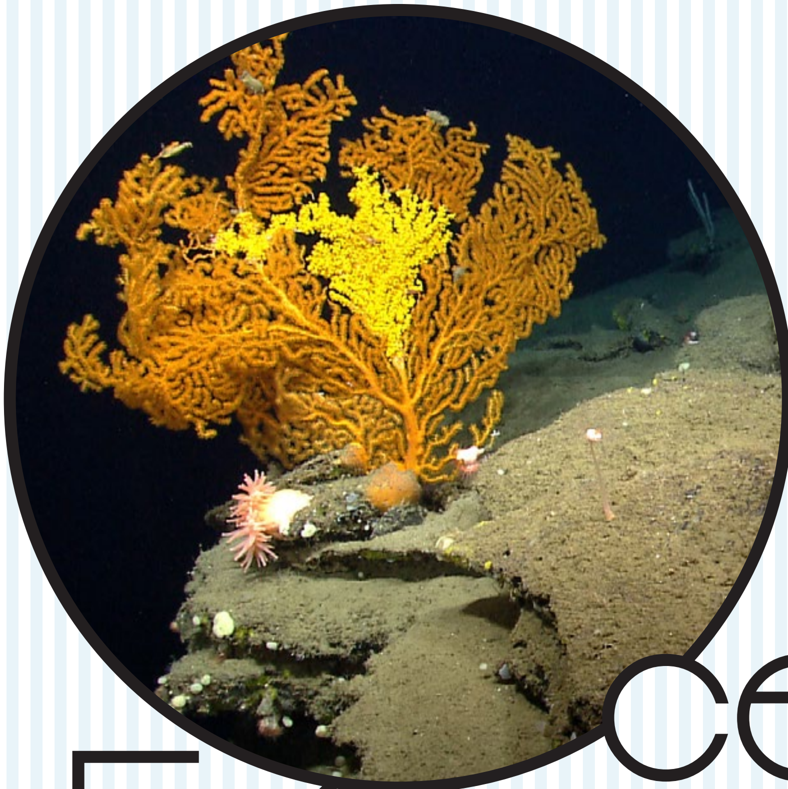


Ocean Exploration

Report on the Workshop to Identify National Ocean Exploration Priorities in the Pacific

July 10th - September 22nd, 2020

Consortium for Ocean Leadership

ACKNOWLEDGEMENTS

The Consortium for Ocean Leadership (COL) would first like to thank the National Oceanic and Atmospheric Administration's Office of Ocean Exploration and Research (NOAA OER) for supporting and co-organizing this workshop. COL would also like to recognize the Breakout Co-Leads and Panel Organizers listed below for their valuable time and admirable dedication in planning and carrying out the workshop, as well as writing the individual breakout reports. The success of this event is largely because of their continuous and focused support over many months. Finally, we need to thank all of those in the ocean exploration community who provided white paper contributions and/or attended the workshop as participants and observers; their input reflected in this report is sure to have significant impact in the coming years.

WORKSHOP MODERATOR

Dr. James A. Austin, Jr. – University of Texas at Austin, Jackson School of Geosciences, Institute for Geophysics

BREAKOUT CO-LEADS

Biology Characterization

Dr. Amanda Demopoulos – United States Geological Survey, Wetland and Aquatic Research Center
Dr. Daniel Wagner – Conservation International

Cultural Heritage

Dr. James Delgado – SEARCH, Inc.
Ambassador Cameron Hume (ret.) – NOAA's Ocean Exploration Advisory Board

Marine Resources

Dr. Ruth Perry – Shell Exploration & Production Company
Jeremy Potter – Bureau of Ocean Energy Management, Pacific Region

Seafloor Characterization

Dr. Larry Mayer – University of New Hampshire, Center for Coastal and Ocean Mapping/Joint Hydrographic Center
David Millar – Fugro

Water Column Characterization

Dr. Nicole Raineault – Ocean Exploration Trust
Dr. Michael Vecchione – NOAA Fisheries and National Museum of Natural History

DE&I IN THE PACIFIC – PANEL ORGANIZERS

Dr. Genene Fisher – NOAA OER – Moderator
Catalina Martinez – NOAA OER – Co-organizer
Dr. Dominique Rissolo – University of California, San Diego – Co-organizer
Bill Thomas – NOAA Office for Coastal Management – Facilitator

DISCLAIMER

TABLE OF CONTENTS

LIST OF ACRONYMS

ADCP . . . . . Acoustic Doppler Current Profiler
AI . . . . Artificial Intelligence
AUV . . . . . . Autonomous Underwater Vehicle
BOEM . . . . . Bureau of Ocean Energy Management
CAPSTONE . . Campaign to Address Pacific Monument Science, Technology, and Ocean Needs
CCZ . . . . . . Clarion-Clipperton [Fracture] Zone
CHIRP . . . . . Compressed High Intensity Radiated Pulse (Sonar)
COL . . . . . . Consortium for Ocean Leadership
ConOps . . . . Concept of Operations
CRADA . . . . Cooperative Research and Development Agreement
CTD . . . . . . Conductivity, Temperature, and Depth (Sensor)
DE&I. . . . . . Diversity, Equity, and Inclusion
DPAA . . . . . Defense POW/MIA Accounting Agency
DTM . . . . . . Digital Terrain Model
eDNA . . . . . Environmental DNA
EEZ . . . . . . Exclusive Economic Zone
EXPRESS . . . Expanding Pacific Research and Exploration of Submerged Systems (Campaign)
FAO . . . . . . Food and Agriculture Organization
FEMA . . . . . Federal Emergency Management Agency
HOV . . . . . . Human Occupied Vehicle
IHO . . . . . . International Hydrographic Organization
IMO . . . . . . International Maritime Organization
IOC . . . . . . Intergovernmental Oceanographic Commission (UNESCO)
ISA. . . . . . . International Seabed Authority
IUCN. . . . . . International Union for Conservation of Nature
MBARI. . . . . Monterey Bay Aquarium Research Institute
MBES . . . . . Multibeam Echosounder
ML . . . . Machine Learning
MPA . . . . . . Marine Protected Area
MSR . . . . . . Marine Scientific Research
NASA . . . . . National Aeronautics and Space Administration
NDPTC . . . . National Disaster Preparedness Training Center
NEPA . . . . . National Environmental Policy Act
NGO . . . . . . Nongovernmental Organization
NHPA . . . . . National Historic Preservation Act
NOAA . . . . . National Oceanic and Atmospheric Administration
NOMEC . . . . National Ocean Mapping, Exploration, and Characterization (Strategy)
NOPP . . . . . National Oceanographic Partnership Program
NSF . . . . . . National Science Foundation
OEAB . . . . . Ocean Exploration Advisory Board
OER . . . . . . Office of Ocean Exploration and Research
OET . . . . . . Ocean Exploration Trust
PCZ . . . . . . Prime Crust Zone
PMEL . . . . . Pacific Marine Environmental Laboratory
ROM . . . . . . Rough Order of Magnitude
ROV . . . . . . Remotely Operated Vehicle
SCOR . . . . . Scientific Committee on Oceanic Research
SSS . . . . . . Sidescan Sonar
SUBSEA. . . . Systematic Underwater Biogeochemical Science and Exploration Analog (Mission)
UNESCO . . . United Nations Educational, Scientific, and Cultural Organization
UNOLS . . . . University-National Oceanographic Laboratory System
USGS . . . . . United States Geological Survey
USM . . . . . . University of Southern Mississippi
USN . . . . . . United States Navy
USS . . . . . . United States Ship
UUV . . . . . . Uncrewed Underwater Vehicle
WHOI . . . . . Woods Hole Oceanographic Institution
WWI . . . . . . World War I
WWII. . . . . . World War II

