current and future impacts to primary productivity
• Quality predictions for dynamic, spatial projected sea level rise, productivity, temperature shifts for climate driven variables relevant to protected resources
• Having oceanographic, climate, and fishery data at appropriate temporal and spatial scales, e.g., oxygen minimum depths finer than 1° and at fine time scales
• What are spatial/temporal patterns of decreasing productivity from increasing stratification and other climate-related oceanographic elements?
• Impact of changes in habitat compression/expansion due to climate change on catchability and susceptibility to exploitation
• Exposure: Better predictions of future changes (subsurface temperature, ocean acidification, changes in frequency and intensity of storms/ENSO cycles)
• Fine scale, interactive spatial and temporal maps that contain layers of relevant biotic, abiotic, and human data.</td></tr>
<tr><td>OceanWatch provides ocean satellite data: SST, chlorophyll, PAR, wind, SSH and currents, eddy kinetic energy, salinity</td><td rowspan="2">Melanie.Abecassis@noaa.gov</td></tr>
<tr><td>Merged ocean color data set (SeaWiFS, MODIS, VIIRS) developed by ESA to look at long-term trends in chlorophyll concentration and primary productivity. Soon to be available on OceanWatch site</td></tr>
<tr><td>Examining impacts of changing El Niño patterns and ocean warming on central Pacific fish catch</td><td rowspan="2">Rusty.Brainard@noaa.gov</td></tr>
<tr><td>Examining changing locations of spawning habitats of skipjack tuna in the Western Pacific from climate change.</td></tr>
<tr><td>Habitat compression and frequency of ENSO events on catchability of billfish in the eastern Pacific Ocean and tropical central Pacific and how exploitation risks are enhanced</td><td>Mark.Fitchett@noaa.gov</td></tr>
<tr><td>Community Vulnerability Social Indicators/Community snapshots may have applicable data</td><td>Danika.Kleiber@noaa.gov</td></tr>
<tr><td>Social component of the West Hawaii IEA to start in October</td><td>Kirsten.Leong@noaa.gov</td></tr>
</table>

Table 1 (continued)

Need for fine-scale information on current and future climate (*cont.*)	
Jeff Maynard is currently working with University of Guam on several outlook reports that predict ecological outcomes at key locations associated with a variety of management regimes. This work currently includes several locations in the Marianas and could be expanded to other locations.	Steve.McKagan@noaa.gov
Vulnerability of islands habitat to coastal flooding/erosion in a changing climate: total water level, as well as magnitude, frequency, and duration projections "TESLA"	John.Marra@noaa.gov
Modeling oceanic-nearshore dynamics in seawater carbonate	Thomas.Oliver@noaa.gov Hannah.Barkley@noaa.gov
Spatial, temporal, and environmental modeling of swordfish length distribution	Michelle.Sculley@noaa.gov
Socioeconomic monitoring	Supin. Wongbusarakum@noaa.gov
Assessing and building social adaptive capacities of fisheries resources and fishing communities	
4-D output from ~12 CMIP5 earth system models	Phoebe.Woodworth-Jefcoats@noaa.gov
Remote sensing data: ocean color data junk in water < 30-m depth, spatial resolution = 1 km at best	*Melanie.Abecassis@noaa.gov*
Lack of information about habitat compression of tuna and tuna-like species due to deoxygenation and the impact on standardized catch per unit effort, a measure of relative abundance	*Jon.Brodziak@noaa.gov*
Oxygen data is periodically objectively analyzed every 3 years in World Ocean Atlas, other more readily available and empirically estimated variables can be used in lieu of oxygen at depth as effective proxies	*Mark.Fitchett@noaa.gov*

Table 1 (continued)

