Summary Report from the 3rd Annual Collaborative Climate Science Workshop, 11–12 September 2019, NOAA's Inouye Regional Center, Honolulu, HI

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Table of Contents

List of Figures

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 and second workshops were held in September 2017 and 2018, respectively (hereafter 1st Workshop and 2nd Workshop). The 3rd Annual Collaborative Climate Science Workshop (hereafter 3rd Workshop) was held at the NOAA Inouye Regional Center (IRC) on 11–12 September 2019. All 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 envisioned the 3rd and subsequent Workshops focusing on progress toward realizing the priorities identified. 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.

The steering committee refined the goal for the 3rd Workshop by further narrowing the focus to specific projects that aligned with priorities identified during the 2nd Workshop. The steering committee felt that such focus would better set up the region for success in realizing the NMFS Climate Science Strategy goal of incorporating climate-related information into living marine resource management and conservation. This decision stemmed from a general consensus among the committee that although the region is currently conducting a great deal of climate science, it is struggling to bring that science into the management realm. Bridging this gap was identified as a priority during the 2nd Workshop (Woodworth-Jefcoats et al., 2019).

Prior to this year's workshop, steering committee members from PIFSC worked with their staffs to identify 3–4 ongoing projects per session theme (see below) that aligned with the priorities identified during the 2nd Workshop (Woodworth-Jefcoats et al., 2019). Session-specific project overviews were delivered by project leads at the start of each session. Workshop participants then broke into small groups to discuss each project. Sufficient time was allotted to allow all participants to discuss each project. Following small group discussions, participants reassembled for a plenary evaluation exercise that allowed them to rate the degree to which each project's science meshed with current management needs. The ranking scale included three options: *not at all*, *somewhat*, and *completely*.

In keeping with previous workshops, each session focused on a specific ecological management component:

- Session 1: Protected species
- Session 2: Essential fish habitat and corals
- Session 3: Pelagic fisheries
- Session 4: Insular fisheries

The projects discussed during each session are listed in Appendix A.

Advancing Scientist–Manager Collaboration in Climate-informed Living Marine Resource Management and Conservation

The 3rd Workshop focused on 15 projects that aligned with the four priorities identified during the 2nd Workshop. This alignment is illustrated below in Fig. 1. Projects were chosen based on not only alignment with established priorities, but also maturity. The steering committee selected projects that were developed well enough to have a sense of what the deliverables will be, but that were in early enough stages to be able to incorporate input from managers. Throughout this report, projects are italicized when they are mentioned in the text to clearly identify and distinguish them from broader climate-related work.

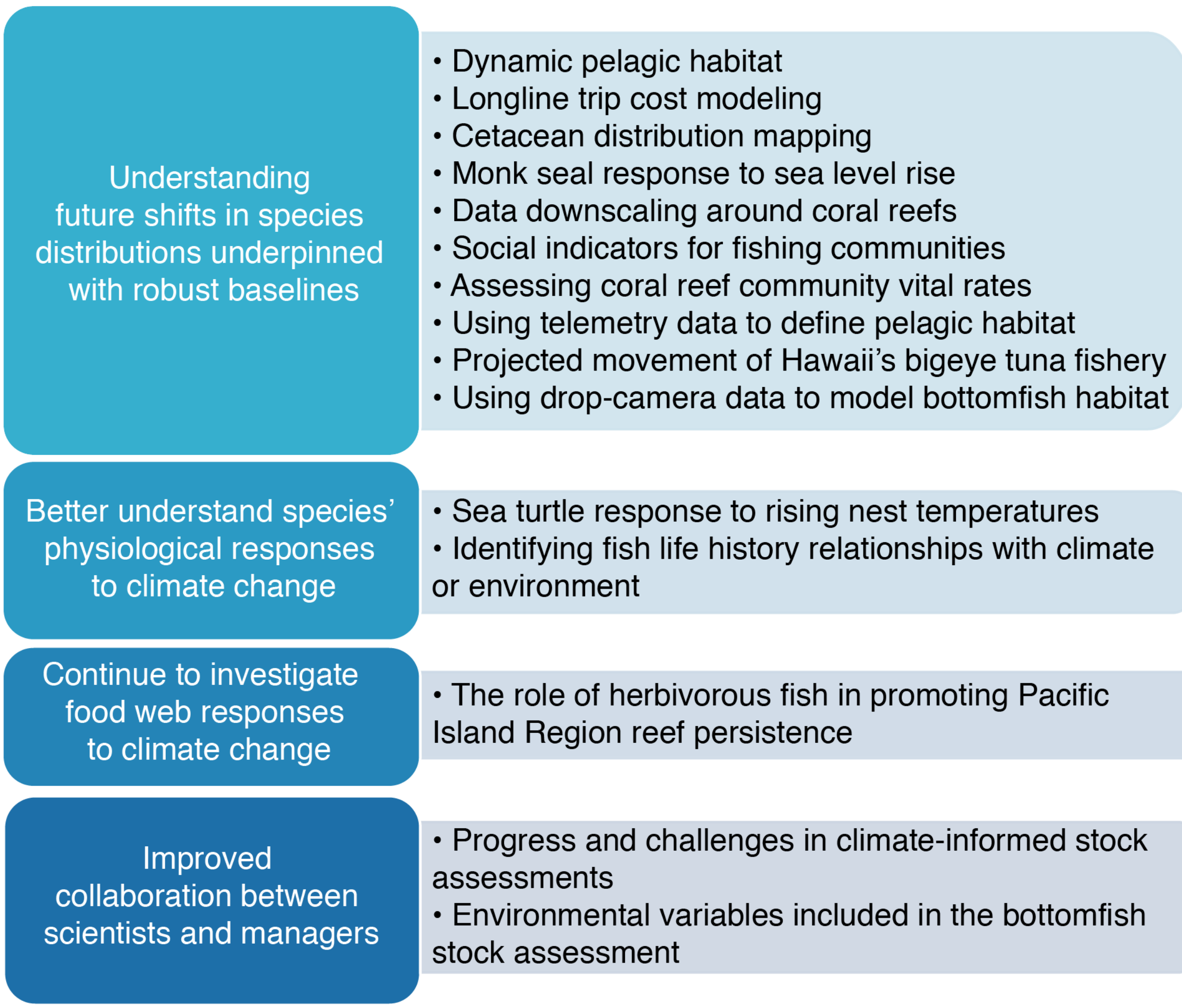

Figure 1. The four regional climate science priorities identified at the 2nd Workshop (left) and the focal projects discussed at the 3rd Workshop that align with these priorities (right).

Alignment between climate science and management needs

After the workshop, project and discussion summaries were paired with results of the evaluation exercise (Appendix B). This approach highlights that there is a broad range in the degree to which the climate science being conducted aligns with current management needs. For example, all participants agreed that work done to include *an environmental variable in the bottomfish stock assessment* fully meets current management needs. There was a similarly positive response to work being done to *gather and use drop-camera data to map bottomfish habitat*. At the other end of the spectrum, all participants felt that work being done to *map cetacean distributions* does not yet fully align with management needs.

The range in the degree to which ongoing climate science work aligns with management needs appears to stem primarily from the range in project maturity. Work that has only recently been undertaken and for which there are only preliminary results was generally less able to meet current management needs. These projects in particular should benefit from continued scientist–manager collaboration, as there is broad scope for forming the resulting science. Going forward, attention should be given by all project participants (both scientists and mangers) to foster collaboration, address needs as they arise, identify and remove barriers to forward progress, request help as it is required, and secure resources when possible.

Another interesting result of the plenary ranking exercise was instances where scientists and managers disagreed in their evaluations. For example, managers felt more confident than scientists that work being done to *model longline trip costs* and to *use telemetry to identify pelagic habitat* addressed their needs. Conversely, several managers felt that work being done to understand the *role of herbivory in reef persistence* and to *downscale data around coral reefs* did not at all meet current management needs, whereas no scientists expressed this opinion. Examples like these point to areas where more scientist–manager communication may be needed to fully explain current needs, as well as limitations and potential applications of ongoing research.

Overall, participants expressed a great deal of enthusiasm for collaborating across the scientist–management divide. In fact, several project leads meet with their management counterparts in the week immediately following the workshop. The steering committee, and indeed PIFSC, hopes to harness this enthusiasm to keep projects moving forward and positively impacting management needs. PIRAP leads are working with local leadership and the Pacific Region Climate Council to ensure projects receive the support they need. These efforts include alerting projects to funding opportunities, sharing updates at the national level to increase awareness of projects, and serving as center-specific liaisons to bring together appropriate project staff.