EXECUTIVE SUMMARY

WORKSHOP OUTCOMES AND NEXT STEPS

The *Workshop to Identify National Ocean Exploration Priorities in the Pacific* takes advantage of an opportunity and a challenge. There is increased general interest and a new national imperative for ocean exploration, which includes ongoing initiatives related to a sustainable Blue Economy. NOAA OER's efforts are but one piece of an increasingly complex national and multi-national initiative to explore, map, and characterize the ocean. Such an exploration effort, in the Pacific and beyond, is so vast that it will take a full community of stakeholders to achieve, certainly over multiple decades.

This workshop, and likely others to come, helps to set the stage for the work that NOAA OER and others, both in partnership with NOAA and independently, are going to conduct in the Pacific. These workshops will also be helpful in informing the broader planning and implementation effort in support of the NOMEC Strategy and potentially other ocean-focused U.S. national strategies. Additionally, such work must involve from the outset relationship building and sustained interactions with Indigenous communities and partners in this region. While discussions at this workshop focused on U.S. ocean exploration, collaboration with multiple partner nations will be needed to meet some of the priorities identified in this report. The imminent United Nations Decade of Ocean Science for Sustainable Development (2021-2030) offers one potential and significant opportunity for broad-scale strategic international collaboration and public engagement.

This workshop, conducted virtually by way of an extended timeline involving two plenaries and separate breakout discussions in five subject areas – seafloor characterization, biology characterization, marine resources, water column characterization, and cultural heritage – generated significant and productive interactions among 59 participants representing 46 different organizations (government agencies, academic institutions, industry, and various private and philanthropic organizations). In addition, there were ~30 observers who attended from various government and private organizations. The closing plenary also included an important panel discussion with cultural practitioners from around the Pacific. Each group generated an executive summary and report from which a number of important take-away messages can be derived. They are summarized below (in no defined order):

Exploration is *human* exploration. All discovery is *human* discovery.

- The importance of storytelling and multiple lines of direct communication with the public (e.g., telepresence, social media, etc.) cannot be overemphasized.

DE&I in the Pacific:

- The *DE&I in the Pacific* panel discussion during the closing plenary was impactful; the cultural practitioners on the panel emphasized that ocean exploration in this region must include local communities, from the outset of planning through execution, data analyses, and application.
- Further, these relationships must be continuously “relational” rather than “transactional.” Partnerships are often pursued because of requirements for funding – that is transactional. Focus on building the relationships by talking about the environment and the communities themselves.
- The imperative of developing and sustaining productive relationships among ocean exploration and Indigenous communities across the Pacific led the panelists to suggest a mechanism for promoting such relationships, before, during, and after ocean exploration expeditions, “…where we might inspire the cultural reboot that resets, realigns, and converges the software of modern science and native ways of knowing…” (Kahu Ramsay Taum, Life Enhancement Institute of the Pacific).
- Consultation is important, but collaboration should be the goal. Involvement of Indigenous communities offers unique opportunities for broad engagement and deeper understanding of the value and human history of the Pacific.
- Traditional Knowledge systems are equivalent to other knowledge systems in a holistic understanding of the Pacific; such inclusivity enhances the ocean exploration enterprise.

Data – Increase Availability, Achieve Standards and Protocols:

- Standards and protocols need to be established so that all stakeholders, across all sectors, can have a clear idea of the requirements for acceptable data. Input from entities outside the federal government will be critical in establishing broadly acceptable standards. Better control and calibration of, as well as sharing of and access to, backscatter seafloor data are also critical.
- Presenting data resources curated at distributed data centers is critical, and the development of an integrated data portal that provides visibility and easy access to all existing ground truth and sample data within the U.S. EEZ would be a useful asset to inform new data acquisition and to ensure that previous investments in data acquisition can be leveraged.
- Data extraction via AI and ML are critical to improve rapid decision making and allow researchers to synthesize quickly the large volumes of data needed to characterize large areas.

Coordinate Existing and Integrate Emerging Technologies:

- Ocean exploration in the Pacific will require the coordinated use of the full spectrum of deep-sea technologies that are available. Emerging technologies will need to be progressively integrated with traditional characterization approaches that have endured the test of time.
- For biological characterization at or near the seafloor (benthic species) and in the water column (pelagic species), *in situ* sample collection and linked training of taxonomists will continue to be essential, to complement and increase the usefulness of emerging technologies. In addition, support of long-term archival collections to maintain the collected specimens is important.

Conduct a “Concepts of Operation” Workshop:

- ConOps in ocean exploration are complex and dependent on vessel and crew capabilities, specific goals/objectives and regions, and overarching mission constraints (e.g., available technologies and partnerships). Specific expedition planning requires knowledge of Pacific operations as a whole and careful consideration of tradeoffs (e.g., sampling vs. mapping and related spatial characterization). Workshop participants acknowledged this complexity and suggest a follow-on workshop to consider such details, first for the Pacific, and then generally in the context of planning and implementation of the NOMEC Strategy and potentially other ocean-focused U.S. strategies.

Plan and Execute "Flagship" Initiatives:

- Dedicated ocean exploration expeditions to target water column characterization priorities, like an oxygen-minimum zone and/or the bathypelagic-mesopelagic transition, should be considered. One possible location to pursue is offshore Hawai‘i, as this region lies near an accessible port in the Pacific basin suitable for a sustained effort.
- Panelists also suggest undertaking dedicated cultural heritage expeditions associated with the WWII Battle of Midway (e.g., to investigate both ship and aircraft wrecks) and/or the lost Pan American *Samoan Clipper* off the coast of American Samoa.
- Prioritizing and promoting marine resources field efforts that purposefully – but not exclusively – inform resource characterization are important. This can be achieved by engaging in resource-specific discussions with key personnel in federal agencies and/or other scientific partners to determine how federal and public-private efforts can supplement resource characterization needs. Public input must also inform these discussions.

Optimize and Facilitate Stakeholder Communication:

- Successful Pacific exploration hinges on the ability to engage, through effective and continuous communication, needs, plans, and outcomes, with the wide diversity of stakeholders that have worked previously and/or are currently working in this region.

