# Do Scientists and Managers Think and Feel the Same About Data? Insights from the Pacific Island Region

# ¿Los Científicos y los Administradores Piensan y Sienten lo Mismo Acerca de los Datos? Perspectivas desde la Región Insular del Pacífico

# Les Sscientifiques et les Gestionnaires Pensent-ils et Sont-ils due Même Avis à Propos des Données? Les Réflexions du Pacifique Insulaire

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## ABSTRACT

Successful coastal management requires an understanding of biophysical and social systems and how they are affected by resource governance. To comprehensively inform an ecosystem approach for managing fisheries and coastal resources in tandem with safeguarding the socioeconomic needs of coastal communities, there is a recognized and growing need to integrate biophysical and social monitoring efforts. This type of coordinated process requires clearly-defined objectives, prioritization of indicators collected, agreement upon best practices to maximize the use and accessibility of collected data, and collaboration throughout the process. In order to inform the prioritization of biophysical and socioeconomic indicators collected in the Pacific Islands, we surveyed marine resource managers and scientists involved in the design and implementation of biophysical or socioeconomic monitoring efforts throughout the region. The responses from 112 participants revealed the relative awareness and perceived importance and usefulness of available indicators, and identified any additional data types considered useful for management. These survey results were further combined with commentary from 55 participants from focus groups to provide recommendations for enhanced integration of biophysical and socioeconomic monitoring. By reviewing indicators collected by monitoring efforts, our study informs the prioritization of indicators for integrated monitoring -- a process that should continue to be iterative in order to maintain the relevancy of data collected in support of adaptive management. Based on the findings, we also provided recommendations to better integrate socioeconomic and biophysical monitoring.

KEYWORDS: Integrated monitoring, Pacific islands, socioeconomic monitoring, biophysical monitoring, data gaps

## INTRODUCTION

In the last decade, social-ecological systems (SES) have become recognized in natural resource management (Berkes and Folke 1998, Berkes et al. 2016), and an ecosystem approach is increasingly being adopted and replacing conventional management focused only on single species or single sectors (Heenan et al. 2016). There are also growing needs to integrate biophysical and social monitoring to generate more comprehensive information on the interactions between biophysical and social systems to better inform ecosystem-based management decisions and to safeguard the socioeconomic needs of island communities. Integrated monitoring (IM) is a coordinated process in which scientists from multiple disciplines collect and analyze social and ecological (biophysical) data to meet the shared objectives of tracking, assessing, and understanding changes over time within SESs, as well as changes in their interactions (Wongbusarakum et al. 2019). Through clearly-defined, interdisciplinary monitoring objectives and implementation, and through merging data sets derived from varying methods, the goal of IM is to inform managers and policy makers about systemic changes and linkages among them to achieve holistic natural resource management, while simultaneously promoting ecological health and human well-being. (Wongbusarakum et al. 2019). In recent years, social sciences have become increasingly applied in this context. Initiatives also involve reviewing and revisiting indicators of the different data sets, as well as considering best practices (including stakeholder engagement and discussions among different monitoring teams) to enhance both data accessibility and data usefulness for management planning and adaptive management.

However, little was known about data awareness, about data usefulness, and about data gaps relevant to managing reefs, fisheries, and other coastal and marine resources. This research project intended to help provide relevant information that would be useful to improve long-term monitoring for coastal and marine management in the Pacific island region. Research questions of this project investigated the perceived importance, availability, and awareness of different existing data types from long-term monitoring, perceptions regarding the level of importance assigned to different kinds of data, needs for any additional types of data considered useful for management, and both challenges to and possibilities for better integrating biophysical and socioeconomic monitoring the Pacific island region. The goal of this research project was not only to inform those working in coastal and marine resource management, monitoring, and conservation, but also to help identify data gaps and improve integrated monitoring.

The National Reef Conservation Monitoring Program (NRCMP) was lunched in 2012 by the Coral Reef Conservation Program (CRCP) of the US National Oceanic and Atmospheric Administration. The goal of the NCRMP is to track socioeconomic and biophysical changes to improve coral reef management (National Oceanic and Atmospheric Administration 2014). The term socioeconomic in this document is used to include economic, socio-cultural, and other human dimensions of resource management. NRCMP monitors island-level changes among the US-affiliated islands in the Pacific, including Hawaii, Guam, the Commonwealth of Northern Marianas, and American Samoa. Most of the ecological and oceanographic observations of the Pacific Reef Assessment and Monitoring Program (RAMP) are now collected every 3 years (formerly every 2 years). Island-wide NCRMP socioeconomic monitoring examines the relationships of jurisdictional households in coastal areas with coral reef resources, as well as their knowledge, attitudes, and perceptions regarding coral reefs and coral reef management (NCRMP Social Science Program 2019). CRCP works with local partners to reduce key threats to coral reefs, including climate change, land-based sources of pollution, and impacts from fishing (National Oceanic and Atmospheric Administration 2014). While the NRCMP focuses on data relevant to reef management at the island level, other state- and site-based long-term monitoring efforts generate various data types relevant to fisheries management and coastal management. While the biophysical monitoring is on-going, numerous socioeconomic surveys and assessments have been conducted in the Western Pacific to start baselines and track changes over time. These include on-going monitoring of regional and island fisheries socioeconomics by the staff of the NOAA Fisheries Pacific Islands Fisheries Science Center (PIFSC), along with site-based socioeconomic assessments by the Socioeconomic Monitoring Guidelines for Coastal Managers in Pacific Island Region (SEM-Pasifika), launched by NOAA and the Secretariat of the Pacific Regional Programme for the Environment (SPREP) (Wongbusarakum and Pomeroy 2008). The NOAA PIFSC socioeconomic monitoring efforts date back as far the 1980's and have produced multiple data sets, particularly in the area of the costs and earnings of different fisheries types. The SEM-Pasifika site-based assessments and monitoring training have been supported by the CRCP and the Pacific Islands Managed and Protected Areas Community (PIMPAC), the National Ocean Service (NOS), and regional and local conservation and resource management partners. To date, there are nearly 20 assessments in the Pacific region.

The results of the project were expected to benefit not only future NCRMP and other socioeconomic monitoring efforts in the Pacific island region, but also other coastal and marine programs in other regions, and other interdisciplinary research and monitoring initiatives.

## METHODS

Main data collecting methods included secondary data review of existing socioeconomic and biophysical data, online survey, and focus groups. The data collecting instruments were reviewed and approved by the NOAA Office of Management and Budget to ensure the level of acceptable time burden for the public. The research is IRB exempted under the project CHS#19449 - Socioeconomics of Western Pacific Fisheries.

**Secondary Data Collection**

We reviewed data types and variables collected by the following data collecting instruments, and they were used to design the list of existing data in the survey questionnaire. For the biophysical data, the Pacific RAMP field collection, led by the Ecosystem Sciences Division (ESD) of the NOAA PIFSC, was the focus of the review. Its methodologies produce an extended time series of interdisciplinary, integrated ecosystem observations of coral reefs around approximately 40 islands, atolls, and shallow-water banks of the Mariana Archipelago, American Samoa, the Hawaiian Archipelago, and the Pacific Remote Islands Marine National Monument (PRIMNM). Pacific RAMP data collections are designed to characterize the status and trends of the distribution, abundance, diversity, and size of corals, other macro and cryptic invertebrates, microbes, algae, and fishes in the context of their benthic habitats and varying oceanographic conditions. The NCRMP establishes consistent and comparable survey and analytical methods and provides a context for comparing surveys across time and space for biological, oceanographic, and socioeconomic metrics (NOAA NCRMP 2014). The RAMP variables are the same as those collected by the Micronesia reef monitoring program led by the University of Guam Marine Lab for the Micronesia Challenge countries. Micronesia Challenge (MC) is a conservation commitment by the Federated States of Micronesia, the Republic of the Marshall Islands, the Republic of Palau, Guam, and the Commonwealth of the Northern Marianas Islands to preserve the natural resources that are crucial to the survival of Pacific traditions, cultures and livelihoods. The overall goal of the Challenge is to effectively conserve at least 30% of the near-shore marine resources and 20% of the terrestrial resources across Micronesia by 2020. For this commitment, biophysical (marine and terrestrial) and socioeconomic monitoring have been conducted to track the ecological and social conditions of different sites in the MC countries.