Avenues to Advance Scientist–Manager Collaboration

The projects discussed during the 3rd Workshop can be grouped into four categories described below for further scientist–manager collaboration. These project categories are roughly ordered in terms of their readiness for management integration. Two projects are ready to be integrated into management-driven mitigation work. About one third of the projects are at a stage where input on current management goals would be particularly informative. Another third of projects will need to overcome critical knowledge gaps before they can begin to meet management needs. Two projects will be ready to address management needs if they can overcome technological hurdles.

Projects ready to be integrated into mitigation work

Two projects have sufficient research and information for acting on a management need. These projects focus on *monk seal response to sea level rise* and *sea turtle response to rising nest temperatures*. Participants noted the critical need to begin mitigation work in French Frigate Shoals and on Tern Island in particular to address issues facing both species. Rising sea levels combined with deteriorating infrastructure and recent severe weather events are leading to monk seal entrapment hazards and a loss of green sea turtle nesting beaches. Building in part from work presented at the 3rd Workshop, regional managers are currently assessing options for mitigating these threats.

Projects ready for collaboration

More than one-third of the projects discussed appear ripe for collaboration with managers. Knowing current management needs related to coral reef habitats could inform the geographic scope of work being done to *downscale reef survey data* and assess the *role of herbivory in reef persistence*. Furthermore, such discussions could focus *data downscaling efforts* on particularly informative variables. Clear input from managers could similarly benefit efforts to define *dynamic pelagic habitat* and to project how climate change may alter its geographic distribution, and in turn the *distribution of the Hawaii longline fishery*. Clear understanding of the strengths and limitations of the work being done to *assess longline fishing trip costs* and to understand *community vulnerability* to climate change could help managers get a sense of how well ongoing work may, or may not, be able to address management needs.

Projects facing knowledge gaps

Five projects will likely have to overcome critical knowledge gaps before they can be realistically applied to meet management needs (though this should not preclude scientist–manager collaboration while these gaps are being addressed). Foremost among these projects is *climate-informed stock assessments* that *include environmental variables*. There is a lack of understanding of mechanistic relationships between the environment and life history for many pelagic and bottomfish management unit species. There are gaps even in attempting to uncover these relationships. For example, *modeling species' habitats* will first require a better understanding of how things such as water temperature, prey distribution, and current velocity are related to species distribution. Independent projects examining these relationships for *bottomfish* and *cetaceans* are underway. The effects of temperature on species' growth rates will also need to be established. Work using a collection of *fish otoliths* is attempting to address this gap.

Projects facing technological hurdles

Participants expressed that the management value of two projects in particular depends heavily on the ability to overcome technological hurdles. An approach called Structure from Motion (SfM) is being tested as a way to monitor *coral reef community vital rates*. However, for the value of this approach to be fully realized, SfM will need to use machine-learning techniques for image analysis. This will require access to high performance computing capabilities. Another project facing a technological hurdle is that *using telemetry data to define fish species' three-dimensional habitat*. If fishery-dependent logbook and observer data could be linked to existing environmental data sets like satellite and reanalysis data (comprehensive records of how weather and climate are changing over time), this would drastically expand the scope and potential impact of this project.

Synergy across projects

There was a fair amount of synergy across the projects discussed. In several instances, the results from one project could inform another project. Going forward, it may make sense for these projects to work together. This could allow the management needs tied to a downstream project to be incorporated earlier in the research process. Four potential synergies are described below.

Pelagic habitat and fisheries

Several projects focused on pelagic habitat and fisheries. The results from *telemetry work* will likely inform the variables and thresholds used to define *dynamic pelagic habitat*. In turn, changing *dynamic pelagic habitat* will lead to movement of pelagic species and therefore of the *longline fisheries*. Geographic changes in species distributions and fishery operating areas will affect things such as protected species interactions (*cetaceans* specifically, with respect to projects presented at the 3rd Workshop) and *longline trip costs*. Finally, changing *trip costs* will influence the degree to which the *fishing industry and communities are vulnerable to climate change*. Each of these linkages is a point where downstream management objectives could be incorporated into the nature of scientific deliverables.

Bottomfish

Another topic with a high potential for synergy was bottomfish. There are ongoing projects to *model bottomfish habitat*, *understand the effects of temperature on bottomfish life history*, and to *incorporate environmental variables into bottomfish stock assessments*. Coordination across these efforts will likely increase their management value, and may potentially expedite the production of *climate-informed bottomfish stock assessments*.

Coral reef communities

Several projects presented involve coral reefs. Results and management needs associated with the *downscaling* work could help identify priority areas for monitoring *coral reef vital rates*. The same applies to work being done to *understand and manage herbivorous fish*.

Species with terrestrial habitat

As discussed above, *monk seals* and *green sea turtles* are facing challenges unique to their terrestrial habitat. For this reason, cross-project scientist–manager collaboration will be particularly impactful. Furthermore, the urgency of the current situation heightens the need to ensure this collaboration happens.

Summary and Next Steps

The goal of the 3rd Annual Collaborative Climate Science Workshop was to advance scientist–manager collaboration on climate-informed living marine resource management and conservation. To achieve this goal, the 3rd Workshop focused on 15 specific projects that were aligned with the 4 priorities identified during the 2nd Workshop (Fig. 1). Participants were enthusiastic about collaborating and the workshop steering committee is looking forward to building on this enthusiasm to move projects forward over the coming year. It is expected that next year's workshop will focus on the progress made on these projects, particularly progress in using science products to inform management.

One of the challenges the region has faced in carrying out the PIRAP (Polovina et al., 2016) has been linking climate science to management. One reason for this challenge is the time frame on which each focuses. Management is generally focused on the near-term future, whereas climate change is often regarded as a distant threat. It is hoped that through ongoing collaboration and dialogue, scientists and managers can find ways to overcome this gap. For example, approaches could include using climate science to inform scenario planning or establishing near-term thresholds for action based on longer-term projected change. Scientist–manager collaboration could also help managers prepare for climate-drive eventualities such as shifting species distributions and relocating fisheries.

The steering committee emphasizes that advancing scientist–manager collaboration and linking climate science to management are only possible if both parties make a concerted and consistent effort toward this goal. Managers must reach out to scientists with their climate-related information needs and questions. Scientists must reach out to managers throughout the research process in order for their work to be impactful. Furthermore, these scientist–manager communications cannot cease. Rather, we need to embrace a new way of doing business. The projects presented at this year's Workshop emphasized this need by demonstrating that the effects of climate change are already being felt in the Pacific Islands region.

Finally, with so much energy focused on the 15 projects included in the 3rd Workshop, it will be important for regional scientists and managers to be cognizant of resulting gaps. The workshop steering committee and PIRAP implementation leads will work to incorporate gap recognition into future planning.

See you next year!

The 4th Annual Collaborative Climate Science Workshop will be held in September 2020. 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

Protected Species: Wednesday, 11 September, 9 am–12 pm

9 am	Welcome and opening remarks	Phoebe Woodworth-Jefcoats
9:15 am	Collaboration roadmap	Jennifer Samson
9:30 am	Project Introductions	

- *Monk seal response to sea level rise* — Jason Baker
- *Sea turtle response to rising nest temperatures* — Summer Martin
- *Cetacean distribution mapping* — Erin Oleson

10 am	Small group discussions	
11:25 am	Plenary project evaluation exercise	
11:45 am	Concluding remarks	Phoebe Woodworth-Jefcoats

Essential Fish Habitat and Corals: Wednesday, 11 September, 1–4 pm

1 pm	Welcome and opening remarks	Phoebe Woodworth-Jefcoats
1:15 pm	Collaboration roadmap	Jennifer Samson
1:30 pm	Project Introductions	

- *Assessing coral reef community vital rates* — Tom Oliver
- *Data downscaling around coral reefs* — Tom Oliver & Tye Kindinger
- *The role of herbivorous fish in promoting Pacific Island Region reef persistence* — Ivor Williams
- *Dynamic pelagic habitat* — Don Kobayashi

2:10 pm	Small group discussions	
3:25 pm	Plenary project evaluation exercise	
3:45 pm	Concluding remarks	Phoebe Woodworth-Jefcoats