Need to understand future shifts in species distribution • Impacts of spatial shifts of fisheries and protected resources and how they affect management dynamics and socio-economics • Predicted shifts in reef, fish, and human communities. Establish a baseline, understanding cause and effect and then using these data to identify winners and losers • Species specific distribution changes due to climate change	
Long-term carbonate chemistry/monitoring of coral reefs across the Pacific Islands	Rusty.Brainard@noaa.gov
Long-term monitoring of coral reef benthic community structure/demographics across Pacific Islands	Rusty.Brainard@noaa.gov Bernardo.Vargas-Angel@noaa.gov
Telemetry data with horizontal tracks and time series of depth and temperature for bigeye thresher, mako, blue, silky, and oceanic white-tip sharks	Melanie.Hutchinson@noaa.gov
Social component of the West Hawaii IEA to start in October	Kirsten.Leong@noaa.gov
At present, MOUSS camera surveys are only measuring size and abundance for the Deep 7 species. We identify other (reef/mesopelagic) species (some may be shifting to deeper depths) but this data is not readily accessible. I am interested in creating a sharable database for this information.	Dianna.Miller@noaa.gov
CAU accretion sensitivity to seawater carbonate	Thomas.Oliver@noaa.gov
Fishery-independent survey for Hawaii Deep 7 bottomfish covers all known habitat in MHI	Benjamin.Richards@noaa.gov
Climate change effects on tuna spawning: climate projections, skipjack tuna thermal range	Roberto.Venegas@noaa.gov
MHI Atlantis – model simulations will give an understanding of how fisheries and protected resources will shift assuming data on thermal tolerance and other physiological limitations are available	Mariska.Weijerman@noaa.gov
Assessing and building social adaptive capacities of fisheries resources and fishing communities	Supin. Wongbusarakum@noaa.gov
Socioeconomic monitoring	
Shifting fishing grounds based on changes in target species' thermal habitat	Phoebe.Woodworth-Jefcoats@noaa.gov
Adequate specification of research priorities for Human Communities: attitudes and values toward protected species and government regulation, especially critical habitats, communication – rational science-based vs. emotionality	*Craig Severance* *sevc@hawaii.edu*

Table 1 (continued)

Need for climate-informed fishery assessments • Incorporating climate drivers into population assessments • Need for climate-informed fishery assessments and setting of catch limits • Is climate affecting the Deep 7 bottomfish and reef fish stocks and/or fisheries?	
Bottomfish abundance trends and environmental drivers (2011 PIFSC Admin Rep.)	Jon.Brodziak@noaa.gov
Pacific Islands Vulnerability Assessment: Analyze the vulnerability of fish and invertebrate stocks to climate change by synthesizing current sensitivity and exposure data, and use expert opinion to rank the relative vulnerability of species. Products include 'species narratives' that identify vulnerable species as well as data gaps.	Jonatha.Giddens@noaa.gov Donald.Kobayashi@noaa.gov
Population models including sex ratio, embryonic death with temperature and assessment of sex ratios at foraging/in-water	Todd.Jones@noaa.gov
Ongoing Deep 7 Hawaii bottomfish stock assessment (draft form) incorporates effect of wind on CPUE, incorporates fishery-dependent estimate from survey	Brian.Langseth@noaa.gov
Hawaii Bottomfish heritage project – oral histories may have observations relevant to climate change? Not yet analyzed for this question	Kirsten.Leong@noaa.gov
Fishery-independent bottomfish surveys (MOUSS cameras) are collecting depth/temperature data at all sites, including at depth (> 200 m) and throughout the water column. As far as I know, no one is sharing or using this data	Dianna.Miller@noaa.gov
Recreating missing population baseline for Pacific reef sharks. Paper published in Conservation Biology (2012). Establishes link between reef shark abundance and oceanic productivity and temperature, which are projected to change	Marc.Nadon@noaa.gov
Fishery-independent survey of Hawaii Deep 7 bottomfish covers all known habitat in MHI	Benjamin.Richards@noaa.gov
The Council developed a framework to incorporate climate change uncertainties in the p* and SEEM analysis	Marlowe. Sabater@wpcouncil.org
The council is supporting the development of ecosystem indictors that will be used to inform fishery management	
MHI Atlantis – model simulations of climate change into population assessments	Mariska.Weijerman@noaa.gov
No general template or consistency between ESA status assessments (e.g., sea turtles) to determine Distinct Population Segments and incorporation of risk due to climate change	*Camryn.Allen@noaa.gov*
Need mechanistic studies quantifying relationships between environmental variables and life history/demographic parameters to further incorporate environment into stock assessments	*Mariska.Weijerman@noaa.gov* *Annie.Yau@noaa.gov*

Table 1 (continued)

