Summary Report from the 2nd Annual Collaborative Climate Science Workshop 4–6 September 2018 NOAA's Inouye Regional Center Honolulu, HI

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Background

In 2016 the National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS) enacted the NOAA Fisheries Climate Science Strategy (Link et al., 2015) as part of its proactive approach to better track, forecast, and incorporate information on changing climate conditions into living marine resource management. Drivers and impacts of climate change vary greatly by geographic location. Therefore, the 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. By creating action plans at the regional level, NMFS is tailoring its response to meet specific climate challenges and forging critical partnerships at the local level.

The first step in implementing the Pacific Islands Regional Action Plan for climate science (PIRAP; Polovina et al., 2016) was identifying the specific information needed by resource managers and the scientific research and data available or being developed. To facilitate this objective, PIRAP authors decided to convene an internal Annual Collaborative Climate Science Workshop as a forum where regional staff can keep abreast of changes on these fronts. The first workshop was held in September 2017 (hereafter 1st Workshop). The 2nd Annual Collaborative Climate Science Workshop (hereafter 2nd Workshop) was held at the NOAA Inouye Regional Center (IRC) on 4 – 6 September 2018. Both workshops were attended by staff from the NMFS Pacific Islands Regional Office (PIRO) and Pacific Islands Fisheries Science Center (PIFSC), NOAA's National Environmental Satellite, Data, and Information Service, and the Western Pacific Regional Fishery Management Council (WPRFMC), as well as by several members of WPRFMC advisory bodies.

During the planning stages for the 2nd Workshop, the steering committee laid out a multi-year cycle of goals to unify the Annual Collaborative Climate Science Workshops. The 1st Workshop focused on broad information gathering and exchange. Managers were free to discuss any information needs, and scientists provided an extensive list of products that may be able to address those needs. The goal for the 2nd Workshop was to narrow the focus and identify priorities for moving forward. The steering committee envisions the 3rd Workshop (2019), and possibly subsequent workshops, focusing on progress toward realizing the priorities identified this year. Eventually, another broad information-gathering workshop will be held and the cycle will repeat. Bringing a cyclical nature to the Annual Collaborative Climate Science Workshops will ensure that each year's workshop is relevant, that our regional climate science is continually moving forward, and that we are never working from a stale set of management information needs or science products.

Prior to this year's workshop, steering committee members from PIRO and WPRFMC worked with their staffs to identify 3 to 5 priority information needs for each day of the workshop. These needs were selected from those identified in 2017 at the 1st Workshop (Woodworth-Jefcoats, 2018; Table 1). The priority information needs were then used to facilitate small group conversations between managers and scientists. Managers spent each afternoon discussing the single priority information need most relevant to their work, while groups of scientists with similar expertise rotated among all the information needs. This structure ensured that all managers were able to speak with all scientists. Participants self-identified into "manager" and "scientist" groups. Managers self-selected their priority of focus.

In keeping with the 1st Workshop, each day focused on a specific ecological component:

- Day 1: Protected species
- Day 2: Coral reefs and insular/bottomfish
- Day 3: Pelagic and highly migratory fish

The priority information needs discussed each day are listed in Appendix A.

Priorities for Advancing Regional Climate Science to Inform Management and Conservation of Living Marine Resources

After the workshop, conversation notes from each small group were synthesized to identify common themes. These themes were then used to identify priorities for advancing regional climate science and climate-informed living marine resource management. Four priorities were identified. Workshop discussions clearly highlighted a single top priority. Three additional supporting priorities were also identified. All four priorities are discussed below.

Top Priority: An understanding of future shifts in species distributions underpinned with robust baselines

Of the priority management information needs identified prior to the workshop, one was common to all 3 days: the need to understand future shifts in species distributions. This need spans from near-shore to pelagic species, from protected to commercially valuable species, and from corals to fish to marine mammals. Implicit in this need, and repeatedly discussed during the small group conversations, is the need for baseline information to which future shifts can be compared. It was consistently noted by workshop participants that the need for baseline information extends beyond species themselves to their habitats and that these habitats extend below the ocean's surface encompassing both seawater characteristics as well as bottom substrates.

Participants discussed a number of facets to the need to understand future shifts in species distributions. Specifically highlighted were availability of prey, impacts of climate change on and at specific life history stages (e.g., spawning), and potential effects of ocean acidification on species. Prey availability will likely influence predators' spatial distributions, abundance, and fitness. Changes in water temperature can also influence species' spatial distributions. The location of species' spawning grounds may shift in accordance with shifts in temperature, impacting fisheries. Ocean acidification can lead to degradation of coral reefs and marine organisms' shells. It may also impact larval fish growth, olfactory performance, and other critical life functions. Such impacts from ocean acidification could in turn influence prey availability or result in species relocating.