For socioeconomic data, we reviewed the 13 core data types used in the NRCMP socioeconomic monitoring; 27 PIFSC socioeconomic and fisheries surveys which were primarily conducted in Hawaii, Guam, CNMI, and American Samoa; and 19 SEM-Pasifika assessments conducted in the Micronesia Challenge countries. Table 1 shows a summary of the existing socioeconomic and biophysical data types. These data types were used in the survey questionnaire to find out the respondents' awareness and their perceived importance on each data type.

To help address data gaps and make recommendations, a literature review was conducted (including Cinner et al. 2018, Colburn et al. 2016, Gombos et al. 2013, Gove et al. 2019, IMM 2008, Kittinger et al. 2012, Kleiber et al. 2018, Leong et al 2019, MEA 2005, Nevitt and Wongbusarakum 2013, Pascua et al. 2017, Whitney et al. 2017, Wongbusarakum 2018, Wongbusarakum 2019). The areas encompassed in the review are:

i) Integrated monitoring — resilience, vulnerability, adaptive capacity, and other social dimensions of

climate change,
ii) Cultural ecosystem services,
iii) Biocultural approaches and indicators, and
iv) Human well-being.

Lists were developed for types of sociocultural and economic and biophysical data that were suggested by the literature and scientific experts as being potentially useful for management but, to the best of our knowledge, had not been not collected in any long-term monitoring program by the time of this study. The lists in Table 2 were then used in the survey questionnaire for the respondents to rate how important they thought each of these data types could be to inform management.

### Samples and Sampling Design

Purposive sampling and snowball sampling were used to recruit the 2 target participant groups. The first group was possible users of socioeconomic and biophysical data, and the second group was people involved in socioeco-

**Table 1.** Existing socioeconomic and biophysical data types used in survey questionnaire

| |
|---|
| **Existing Socioeconomic Data Types** |
| 1. Demographics, incl. general communities, fishers, and vulnerable populations |
| 2. Community well-being, including health |
| 3. Types and proportions of community livelihoods, employment, and income |
| 4. Livelihood sustainability, (occupational) diversity and flexibility |
| 5. (Equitable) access to resources/assets |
| 6. Resource dependency `for provisioning ecosystem services (including livelihoods, e.g. commercial and subsisting fisheries) |
| 7. Personal disruption due to unemployment, poverty level or interrupted education |
| 8. Housing (rent, number of rooms, with plumbing) |
| 9. Labor force |
| 10. Physical infrastructure and coastal development |
| 11. Resource governance, management, and institution |
| 12. Attitudes towards coastal and fisheries management |
| 13. Understanding of environmental regulations |
| 14. Attitudes towards coastal and fisheries enforcement and compliance |
| 15. Awareness of and attitude towards marine protected areas |
| 16. Community participation in resource stewardship |
| 17. Participation in recreational and tourism marine activities |
| 18. Ability of communities to decide and act in order to create change |
| 19. Economic/monetary value of marine and coastal species and resources |
| 20. Economic impact of dive/snorkel tourism |
| 21. Non-monetary/non-extractive value of marine and coastal species and resources by communities |
| 22. Perceived conditions of coastal and marine resources |
| 23. Awareness and knowledge of marine and coastal resources |
| 24. Perceived anthropogenic threats to natural resources |
| 25. Perceived climate threats and natural hazard risks to communities |
| 26. Learning and knowledge to adapt to climate change impacts |
| 27. Participation in fishing activities, (including gear, effort and catch) |
| 28. Fisher classification based on purpose of fishing (e.g. commercial, recreational, subsistence, cultural, etc) |
| 29. Proportion of population being reliant on commercial and recreational fisheries |
| 30. Commercial fisheries economic data (cost/expenses and revenue) and impact assessment |
| 31. Recreational fisheries economic data and assessment |
| 32. Seafood industry economic trends and impacts, incl. fish trade (dealer, amount and value of fish sold) |
| 33. Participation in seafood markets (catch disposition, sales, market utilization, perceptions of market conditions) |
| 34. Perceived fishing conditions |
| 35. Social and cultural uses of fishing |
| **Existing biophysical data types** |
| 36. Coral size structure |
| 37. Coral condition |
| 38. Benthic percent cover |
| 39. Coral growth |
| 40. Rugosity |
| 41. Fish abundance |
| 42. Fish size structure |
| 43. Occurrence of protected species |
| 44. Occurrence of macroinvertebrate key species |
| 45. Microbial biodiversity |
| 46. Cryptobiota diversity (i.e., small marine organisms that live predominantly within the complex reef structure) |
| 47. Sea level rise |
| 48. Water temperature |
| 49. Water chemistry (e.g., DIC, TA, DO, pH, dissolved inorganic nutrients, chlorophyll-a, salinity, fluorescence) |
| 50. Light (irradiance from remote sensing) |
| 51. Benthic accretion/bioerosion |
| 52. Meteorology (air temperature, wind speed, wind direction, humidity, etc) |
| 53. Large-scale climate forcing (El Niño/La Niña, Pacific Decadal Oscillation) |
| 54. Physical oceanography (e.g., ocean currents, wave metrics including height, period, power, and direction) |
| 55. Marine debris (sightings of man-made debris) |

nomic and biophysical monitoring design and implementation. As there had been no previous studies describing the populations of these groups and we did not know the total possible numbers, the purposive sampling design process was used. It started with consultations with known data users identified by relevant institutions in the Pacific island region as the most appropriate people to participate in the survey. These became the first target samples. The criteria of our target respondents are that they be adults, eighteen years or older, who could represent agencies, organizations, programs or groups that may use the long-term biophysical and socioeconomic data collected in the Pacific Island region, and/or who were involved in designing and implementing such monitoring. The people who participated in the first round of surveying were asked to recommend other appropriate participants who were then invited to also participate in the survey.

The data users in this project came from fisheries and coastal resource management agencies, conservation organizations and community groups in the Pacific island region. These included the Western Pacific Regional Fishery Management Council (WPRFMC), National Marine Monuments in the Pacific island region, the Guam Department of Agriculture's Division of Aquatic and Wildlife Resources (DAWR), the American Samoa Department of Marine and Wildlife Resources (DMWR), the CNMI Department of Lands and Natural Resources, Division of Fish and Wildlife (DFW), the NOAA PIFSC, The Nature Conservancy (TNC), Conservation International (CI), the Micronesia Conservation Trust (MCT), Kua, and Kai Kuleana.