Need for climate-informed management frameworks • How do we persuade managers to elevate the priority of and incorporate climate into management, e.g., proactive packaging of scenarios • Develop strategies for resilience based management (recognizing the predicted massive loss of coral reef habitats due to climate) • Have effective fisheries management in place now to adapt to a changing climate, resources, environment • Long-term commitment to precautionary principle beyond political timescales	
Incorporating considerations of climate change into an ecosystem approach to fisheries management: Heenan et al. 2015 Marine Policy	Rusty.Brainard@noaa.gov
Excavating parrotfishes are a focus of climate resilience based management interventions, due to their role as ecological engineers on coral reefs. We are performing an Indo-Pacific wide assessment to understand how natural environmental drivers, such as temperature, reef biogeography and cyclones, influence the distribution and abundance of these fishes. This will provide context and understanding on management targets for these fishes on different reef types subject to different environmental conditions.	Adel.Heenan@gmail.com
Social component of the West Hawaii IEA to start in October	Kirsten.Leong@noaa.gov
Using CCVA data for US Pacific Island Reefs to support RBM strategy development	Thomas.Oliver@noaa.gov
The Council is developing the "Living Fishery Ecosystem Plans" that allow the Council to adapt real-time to changes in fishery management needs	Marlowe. Sabater@wpcouncil.org
The Council is supporting the development of ecosystem indicators that will be used to inform fishery management	
MAFAC Resilience Working Group white paper on management actions that allow a nimbler response to changes in fisheries	Sylvia. Spalding@wpcouncil.org
Coral reef (fish, coral, community) effects: early life stage data for marine species (coral, fish, coral communities, etc.), identify/collect height information to understand coral/algae effects, current/waves changes/magnitudes	Roberto.Venegas@noaa.gov
MHI Atlantis – scenario simulations	Mariska.Weijerman@noaa.gov
Assessing and building social adaptive capacities of fisheries resources and fishing communities	Supin. Wongbusarakum@noaa.gov
Socioeconomic monitoring	
Catch and effort data for non-commercial fisheries throughout Council region. HMRFSS and MRIP raw data, some utility but catch expansions highly suspect. No similar data effort for commonwealth and territories.	*Craig Severance* *sevc@hawaii.edu*

Table 1 (continued)

Need for climate-informed management frameworks *(cont'd)*	
Understand scope for herbivore management to improve coral resilience: what are key herbivores? What are threshold abundance levels? What is local carrying capacity/scope for recovery of herbivores if better managed?	*Ivor.Williams@noaa.gov*
What are source/sink areas (i.e., areas that can be seed banks if well protected)?	
Need to understand how species will be affected by changing climate conditions • Adaptive capacity of habitats and protected resources • Data that can help us understand and predict how changes in oceanographic conditions (at various geographic scales) will affect biological parameters of key species • How biology changes sensitivity in response to climate (growth, mortality, spawning, reproductive viability)	
Reef bioerosion rates across Pacific Islands	Rusty.Brainard@noaa.gov Thomas.Oliver@noaa.gov
Reef accretion rates across Pacific Islands	
Long-term monitoring of distribution, abundance, diversity, size of reef fishes across Pacific Islands	Rusty.Brainard@noaa.gov Ivor.Williams@noaa.gov
Recruitment success and failure of billfish due to AMO, northern equatorial current, and degradation of NECC and ECC (specifically sailfish, blue marlin, black marlin)	Mark.Fitchett@noaa.gov
Recruitment dynamics of Kona crab in MHI: is recruitment drive by environment or density dependent? Is recruitment failure due to climate-driven shifts in circulation?	
I'm doing a piggyback project, which involves collecting algal specimens along fish survey transects at Jarvis on MARAMP 2017 survey efforts. These collections are intended to ground-truth identifications of specimens from photo IDs. I proposed to compare pre/post-El Niño algal/benthic community using my data and Peter Vroom's previous data to take a closer look at the benthic community shift into an algal dominated environment.	Louise.Giuseffi@noaa.gov

Table 1 (continued)