Pelagic Fisheries: Thursday, 12 September, 9 am–12 pm

9 am	Welcome and opening remarks	Phoebe Woodworth-Jefcoats
9:15 am	Collaboration roadmap	Jennifer Samson
9:30 am	Project Introductions	

- *Progress and challenges in climate-informed stock assessments* — Michelle Sculley
- *Using telemetry data to define pelagic habitat* — Melanie Hutchinson

	o *Projected movement of Hawaii's bigeye fishery*	Don Kobayashi
	o *Longline trip cost modeling*	Michel Chan
10:10 am	Small group discussions	
11:25 am	Plenary project evaluation exercise	
11:45 am	Concluding remarks	Phoebe Woodworth-Jefcoats

Insular Fisheries: Thursday, 12 September, 1–4 pm

1 pm	Welcome and opening remarks	Phoebe Woodworth-Jefcoats
1:15 pm	Collaboration roadmap	Jennifer Samson
1:30 pm	Project Introductions	
	o *Using drop-camera data to model bottomfish habitat*	Felipe Carvalho
	o *Identifying fish life history relationships with climate or environment*	Erin Reed
	o *Environmental variables included in the bottomfish stock assessment*	Brian Langseth
	o *Social indicators for fishing communities*	Kirsten Leong
2:10 pm	Small group discussions	
3:25 pm	Plenary project evaluation exercise	
3:45 pm	Concluding remarks	Phoebe Woodworth-Jefcoats

Appendix B: Project and Discussion Summaries

Monk seal response to sea level rise

Project Overview: Monk seals require terrestrial habitat (e.g., for pupping and resting). Already limited and diminishing terrestrial habitat in the northwestern Hawaiian Islands (NWHI) is expected to be further limited due to sea level rise (SLR). This important habitat is at risk from extreme storm events, as evidenced by the impacts of Hurricane Walaka on French Frigate Shoals in early October 2018. Mitigation in a variety of forms is required to address these current and future threats.

Discussion: There are knowledge gaps related to understanding of the potential nature, extent, and timing of future SLR and extreme storm impacts as well as the range of potential near- to long-term mitigation measures and their efficacy. The issue, understanding potential terrestrial habitat loss due to elevated water levels in the NWHI and identifying measures to mitigate these losses, calls for leveraged collaboration as: 1) it applies to other protected species such as turtles and seabirds and 2) it crosses a myriad of agency jurisdictional/management boundaries as well as institutional/organizational interests.

Next Steps: Commence regular discussions among a small group of research and managers to start framing the issue and identifying desired outcomes. Then work outward to include a broad range of stakeholders and build to a coordinated plan of action related to conserving terrestrial habitat in the NWHI.

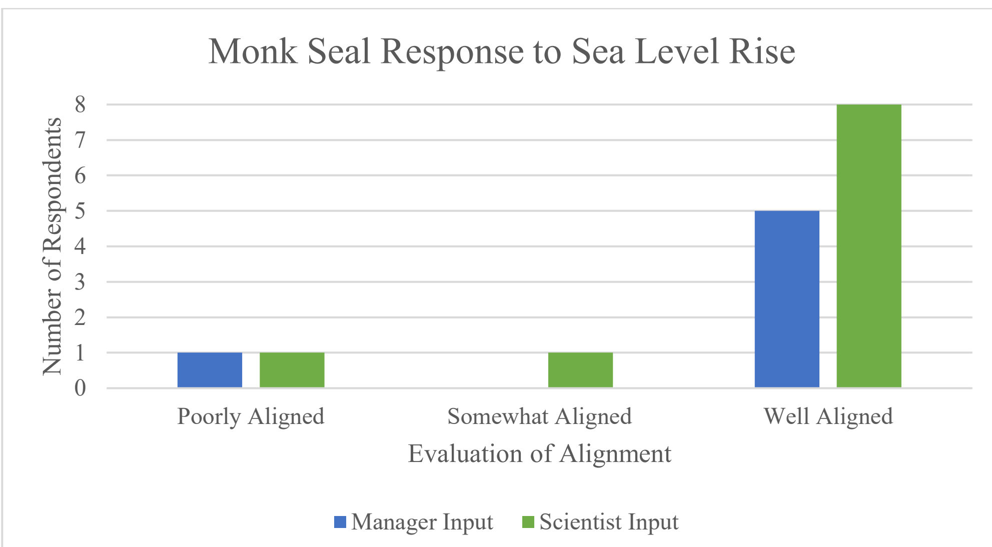

Figure 2. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to monk seal response to sea level rise.

Sea turtle response to rising nest temperatures

Project Overview: Warming temperatures have been shown to alter the sex ratio of green sea turtles. The increased heat during the incubation period both increases the number of females, and at higher thresholds, increases embryonic death. Present viability analysis relies exclusively on nester abundance data and does not quantitatively include climate change impacts. However, climate-driven population viability models of nester abundance will directly inform Endangered Species Act management of marine turtle population segments.

Discussion: There are many opportunities to expand this work to encompass greater understanding of the ecology and biology of green sea turtles. However, major knowledge gaps remain. Collaborations may help to resolve some of the more critical gaps, such as understanding foraging opportunities and learning from the successes of others relative to wildlife translocation. Further communication about science needs is required in areas such as what science can better inform mitigation activities, and what previous mitigation activities have achieved success. Major discussion surrounded the decay of the Tern Island facility and what can be done to mitigate the potential for mortality events.

Next Steps: There are very few viable nesting habitats remaining. With so few nesting habitats, their relative importance is increased. There is a need to focus resources to "fix" both Tern Island and French Frigate Shoals to offer near-term reproductive opportunities.

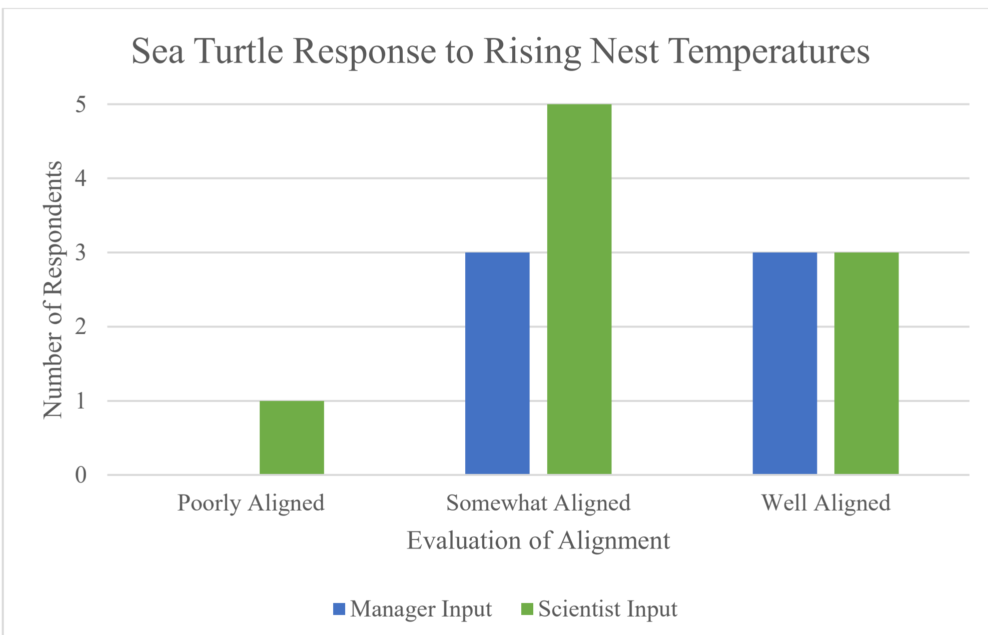

Figure 3. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to sea turtle response to rising nest temperatures.

Cetacean distribution mapping

Project Overview: This project is producing spatially-explicit species density and distribution models around Hawaii based on large-scale cetacean surveys. A range of environmental and geographic variables are being used to inform these models. Currently, about ten species are being modeled. This work builds off similar efforts undertaken by the Southwest Fisheries Science Center for the California Current region. It's important to note that such models have variable success, particularly during anomalous conditions. While this work is so far focused on current management needs, there is interest in expanding efforts to address issues related to the longline fishery.