For those who were involved in monitoring, we started with leads for physical and biological monitoring teams (such as fish, coral and benthic, and ocean and climate change teams) at the PIFSC ESD, Global Socioeconomic Monitoring Coordinator at CRCP, the NCRMP tool developers and data analysts, research partners (such as University of Guam Marine Lab, University of Hawaii, and researchers from conservation organizations), key individuals involved in socioeconomic monitoring efforts in the Pacific islands and other regions (such as PIFSC Socioeconomic and Human Dimension team staff, NOS NCCOS Hollings Marine Lab socioeconomic team members, socioeconomic monitoring (Global Socioeconomic Monitoring Initiative for Coastal Management, also known as SocMon or SEM-Pasifika) regional coordinators and island points of contacts, Micronesia Challenge technical and monitoring advisors, and other partners involved in biophysical and socioeconomic monitoring, including NGOs such as TNC, CI, and MCT.

**Survey**

The survey questionnaire has 2 parts. Part 1 was designed to be completed by all participants. The questions in part 1 were to understand the background of the survey respondents, awareness of monitoring data availability, their use, and the perceived importance of each of the data types for management. It also examines the participants' opinions about how useful the new types of biophysical and social data suggested by literature and relevant scientific experts are for management. Part 2 has 3 sections (biophysical monitoring, sociocultural and economic monitoring, and management) and each respondent was asked to select and fill out only one section that was most relevant to their work. In all sections, the aim was to collect information about the types of monitoring data that are known to, and deemed important by, those involved in coastal and marine resource management, but also to identify and help fill data gaps with the aim of improving integrated monitoring.

A pretest with 6 data users or people who had done monitoring-related work were conducted prior to the official survey to allow for the refinement and correction of any methodological issues that were identified. The final survey was administered online by Survey Monkey from May 5 through June 30, 2019. From a total of 168 invitations, 112 people (67%) voluntarily participated in the survey.

**Table 2.** Potential socioeconomic and biophysical data types in survey questionnaire

| |
|---|
| **Potential useful sociocultural and economic data types not currently collected by long-term monitoring** |
| 1. Cultural heritage and connection to place<br>2. Spiritual connection to nature and species<br>3. Connection and sense of place and identity<br>4. Social relations and network<br>5. Existence value of resources (including nature as being a source of inspiration, creativity, and aesthetics)<br>6. Gender issues (division of resource use, management, and gender equity)<br>7. Willingness-to-pay for coral reef protection/conservation<br>8. Community resilience to climate impacts and natural disasters<br>9. Application and impact of aquaculture<br>10. Access to information on coastal and marine resources |
| **Potential useful biophysical data types not currently collected by long-term monitoring** |
| 11. Reproduction or fecundity of organisms<br>12.Recruitment or connectivity of organisms<br>13. Mortality rates of organisms<br>14. Metabolic performance of organisms<br>15. Land-based sources of pollution, water quality, sedimentation, nutrient inputs<br>16. Other measures of habitat/structural complexity<br>17. In situ measurements of light (e.g., irradiance of photosynthetically active radiation [PAR])<br>18. Regulating ecosystem services (e.g carbon sequestration and storage, erosion prevention, moderation of extreme events) |

### Focus groups

A list of semi-structured question was used to guide the discussion and to be complementary to the survey. Four focus groups were conducted in May 2019 in conjunction with meetings where potential data users and monitoring team members were present. These included 2 focus groups (with 12 and 9 participants) at a meeting for Atlantis modeling, a group of 18 participants at the US National Integrated Ecosystem Assessment, and a group of 15 participants at the indicator meeting with the Hawaii Division of Aquatic Resource (DAR) 30x30 initiative. The 30x30 initiative has a goal to effectively manage at least 30% of Hawai'i nearshore marine areas by 2030 to ensure a healthy near shore ecosystem and fisheries that sustain the people and economy of Hawai'i. Meetings were held in 2019 to identify and prioritize biophysical and social indicators and institutionalize monitoring and data analysis.

The group discussion participants were current and potential data users, monitoring team members, as well as community facilitators and community representatives from Hawaii in the last group. Atlantis is a deterministic biogeochemical and biophysical modeling system that simulates the functioning of marine food webs and fisheries to serve as a policy exploration tool for ecosystem-based management. It is an 'end-to-end' model, in that it represents ecosystem components from marine bacteria to apex predators and human beings. Sub-models include consumption, biological production, waste production, reproduction, habitat dependency, age structure, mortality, decomposition and microbial cycles. The spatial domain is resolved in three dimensions using irregular polygons to represent biogeographic features. Exchange of biomass occurs between polygons according to seasonal migration and foraging behavior, while water movement, heat and salinity flux across boundaries can be represented by a coupled hydrodynamic model.

### Data Analysis

Survey Monkey provided descriptive statistics. The raw data and verbatim were also downloaded for further analyses with SPSS Version 24. Descriptive statistics were performed to find out results and differences among the difference sub- groups such as those who worked in the Pacific islands, fisheries managers (federal and jurisdictional), social scientists, and biophysical scientists. Given that we used a non-probability sampling approach, the results will be presented in this paper in a qualitative, rather than a quantitative manner. On all tables, the rankings from 1st to 5th represents the five answers in descending sequence that received the greatest numbers of responses out of the total possible choices. If there is a tie, this is reflected in the items having the same ranking. The percentages of the results are not reported and only used to help guide our understanding of answers most frequently mentioned by the survey respondents. Input from the focus groups provided a very wide range of opinions by the participants. They were used to complement the results of the survey data and to inform the discussions.

## KEY RESULTS

### Participant Profiles

The focal areas of work among the respondents were as follows: 34% fisheries management, 39% socioeconomic research or monitoring, and 27% biophysical research or monitoring. 75 people worked in the Pacific Islands (Hawaii, American Samoa, CNMI, Guam, FSM, Palau, RMI, PRIAs), and 84 worked in NCRMP areas (Hawaii, American Samoa, CNMI, Guam, Southeast USA, Caribbean). There is considerable overlap between the 2 geographical groups, with 62% of the respondents working in both the Pacific islands and NCRMP areas.

### Awareness of Existing Data

For socioeconomic data, very high numbers of respondents were most aware of demographics (including general communities, fishers, and vulnerable populations); participation in fishing activities (including gear, effort and catch); types and proportions of community livelihoods, employment, and income; and commercial fisheries and economic data (cost/expenses and revenue and impact assessment). The respondents in the Pacific Islands were uniquely aware of the labor force while the managers were also aware of various fisher classifications based on the purposes of fishing (e.g. commercial, recreational, subsistence, cultural, etc.). The majority of the respondents were least aware of: the ability of communities to decide and act in order to create change (agency), issues of equitable access to resources/assets; learning and knowledge in adapting to climate change impacts; and personal disruptions due to unemployment, poverty, or interrupted education. The respondents in the Pacific islands were, however, least aware of the non-monetary/non-extractive value placed on marine and coastal species and resources by local communities.

The top four types of biophysical data that all respondents were most aware of were water temperature, large-scale climate forcing, fish abundance, and sea level rise. The fifth most well-known dataset among respondents in the Pacific Islands focused on coral condition. Managers exhibited levels of awareness in response to only datasets of water temperature and large-scale climate forcing, whereby all but one respondent were aware of such existing data. Jurisdictional managers report higher levels of awareness for meteorology and physical oceanography when compared to federal managers. There was considerable consistency among the groups of respondents in relation to the datasets about which they were least aware: the diversity of cryptobiota and microbes, benthic accretion/bioerosion, and marine debris.