Need to understand how species will be affected by changing climate conditions *(cont'd)*	
Changes in life history across the Mariana Archipelago. Data set: collection of 6 species of commercially harvested reef fish from Uracus to Guam. To be expanded to ~10 species during SE-18-03. Goal: to determine the magnitude and generality of life history variation across the latitudinal gradient of the Mariana Archipelago. Will include extrapolations from uninhabited to populated locations to infer "natural" trait values in heavily fished areas.	Brett.Taylor@noaa.gov
To address magnitude of change in life history traits across latitudinal gradient of sea surface temperature. Data set: age-based demographic samples from 12+ populations of bluespine unicornfish across the Pacific basin. Future work could extrapolate patterns through time based on climate projections.	
To address magnitude of change in life history traits across spatial environmental gradients: Data set: demographic population samples (age-based demographic data) from 40+ populations of bullethead parrotfish across the entire Indo-Pacific, Goal: to examine the drivers and relative magnitude of variation related to sea surface temperature and productivity (chl-*a*). Future work could extrapolate patterns through time based on climate projections.	
Need to understand how climate change will impact infrastructure • How does climate affect the frequency of severe weather events and their impact on fisheries infrastructure?	
Community Vulnerability Social Indicators may identify some vulnerable infrastructure	Danika.Kleiber@noaa.gov
Social component of the IEA to start in October	Kirsten.Leong@noaa.gov
Information on storms	John.Marra@noaa.gov
Old data: effort triggers, fish flow, and customary exchange in American Samoa and CNMI	Craig Severance sevc@hawaii.edu
SAFE reports tracking named storms and hurricanes and may monitor ex-storms in future	Sylvia. Spalding@wpcouncil.org
Assessing and building social adaptive capacities of fisheries resources and fishing communities	Supin. Wongbusarakum@noaa.gov
Socioeconomic monitoring	
Baseline data on fishing communities and fishery dependent communities at a finer scale focused on harbor ramps, boat building and repair facilities, wholesalers, processors, retailers, including fishing gear businesses	*Craig Severance* *sevc@hawaii.edu*

Table 1 (continued)

Need for spatial ecosystem and habitat models • Spatial ecosystem models (Atlantis-like) for analyzing trade-offs • Better dynamic spatial habitat models for "critical habitat"/listed corals to understand habitat shifts and prey dynamics • Climate informed ecosystem modelling to support management	
Spatial drivers of coral size structure	Marie.Ferguson@noaa.gov Thomas.Oliver@noaa.gov
The Council and PIFSC's Pacific Islands Fisheries Research Program supports the development of an Ecosim model for the American Samoa coral reef ecosystem. This incorporates climate change variables in future projections of impacts.	Marlowe. Sabater@wpcouncil.org
The Council supports the development of Atlantis model for the Western Pacific jurisdiction through the Pacific Islands Fisheries Research Program. This incorporates climate change impacts and projections.	
Habitat use analysis of coral taxa, protected species tool box	Dione.Swanson@noaa.gov Thomas.Oliver@noaa.gov
MHI Atlantis model	Mariska.Weijerman@noaa.gov
Need for improved communication of climate science • Improved communication to general audiences (non-scientists) regarding impacts of climate change	
OceanWatch program provide satellite data, develops climate indicators for various projects, and has visualization tools on its website	Melanie.Abecassis@noaa.gov
In the CNMI and Guam this outreach occurs via targeted programs like 'eyes on the reef', ad hoc opportunities such as expert panels during public showings of films like 'Chasing Corals' and during one off events like student expos associated with earth day	Steve.McKagan@noaa.gov
Communicating climate change and NOAA research on it – survey conducted by the NOAA Marine Fisheries Advisory Committee (MAFAC) Resiliency Working Group	Sylvia. Spalding@wpcouncil.org
Train-the-Trainer and fishing community workshops on climate and fisheries: Sept 28 Hawaii, Oct 14 and 16 American Samoa, Nov 15 and 17 CNMI and Guam	
Climate chapter of annual Stock Assessment and Fisheries Evaluation (SAFE) reports for the Fishery Ecosystem Plans (FEPs) for the Western Pacific Region	
Basic knowledge of science of communication, no current funding or research agenda for audience research related to climate change specifically, but interest from PR (PIRO)/PS (PIFSC) for upcoming year	Kirsten.Leong@noaa.gov

Table 1 (continued)