Several participants alluded to the need to examine species shifts in an ecosystem context because the shift in one species' distribution can affect the distribution of other species. This approach aligns well with a number of other NMFS initiatives, including ecosystem-based fisheries management, integrated ecosystem assessments, the Fisheries and the Environment program, PIRO's Strategic Plan: 2016 – 2020, and the Next Generation Stock Assessment enterprise. Several examples highlight the importance of this broader ecosystem context. The first is the above-mentioned change in prey distribution. As prey move, their predators are expected to move as well. Another example is that of fisheries moving in response to the shifting distribution of their target catch. Fisheries are also affected by shifts in protected species' distributions as fishers seek to avoid protected species interactions. Finally, because species have different spatial distributions at different life stages, a change at one life stage can put fisheries that don't normally interact into competition with one another. For example, this could occur when Fishery A begins interacting with an early life stage of Fishery B's target species, potentially reducing the abundance of that species subsequently available to Fishery B.

Workshop participants raised a number of potential approaches to clearly define habitat requirements, establish species distribution baselines, and monitor environmental change and distributional shifts. While these approaches extend beyond supporting the region's many ongoing monitoring programs, participants repeatedly highlighted the importance of these programs as a component of any effort to address this information need. One often-mentioned approach was genetics. Another was additional data collection by longline observers (including collection of samples for genetic analysis). Several participants also mentioned citizen science, partnerships with commercial vessels, and cooperative research.

Given that this topic was discussed in relation to every living marine resource mentioned during the workshop, the need to **understand future shifts in species distributions and to underpin these shifts with robust baselines** is clearly the top priority emerging from this year's workshop.

Secondary Priorities

The three secondary priorities discussed below were identified based on information needs that spanned multiple workshop days (Appendix A) and common themes across the workshop's small group discussions.

Better understand species' physiological responses to climate change

Two priority information needs were discussed on 2 of the 3 workshop days. One of these needs was the need to understand how species will be affected by changing climate conditions, including understanding how these impacts might cascade through the food web. In discussions on this need, participants highlighted the need for better understanding of the physiological impacts of climate change across species' full vertical habitats – not just at the ocean's surface. For example, changing ocean temperatures can influence growth rates or trigger changes in reproductive patterns. Such changes in growth rates would alter species' maximum sizes and size- or age-at-maturity. The later may have fisheries management implications because the size and age of a species' recruitment to a fishery would change.

Long-term monitoring programs that are already in place were identified as one path to gaining insight into how species are responding to changing climate conditions. They could also help link biological responses with climate events. Other strategies identified to further understanding of species' responses to climate change include focusing efforts on critical life stages (e.g., nesting), incorporating traditional ecological knowledge, and conducting more physiological research.

Building on the top priority emerging from this workshop, an additional priority is to **better understand species' physiological responses to climate change**.

Continue to investigate food web responses to climate change

Discussions on the need to understand how climate impacts might cascade though the food web included many of the same points that were raised for the need to understand future shifts in species distributions. For example, many conversations mentioned the need to understand prey movement at all trophic levels. Furthermore, food web responses will also be shaped by species' movement and physiological responses to climate change.

Several approaches to unraveling food web effects were suggested. A number of participants mentioned the utility of diet studies, including gut contents, fatty acid, and stable isotope analyses. Many conversations highlighted the importance of linking lower trophic levels to environmental change and fisher response to target species change, highlighting the lack of understanding of mid trophic levels. Improved understanding of this component of the food web could enable linking environmental change to fishery change. The potential role of genetics work, including environmental DNA, was highlighted as well.

Continuing to investigate food web responses to climate change emerged as an additional priority, especially in light of NMFS's many ecosystem-based management initiatives.

Improved collaboration between scientists and managers

The need for climate-informed fishery assessments and management frameworks was also discussed on 2 of the 3 workshop days. Much of the discussion around this topic could be summed up by the word "mismatch." Conversations included topics about mismatches between what we would like to incorporate into management and the state of our present knowledge, between the speeds at which management and science move, between the nature of climate variability and of climate change, and even between those conducting assessments and those using assessments to set policy.

Discussions on this need also identified possible ways to overcome these mismatches. Mechanistic linkages between environmental change and species' responses, with thresholds for management action, could help bridge slow-moving science and faster-paced management. However, in many cases identifying these mechanistic linkages requires a better understanding of both baseline conditions and of how species will respond to future change. It's also important to note that as climate change unfolds, the relationships between species and their environment may change. Furthermore, changes to habitat could confound these relationships.