Partnerships are Essential for Success:

- Beyond stakeholder communication, incentivizing collaboration amongst partners to assure participation is critical. Traditional mechanisms (e.g., CRADAs and NOPP) that have been effective on a project scale or between a limited number of organizations will not be sufficient for the national-scale collaboration needed to meet ocean exploration, mapping, and characterization goals; a more robust and reimagined NOPP could serve as a such a vehicle. However, barriers still exist with respect to technology transfer and data handling, particularly with industry.
- A nimble and adaptive public-private partnership model is now being implemented off the U.S. West Coast (see the Marine Resources Breakout Report, *p.33*). Early successes like this demonstrate great promise for broader applications through the NOMEC Strategy and potentially other national ocean exploration strategies.

A Potential National Ocean Exploration Program:

- A successful national program for seafloor characterization requires a combination of nationwide management and robust coordination with and among scientists and managers implementing regional field efforts. This is also true for other ocean exploration initiatives.

Geographic Priorities:

- Beyond the areas already highlighted for dedicated ocean exploration campaigns, the breakout groups note many geographic areas as particularly high priorities. Some examples include deep-water areas around Hawaiʻi and off California, the northern Mariana arc, various Pacific MPAs, the Cascadia margin, and the Aleutian Islands. The white papers submitted for this workshop are a valuable resource in this regard.

The *Workshop to Identify National Ocean Exploration Priorities in the Pacific* has focused on the potential and the promise of ongoing and future ocean exploration activities in the Pacific. This report should give expedition strategists an effective blueprint for those detailed planning activities. Workshop outcomes should also benefit the development of relevant national strategies and implementation plans for ocean exploration, in the Pacific and beyond, for years to come.

For additional details, please see the following executive summaries for each of the five thematic breakout reports.

SEAFLOOR CHARACTERIZATION EXECUTIVE SUMMARY

The seafloor characterization breakout discussion focused on strategies and tools needed to identify and prioritize areas that are appropriate for more detailed characterization, as identified in the other breakout groups; however, the continuum of these strategies and tools represents a multi-scale approach that must be considered from the outset.

- For large-area underway mapping, foundational systems include low frequency (12-30 kHz) acoustic systems, with primary data including multibeam sonar bathymetry, backscatter (seafloor and water column), quantitative fisheries echo sounders, and sub-bottom profiling; requirements for magnetics/gravity data at this scale should be established by cultural heritage experts.
- Standards and protocols need to be established, so that all stakeholders, across all sectors, can have a clear idea of the requirements for acceptable data. Input from those outside the government will be critical in establishing broadly acceptable standards. Better control and calibration of, as well as sharing of and access to, backscatter seafloor data, are critical.
- A national database (or similar) that provides visibility and easy access to all existing ground truth and sample data within the U.S. EEZ would be a useful asset.
- Numerous software tools and approaches are being developed for the quantification and remote characterization of seafloor properties; however, these techniques will require more effort in the calibration of MBES backscatter and the ability to share processed backscatter data widely.
- ConOps are complex and dependent on vessel and crew capabilities, on specific goals and regions, and on overarching mission constraints. These decisions need to be made by those with the broad picture of all these issues and careful consideration of the tradeoffs. However, the general consensus of the seafloor characterization breakout group is that, where possible, sampling should be part of mapping, exploration, and characterization surveys.
- New technologies and capabilities that can enhance seafloor characterization include: long-range, uncrewed platforms that can support large acoustic arrays and launch and recover other vehicles; calibrated backscatter systems; sparse array technology; enhanced data telemetry capabilities; edge-based processing tools, including AI and ML techniques; and better tools for data management and data sharing.
- Partnerships are essential for the success of U.S. national strategies for ocean mapping, exploration, and characterization. Communication of needs amongst partners is critical, as are mechanisms to incentivize partner participation. CRADAs and NOPP are mechanisms that have worked in the past, but barriers still exist with respect to technology transfer and data handling. Involvement of local communities offers unique opportunities for broad engagement and buy-in.
- Seafloor characterization can benefit a sustainable Blue Economy in many ways, including identification of critical fisheries habitat, aquaculture sites, gas seeps, geohazards, and potential mineral deposits. Identification and characterization of potentially polluting wrecks may also lead to job-generating mitigation efforts and the prevention of pollution that may be a significant threat to existing sustainable Blue Economy jobs in fishing and eco-cultural tourism.
- A successful national program for seafloor characterization requires a combination of nationwide management and robust coordination with and among scientists and managers implementing regional field efforts. The U.S. Department of State should continue its efforts to obtain data from foreign scientists who conduct MSR under diplomatic consent.

BIOLOGY CHARACTERIZATION EXECUTIVE SUMMARY

The biology characterization breakout group aimed to prioritize strategies, tools, data, and partnerships that are needed to conduct baseline biological characterizations of deep-sea (>200-meter depths) benthic habitats across the U.S. EEZ in the Pacific Ocean basin. The group included representatives from a variety of stakeholders that are actively working in the region, including researchers and managers from government agencies, academic institutions, nongovernmental institutions, and the private sector. Participants highlighted that exploration needs to link directly to resource management, protection, and stewardship, since the region includes many Pacific Island communities that are highly dependent on their ocean resources. This work will inevitably include passage through international waters; thus, deep-sea exploration in the Pacific will not only inform U.S. management actions, but also those of other countries, as well as international policies. Given the captivating nature of many deep-sea benthic species and habitats, exploration will provide a gateway to engage the broader community, including scientists, resource managers, policymakers, educators, cultural practitioners, and the public.

- Despite recent initiatives that focused on the deep waters of the Pacific, the vast majority of deep-sea benthic habitats in this region are still virtually unknown, so exploration will continue to focus on some of the most basic questions, such as identifying the species and habitats. This will require collecting physical samples, as well as working closely with taxonomic experts to identify them. Given the large extent of the Pacific, exploration will need to focus on more fully characterizing a few representative sites well, and then extrapolating data onto similar features across the broader region using predictive habitat models. These models will require high-quality data sets that should be collected in priority exploration areas such as MPAs, which besides being largely unexplored, also provide places to test new management measures.
- Essential data variables to capture include information on species identities, sizes, conditions, abundances, and distributions, as well as environmental data on temperature, salinity, dissolved oxygen, fluorescence, turbidity, currents, total alkalinity, pH, and carbonate chemistry. Sound is a data variable that is largely unexplored in the deep sea and therefore represents another opportunity for future exploration. Understanding the scales of variability and connectivity is particularly important for deep-sea benthic characterization and needs to be linked to efforts to characterize the overlying water column. Exploration will require the coordinated use of the great wealth of deep-sea technologies that are available. Emerging technologies will need to be progressively integrated with traditional characterization approaches that have endured the test of time. *In situ* sample collections will continue to be essential, and funding should be set aside so that taxonomists can rapidly identify collected specimens, as well as to help train the next generation of explorers with this knowledge. Additionally, it is important to support long-term archival collections to maintain the collected specimens.
- Priority geographic areas for exploration include Central Pacific seamounts, particularly those found within the PCZ and the CCZ, Pacific MPAs, and areas along the Aleutian Islands and the Cascadia margin. The biology characterization breakout group suggests possible approaches for prioritizing specific areas for exploration, such as focusing on key areas that may be imminently impacted by human activities (i.e., seabed mining and bottom fisheries), areas that may be vulnerable to disturbance due to underlying hazards (i.e., seafloor instability or landslide-prone areas), and/or regions that might be particularly susceptible to climate change impacts.
- Successful Pacific exploration hinges on the ability to engage the wide diversity of stakeholders that work within this region, who should be engaged early and often to ensure data are collected and disseminated in a culturally appropriate way, that local knowledge is strategically incorporated into expedition planning, and that information from exploration is disseminated to local stakeholders in a timely manner. Given the vast area that needs to be explored and the diversity of systems within it, no one organization will be able to do it alone.