Need for baseline information on species' and stocks' demographics • Baseline information for protected resources including diet, prey dynamics, abundance, distribution, etc. • Better stock definitions for managed species to help understand future movements, geographic relocations due to climate	
Telemetry data with horizontal tracks and time series of depth and temperature for bigeye thresher, mako, blue, silky, and oceanic white-tip sharks	Melanie. Hutchinson@noaa.gov
PIR grant funded sea turtle projects (monitoring, baseline data)	Irene.Kelly@noaa.gov
Hawaii and Pacific Islands environmental indicators: monitoring, patterns, and trends	John.Marra@noaa.gov
PIFSC PSD conducts surveys on distribution, abundance, movements, and structure of cetaceans, turtles, and monk seals (systematic surveys, satellite tagging, genetic sampling)	Erin.Oleson@noaa.gov
MTBAP and HMSRP use stomach contents, stable isotopes, and other measures to examine diet	
Very little is known about diet components and flexibility in diet for most cetaceans	*Erin.Oleson@noaa.gov*
Constrained by how management (RFMOs) are set up	*Annie.Yau@noaa.gov*
Need to better understand how communities prioritize resources • Better understanding of priorities/values of human communities around climate impacts	
Baseline attitudes, preferences of Hawaii non-commercial fishers toward various marine threats (climate change, sea level rise, marine mammal interactions), 2015 survey	Justin.Hospital@noaa.gov
The CNMI is currently developing a new reef economic evaluation study to replace the previous 2006 study which should include climate consideration. The previous study was - van Beukering et al., 2006.	Steve.McKagan@noaa.gov
State/Territorial surveys of fishing community attitudes about climate change – conducted by members of WPRFMC's Marine Planning and Climate Change Committee	Sylvia. Spalding@wpcouncil.org
Supin has worked a lot in this area especially at the community level	Supin. Wongbusarakum@noaa.gov
Need to better understand climate's impact on intermediate trophic levels • Understanding impacts of climate change distribution and dynamics of intermediate trophic levels (indirect) • Better understanding of climate impacts on the general distribution, status, and trends of mid-trophic species	
SEAPODYM micronekton model, developed by Patrick Lehodey CLS, France	Melanie. Abecassis@noaa.gov
Ecological impacts of ocean acidification on cryptobiota, monitoring of cryptic invertebrates of nearshore habitats of Pacific Islands Region	Rusty.Brainard@noaa.gov Molly.Timmers@noaa.gov

Table 1 (continued)

Need to better understand climate's impact on intermediate trophic levels (*cont.*)	
MHI Atlantis – model simulation of climate change (projected temperature increase and ocean acidification) on insular ecosystem including intermediate trophic levels	Mariska. Weijerman@noaa.gov
Lancetfish diet time series addresses spatial and temporal changes in mid-trophic levels in subtropical gyre	Phoebe.Woodworth-Jefcoats@noaa.gov
Need commitment to long-term monitoring • Commitment to long-term monitoring to inform, validate, and improve models	
Long-term carbonate chemistry/monitoring of coral reefs across the Pacific Islands	Rusty.Brainard@noaa.gov
Long-term monitoring of coral reef benthic community structure/demographics across the Pacific Islands	Rusty.Brainard@noaa.gov Bernardo.Vargas-Angel@noaa.gov
The Council is working with the PIFSC on developing the ecosystem consideration module in the Stock Assessment and Fishery Evaluation (SAFE) report	Marlowe. Sabater@wpcouncil.org
The Council is developing the data integration module of the SAFE report. This module aims to integrate environmental/climate variables in the fishery-dependent data (coral reef & bottomfish) so that the interpretation of fishery trends is in an ecosystem context	
Other needs related to sensitivity to climate change • Other science/efforts related to sensitivity to climate change	
Monk seals – several studies have highlighted climate-related impacts, including sea level rise and potential habitat loss, changing productivity (TZCF position) as related to survival, and ocean currents that impact debris and entanglement	Jason.Baker@noaa.gov
Ecological impacts of ocean acidification: long-term monitoring of production and removal of calcium carbonate of nearshore marine ecosystems of the Pacific Islands Region. The balance of production and removal provides essential information about long-term survival/persistence of coral reefs and associated ecosystem services they provide, including coastal protection (wave dynamics) influencing sea level rise impacts	Rusty.Brainard@noaa.gov
Climate vulnerability assessments underway for turtles, and later mammals	Todd.Jones@noaa.gov
Vulnerability assessments related to sea level rise have been developed for Saipan, Tinian, and Rota in the CNMI: http://www.crm.gov.mp/resources/files/Rota_Tinian_ CC_VulnerabilityAssessment_Final.pdf	Steve.McKagan@noaa.gov

Table 1 (continued)