### Perceived Importance of Existing Data

*Socioeconomic data* — For all groups of respondents the most important type of socioeconomic data is resource dependency for provisioning ecosystem services, including livelihoods, e.g. commercial and subsisting fisheries. For the Pacific island group, participation in fishing activities is also the most important, followed by demographics, proportion of population being reliant on commercial and recreational fisheries, and social cultural uses of fishing (Table 3). When breaking down managers into federal and jurisdictional groups, jurisdictional managers tend to be more focused on localized issues and federal managers tend to be more focused on macro issues. Federal managers found more importance in data related to fisher classification, commercial fishing and resource governance data. Jurisdictional managers found more importance than federal managers in data related to participation in fishing activities, fishing reliance, understanding of environmental regulations, and community participation in resource stewardship.

Particularly interesting observations include:

i) Data on governance and fisher classification made it to the manager group's 2nd and 3rd "very important" categories, but not for social scientists or biophysical scientists.
ii) Data on commercial fisheries economic data (cost/ expenses and revenue) and impact assessment* made it into the top 5 "very important" category of all groups, but managers.
iii) Biophysical scientists tend to find data on resource extraction and fishing participation as most important.
iv) Social and cultural uses of fishing are rated "very important" by Pacific island group and managers.
v) Commercial fisheries economic data is more important to federal managers than it is to jurisdictional managers

The types of socioeconomic data that are collected but considered the least important by more than ¾ of the people are:

i) Housing (rent, number of rooms, with plumbing),
ii) Personal disruption due to unemployment, poverty level or interrupted education, and
iii) Labor force.

For the open-ended question about the most useful data types, both existing or only potential, in relation to their work, more than half of the managers chose "Resource use/fishing reliance/fishing frequency/ Livelihoods," while just under half selected "economic information" (Table 4).

*Biophysical data* — All groups of respondents agreed on the top five most important types of biophysical data that currently exist for the purpose of coastal and fisheries management: measures of fish populations (abundance and size structure), followed by coral condition and then measures of environmental conditions (water temperature and large-scale climate forcing) (Table 5). The relative importance of these same or similar types of indicators all remained the highest when responses were summarized by profession (managers, social scientists, and biophysical scientists): fish-related metrics, coral condition, and various measures of oceanic conditions, including physical oceanography and water chemistry. Notably, all three groupings of professions agreed that all fish-related metrics were either moderately or very important for management

**Table 3**. Socioeconomic data types with highest importance rating

| **Most important existing socioeconomic data** | **All** | **Pacific islands** | **Manager (all)** | **Manager (federal)** | **Manager (Jurisdic-tional)** | **Social scientist** | **Biophysical scientist** |
|---|---|---|---|---|---|---|---|
| Resource dependency for provisioning ecosystem services (including livelihoods, e.g. commercial and subsisting fisheries) | 1st | 1st | 1st | 2nd | 3rd | 1st | 1st |
| Demographics, incl. general communities, fishers, and vulnerable populations* | 3rd | 3rd | 4th | 4th | 3rd | 3rd | 2nd |
| Participation in fishing activities, (including gear, effort and catch)* | 2nd | 1st | 2nd | 2nd | 1st | 1st | 4th |
| Proportion of population being reliant on commercial and recreational fisheries | 4th | 4th | 4th | | 1st | 5th | 2nd |
| Fisher classification based on purpose of fishing (e.g. commercial, recreational, subsistence, cultural, etc.) | 5th | | 2nd | 1st | 3rd | | |
| Commercial fisheries economic data (cost/ expenses and revenue) &impact assessment* | 5th | | | 4th | | 3rd | 5th |
| Types and proportions of community livelihoods, employment, and income* | 5th | | | | | | |
| Resource governance, management and institutions | | | 3rd | 4th | | | |
| Social and cultural uses of fishing | | 5th | 5th | | 3rd | | |
| Perceived climate threats and natural hazard risks to communities | | | 5th | | | | |
| Understanding of environmental regulations | | | | | 3rd | | |
| Community participation in resource stewardship | | | | | 3rd | | |

purposes. Social scientists also appeared to value data on sea level rise greater than the other professions, with all social scientists considering such datasets to be moderately or very important. Biophysical scientists also seemed to value the indicator of coral condition less than managers and social scientists, with the top five most important metrics consisting only of measures of fish populations and oceanic conditions. Federal managers also identified sea level rise, rugosity and temperature data as important, while jurisdictional managers identified physical oceanography and benthic cover data as important.

When asked the open-ended question about the types of biophysical data that are most useful for their work, the majority of managers that responded indicated that data about benthic and fish communities were useful (e.g., measures of abundance, size structure, recruitment, and condition/health). Other types of data mentioned by multiple respondents included metrics of land use and water quality, fisheries-related data, insight on climate change (e.g., sea level rise and warming events), and an understanding of the life histories of organisms (e.g., connectivity patterns, early-life stages, and reproduction) (Table 6). Measures of climate and weather, physical oceanography and seawater conditions, and habitat (e.g., mapping, rugosity, reef accretion) were also listed by a few respondents.

When we asked managers to rank existing biophysical and socioeconomic data sets collected by long-term monitoring programs in terms of their usefulness in making management decisions, more than half of them gave high or very high rankings to biophysical data, while a much smaller number of managers identified the socioeconomic data as being most useful. Nearly half of the people surveyed chose "little" and "moderately" useful in ranking existing types of socioeconomic data. More than half of the managers gave high and very high ranking in relation to the extent to which sociocultural and economic data might be improved to better inform management decisions. The social scientist respondents gave a higher rating in regard to the management usefulness of existing types of sociocultural and economic data collected by long-term monitoring programs in general. However, more than half of them gave ratings of "little" and "moderate" usefulness for existing data in the monitoring programs with which they are themselves involved. This differs from the results with the biophysical scientists, among whom half considered the usefulness to be high or very high.

## Suggested Additional Indicators and Data Types Useful for Management

*Socioeconomic data* — Top mentioned additional data types considered most important but were not yet collected are "Community resilience to climate impacts and natural disasters", followed by "Cultural heritage and connection

**Table 4.** Socioeconomic data types considered most useful by managers

| Most useful socioeconomic data for managers (open-ended question) | Ranking |
|---|---|
| Resource use/fishing reliance/fishing frequency/Livelihoods: | 1st |
| Economic information | 2nd |
| Participation in management/governance | 3rd |
| Cultural heritage | 4th |
| Attitudes toward management | 4th |
| Perceived resource conditions | 4th |

**Table 5.** Biophysical data types with highest importance rating

| Most important existing biophysical data | All | Pacific islands | Manager (all) | Manager (federal) | Manager (Jurisdictional) | Social scientist | Biophysical scientist |
|---|---|---|---|---|---|---|---|
| Fish abundance | 1st | 1st | 1st | 1st | 1st | 1st | 4th |
| Fish size structure | 2nd | 2nd | 2nd | 2nd | 1st | 3rd | 1st |
| Coral condition | 3rd | 3rd | 5th | | | 1st | |
| Water temperature | 4th | 4th | | 4th | | 4th | 5th |
| Large-scale climate forcing (El Niño/La Niña, Pacific Decadal Oscillation) | 5th | 5th | 3rd | 3rd | 1st | | 1st |
| Physical oceanography (e.g., ocean currents, wave metrics including height, period, power, and direction) | | | 4th | | 1st | | |
| Water chemistry (e.g., DIC, TA, DO, pH, dissolved inorganic nutrients, chlorophyll-a, salinity, fluorescence) | | | | | | 5th | 1st |
| Rugosity | | | | 5th | | | |
| Sea Level Rise | | | | 5th | | | |
| Benthic percent cover | | | | | 1st | | |

to place" and "Connection and sense of place and identity" for multiple groups (Table 7). Community resilience can be defined as the ability of a community to cope with and absorb shocks and disturbances, to resist shifts, and to respond and adapt in ways that the community can maintain their essential functions, identity, and social structure (adapted from Berkes and Folker 1998, Sterling et al. 2017). In the focus groups conducted for this project, representatives from the communities emphasized the importance of considering cultural resources as no less critical that natural resources, and of acknowledging that local knowledge can be as useful as scientific knowledge. Connection to place has a "strong bearing on cultural identity, rootedness and belonging, sense of responsibility and stewardship, social engagement, and natural resource management. Connectedness to place encompasses historical, physical, emotional, and/or spiritual bonds between people and their local environment." (Dacks et al. 2019).