Discussion: The focus of most discussions was on interactions between false killer whales (FKWs) and Hawaii longline fleets, and to a lesser extent on sperm whale interactions with American Samoa longliners. There is a need for climate-informed projections that include where target fish (bigeye tuna) and fisheries will go (with respect to cetacean abundance) and to analyze efficacy of bycatch reduction management (e.g., southern exclusion zone closure). The following additional questions arose: What is the ability of FKWs to adapt to climate change? What is the balance between declining abundance vs. growth vs. geographic redistribution? Are there potential pilot projects that could be built based on experiences in the California Current region?

Next Steps: In the near-term, this project will expand from visual survey data to include acoustic data. Additional future steps include expanding to additional species, modeling Territorial distributions, and addressing challenges related to climate change projections (e.g., how to accurately model conditions that do not currently exist).

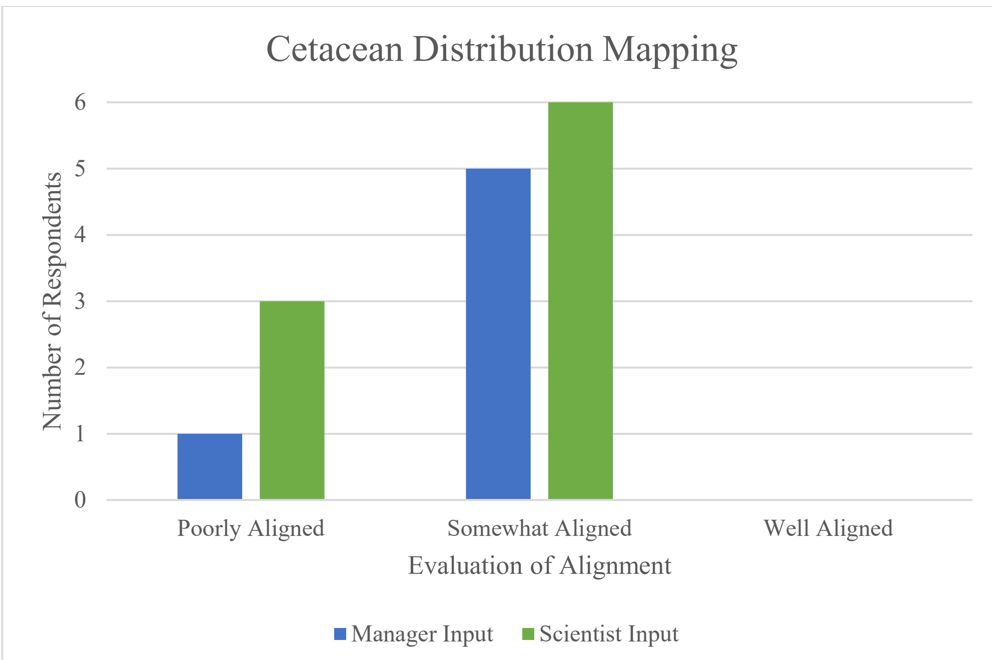

Figure 4. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to cetacean distribution mapping.

Assessing coral reef community vital rates

Project Overview: Structure from motion is a photogrammetric range imaging technique for estimating three-dimensional structures (like coral reefs) from two-dimensional images. The images take substantial hands-on time to piece together and finding ways to automate this process will dramatically expand its utility. This process is a game changer because it allows for large-scale mark and recapture experiments and tracking the growth, “shrinkage”, mortality, and recruitment of thousands of the coral colonies without actually marking colonies.

Discussion: Once the throughput issue is resolved there are many applications for this tool and it should be applied strategically. For example, analyses could be conducted before and after essential fish habitat federal actions to determine efficacy. It can be used to monitor sensitive sites to track losses or ecosystem level recovery, particularly after an invasive species outbreak. It can be used to monitor bleaching, recovery, and trends at specific locations in marine national monuments, among other activities. Structure from motion can also inform proactive management activities towards achieving successful restoration. Applications in the mesophotic realm would allow for understanding that "shadow zone" and the habitat located there.

Next Steps: The gaps surrounding the automation are large and include the following: computing power, processing time, and active participation from coral identification experts. The process would benefit from machine learning techniques and the application of the coral identification expertise would inform any machine learning activities. The resolutions of these gaps are key to the success of the project in the larger scope.

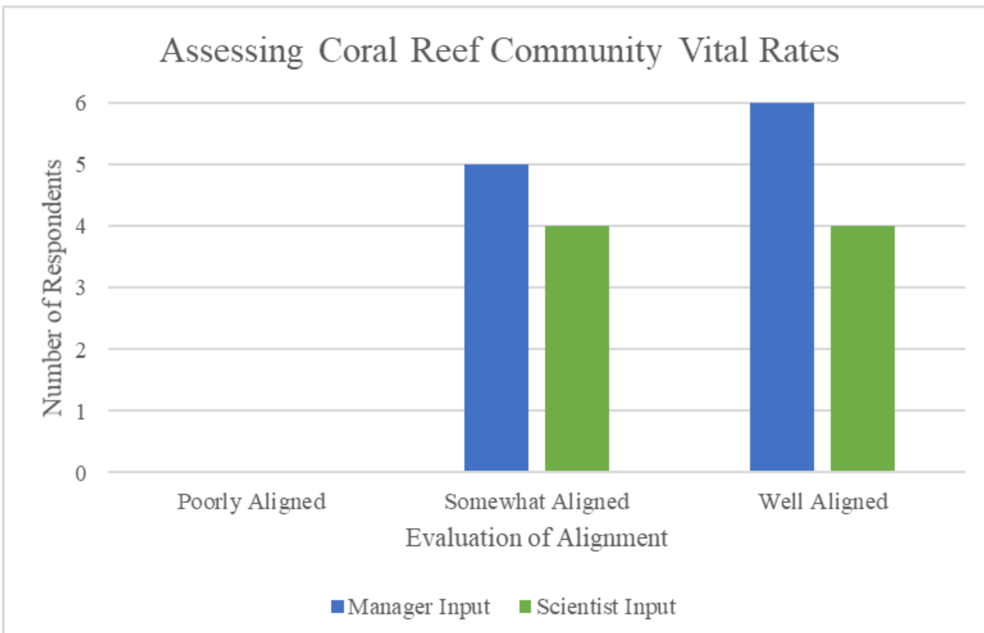

Figure 5. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to assessing coral reef community vital rates.

Data downscaling around coral reefs

Project Overview: This project involves downscaling island-scale coral reef community data to gain more meaningful insights into drivers of change. Often different drivers are of greater or lesser importance in different coastal regions of the same island. For example, one side of an island may be more subject to land-based run-off while another side may be more heavily impacted by temperature-driven bleaching events. Downscaling allows identification of such drivers as well as the longer-term coral reef community response.

Discussion: Discussions on this topic focused primarily on how and why downscaling is conducted. For example, what data are used (data used can be tailored to the question being asked), why is downscaling necessary (to bridge existing long-term time series with current management needs). Possible applications include determining appropriate reference states for management decisions, Hawaii's 30×30 initiative, and informing future sampling efforts.

Next Steps: In FY20 staff will be applying this method to understand bleaching impacts in Guam and CNMI. Work will also be conducted to identify spatial drivers of trends. Collaboration with managers would help ensure that the scale of downscaling matches specific management needs.

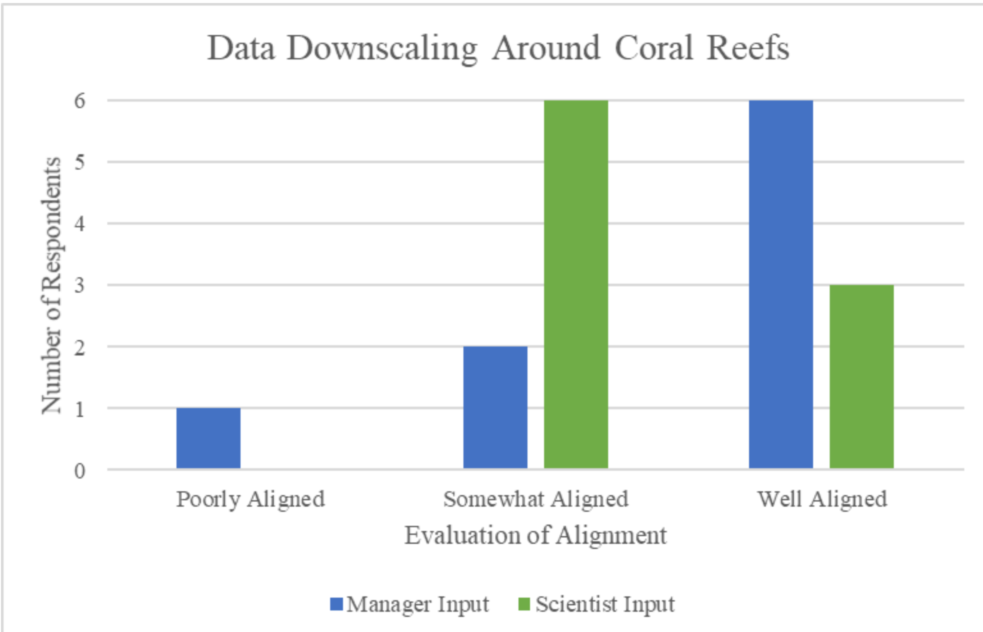

Figure 6. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to downscaling data around coral reefs.