Need to understand how climate change will impact protected species interactions • How might climate impact fisheries and all human interactions with protected resources (development, tourism, etc.)?	
Workshop on factors influencing albatross interactions in the Hawaii Longline Fishery (identifying drivers and quantifying impacts), looking at environmental factors (including oceanography and possible links with El Niño), (Council/PIFSC/PIRO)	Asuka. Ishizaki@wpcouncil.org
Understanding environmental drivers associated with marine turtles (olive ridley, leatherback) interactions	Todd.Jones@noaa.gov
Monk seal program tracks fisheries interactions in MHI *better data always desired*	Stacie.Robinson@noaa.gov
MHI Atlantis – model simulations will increase understanding of the climate effects of fisheries interactions and other human activities	Mariska. Weijerman@noaa.gov
Need to for information to gauge social adaptive capacity • Baselines, predictions, and perceptions of climate impacts on ecosystem services (social adaptive capacity) • How will climate impact the degree of human dependency on fisheries?	
Social component of the IEA to start in October	Kirsten.Leong@noaa.gov
Climate and fisheries workshops for fishing communities and Marine Planning and Climate Change Committee meetings	Sylvia. Spalding@wpcouncil.org
Socioeconomic monitoring	Supin. Wongbusarakum@noaa.gov
Assessing and building social adaptive capacities of fisheries resources and fishing communities	
Survey instruments for different island areas (state/territories)	*Sylvia. Spalding@wpcouncil.org*
Other needs related to exposure to climate change • Other science related to exposure to climate change	
Ecological impacts of ocean acidification on island ecosystems across the US Pacific Islands. We are monitoring (long-term) carbonate chemistry of nearshore seawater around most islands. Water samples are collected since 2005 and analyzed for dissolved inorganic carbon (DIC) and total alkalinity (TA), plus salinity. We compute pH and saturation state across the PIR.	Rusty.Brainard@noaa.gov
Long-term monitoring of nearshore vertical thermal structure around most of the US Pacific Islands. Temperature recorders at depths of 1, 5, 15, and 25 m around ~4 sides of islands to monitor stratification and mixing.	Rusty.Brainard@noaa.gov Thomas.Oliver@noaa.gov

Table 1 (continued)

Other needs related to climate change's impact on social systems • Other science/efforts related to social systems and climate change	
Community Vulnerability Social Indictors Analysis of secondary data (e.g., Census) for fishing communities, can be analyzed with respect to climate change (sea level rise)	Danika.Kleiber@noaa.gov
Vulnerability of coastal communities and fisheries (commercial and recreational) to climate change	Mariska. Weijerman@noaa.gov
Need for international partnerships • Buy-in by international partners to incorporate climate data into assessments, improve transparency, data sharing, and communication	
Assessment report of 2014 – 2016 El Nino, impacts on Pacific Island countries	Michael Rupic michaelcrupic@ucla.edu
Fishermen concerns about confidential information/ "trade secrets" becoming public	*Michelle.Sculley@noaa.gov*
Need for technical data mining tools • Use modern technical tools and capabilities to mine historic data sets for improving climate models (e.g., neural networks)	
Paleoclimate records from coral cores to better reconstruct climate changes across Pacific Islands region	Rusty.Brainard@noaa.gov
Language barriers to accessing old data/papers (e.g., some are in Japanese)	*Johanna.Wren@noaa.gov*
Other needs related to climate change's impact on protected species • Other climate science related to protected species	
Climate change vulnerability assessment for Pacific Marine National Monuments through a grant from PIRO awarded to Texas A&M University, completed in 2016	Heidi.Hirsh@noaa.gov
Need for clear data collection protocols • Clear data collection protocols that improve sharing information across agencies so we can expand available data	
PARR team working on streamlining some of the data collection procedures (e.g., CTD)	Jesse.Abdul@noaa.gov Melanie. Abecassis@noaa.gov

Table 1 (continued)