For the specific groups, access to information on coastal and marine resources are rated high for the respondents working in the Pacific island region, managers and biophysical scientists. The biophysical scientist group also rate willingness to pay for coral reef protection/ conservation high.

*Biophysical data* — All analyzed groupings of respondents agreed on the three most important types of biophysical data that are not currently being collected: land -based sources of pollution, recruitment or connectivity patterns of organisms, and mortality rates of organisms (Table 8). However, when breaking down managers into federal and jurisdictional, federal managers also identified a need for regulating ecosystem services and reproduction of organisms. Jurisdictional managers did not identify data on land-based sources of pollution as a top need.

Given the conventional methods for testing *in situ* levels of land-based sources of pollution are dependent on water samples collected during Pacific RAMP sampling, those data provide a snapshot of a single point in time and are not likely to capture the temporal variability in pollutants (which may further depend on rainfall patterns, levels of development, land use, etc.) and the impacts on the near-shore habitats. Recruitment is considered very important because it helps identify areas with weak recruitment that are less likely to recover from disturbance or stressors. Currently, proxy indicators are being used, including coral estimates of juvenile density and size classes of fish. To explore connectivity between populations would entail using techniques such as biophysical modeling or genetic approaches. Suggestion is to have a combined sampling design with not only stratified random sampling but also fixed sites so that we can monitor rates, like recruitment rate and mortality rate. (B. Huntington, Ecosystem Sciences Division, NOAA Pacific Islands Fisheries Science Center, personal communication, October 2, 2019).

*Data gaps in better managing resources and addressing human well-being* — When managers were asked to report any missing data that could be useful in the simultaneous management of resources and human well-being, 20 out of 31 managers answered this open-ended question. The most mentioned answer for social data was community well-being. Several respondents were specifically interested in identifying both the sources and destination markets of fishery catches. More biophysical data on effects of marine protected areas (MPAs) and restoration on fish, and fish function (e.g., herbivory), habitat use, and connectivity were listed as needed by multiple respondents.

**Table 6**. Biophysical data types considered most useful by managers

| Most useful biophysical data for managers (open-ended question) | Ranking |
|---|---|
| Benthic community: cover, coral recruits, coral health | 1st |
| Fish community: abundance, sizes | 2nd |
| Land use, water quality, sedimentation | 3rd |
| Fishery-related data | 4th |
| Life history: connectivity, early-life stages, reproduction | 4th |
| Climate change: sea level rise, warming events and thermal stress, | 5th |

**Table 7.** Most important types of sociocultural and economic data that are not yet collected

| Most important type of sociocultural and economic data that are not yet collected | All | Pacific islands | Manager (all) | Manager (federal) | Manager (Juris-dictional) | Social scientist | Biophysical scientist |
|---|---|---|---|---|---|---|---|
| Community resilience to climate impacts and natural disasters | 2nd | 1st | 1st | 1st | 1st | 1st | 1st |
| Cultural heritage and connection to place | 1st | 3rd | | | 2nd | 2nd | |
| Connection and sense of place and identity | 3rd | | 3rd | 3rd | 2nd | 3rd | |
| Access to information on coastal and marine resources | | 2nd | 2nd | 2nd | 4th | | 3rd |
| Willingness to pay for coral reef protection/conservation | | | | | | | 2nd |

**Collaboration Among Managers, Natural Scientists and Social Scientists**

Most managers felt that it is important for the monitoring teams to work across social and natural scientific disciplines and to collaborate with one another. Slightly more than half of them also thought that the difficulty is high and very high in combining biophysical and socioeconomic data in ways that are informative for management decisions. They also expressed high interest in working with monitoring teams to make sure that the data produced address their management needs (Figure 1). Roughly half of the managers participating in the survey reported that they had already worked at high and very high levels directly with people who design or implement long-term biophysical monitoring, while the majority reported that they were doing so with people engaged in socioeconomic monitoring. This is confirmed by the majority of social and biophysical scientists who perceived their work to be collaborative with resource managers.

Fifty percent of social scientist respondents rated collaborative work with natural scientists as being at moderate levels, while one out of four said that collaboration is high or very high. However, the perception shifts when natural scientists rate their collaborative work: half of them indicated that they had little or no collaboration with social scientists (Figure 2). Concerns about the level of community engagement are highly integrated into managers' work, moderately so into the work of social scientists, and relatively much lower into the work of biophysical scientists.

**Table 8.** Most important types of biophysical data that are not yet collected

| Most important type of biophysical data that are not yet collected | All | Pacific islands | Manager | Manager (federal) | Manager (Juris-dictional) | Social scientist | Biophysical scientist |
|---|---|---|---|---|---|---|---|
| Land-based sources of pollution, water quality, sedimentation, nutrient inputs | 1st | 1st | 1st | 1st | | 1st | 2nd |
| Recruitment or connectivity of organisms | 2nd | 2nd | 2nd | | 1st | 2nd | 1st |
| Mortality rates of organisms | 3rd | 3rd | 3rd | | 2nd | 3rd | 3rd |
| Reproduction or fecundity of organisms | | | | 2nd | 3rd | | |
| Regulating ecosystem services (e.g carbon sequestration and storage, erosion prevention, moderation of extreme events) | | | | 2nd | | | |