The role of herbivorous fish in promoting Pacific Island Region reef persistence

Project Overview: This project involves efforts to mitigate the effects of climate change on coral reefs. Scientists are investigating the herbivory on algae as a means to reduce stress to corals because of climate change. In FY19 scientists completed a review on herbivore management and coral reef persistence and established a database of bite rate and size for main Hawaiian Islands (MHI) species. Next, they will collate with other survey data sets and begin analysis. Partnerships include the State of Hawaii's Division of Aquatic Resources (30×30 initiative) and The Nature Conservancy.

Discussion: Discussions focused on the role of this research in the larger State of Hawaii 30×30 initiative. The need for recruitment of manpower for monitoring herbivory sites and the need for overall project management were also discussed. The question arose of how to effectively monitor coral reef species after the designation of Ecosystem Component Species. Management needs for essential fish habitat assessments were discussed, as was the question of how to prioritize areas for recovery (e.g., what are indicators of algae danger? what guidance is needed on where and how herbivory would be effective?).

Next Steps: One next step includes potential grant funding for management of a volunteer network to monitor herbivory data-gathering sites. More broadly, continued conversation with management about their needs for essential fish habitat work is planned.

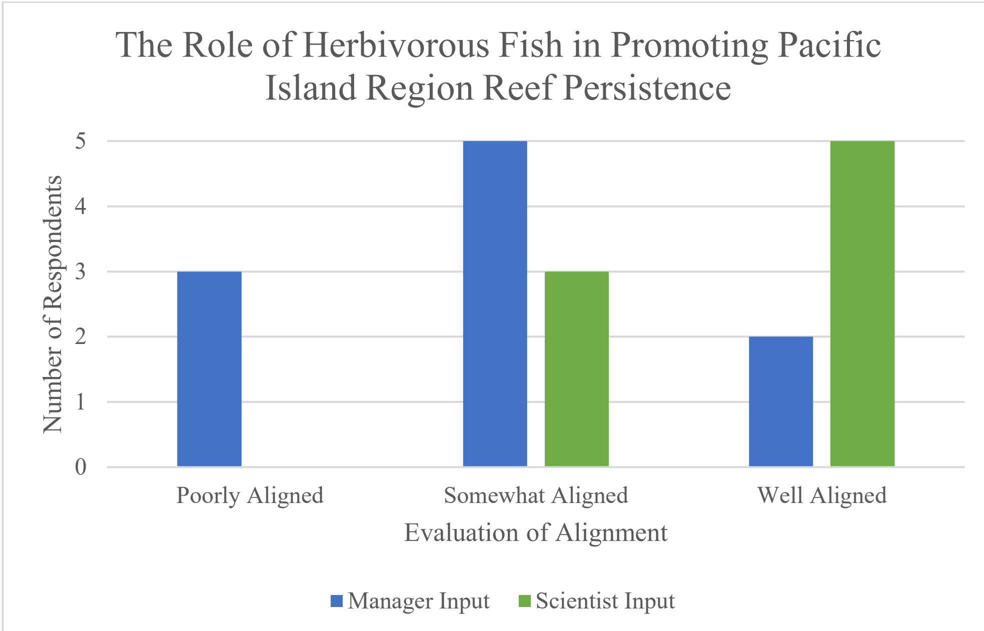

Figure 7. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to the role of herbivorous fish in promoting Pacific Island Region reef persistence.

Dynamic pelagic habitat

Project Overview: The goal of this project is to identify the preferred habitat of bigeye tuna and commercially important non-target species and develop environmental indictors that allow us to determine fish distributions and anticipate shifts in those distributions. It involves a range of approaches, from determining how eddies and fronts influence catch composition to understanding how climate variability and change are projected to affect species distributions.

Discussion: This project is in its infancy, so there is much scope for incorporating management needs. Bigeye tuna are the project's focus because of their commercial importance, but it is possible to include other species (e.g., striped marlin). A number of gaps were identified, including the influence of El Niño–Southern Oscillation cycles, questions surrounding life history, and data collection limitations.

Next Steps: Next steps for this project fall into two categories: establishing management needs and overcoming data gaps. Collaboration with managers will help focus the project's goals and inform the production of indicators. Creativity and partnerships will likely be needed to overcome data gaps, particularly as they relate to a paucity of fishery-independent information and questions surrounding spawning behavior and life history.

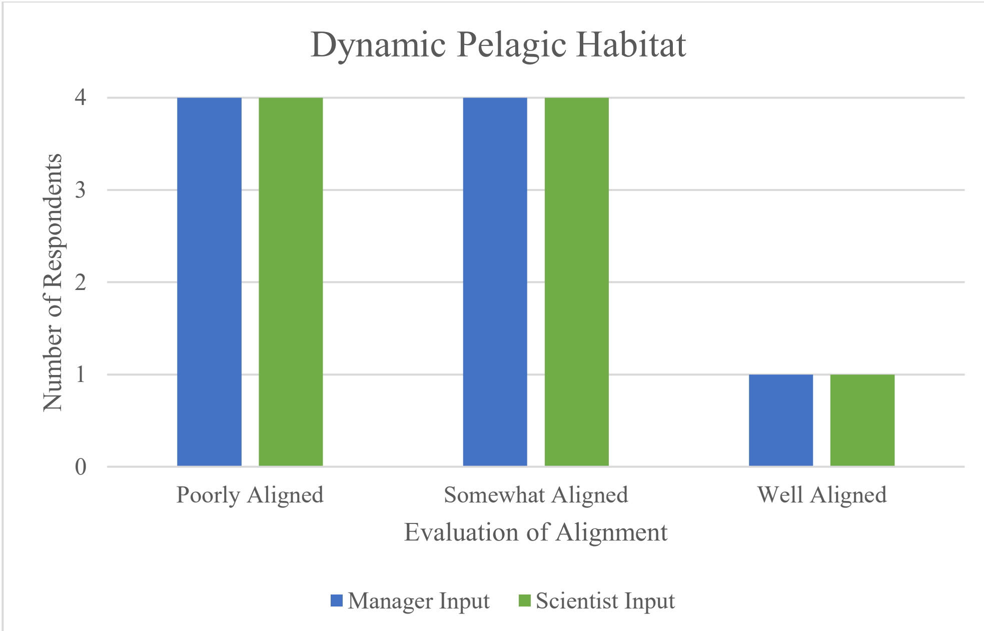

Figure 8. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to dynamic pelagic habitat.

Progress and challenges in climate-informed stock assessments

Project overview: This project focused primarily on the challenges to conducting climate-informed stock assessments (though recent progress in the swordfish stock assessment was touched upon). The main challenges include the need to identify mechanisms linking environmental conditions to stock dynamics, the lack of fishery-independent data in the region, and there being little staff time to devote to exploring new climate-informed stock assessment models.

Discussion: Discussion on this topic delved into the challenges associated with climate-informed stock assessments. These challenges include unknown stock structures, unknown prey resources, uncertainty surrounding mechanistic relationships (including uncertainty about which variables should, and can, be monitored), and challenges aligning science with current management frameworks. The value of current efforts and data was also noted, including the high quality of Hawaii's observer data, work being done by PIRO's Sustainable Fisheries Division, and emerging partnerships between PIFSC's Ecosystem Sciences Division and Fisheries Research and Monitoring Division.

Next Steps: The current lack of both data streams and understanding of mechanistic relationships will be challenging obstacles to overcome. One possible avenue toward this would be allocation of staff time specifically to examining these questions, beginning with evaluating mechanisms using existing data. Collaboration between scientists and managers would help ensure these efforts are focused on high-priority species and/or needs.