MARINE RESOURCES EXECUTIVE SUMMARY

Despite economic and national security issues that increase national attention on the importance of energy and mineral resources, there remains a very limited understanding of these resources within U.S. Pacific waters. Ocean exploration can serve an important role in addressing this need.

Appropriate sustainable management of energy and mineral resources requires an understanding of the resources and the surrounding environment. While the traditional NOAA OER energy- and mineral-related efforts focus on locating and characterizing sensitive biological communities in areas that could be impacted by future extraction, the questions of how ocean exploration efforts can enhance the understanding of the actual resources has only rarely been discussed.

The marine resources breakout group focused its discussions on how ocean exploration can have a greater impact on this understanding. Although the baseline information about the surrounding environment is also a critical contribution of exploration for stewardship and management, it was not the focus of this breakout group. Such baseline information about biological diversity would inform stakeholders about the potential genetic resources that could lead to natural product discoveries and support a sustainable Blue Economy, but this was also not a focus of this discussion.

This breakout group's assessment is that ocean exploration efforts can likely make greater progress on understanding U.S. Pacific EEZ mineral resources than energy resources. This is largely because understanding energy resources requires substantial subsurface work beyond the scope of historical exploration and NOAA OER activities. However, NOAA OER and others can help advance understanding of critical mineral resources – as well as associated biological communities – if adjustments are made to where exploration is conducted and how samples are collected.

The following suggestions are provided for high level consideration on how ocean exploration efforts could better advance understanding of energy and mineral resources in U.S. EEZ waters in the Pacific:

- Prioritize and promote future ocean exploration field efforts that purposefully – but not exclusively – inform resource characterization. Engage in resource-specific discussions with key federal personnel, Indigenous leaders, and scientific partners to determine how federal and public-private efforts can supplement resource characterization needs. Allow public input.
- Areas of significant economic potential, and industry interest, within the U.S. EEZ should be the highest exploration priorities for resource characterization. For minerals, this is primarily in the Central and Western Pacific.
- Strengthen public-private partnerships to advance marine mineral mapping and characterization.
- Establish a venue or platform for parties to communicate and discuss needs, plans, and outcomes. This will help connect the needs of the marine resource community with the capabilities of the more traditional ocean exploration community and vice versa.
- Explicitly state the need and importance for geological and habitat characterization efforts that other organizations can and should conduct following initial exploration efforts to characterize resources. Without these statements, stakeholders are likely to assume inaccurately that the exploratory efforts alone are enough.
- Help facilitate systematically ground-truthing USGS offshore mineral maps.
- Identify standard location(s) to gather exploration and characterization data appropriate for synthesis and discovery efforts, including from industry partners, and define necessary data collection standards.
- Work with appropriate parties to define a baseline habitat characterization for areas of potential mineral and/or energy interest. This information is critical to subsequent monitoring efforts if extraction is pursued.

WATER COLUMN CHARACTERIZATION EXECUTIVE SUMMARY

Water column characterization has long been recognized as an important component of a national ocean exploration program, including in the initial advice from the scientific community in 2007 for NOAA Ship *Okeanos Explorer*. Following that report, development of methods using a two-body ROV system for direct observation of water column biology began in 2012. Additionally, subsequent planning workshops for regional ocean exploration campaigns have received recommendations for midwater exploration. In 2016, the National Academies Keck Futures Initiative convened an interdisciplinary workshop to brainstorm ideas and to develop proposals for improved methods to understand the mesopelagic (National Research Council, 2018). Shortly thereafter, in 2017, NOAA OER also sponsored a workshop, *From Surface to Seafloor*, focusing on the development of a more comprehensive framework for multi-disciplinary midwater exploration. Despite these calls for action, little systematic progress has been made. A few dedicated midwater dives, in addition to limited time at the end of some benthic dives, have occurred on some NOAA OER-sponsored expeditions. A national ocean exploration program that includes dedicated characterization of the water column as a primary component would significantly improve our knowledge and understanding of the largest and least-explored ecosystem on Earth (Webb et al., 2010), by providing the resources and partnerships necessary to build a community of scientists, technologists, and stakeholders to develop and test informed strategies.

The following should be included as tenets of a potential ocean exploration program for water column characterization:

- Devote ship time to dedicated expeditions for addressing large data gaps in the water column.
- Build partnerships with groups to aid in rapid image- and data-analysis tools and leverage the strength and resources of commercial, governmental, academic, and nonprofit institutions.
- Support the development and testing of water column-specific technologies to improve our ability to collect, analyze, and visualize appropriate data within this four-dimensional environment.
- Develop efficient and effective characterization protocols by utilizing multiple complementary techniques and approaches (e.g., nets, acoustics, imaging, and *in situ* sensing) to execute multi-disciplinary programs.
- In addition to standardized characterization, determine how best to target specific pelagic phenomena, such as oxygen-minimum zones and the bathypelagic-mesopelagic transition (particularly in areas targeted for uses such as mining), to support informed decision making regarding a sustainable Blue Economy.