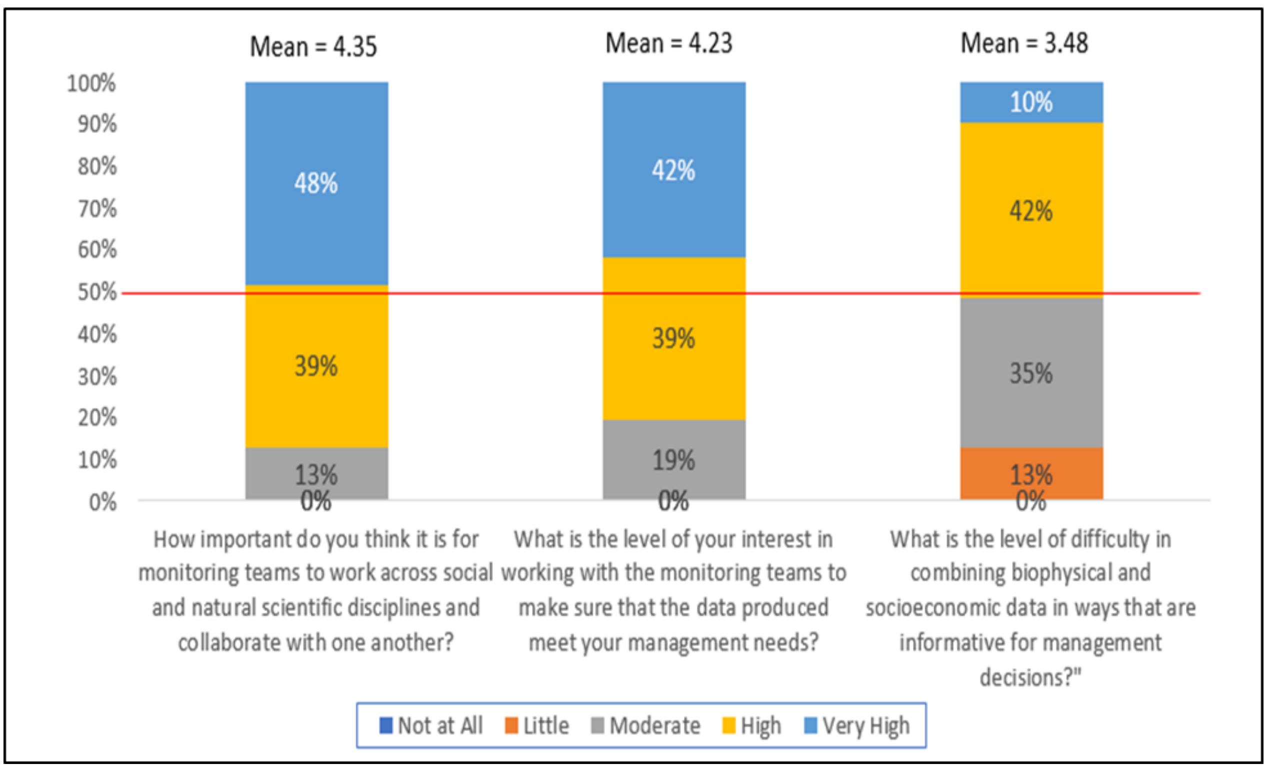


**Figure 1.** Perceptions of managers on collaboration

## DISCUSSION

Much of the existing data was collected for specific purposes, most often without any plan for being integrated with data collected for other purposes in order to better explain social-ecological systems or to support ecosystem-based management. As a result, there are inherent mismatches in scale and in comparability, making the "add on" integration of existing data sets difficult, meaningless, or impossible. Yet, evidence strongly suggests that the various data types about which people are generally aware and which they consider important can be much more comprehensively linked to realize the interdependent aims of environmental conservation and societal wellbeing (Table 9). For example, monitoring coral reef conditions alone simply tracks changes in biophysical conditions. But, the information generated becomes part of integrated monitoring only if it is explicitly linked to human activities that influence the biophysical conditions of coral reefs. Similarly, changes in sea surface temperature and mass coral bleaching become dimensions of integrated monitoring only when the impacts of coral bleaching on the marine resources that coastal communities depend upon and the mitigation efforts made by people are considered. The same applies to fish abundances and sizes. Unless these can be linked to fisheries and livelihoods (e.g. what species are targeted by fishers, the degree of dependence upon fishing of a given community), as well as to other impacts from biophysical or social factors, they cannot, by themselves, be considered elements of integrated monitoring. Likewise, demographic studies cannot by themselves provide information to better understand social-ecological systems unless the demographic changes (e.g. population distributions, occupational shifts) are used to help explain changes in ecological systems. Among the areas in which more cogently integrated monitoring would serve well are those implied by the socioeconomic and biophysical data gaps that were identified by respondents in the survey. The most significant of these data gaps are community resilience and well-being, particularly in relation to the cultural aspects thereof. Yet, understanding community resilience implies understanding of relevant biophysical conditions and changes. Similarly, the most commonly noted biophysical data gaps centered on land-based sources of pollution and other anthropogenic stressors which are inseparable from human activities and development. Without social data, land-based sources of pollution are not only among the most difficult to pin down by biophysical monitoring alone, they are also among the most challenging for management to pinpoint and enforce.

Most existing socioeconomic data is considered important and respondents are generally well-aware of its existence. This includes data related to demographic and economic indicators, particularly in the fisheries sector. The biophysical data that has attracted the greatest awareness, and is considered most important, is data about fish and wider factors such as coral habitat and oceanographic and climate conditions. In this study, the fisheries-related socioeconomic and biophysical data types that were ranked highest in importance are quite complementary to one other and the levels of awareness reported were also high. For example, the social data types related to fishing and provisioning ecosystem services (i.e. participation in fishing activities, resource dependency, fisher classification based on fishing purposes, proportion of population being reliant on commercial and recreational fisheries, and

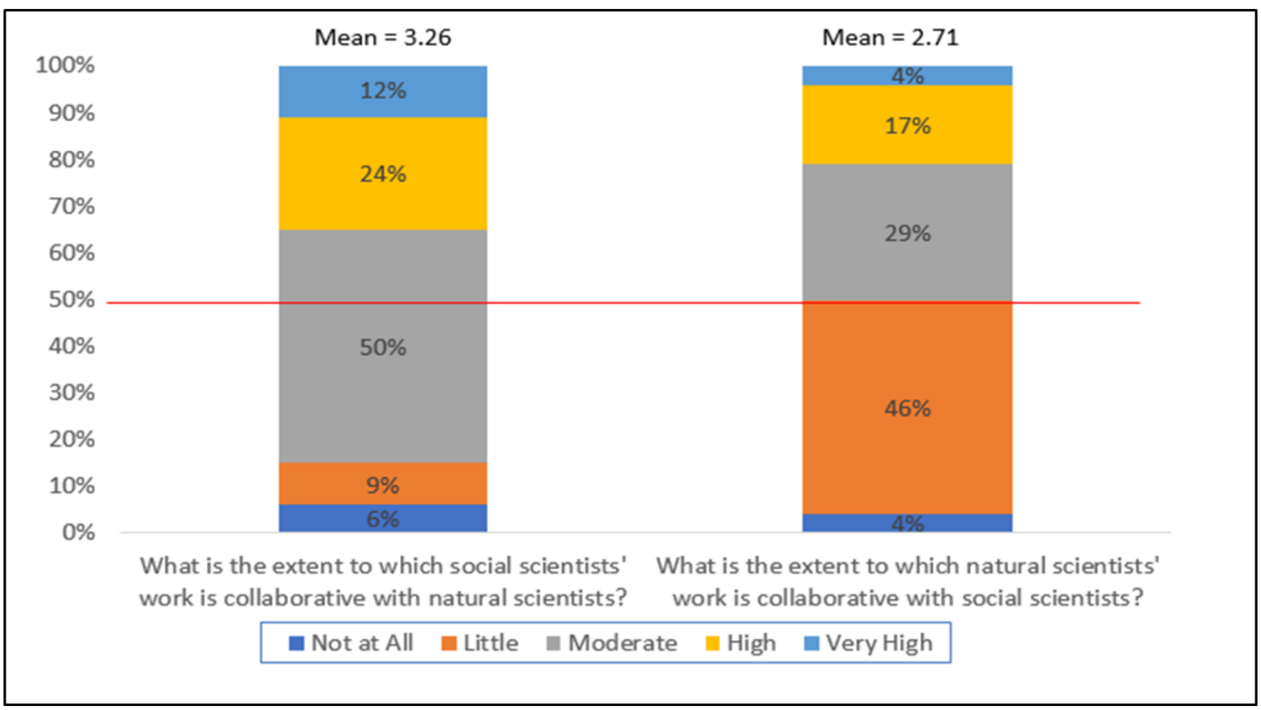


**Figure 2.** Perceptions of social scientists and biophysical scientists on collaboration with each other

commercial fisheries economic data), as well as general demographics could be linked with the abundance and size structure of fish as well as condition of coral reef habitat for fisheries resources and physical oceanography. Expanding and more finely analyzing each of the data sets could thus enhance understanding changes in other data sets as well as shedding light on patterns of influence among them.