Need to understand whether management actions will influence climate system • How our management actions would have an impact on climate, e.g., carbon footprint for vessels traveling farther to fish needing more fuel and ice, imports	
Knowledge of possible publication on this topic	Rusty.Brainard@noaa.gov
Need to understand how specific life stages are impacted by climate change • Can we identify the most important drivers or variables for each life stage/habitat for each protected resource species (direct and indirect)?	
CRP collects data on occurrence and abundance of cetaceans in Hawaii and other PIR areas and is involved in analyses to relate those measures to remotely-sensed oceanographic variables to better understand habitat relationships and develop predictive models of distribution/abundance with specific conditions	Erin.Oleson@noaa.gov
Need to understand how climate change impacts might cascade through food webs • Understanding cascading effects through the food web	
Validation of integrative systemic indicators on the trophic composition of coral reef communities, how these vary across existing spatial gradients in the environment, how they may vary in the future given SST and chlorophyll projections	Adel.Heenan@gmail.com
Need to understand synergy between climate change impacts • Teasing out the fleet behavior in response to economic drivers that are affected by climate change, e.g., impacts on fish distribution in conjunction with fuel prices (synergy between factors)	
I have a proposal (FY19) to try to examine whether the Hawaii longline fishery location decisions are economic, oceanographic, or management driven	HingLing.Chan@noaa.gov
Need to understand pelagic impacts of ocean acidification • Sensitivity of prey (or target) species to ocean acidification, e.g., calcareous plankton, larval fish	
No science products or limitations identified	

APPENDIX 1—LIST OF ACRONYMS USED IN TABLE 1

AMO	Atlantic Multidecadal Oscillation
CAU	Calcification Accretion Unit
CCVA	Climate Change Vulnerability Analysis
Chl-a	Chlorophyll-a
CLS	Collecte Localisation Satellites
CMIP5	Coupled Model Intercomparison Project, 5th phase
CNMI	Commonwealth of the Northern Mariana Islands
CPUE	Catch Per Unit Effort
CRP	Cetacean Research Program
CTD	Conductivity-Temperature-Depth
ECC	Equatorial Counter Current
ENSO	El Niño – Southern Oscillation
ESA	Endangered Species Act
ESA	European Space Agency
HMRFSS	Hawaii Marine Recreational Fisheries Statistical Survey
HMSRP	Hawaiian Monk Seal Research Program
IDs	Identifications
IEA	Integrated Ecosystem Assessment
MAFAC	Marine Fisheries Advisory Committee
MHI	Main Hawaiian Islands
MARAMP	Mariana Archipelago Reef Assessment and Monitoring Program
MRIP	Marine Recreational Information Program
MODIS	Moderate Resolution Imaging Spectroradiometer
MOUSS	Modular Optical Underwater Survey System
MTBAP	Marine Turtle Biology and Assessment Program
NECC	North Equatorial Counter Current
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PAR	Photosynthetically Available Radiation
PARR	Public Access to Research Results
PIFSC	Pacific Islands Fisheries Science Center
PIR	Pacific Islands Region
PIRO	Pacific Islands Regional Office
PR (PIRO)	Protected Resources (Pacific Islands Regional Office)
PS (PIFSC)	Protected Species (Pacific Islands Fisheries Science Center)
PSD	Protected Species Division
RBM	Resource Based Management
RFMOs	Regional Fishery Management Organizations
SAFE	Stock Assessment and Fishery Evaluation
SeaWiFS	Sea-Viewing Wide Field-of-View Sensor
SE-18-03	SE-18-03 is a planned PIFSC research cruise to the Marianas that will focus on fish life history
SEEM	Social, Economic, Ecological, and Management Uncertainty
SSH	Sea Surface Height
SST	Sea Surface Temperature
TESLA	Time-varying Emulator for Short- and Long-Term Analysis of Coastal Flooding
TZCF	Transition Zone Chlorophyll Front
VIIRS	Visible Infrared Imaging Radiometer Suite
WPRFMC	Western Pacific Regional Fishery Management Council

APPENDIX 2— AGENDA

Tuesday, 19 September 2017

1:00pm	Welcome and introduction
1:15pm	National Climate Assessment update from Jeff Polovina
1:30pm	Small group discussions to identify climate-related management and stakeholder information needs related to protected species
2:00pm	Reconvene and share lists with full group
2:30pm	Break
2:45pm	Snow carding exercise to identify individual science products that can meet identified information needs
3:15pm	Review snow cards
3:45pm	Wrap up and adjourn

Wednesday, 20 September 2017

1:00pm	Welcome and introduction
1:15pm	Small group discussions to identify climate-related management and stakeholder information needs related to coral reefs and insular/bottomfish
1:45pm	Break
2:00pm	Reconvene and share lists with full group
2:45pm	Snow carding exercise to identify individual science products that can meet identified information needs
3:15pm	Review snow cards
3:45pm	Wrap up and adjourn