CULTURAL HERITAGE EXECUTIVE SUMMARY

- Exploration is human exploration. All discovery is human discovery. What lessons can our discoveries teach us for humankind's future? Our exploration must engage with living cultures, societies, and groups for whom the past, as well as the oceans today, have relevance and meaning. This can be achieved through collaboration, transparency, and public outreach.
- Exploration, mapping, and characterization must be inclusive regarding participation from scientists and non-scientists across a variety of disciplines, and by individuals who reflect human diversity.
- We should consider characterization that offers an opportunity to find less visible or tangible traces of the past, such as largely or completely consumed wooden wrecks, but also features of cultural significance, such as the Bowie Seamount, known to the Haida Tribe as SGaan Kinghlas and considered spiritually important to members of that living culture.
- Initial seafloor mapping is an invaluable guide to enable identification of human interaction with the ocean environment. For cultural heritage, we should identify key ocean routes where evidence may be found on the seabed, such as patterns for Polynesian navigation, European and American sailing trade routes, established routes for regular trans-Pacific steam voyages, sites of major sea battles, and the routes of significant seabed cables of the past.
- A primary focus of identifying cultural heritage as part of the overall strategy for ocean exploration is to locate and characterize shipwrecks, aircraft, and other human-made artifacts in the Pacific. Another is to search for and identify the location of potentially polluting shipwrecks that may also be historic. A third is to examine existing finds and data that build towards a cultural heritage strategy for the Pacific and sharing of lessons learned. Our exploration must also contemplate unintentional or surprise discoveries, perhaps evidence of early transmigration or trade routes; these searches can be aided by available knowledge of human history.
- Cultural heritage can and should be used to excite larger public interest in the oceans, ocean exploration, and support of ocean issues. High-value targets of opportunity should be considered. Cultural heritage is found at times when it is least expected; therefore, planning for cultural heritage encounters should be included on any exploration mission through a known strategy to activate cultural heritage scientists and specialists as needed.
- The cultural heritage breakout group identified six potential signature missions: a) the full span of the Battle of Midway, including downed aircraft; b) the pioneer Pacific aircraft *Samoan Clipper*; c) the iconic battleship USS *Pennsylvania* off Kwajalein; d) the waters off the Northern Mariana Islands, an ancient maritime highway and the setting of modern losses of ships and aircraft; e) the "Kelp Highway," seeking evidence of early human migrations into the Americas following the now-drowned coastline at the 100-meter depth level and shallower in the U.S. EEZ, from Beringia (Alaska) to Baja California; and f) the veteran destroyer USS *Stewart*, scuttled in Bodega Canyon (off California) as part of a larger mission to explore that canyon in Greater Farallones National Marine Sanctuary.

INTRODUCTION

FIGURE i: *A screenshot from the virtual opening plenary meeting on July 10, 2020.*

COL, in partnership with NOAA OER, hosted the *Workshop to Identify National Ocean Exploration Priorities in the Pacific* throughout July, August, and September 2020. This workshop presented an opportunity to convene decision-makers in the ocean exploration community, as well as a variety of diverse stakeholders, to discuss common data priorities, needed capabilities and resources, and a shared vision for a potential national ocean exploration program. Participants included representatives from across the ocean exploration enterprise, including government, academia, industry, and private and philanthropic organizations. Focusing on the Pacific Ocean basin as a framework for the discussions, primarily in the U.S. EEZ but also in key international areas, workshop participants identified the data needed for characterization to support multiple stakeholder information needs, opportunities for partnerships and collaborations, and the resources and capabilities required to achieve common priorities. These interactions also served as an opportunity to highlight the importance of forming relational and sustainable partnerships with Indigenous communities throughout the Pacific.

The outcomes of this workshop will serve NOAA OER's expedition planning purposes, as well as community-wide strategies and coordination where interests and resources are aligned. The findings may also aid the interests of other U.S. and international initiatives. For example, the priorities outlined in this report are relevant to the missions and interests of several federal agencies, as well as various industry and private organizations, and can be used to inform implementation of the NOMEC Strategy and potentially other ocean-focused strategies. These findings may also provide strategic inspiration for the ocean exploration community to organize and take advantage of the U.N. Decade of Ocean Science for Sustainable Development, which launches in January 2021 and has begun its process for endorsing programs, projects, and other actions. The "flagship" initiatives identified during this workshop may serve to organize multi-partner and multi-national teams in the context of U.N. Decade projects.

COL solicited for white papers in February 2020 to gather information from the community regarding geographic and thematic priorities for exploration in the Pacific, and to guide development of the workshop agenda and breakout discussions. A list of these white papers is included at the end of this report (*Appendix E*) and they are publicly available on the *COL website*. In addition, workshop attendees were encouraged to review the white papers from the 2014 workshop hosted by OET on *Telepresence-Enabled Exploration of the Eastern Pacific Ocean*, which are also available on the *COL website*.

This virtual workshop took place in three parts: 1) an opening plenary held on July 10, 2020, followed by 2) a series of breakout sessions held throughout July and August 2020, and finally 3) a two-day closing plenary on September 21-22, 2020. Workshop participants were assigned to one of five thematic breakout topics: seafloor characterization, biology characterization, marine resources, water column characterization, and cultural heritage. Two co-leads identified in advance moderated each breakout discussion over the course of four hours, divided into two separate two-hour virtual meetings. The following questions were posed to participants and are provided here for context:

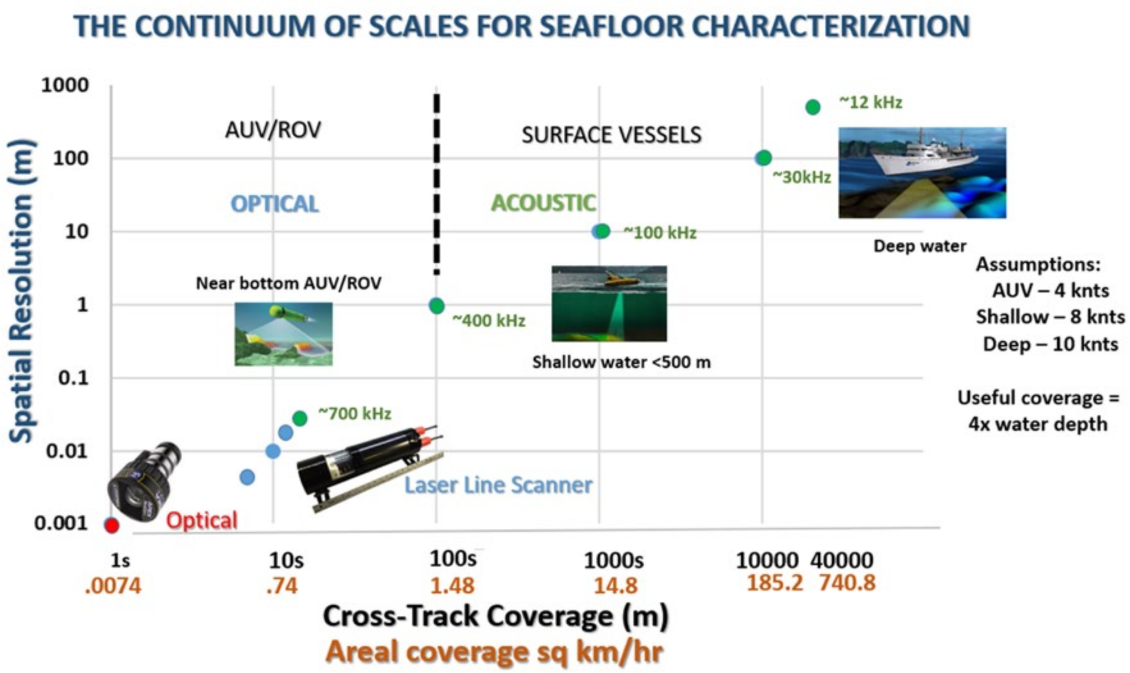
- What are the data requirements that define “characterization” for this topic?
- What new data are needed for this topic? What are the gaps in existing data?
- What existing capabilities (technologies, platforms, etc.) are available to collect needed data?
- What new capabilities (technologies, platforms, etc.) would further enable collection of needed data?
- What existing partnerships can be leveraged to facilitate exploration?
- What new partnerships would enable further or more effective exploration in the Pacific?
- What is the relevance/importance of this topic to a sustainable Blue Economy?
- How might your discussions about capabilities, partnerships, and relevance to a sustainable Blue Economy in the Pacific inform the implementation of a broader national ocean exploration program?
- What aspects of a national program would be most beneficial compared to separate regionally managed programs?
- Identify priority geographic regions for exploration that are critical for this topic in the Pacific Ocean. In addition, identify priority regions globally that may be critical for this topic.