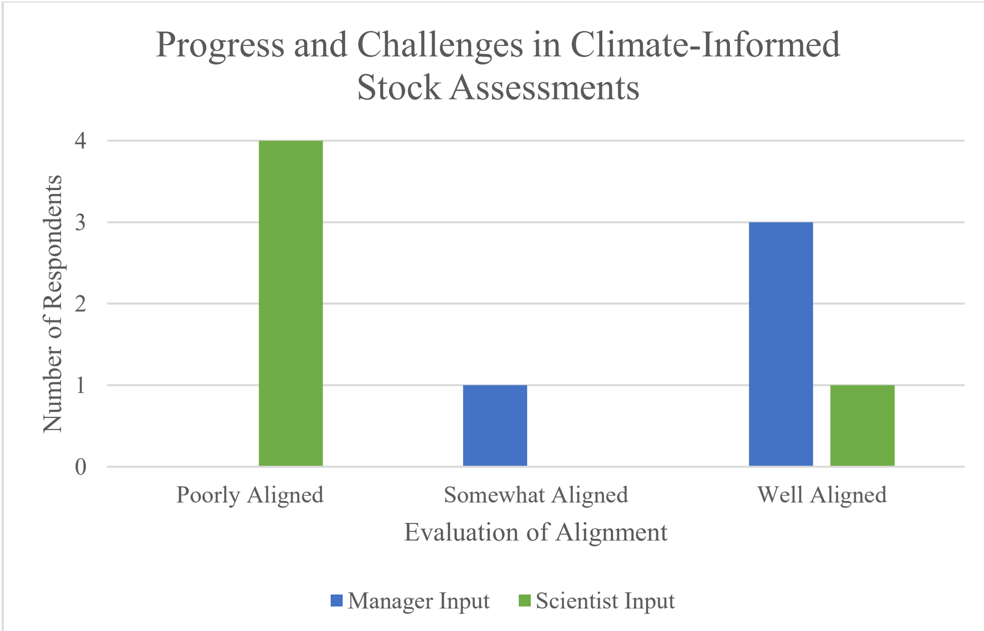

Figure 9. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to climate-informed stock assessments.

Using telemetry data to define pelagic habitat

Project overview: This project is aggregating existing tagging data from large pelagic fish (tunas, marlins, and sharks) to gain insight into species' preferred thermal habitat below the ocean's surface. Fish have strong thermal habitat preferences, which means their spatial distribution will be directly affected by climate change. Knowing species' preferred thermal habitat will allow scientists to project these distributional changes, and in turn project potential fishery impacts.

Discussion: Discussions on this topic focused primarily on coordinating broader complimentary efforts. Historically, tagging researchers have been reluctant to share their data. This means it is hard to know what's available, but things are starting to change (e.g., Animal Telemetry Network). Numerous potential collaborators were identified. Another deeply discussed topic was linking environmental data to fisheries data, such as logbook and observer data. This effort would yield large returns. Challenges related to small sample sizes were also discussed.

Next steps: Two avenues for progress were raised. One, engagement in the Animal Telemetry Network was recommend, as was engagement of numerous potential collaborators. Two, collaboration with the Alaska Fisheries Science Center to expand efforts to link environmental and fisheries data was discussed.

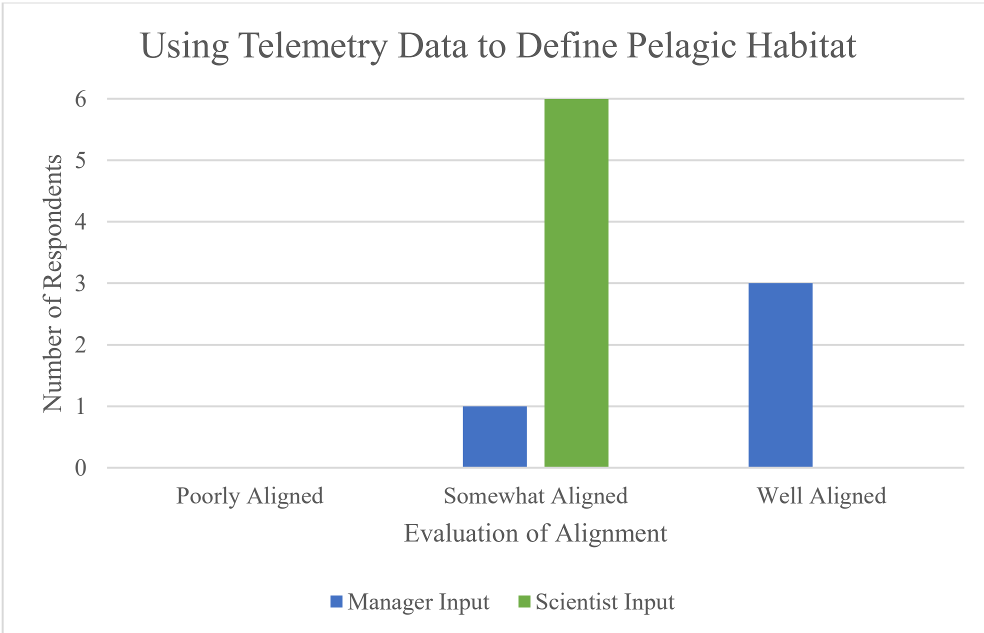

Figure 10. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to using telemetry data to define pelagic habitat.

Projected movement of Hawaii's bigeye fishery

Project Overview: The goal of this project is to understand what environmental factors affect the spatial footprint of Hawaii's longline bigeye tuna fishery. To this end, work is being done to link spatial distributions of catch rates and composition to environmental variables such as ocean temperature and productivity. Once these relationships are established, climate models can be used to project the likely movement of the fishery over time. Understanding this movement can inform industry and management decisions.

Discussion: The discussions on the project focused on knowledge gaps and how they could potentially be addressed through further scientist–manager collaboration. This project relies heavily on observer data, leaving gaps around spatial management measures, stock structure, and identification of nursing and spawning hotspots. Collaboration with managers could potentially lead to observers gathering information on species' sex, as well potential dynamic spatial management based on spawning areas and purse seine interactions. The need for international collaboration was also noted, for example with Japan for information on larval distributions.

Next Steps: In the near-term, further conversation between scientists and managers is needed to better define the current management questions surrounding movement of Hawaii's bigeye fishery. Enhanced observer data collection could potentially provide information on spawning behavior.

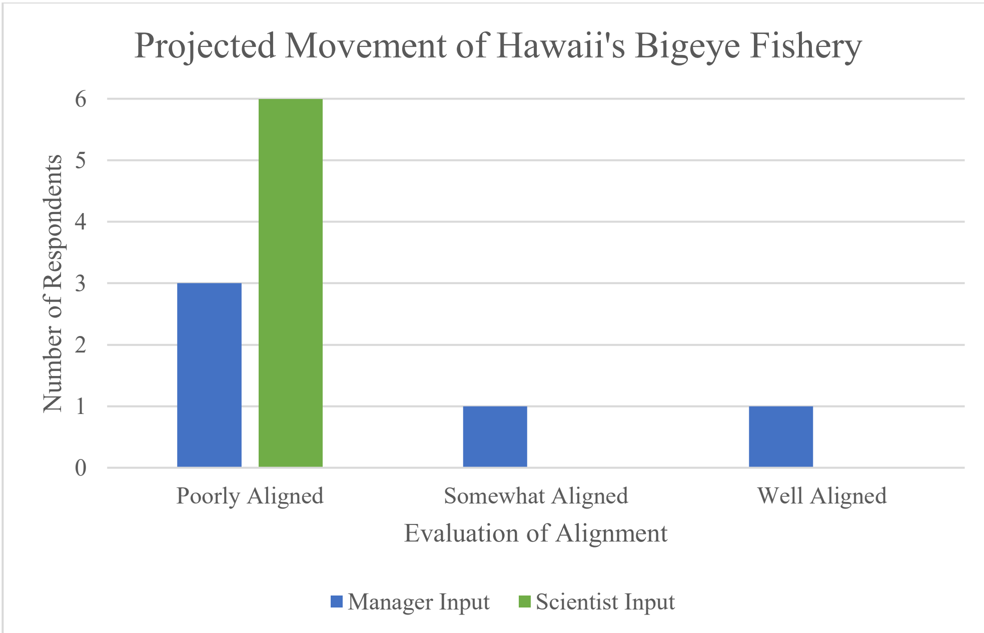

Figure 11. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to projected movement of Hawaii's bigeye fishery.