Thursday, 21 September 2017

1:00pm	Welcome and introduction
1:15pm	Small group discussions to identify climate-related management and stakeholder information needs related to pelagic and highly migratory fish
1:45pm	Break
2:00pm	Reconvene and share lists with full group
2:45pm	Snow carding exercise to identify individual science products that can meet identified information needs
3:15pm	Review snow cards
3:45pm	Wrap up and adjourn

APPENDIX 3— LIST OF PARTICIPANTS WITH AFFILIATIONS

Melanie Abecassis	Pacific Islands Fisheries Science Center
Seema Balwani	National Environmental Satellite, Data, and Information Service
Rusty Brainard	Pacific Islands Fisheries Science Center
Jon Brodziak	Pacific Islands Fisheries Science Center
Melanie Brown	Pacific Islands Regional Office
Valerie Brown	Pacific Islands Regional Office
Hing Ling Chan	Pacific Islands Fisheries Science Center
Emily Crigler	Pacific Islands Regional Office
Lorilee Crisostomo	Western Pacific Regional Fishery Management Council, Marine Planning and Climate Change Committee Chair
Paul Dalzell	Western Pacific Regional Fishery Management Council
Sarah Ellgen	Pacific Islands Regional Office
Mark Fitchett	Pacific Islands Fisheries Science Center
Jonatha Giddens	Pacific Islands Fisheries Science Center
Louise Giuseffi	Pacific Islands Fisheries Science Center
Dawn Golden	Pacific Islands Regional Office
Lesley Hawn	Pacific Islands Regional Office
Adel Heenan	Pacific Islands Fisheries Science Center *Now at Bangor University*
Heidi Hirsh	Pacific Islands Regional Office
Justin Hospital	Pacific Islands Fisheries Science Center
Evan Howell	Pacific Islands Fisheries Science Center
Asuka Ishizaki	Western Pacific Regional Fishery Management Council
Ariel Jacobs	Pacific Islands Regional Office
T. Todd Jones	Pacific Islands Fisheries Science Center
Irene Kelly	Pacific Islands Regional Office
Danika Kleiber	Pacific Islands Fisheries Science Center
Mike Lameier	Pacific Islands Regional Office
Kirsten Leong	Pacific Islands Fisheries Science Center
Beth Lumsden	Pacific Islands Fisheries Science Center
Michelle Mansker	Pacific Islands Regional Office
John Marra	National Environmental Satellite, Data, and Information Service
Michelle McGregor	Pacific Islands Regional Office
Steve McKagen	Pacific Islands Regional Office

APPENDIX 3 (continued)

Lyn McNutt	Western Pacific Regional Fishery Management Council, Marine Planning and Climate Change Committee member
Dianna Miller	Pacific Islands Fisheries Science Center
Marc Nadon	Pacific Islands Fisheries Science Center
Erin Oleson	Pacific Islands Fisheries Science Center
Thomas Oliver	Pacific Islands Fisheries Science Center
Risa Oram	Pacific Islands Fisheries Science Center
Jeff Polovina	Pacific Islands Fisheries Science Center
Jennifer Raynor	Pacific Islands Fisheries Science Center
Stacie Robinson	Pacific Islands Fisheries Science Center
Michael Rupic	National Environmental Satellite, Data, and Information Service intern from University of California, Los Angeles
Marlowe Sabater	Western Pacific Regional Fishery Management Council
Jennifer Samson	Pacific Islands Fisheries Science Center
Michelle Sculley	Pacific Islands Fisheries Science Center
Craig Severance	Western Pacific Regional Fishery Management Council, Scientific and Statistical Committee member
Sylvia Spalding	Western Pacific Regional Fishery Management Council
Roberto Venegas	Pacific Islands Fisheries Science Center
Mariska Weijerman	Pacific Islands Fisheries Science Center
Ivor Williams	Pacific Islands Fisheries Science Center
Supin Wongbusarakum	Pacific Islands Fisheries Science Center
Phoebe Woodworth-Jefcoats	Pacific Islands Fisheries Science Center
Johanna Wren	Pacific Islands Fisheries Science Center
Annie Yau	Pacific Islands Fisheries Science Center

Available upon request from Phoebe.Woodworth-Jefcoats@noaa.gov:

Appendix 4— Daily "Top Priority" information needs, available science products, and current limitations (note that all this information is consolidated into Table 1)

Appendix 5—Detailed small group discussion notes