While there was a wide range of existing socioeconomic data that was considered important, the findings show that managers do not currently rank the utility of sociocultural and economic data as very high, regarding it as generally less useful than biophysical data. In keeping with this, the extent to which sociocultural and economic data can be improved was also regarded as very high (Figure 3). While the study did not produce conclusive information as to the low utility ranking of socioeconomic data, a few discussion points may be relevant as follows.

First, many agencies mandate reporting and recommendations that are based on biophysical data (e.g. stock assessment), yet it is rare to find explicit mandates regarding socioeconomic data. This may have the preemptive effect of comparatively lowering perceptions about the usefulness of the socioeconomic data.

Secondly, when compared with social data, the biophysical data types collected through the NRCMP program in the Pacific Islands region are much more uniform and standardized across sites. This data is thus relatively easier to apply since it is comparable across jurisdictions. The social data types, on the contrary, exhibit considerable internal variation and nuance. Even within a given data type, questions are typically place-based and tailored to suit the social, economic and cultural contexts of the study sites. As a result, the transferability of social data types is more difficult and may appear to be less useful in drawing conclusions at larger scales or in making comparison across sites. Moreover, the process of generating

**Table 9.** Comparison for most important socioeconomic and biophysical data types

| Most Important Socioeconomic Data Types | Most Important Biophysical Data Types |
|---|---|
| Participation in fishing activities, (including gear, effort and catch) | Fish abundance |
| Resource dependency for provisioning ecosystem services (including livelihoods, e.g. commercial and subsisting fisheries) | Fish size structure |
| Fisher classification based on purpose of fishing (e.g. commercial, recreational, subsistence, cultural) | Coral condition |
| Proportion of population being reliant on commercial and recreational fisheries | Large-scale climate forcing (El Niño/La Niña, Pacific Decadal Oscillation) |
| Commercial fisheries economic data (cost/expenses and revenue) | Physical oceanography (e.g., ocean currents, wave metrics including height, period, power, and direction) |
| Resource governance, management, and institutions | Water chemistry (e.g., DIC, TA, DO, pH, dissolved inorganic nutrients, chlorophyll-a, salinity, fluorescence) |
| Demographics, incl general communities, fishers, and vulnerable populations | Water temperature |

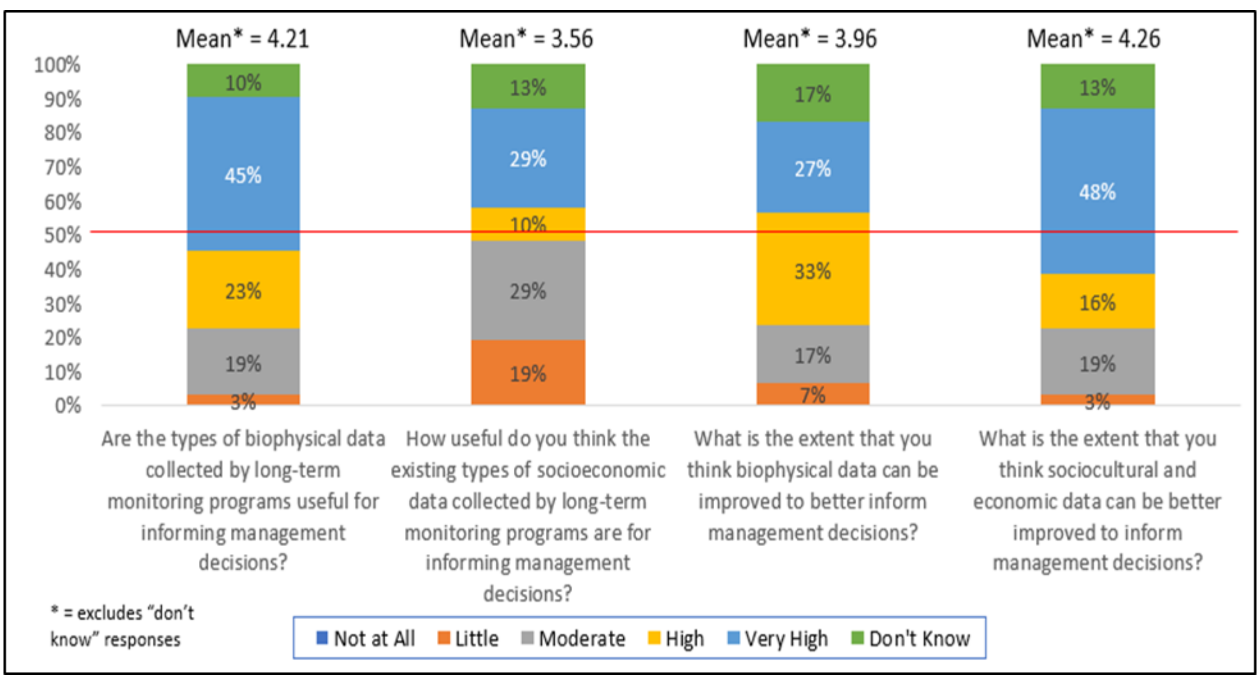


**Figure 3**. Perceptions of managers on the data usefulness for management decisions

socioeconomic data necessarily fuses qualitative and quantitative information, further contributing to the challenge of establishing scalable insights. Understanding the scale differences among data sets would help in assessing the opportunities and limitations of existing data, in forming more realistic and achievable research objectives, and in determining both appropriate project scope and the types and levels of resources needed to achieve those objectives.

Lastly, currently existing socioeconomic data types may not adequately address recent and rapidly forming demands for data on different human well-being domains and on evidence regarding linkages among natural resource management and societal well-being across all regions and biomes (McKinnon et al. 2017, Cheng et al. *In review*). These demands are evident in the Pacific Island region, and respondents in this study whose work is related to managing resources confirmed the importance of addressing them when they identified community well-being being as the single most important missing data type that would be useful for managing resources and benefiting human well-being. The existence of these demands is also confirmed by the importance granted to several existing social data types, such as resource dependency for provisioning ecosystem services, reliance and participation in fisheries of different types (e.g. commercial, recreational, subsistence, cultural, etc.), and the types and proportions of community livelihoods. One implication of this is that the social indicators incorporated in monitoring must be expanded to track community well-being data needs, including social resilience and such intangible aspects of well-being as culture and safety.

One of the most frequently identified gaps in socioeconomic data — "community resilience to climate impacts and natural disasters" — is critical for managing coastal and island sites where climate events are becoming increasingly noticeable and where their impacts have become more severe and frequent over the past decade. Addressing this data gap is an excellent opportunity to develop integrated monitoring efforts in which data from multiple disciplines are utilized to better understand relevant baselines and track changes. Conventional climate vulnerability assessments have focused mainly on the biological and physical aspects of ocean and climate conditions, and on factors that influence habitat conditions and species. These include fish abundance and size, coral conditions, water temperature, large-scale climate forcing (including El Niño/La Niña, Pacific Decadal Oscillation), water chemistry, and others. While data on these factors help managers detect new conditions and changes in the habitats and species upon which communities are reliant for all ecosystem services, integrating this biophysical data with data regarding communities' vulnerabilities to potential disturbances to their socioeconomic conditions and their social adaptive capacity (or the ability of people to cope with, respond to, and adjust to impacted physical environments and ecosystems) opens prospects for a more holistic and finely-grained understanding of vulnerability to climate change. Such understanding of social-ecological systems would allow management to not only better manage natural resources but also more effectively mitigate and adapt to climate impacts. Despite the importance, funding for social science on climate mitigation represented only 0.12% of all research funding (Overland and Sovacool 2020).