Longline trip cost modeling

Project Overview: This project involves developing trip cost models for the Hawaii and American Samoa longline fisheries using data collected from observed trips (~ 13% of trips for Hawaii and < 10% for American Samoa). The potential connection to climate change is how travel distance could change (which would impact fishing trip costs and profitability).

Discussion: Data has decreased over recent years because trip operators are hesitant to provide information. Researchers were interested in getting feedback from managers about addressing management goals. Right now, models do not include climate change but there was a suggestion to use El Niño years as a test case to identify variables that affected profitability. United Nations efforts to establish closures on the high seas have potential impacts to fleets. Managers were also interested in knowing the impact of the Papahānaumokuākea Marine National Monument creation (e.g., a before and after analysis).

Next Steps: Researchers could look at specific years for climate impacts. Research initiatives have repercussions for climate change impacts, and creation of monuments and other closure areas. Observer debriefers may need to push more for data or outreach to captains about the importance of trip cost information to continuously bring in data.

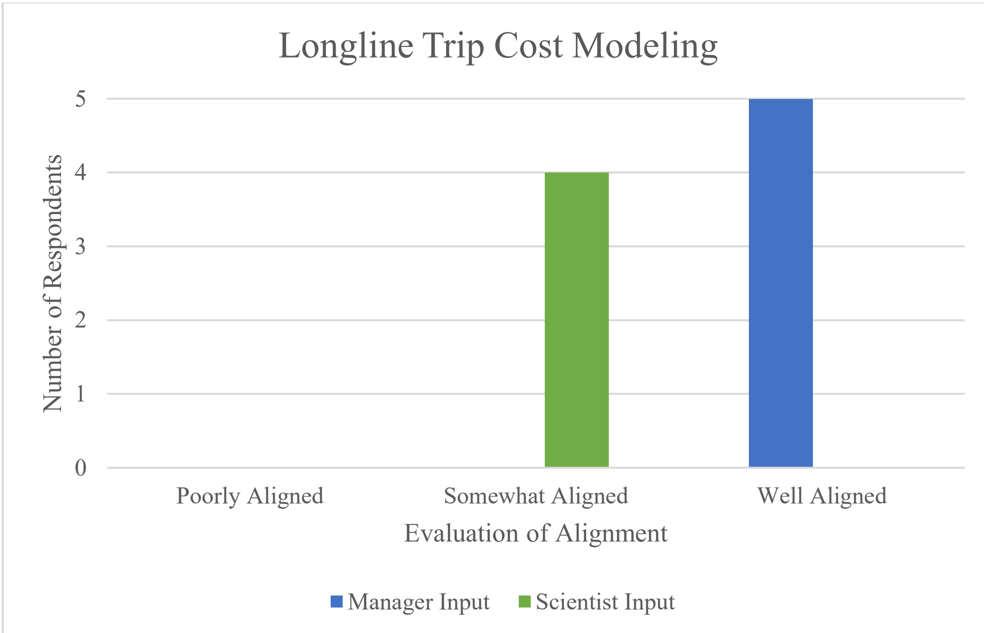

Figure 12. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to longline trip cost modeling.

Using drop-camera data to model bottomfish habitat

Project Overview: The Bottomfish Fishery-Independent Survey in Hawaii (BFISH) is designed to produce accurate, precise, and market-free species-specific, size-structured abundance estimates for use in the Deep7 stock assessment. To conduct the survey, two different types of gear are used: fishing and a drop-camera system. Each give a different perspective on what is going on in the environment. The survey domain comprises the 75-400 m depth range around the eight main Hawaiian Islands, which is over 6000 km^2 from Niihau to the Big Island.

Discussion: The drop-cameras offer the opportunity to collect additional climate-related data that would inform both the survey and the assessment. The link to climate here is unclear. Climate data will improve our understanding of fishery movement and why they are moving. Understanding the prey distributions would expand the climate link and its impacts on other biological activities (e.g., spawning aggregations). Attaching temperature-depth recorders and oxygen sensors to the cameras would provide insight into species' environmental preferences. Another useful data stream would be current dynamics, which would allow an understanding of the local environment and fishes' reaction to change. According to fishers, these are crucial data. A regional ocean model would be informative but may not have the fine scale resolution needed. This work could also help identify the gene flow from the MHI to the NWHI. There should be some temperance of expectations surrounding eDNA and its ability to identify present species.

Next Steps: The near-term next steps include expanding the data gathered from the camera array. Affixing some additional sensors, such as a pH meter, because the differences in pH are exacerbated at depth, a current meter or acoustic Doppler current profiler to understand the oceanography at depth, and an oxygen sensor. All of these would expand our understanding of the impact of world the fish is living in and how climate change is impacting that world.

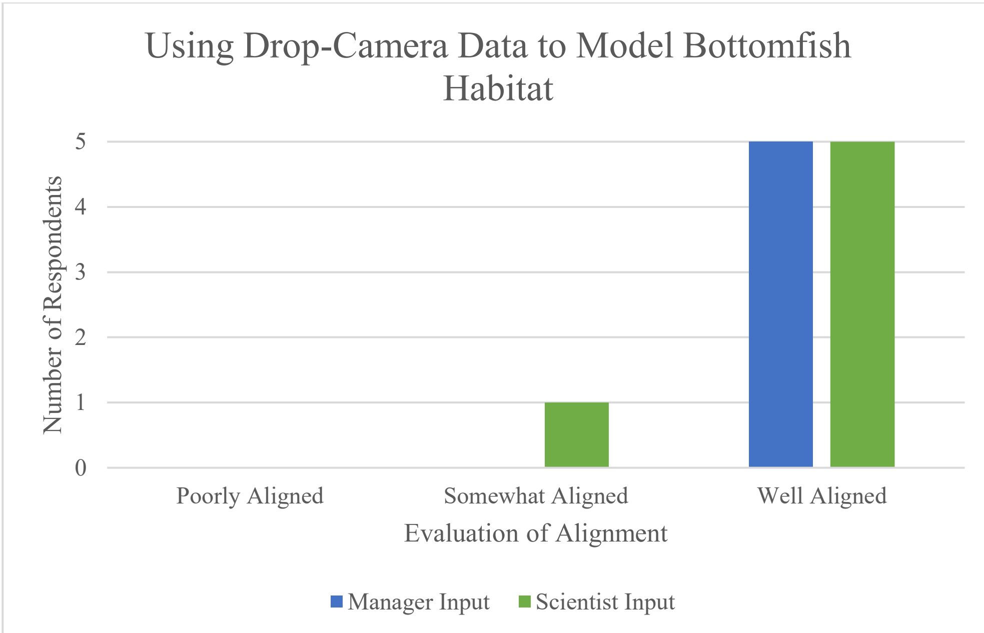

Figure 13. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to using drop-camera data to model bottomfish habitat.

Identifying fish life history relationships with climate or environment

Project Overview: This work involves examining fish life history characteristics with relationships to climate variability and environment to better understand how fishes may respond in a changing climate. The first and main project discussed was work that involved examining patterns in fishes' otoliths in order to better understand how climate variability and the environment affects fishes' growth rate. The creating of time series constructed from biochronologies using otolith ring width increments is the main method of this project. It is quite similar to the analysis of tree rings (dendrochronology). This approach is also known as schlerochronology, or the use of dendrochronology techniques on aquatic organisms such as invertebrates and fish. The project has the potential to provide insight into how growth rate varies with temperature, other environmental variables, and climate variability. The second project involves examining otoliths and gonads across a latitudinal, and hence thermal, gradient. Region specific collections of otoliths and gonads will be used to identify common patterns of all life history aspects such as age, growth, and reproduction across a latitudinal gradient.

Discussion: Discussion on this topic was wide-ranging. Multiple participants raised questions about how the results could inform management, given the challenges in managing bottomfish and reef fish fisheries. Several participants also pointed out that if this work were to establish a clear relationship, it could enable predictive power that would benefit both industry and management. The challenge in accounting for the effects of fishing, the identification of potential thermal thresholds, and practices used to inform previous assessments were also discussed.

Next Steps: At this point, the next steps appear to be largely tied to further scientific progress. PIFSC scientists are still analyzing the results of otolith data from the Marianas. A feasibility analysis is being prepared for the dendrochronology work. Participants raised several potential academic collaborations.