Each group generated a report following the breakout meetings; these are presented in the following sections.

SECTION 1:
SEAFLOOR CHARACTERIZATION BREAKOUT REPORT

THE FOCUS OF THE SEAFLOOR CHARACTERIZATION BREAKOUT DISCUSSION

For the purposes of this discussion, the seafloor characterization breakout group agreed to use the definitions of mapping, exploration, and characterization as outlined in the NOMEC Strategy. As such, discussions of mapping and exploration focused on broad areal coverage, while characterization focused on “specific areas of interest” and in “direct support of specific research, resource management, policymaking, or applied mission objectives.” Other breakout groups – marine resources, biology characterization, cultural heritage – focused on specific applications that require detailed characterization tools. Yet, in a global ocean that is less than 20% mapped and a U.S. EEZ that is less than 45% mapped, the fundamental question remains: How does the ocean exploration community determine where “specific areas of interest” are? This group thus focused on strategies and tools needed to identify and prioritize areas that are appropriate for more detailed characterization. How will the ocean exploration community ensure that deep-sea corals, critical benthic habitats, vent communities, seabed seeps, and/or mineral deposits (and other non-biological marine resources) are able to be identified from initial mapping? Can potential cultural heritage targets be identified? Given these diverse objectives, the continuum of tools and approaches to the seafloor represents a multi-scale approach that must be considered from the outset (Figure 1.1).



Areal coverage sq km/hr	.0074	.074	1.48	14.8	185.2	740.8
NUMBER OF YEARS!!!! TOTAL OCEAN	~6,000,000	~600,000	~28,000	~2800	~224	~57
				~200 ship years >200m		
US EEZ	~175,105	~17,510	~875	~87	~7	~2

FIGURE 1.1: *The continuum of scales for seafloor characterization. ROM calculations of spatial resolution for given sensors versus cross-track coverage (black labels). Spatial coverage is converted to areal coverage using the assumptions listed. The bottom table lists ROM estimates for time required to cover total ocean and U.S. EEZ seafloor at different rates of areal coverage.*

Ideally, the entire U.S. EEZ should be characterized at the finest resolution possible, much like the community has been able to do on the ~29% of Earth not covered by water. As indicated in Figure 1.1, given the limited propagation of light in the ocean, such a goal is neither practical nor financially feasible, so a seafloor characterization strategy must define what data sets need to be collected during initial mapping and exploration that may provide indicators for where more detailed efforts must be focused. Once that is done, the needs for either generic or application-specific detailed characterization can be defined.

DATA REQUIREMENTS, TECHNOLOGIES, AND PLATFORMS

The seafloor characterization breakout group envisions a hierarchal approach to seafloor characterization, with the first pass conducted during the mapping and true exploration phase. In the deep ocean (>200-meter depths, which is the defined focus of this workshop), initial mapping will be conducted by large (typically >50 meters) crewed surface vehicles or, in the not-too-distant future, by, and/or augmented by, the use of large (typically >25 meters), long-duration, uncrewed (autonomous) surface vessels capable of mapping at relatively high-speeds (~10 knots or more) and carrying the large acoustic arrays necessary for full-ocean depth mapping. As with all acoustic systems, there are tradeoffs among frequency, propagation range, spatial resolution, and array size. For full ocean depths, 12-kHz multibeam sonars must be used to overcome attenuation in the water column. Increasing the frequency will allow higher spatial resolution from a smaller array, but will have a more limited depth range. A 30-kHz system, while capable of mapping beyond 5,000 meters of water depth, can do so only with a very narrow swath and thus is optimal with respect to bottom coverage only up to depths of ~2,500 meters. Therefore, in establishing the suite of systems required, the tradeoffs among resolution, range, vessel size, speed, and linked cost must all be taken into consideration.

FOUNDATIONAL DATA SETS FOR INITIAL MAPPING, EXPLORING, AND CHARACTERIZATION

In the Seafloor Characterization Matrix at the end of this section (Table 1.1), we present an overview of the foundational systems required for initial mapping and exploration data collection. These systems allow the first steps for seafloor characterization and the identification of specific areas of interest where more detailed characterization is warranted. The initial assumption is that these data would be collected underway at full speed (to maximize coverage); the question of stopping for sampling or deployment of high-resolution assets (AUVs or ROVs) will be discussed later. For initial mapping, the acoustic systems are limited to low frequency (12-30 kHz), with primary data including multibeam sonar bathymetry, backscatter (seafloor and water column), quantitative fisheries echo sounders (operating over a range of frequencies), and sub-bottom profiling. The collection of non-acoustic underway data (e.g., magnetics and gravity) would have scientific value and should be encouraged, but may not be essential in the context of seafloor characterization except in relatively shallow waters.

STANDARDS AND PROTOCOLS

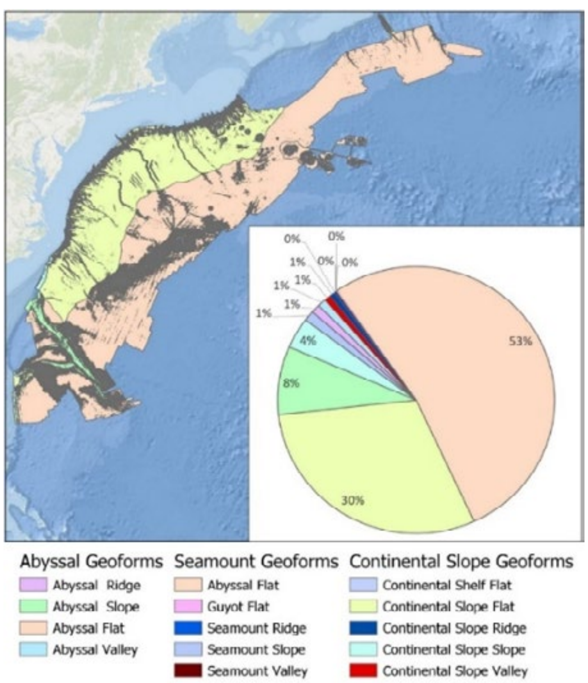
The details of standards and protocols for collection of these data types are beyond the scope of this report; however, numerous seafloor characterization breakout participants from various sectors called for standards to be established, so that all stakeholders, across all sectors, can have a clear idea of the requirements for acceptable data. For example, the hydrographic community has established guidelines for the collection of multibeam bathymetry (*IHO SP 44*) in support of nautical charting, and the GeoHab Backscatter Working Group has offered best-practices for the collection of backscatter data in support of habitat mapping (GeoHab, 2015), but neither of these was developed for broad objectives, such as those highlighted in the NOMEC Strategy. Ongoing efforts within NOAA OER, as well as for broader U.S. national strategies, are critical, though concern was expressed that input from those outside the government (i.e., private sector, academic, and philanthropic stakeholders) will be critical in establishing broadly acceptable standards. There were numerous calls for better controls and calibration of backscatter data, as well as widely sharing processed backscatter data.