The other key areas of data gaps—"cultural heritage and connection to place" and "connection/sense of place and identity"—are important attributes of community wellbeing, particularly those fully or partially intangible dimensions of well-being that are more difficult to capture quantitatively (Dacks et al. 2019). At the same time, addressing the identified biophysical data gap regarding "land-based sources of water quality, sedimentation, and nutrient inputs" will require integrating both biophysical and socioeconomic data (such as human population distribution and coastal development activities) to realize more holistic ecosystem-based management solutions.

## RECOMMENDATIONS

Results of the existing data and data gaps point to the following main areas of focus in conducting long-term marine and coastal integrated monitoring in the Pacific island region:

i) **Clearly defining the purpose of data application, monitoring objectives, relevant scale(s), and ways to link biophysical and socioeconomic data sets. Integrated monitoring is a long-term activity that, to be successful, requires strategic thinking from the beginning, collaborative implementation throughout, and effective communication among team members and data users**. To this end, we emphasize that the purposes of integrated monitoring need to be clearly articulated and that appropriate strategies must be developed to help materialize them. It is critically important to have leadership commitment to long-term support, as well as commitments from those who collect data, to collaborate in achieving more holistic understandings of changes in social-ecological systems and their interactions. Without these, data gaps and mismatched data scales will remain unresolved.

ii) **Integrated monitoring should balance social and ecological components to support an ecosystem approach and more holistic management practices.** The potential uses and limitations of existing data types should be reviewed and understood, especially in connection with the complementary contributions of biophysical and social sciences. A shift is needed from the paradigm of biophysical data based monitoring to one in which biophysical and socioeconomic data make equally significant contributions. Otherwise, the social scientific dimension of the integrated monitoring will not receive the long-term commitment and resources needed to enable substantial levels of contribution, even when useful data sets or indicators are identified. Integrated monitoring objectives can be met, not only through making use of the different data sets already being produced, however, but also through establishing regular meetings and iterative frameworks that will foster collaborations among different disciplinary teams as they contribute to bringing these data sets together and understanding linkages among the different systems. Discussions about how to combine data sets to gain more holistic understandings of management issues is crucial to tracking and understanding changes in, and interactions among, social-ecological systems.

iii) **Establishing an interdisciplinary monitoring team comprising members with relevant biophysical and social scientific expertise, and strengthening collaboration among scientists from different disciplines, data users (such as managers, policy makers, and communities), and those who provide resources to support collaborative work**. Strategic monitoring partnerships of different organizations and programs should be developed so that diverse data types and more holistic information can be generated and brought together. The team would be charged with working together, not only to design and identify the indicators and how they can complement one another in a larger picture, but also to analyze and bring together the different existing data sets. The interaction levels among the different team members may vary depending on levels of integration, ranging from isolative, to collaborative, to integrated (Wongbusarakum and Heenan 2019). We recommend that there be a dedicated facilitating coordinator organizing the strategy identification and planning meeting(s) with leadership representatives, monitoring team leads and collaborative partners, including managers, and summarizing the agreed purposes, strategies, research objectives, and expected applications of the data. The coordinator should be responsible for bringing together members from different disciplines throughout the monitoring process to communicate, collaborate, create, and adapt transdisciplinary work.

iv) **Standardizing data types and data collecting instruments to allow for scaling up regional data and/or comparisons across sites while maintaining place-based local scale socioeconomic monitoring to benefit site management**. A regional socioeconomic monitoring plan for the Pacific islands should consider standardizing the data collected at various sites in relation to similar variables, while at the same time taking advantage of and continuing to collect data that are place-based and important for site management, even when they are non-standardized. These latter types of data are those identified as most needed socioeconomic data types, and the appropriate scales for their collection should be determined both locally and contextual. To move from the current way of data collection to one that is regional does not mean that everything should be done uniformly. Instead, it means that the different purposes of each data type and the existence of varying needs and values will be taken robustly into consideration. It also means collaborations and partnerships within federal programs and with outsider partners will be crucial to realizing the synergies needed to generate useful data at different scales and for different purposes. The monitoring of region-scale data efforts should be led by regional research organizations with participation from sites involved to define a set of regionally apt indicators to be monitored consistently over the long-term. Continuing site-based monitoring ensures that regional socioeconomic monitoring plans are responsive to the needs of specific islands and sites, that the local values and needs are taken into consideration, and that the data can be used to informed specific sector or site management decisions. When possible, the analyzed results of site-based and standardized higher monitoring should be bridged and used for more holistic understanding.

v) **Addressing community well-being data gaps through biocultural approaches.** In the Pacific Islands, where even the most recently established communities have been in place for centuries or millennia, connectedness to place is often informed and driven by knowledge of genealogies, historical events, and multi-generational experiences of survival and thriving in place (Morishige et al. 2018 in Dacks et al. 2019). It is critical for any type of monitoring design to take critical account of relevant histories and historical ecologies. As community well-being is culturally-mediated and context-specific, we propose that biocultural approaches should be applied in the monitoring process to define "cultural heritage" and "connection to place", and to identify indicators that are locally relevant, starting with and building upon local cultural perspectives to fill existing gaps in indicators as required to measure locally-defined definitions of success (Sterling et al. 2017). While relevant questions may be added to existing monitoring tools (e.g. cultural purpose of fishing in addition to sale or household consumption), several frameworks have been developed to address how best to collect additional data for cultural heritage and connection to place in Hawaii. These include Gould et al. 2014, Pascua et al. 2017, Morishige et al. 2018, Dacks et al. 2019, and Leong et al. 2019. Since there are multiple methods for studying culture, we would recommend that community members, anthropologists, and other academic experts be consulted, and that other more "in -depth" considerations are given to place-based monitoring of cultural heritage and other aspects of culture.

## CONCLUDING REMARKS

Scientific studies and monitoring efforts have produced incredible amounts of data. The next questions are how to make all of these data accessible; how identified data gaps can be filled; and how different data types can be brought together in ways that help improve understanding interconnections among social and ecological systems and their changes. Such understanding is important to develop ecosystem-based management strategies and practices that are themselves adaptive and self-improving in order to better manage and conserve our natural resources and improve the well-being of our communities. Importantly, social sciences should play an equal role in the integrated monitoring of social-ecological systems, and communities should have a voice and decision-making power in place-based research. The recommendations above drive home the significance of a paradigm shift for monitoring strategies and design, and for staffing monitoring teams that comprise people with different disciplinary expertise and that are open to interdisciplinary collaboration and incorporating community and stakeholder input into determining and achieving research aims. The recommendations also emphasize that monitoring results should not only improve understanding of biophysical changes, but also of societal changes, particularly community well-being. To complete this shift will require considerable commitment and support, especially from leadership and those setting program policies. Integrated monitoring, at its best, will be strategically designed from the very beginning to ensure that qualified staff and resources are available to produce and/or consider different data types at the scales useful for management. Monitoring should be conducted for periods of time adequate for generating the desired data, integrating the different data sets, communicating the results, and discussing how best to use them. We hope that the results and lessons from this study will provide insights applicable to other sites and regions.

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