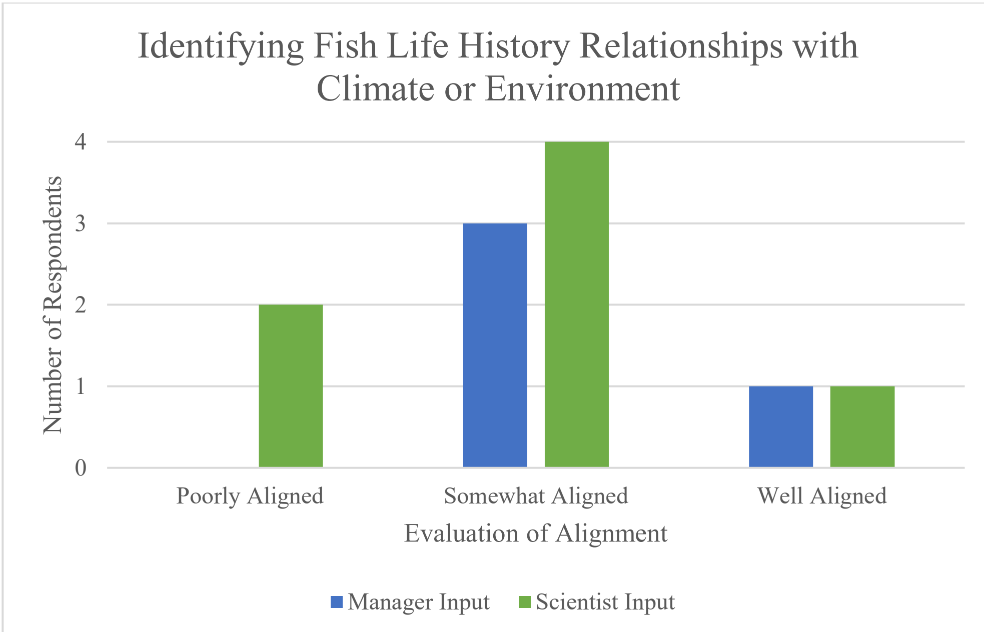

Figure 14. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to identifying fish life history relationships with climate or environment.

Environmental variables included in the bottomfish stock assessment

Project Overview: In 2018, scientists included wind speed as a factor affecting catch rate in the MHI bottomfish stock assessments. Wind speed was found to have a significant inversely proportional effect on catch rates. Wind was included because of the expectation that windier weather makes fishing more difficult and therefore could decrease catch rates.

Discussion: Scientists were curious what other factors would be of interested to managers; e.g. temperature, surface currents, currents at depth. The need to understand the relationship between wind and large-scale climate factors was also discussed. One knowledge gap raised was that it is currently unknown how climate affects bottomfish life history.

Next Steps: If there is evidence that species distributions will shift due to climate changes, this information could be incorporated into management documents.

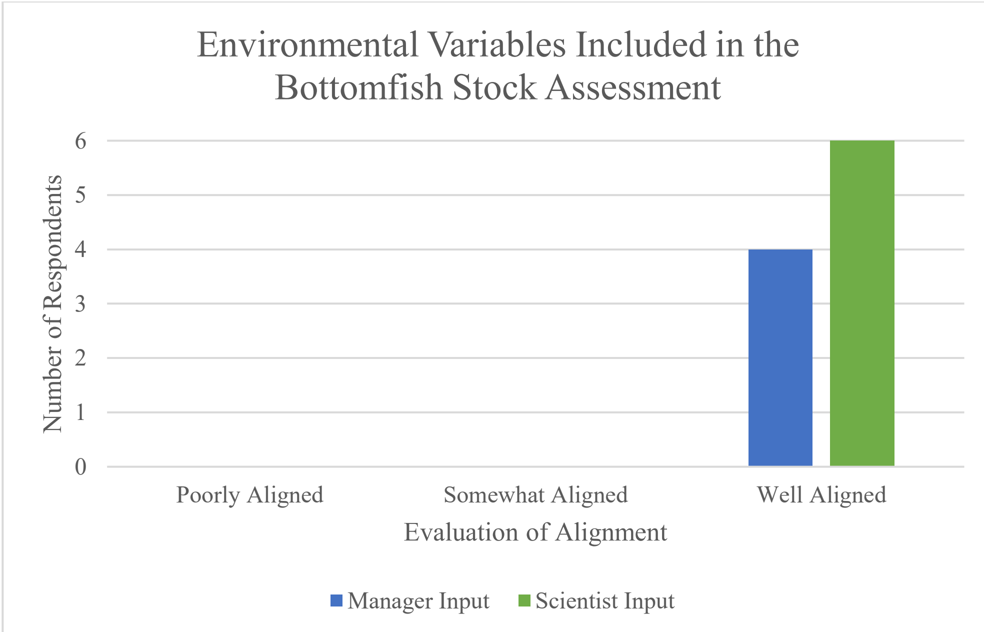

Figure 15. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to environmental variables included in the bottomfish stock assessment.

Social indicators for fishing communities

Project Overview: This project examines the vulnerability of fishing communities across Hawaii based on a suite of factors. Communities are delineated based on geography at roughly a moku scale. Currently, the project is working on examining vulnerability in relation to specific fisheries and species. Understanding this relationship could allow for projections of how different communities may be impacted by climate change. For example, if a community is particularly reliant on a species that is projected to be displaced by climate change, this community could be particularly vulnerable.

Discussion: Discussions focused on information gaps that could be addressed going forward. These included new indicators more directly tied to fish/fishing (e.g., diet/health) as well as improved understanding of: the relationship between where people live and where they fish, spatial changes in fish distributions, and changing fisher demographics and behavior. Data on non-commercial fish catch and the fate of fish caught (i.e., eaten, sold, etc.) would enhance vulnerability estimates. It was also noted that the project could potentially be molded to better address current management needs.

Next Steps: Two specific next steps were identified. One recommendation was for better communication between PIFSC and PIRO to explore how this information could be used in the social impact assessment sections of planning documents that are required by the National Environmental Protection Act. Two, participants noted that this information could be included in the Council's annual Stock Assessment and Fisheries Evaluation reports, but that Plan Team approval would be needed to do so.

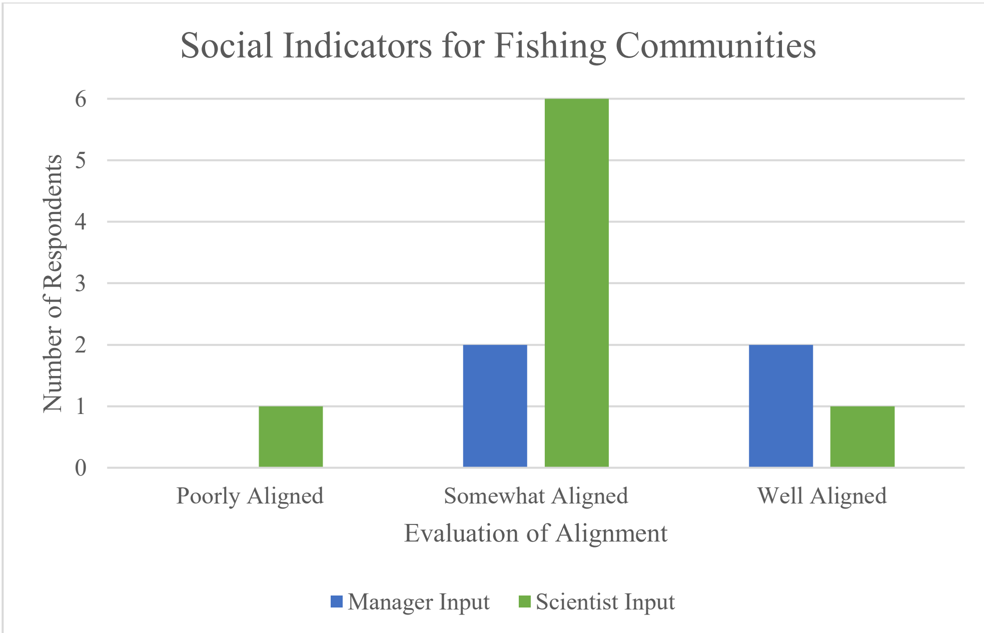

Figure 16. Results from plenary exercise evaluating the degree to which current scientific work aligns with current management needs related to social indicators for fishing communities.

Appendix C: List of Participants with Affiliations

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