SELECTING "SPECIFIC AREAS OF INTEREST" FOR DETAILED CHARACTERIZATION

Given that ~56% of the U.S. EEZ is unmapped (Greenaway et al., 2020), and as demonstrated in Figure 1.1, the time required for detailed characterization is orders of magnitude greater than that required for initial mapping. Therefore, a fundamental challenge facing the ocean exploration community is how to determine where more detailed characterization is warranted. Several approaches were proposed:

Directed by preexisting knowledge or models: In some cases, preexisting knowledge and/or conceptual models will provide enough justification to choose areas for detailed characterization, even if these areas are completely unmapped. Examples of this would be historic knowledge of the potential location of cultural heritage sites or knowledge of shipping routes where a high probability of cultural heritage sites might be located. Ecosystem models may prescribe a high likelihood of certain habitats in particular regions or environments (e.g., seamounts, canyons, etc.), while understanding the best environments for seafloor mineral deposits may determine appropriate areas before any mapping is done. In these cases, such direction needs to come from the experts found in other breakout groups. A particularly important aspect of this approach that addresses the partnership issue is that shared data (particularly rare ground-truth data) among the broad community can lead to a rapid acceleration of the conceptual models that can in turn lead to a better selection of sites for detailed characterization. To this end, the seafloor characterization breakout group discussed the desire for a national database (or similar tool) that would provide visibility and easy access to all existing ground truth and sample data within the U.S. EEZ.

Quantitative tools for seafloor characterization: With increases in both the spatial resolution and bandwidth of current MBES systems, long-standing research efforts to characterize the seafloor remotely have gained momentum. Two approaches seem particularly promising, depending on the application – quantitative geomorphometry, and analysis of both the angular and frequency dependence of backscatter. The ability to collect full-coverage, high-resolution multibeam data, in combination with three-dimensional visualization tools, provides an immediate qualitative capability to identify key physiographic features (e.g., seamounts, canyons, etc.); such an approach can be quantified and has been shown to identify consistent and reproducible characterization for large regions automatically and objectively (Figure 1.2a), with important habitat ramifications (Sowers et al., 2019, 2020). At a finer scale, similar approaches can be used (in conjunction with a conceptual ecosystem model) to detail the potential location of features like cold-water corals (Figure 1.2b).



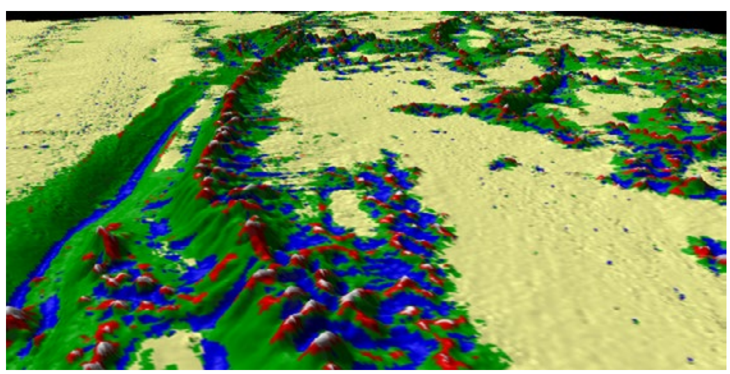
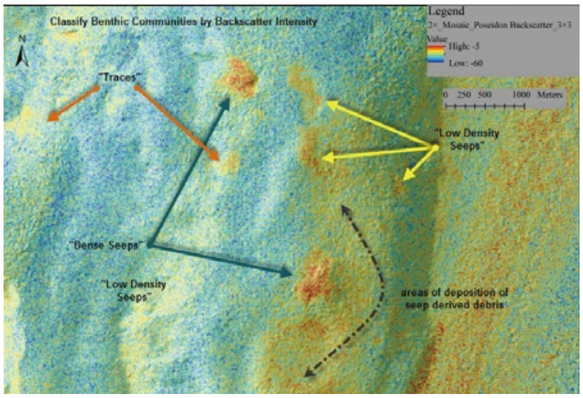


FIGURE 1.2a (LEFT): *GeoForm analysis applied to large MBES data sets collected in support of U.S. extended continental shelf efforts.*
FIGURE 1.2b (RIGHT): *GeoForm analysis of NOAA Ship* Okeanos Explorer *MBES data collected on Blake Bahama Plateau showing regions of high probability for cold-water corals as red and white areas (Sowers et al., 2019,2020).*

Similar advances have been made in our ability to use backscatter (both seafloor and water column) to characterize the seafloor. In a qualitative sense, backscatter has often been used to separate hard from soft seafloors (Figure 1.3a), but new techniques are being developed to use both the angular response and frequency response of backscatter to provide quantitative estimates of seafloor type (Figure 1.3b). The application of these techniques will require much more effort in the calibration of MBES backscatter, which is identified as an important need, as is the need to share processed backscatter data widely.



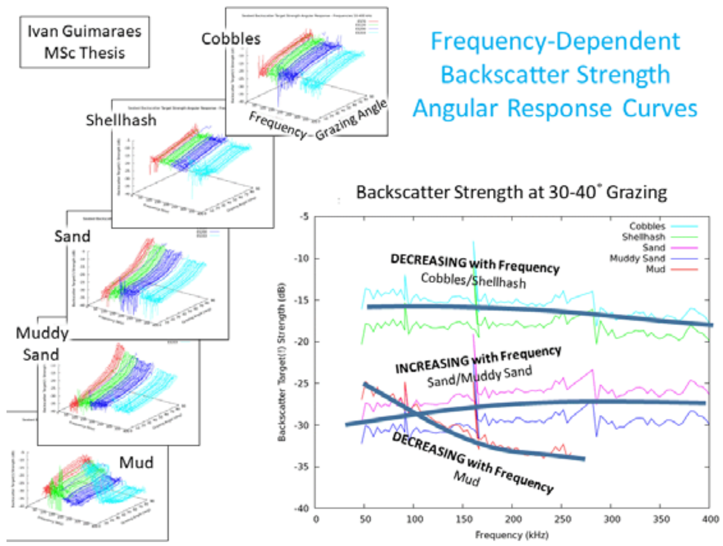


FIGURE 1.3a (LEFT): *Use of qualitative MBES backscatter to identify cold-seep communities (Digby et al., 2016).*
FIGURE 1.3b (RIGHT): *Use of both angular and frequency response curves to identify seafloor type remotely (Guimaraes, 2020).*