The mismatch between climate variability and change echoes the mismatch between most management timeframes and the long-term nature of climate change. Over the next 1 – 10 years, the timeframe of stock assessments (and the fisheries management which they inform), habitats, and species will see a greater impact from climate variability than from climate change. However, climate variability is challenging to predict. This is another situation where thresholds for management action could be particularly useful, especially if paired with robust seasonal-scale forecasts produced by other NOAA line offices.

A data science layer, or data analysis "middle layer," was suggested as a mechanism to better match scientists and managers. This would involve the two groups co-producing results from data analyses, either through direct collaboration or through a data scientist and/or science communicator.

It's challenging to identify a single priority for moving forward to address the need for climate-informed fishery assessments and management frameworks, given the wide range of topics discussed by scientists and managers. That said, these conversations repeatedly touched on the importance of communication across all sectors involved in projecting and responding to climate's effects on living marine resources. **Improved collaboration between scientists and managers** is also a priority for moving forward, given that PIFSC and PIRO are located in the

same building and have strong contacts with WPRFMC. Furthermore, progress toward meeting these priorities will be expedited by greater collaboration and is only meaningful if it is effectively communicated.

Summary and Next Steps

A synthesis of the small group discussions that took place during the 2nd Annual Collaborative Climate Science Workshop identified four priorities for moving forward with climate science to inform living marine resource management and conservation. The top priority is:

- understand future shifts in species distributions underpinned with robust baselines.

Three additional priorities were identified to support the above top priority and to advance regional climate science and climate-informed management more broadly:

- Better understanding of species' physiological responses to climate change,
- Continue to investigate food web responses to climate change, and
- Improve collaboration between scientists and managers.

Workshop participants discussed a number of strategies for realizing these priorities. Identifying priority species and habitats based on management needs and ecological function could help focus monitoring and research efforts. Diet studies, including gut contents, stable isotope, and fatty acid analyses can provide insight into predator-prey relationships. They can also provide insight into the data-poor mid trophic levels. Genetics work and environmental DNA have the potential to establish species distribution baselines. Establishing mechanistic linkages among species and between species and their habitat may enable setting thresholds for management action, helping to bridge the gap between climate variability and climate change.

The PIRAP (Polovina et al., 2016) and the summary report from the 1st Workshop (Woodworth-Jefcoats 2018) are also helpful resources when identifying routes to advance these priorities. For example, myriad long-term monitoring efforts mentioned in the small group conversations and included in the PIRAP will support the establishment of robust baselines and potentially help identify both distributional shifts and physiological and food web responses to climate change. Likewise, existing telemetry data could inform species distribution baselines and environmental data collected during fishery-independent bottomfish surveys could inform both baselines and time series of subsurface habitat. Vulnerability assessments for fish, turtles, marine mammals, and coral reefs (all PIRAP action items) can help identify priority species. Ecosystem modeling efforts detailed in the PIRAP and the 1st Workshop's summary report can also help identify priority species, as well as evaluate potential management strategies. Climate indicators and data visualization tools, such as those provided by OceanWatch and listed in the 1st Workshop's summary report, can be used to facilitate collaboration between scientists and managers and enhance communication of research results.

Finally, it is worth noting that the four priorities identified at this year's workshop echo the data gaps highlighted at the 1st Workshop: lack of baseline population information and lack of clear mechanistic understanding about the impact of environmental change on species' life histories, diet, abundance, and range (Woodworth-Jefcoats, 2018). While the lack of baseline population was identified as a priority going into the 2nd Workshop, the lack of clear mechanistic understandings was not. Focusing on the four priorities identified this year, and the top priority in particular, will most broadly advance our ability to incorporate changing climate conditions into regional management. It will also help inform regional NMFS planning as it relates to

climate science and the management of living marine resources in the Pacific's changing environment.

See you next year!

The 3rd Annual Collaborative Climate Science Workshop will be held in September 2019. If you would like to help plan the workshop or provide feedback on this year's workshop, please contact a member of the workshop steering committee:

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Appendix A—Agenda

Tuesday, 4 September: Protected species

1:00pm Welcome and introduction

1:10pm Introductory example of climate science being used toward a specific management need by T. Todd Jones

1:20pm Explanation of facilitated activity to align management needs and available science

1:30pm Introduction of the day's priority management information needs:

- Need for baseline information on species' and stocks' demographics
- Need to understand future shifts in species distribution
- Need to understand how climate change will impact protected species interactions
- Need to understand how climate change impacts might cascade through the food web
- Other needs related to sensitivity to climate change (specifically the need for vulnerability assessments for all protected species)

1:40pm Facilitated activities, including a 10-minute break

3:50pm Wrap-up and adjourn

Wednesday, 5 September: Coral reefs and insular/bottomfish

1:00pm Welcome and introduction

1:10pm Introductory example of climate science being used toward a specific management need by Shannon Ruseborn

1:20pm Explanation of facilitated activity to align management needs and available science

1:30pm Introduction of the day's priority management information needs:

- Need for climate-informed fishery assessments and management frameworks
- Need to understand future shifts in species distribution
- Need to understand how species will be affected by changing climate conditions
- Need for spatial ecosystem and habitat models

1:40pm Facilitated activities, including a 10-minute break

3:50pm Wrap-up and adjourn

Thursday, 6 September: Pelagic and highly migratory fish

1:00pm Welcome and introduction

1:10pm Introductory example of climate science being used toward a specific management need by Brian Langseth

1:20pm Explanation of facilitated activity to align management needs and available science

1:30pm Introduction of the day's priority management information needs:

- Need for climate-informed fishery assessments and management frameworks
- Need for fine-scale information on current and future climate in order to understand future shifts in species distribution
- Need to understand synergy between climate change impacts (i.e., socioeconomics of the Hawaii longline fleet in response to changing climate)
- Need to understand how species will be affected by changing climate conditions (i.e., how climate change impacts might cascade through food webs and impacts of ocean acidification on pelagic fisheries)

1:40pm Facilitated activities, including a 10-minute break

3:50pm Wrap-up and adjourn

Appendix B—List of Participants with Affiliations[1]

Melanie Abecassis	Pacific Islands Fisheries Science Center
Allen Andrews	Pacific Islands Fisheries Science Center
Seema Balwani	National Environmental Satellite, Data, and Information Service
Hannah Barkley	Pacific Islands Fisheries Science Center
Rusty Brainard	Pacific Islands Fisheries Science Center
Amanda Bradford	Pacific Islands Fisheries Science Center
Desiree Brint	Pacific Islands Regional Office
Tia Brown	Pacific Islands Fisheries Science Center
Lorilee Crisostomo	Western Pacific Regional Fishery Management Council, Marine Planning and Climate Change Committee chair
Katie Davis	Pacific Islands Fisheries Science Center
Sarah Ellgen	Pacific Islands Regional Office, Workshop Steering Committee Member
Mark Fitchett	Western Pacific Regional Fishery Management Council
Erik Franklin	University of Hawaii at Mānoa, Western Pacific Regional Fishery Management Council Scientific and Statistical Committee member
Jonatha Giddens	Pacific Islands Fisheries Science Center
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Krista Graham	Pacific Islands Regional Office
Richard Hall	Pacific Islands Regional Office
Justin Hospital	Pacific Islands Fisheries Science Center
Evan Howell	Pacific Islands Fisheries Science Center
Robert Humphreys	Pacific Islands Fisheries Science Center

[1]Remote participation from Guam and CNMI was impaired due to Typhoon Mangkhut.

Melanie Hutchinson	Pacific Islands Fisheries Science Center
Asuka Ishizaki	Western Pacific Regional Fishery Management Council
Ariel Jacobs	Pacific Islands Regional Office, Workshop Steering Committee Member
Hoku Johnson	Pacific Islands Fisheries Science Center
T. Todd Jones	Pacific Islands Fisheries Science Center
Alex Kahl	Pacific Islands Regional Office
Irene Kelly	Pacific Islands Regional Office
Tye Kindinger	Pacific Islands Fisheries Science Center
Eric Kingma	Western Pacific Regional Fishery Management Council
Don Kobayashi	Pacific Islands Fisheries Science Center
Brian Langseth	Pacific Islands Fisheries Science Center
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Kirsten Leong	Pacific Islands Fisheries Science Center
Charles Littnan	Pacific Islands Fisheries Science Center
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Michael Marsik	Pacific Islands Regional Office
Jonathan Martinez	Papahānaumokuākea Marine National Monument
Randy McIntosh	Pacific Islands Regional Office
Steven McKagan	Pacific Islands Regional Office
Marc Nadon	Pacific Islands Fisheries Science Center

Erin Oleson	Pacific Islands Fisheries Science Center
Thomas Oliver	Pacific Islands Fisheries Science Center
Joseph O'Malley	Pacific Islands Fisheries Science Center
Michael Parke	Pacific Islands Fisheries Science Center
Frank Parrish	Pacific Islands Fisheries Science Center
Noah Pomeroy	Pacific Islands Fisheries Science Center
Susan Pultz	Pacific Islands Regional Office
Jennifer Raynor	Pacific Islands Fisheries Science Center
Erin Reed	Pacific Islands Fisheries Science Center
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Ivor Williams	Pacific Islands Fisheries Science Center
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Johanna Wren	Pacific Islands Fisheries Science Center
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