CONOPS: INCLUDING SAMPLING FOR CHARACTERIZATION DURING INITIAL MAPPING AND EXPLORATION

There was significant discussion as to what ConOps should be for initial mapping, exploration, and characterization surveys (i.e., not detailed characterization surveys for a specific application). Should such surveys only involve the collection of foundational data sets described above, or should they also carry tools needed for the next levels of detailed characterization (AUV and ROV), and in addition be able to stop for detailed surveys or other types of sampling (e.g., coring, dredging, net tows, etc.)? Or should ocean exploration campaigns be planned in cruise pairs – initial broad area mapping followed by a detailed characterization expedition? The latter approach minimizes transit to distant regions but, depending on vessel capabilities, may be less efficient if crews and equipment need to be changed between expeditions. Such logistical considerations are extremely complex and very dependent on vessel and crew capabilities, on specific goals and regions, and on overarching mission constraints. Nonetheless, the consensus of the seafloor characterization breakout group is that when possible, sampling should be part of mapping, exploration, and characterization surveys.

DETAILED CHARACTERIZATION

Once “specific areas of interest” are identified through the methods described above, the tools and data required of the next level of detail of surveys should be defined by domain and application experts. To facilitate the identification of the appropriate tools and data sets, please see the Seafloor Characterization Matrix at the end of this section (Table 1.1). The details provided by application-specific use-cases may also serve to inform the general mapping approaches. With this approach, needs (tools and data sets) can be defined by the products required by the various use-cases.

NEW TECHNOLOGIES AND CAPABILITIES

The collection of the fundamental data sets needed for initial mapping, exploration, and characterization are constrained by the laws of physics, which define the tradeoffs among resolution and range of MBES systems. However, efficiencies can be gained through innovations, including:

- Large, long-range autonomous or uncrewed platforms that can support large arrays offer savings on crew and some fuel costs.
- Wind- and/or solar-powered, long-range autonomous or uncrewed platforms that can support large arrays offer savings on crew costs, ever greater savings on fuel, and have potential for very long deployments, saving greatly on transit times.
- Large, long-range autonomous or uncrewed platforms that can support large arrays and host ROVs or AUVs could provide a similar capability to traditional crewed ocean exploration vessels.
- Increased emphasis on calibration of backscatter data to facilitate quantitative characterization using angular and frequency dependence.
- The potential for application of sparse array technology using autonomous vehicles could theoretically provide 1-meter resolution in 4,000 meters of water depth – a true game-changer.
- Increased bandwidth satellite telemetry would facilitate data transmission from vessels offshore and distributed cloud-based processing.
- Development of better edge-based processing tools is needed to support autonomous operations, including applications of AL and ML techniques.
- Better tools for data management, for 1) sharing data and databases, and 2) sharing knowledge of where data, including ground truth and sampling data, exists or not (for gap analyses).

PARTNERSHIPS

The magnitude of the tasks at hand makes the need for partnerships essential. NOAA OER has limited mapping, exploration, and characterization assets, but the collective assets of other federal agencies, the military, the private sector, the academic community, and interested NGOs offer a formidable suite of tools that, if organized and coordinated, could provide much greater capacity and competency to meet the challenge. In particular, NGOs have more flexibility in the deployment and use of their assets; however, they must find ways to ensure that they are aware of high priority areas and have the appropriate gap-analysis tools and protocols to collect and provide data to appropriate databases. Industry also has tremendous capabilities and is often anxious to help, but again, communication of needs is essential, and mechanisms must be found to incentivize their activities. CRADAs and NOPP were highlighted as mechanisms that have worked well in the past to promote partnerships; however, the failure to recognize that seafloor characterization is not only a hardware development problem but also a major data-handing challenge, and also the lack of planning with respect to adoption of successful innovation, are obstacles to successful partnerships. In some situations (i.e., working around Pacific Islands, the Pacific Northwest, and Alaska), teaming with local communities, including local Indigenous communities, and exploring crowd-sourced data collection and citizen science, can be valuable additions. Coordination with other global initiatives, such as the Nippon Foundation Seabed 2030 project and the U.N. Decade of Ocean Science for Sustainable Development, are also potential mechanisms to identify and establish partnerships.

A SUSTAINABLE BLUE ECONOMY

The potential for a successful seafloor characterization program with respect to a sustainable Blue Economy are manifest. The robust identification of fragile and essential fisheries habitats will help sustain all components of the commercial and recreational fisheries industries (as well as the environment), as appropriate policy and management decisions are made. Seafloor characterization can also play an important role in siting locations to support aquaculture development. The use of seafloor characterization for locating gas seeps and cold-seep communities has already been demonstrated to be a valuable component of offshore oil and gas exploration, and can also support appropriate policy development and management decisions. Additionally, the identification of geohazards provides an important contribution to safety and risk reduction (i.e., insurance/reinsurance). Identification and characterization of potentially polluting wrecks may also lead to job-generating mitigation efforts and the prevention of pollution that may be a significant threat to existing sustainable Blue Economy jobs in fishing and eco-cultural tourism. To this end, preparation for submissions, planning, and execution should include reference to the NOAA study on potentially polluting wrecks as primary targets or for piggyback missions. Finally, new tools that may be developed to identify the distribution of polymetallic deposits and critical minerals could also make an important contribution. A project of this scale will also provide economic development and create jobs.

NATIONAL OR REGIONAL PROGRAM

There is near-consensus by the seafloor characterization breakout group that a program of this magnitude can only be managed efficiently on a national level. While applications may vary regionally, the approaches taken are universal, and the development and deployment of tools and platforms can only be done efficiently through a national program. Additionally, there is a critical need for interagency coordination among federal government players, as well as an equally important need to coordinate with nongovernment actors in the private sector, academia, and philanthropic communities. How engagement with these nongovernment stakeholders will occur is not obvious or visible yet, but is seen as a critical priority.

REGIONAL PRIORITIES

While the selection of specific regional priorities is largely left to the other breakout groups, the Aleutian Islands are an area of common interest by many in the seafloor characterization group.

ADDITIONAL CONCERNS

The issue of the availability of data collected by foreign entities in the U.S. EEZ was raised. There is interest in ensuring that such data being collected in the U.S. EEZ are shared with the United States, and in particular, data collected by foreign scientists who have received consent to conduct MSR. The U.S. Department of State must continue its efforts to obtain reports and data from foreign scientists who conduct MSR under diplomatic consent.

REFERENCES

Digby, A., Puentes, V., and León, J. (2016). Cold Seeps Associated with Structured Benthic Communities: More Accurate Identification and Evaluation Using a New Multibeam Survey Methodology in the Offshore Southern Colombian Caribbean. *International Journal of Geosciences*, 7(5), 761-774. http://dx.doi.org/10.4236/ijg.2016.75058

GeoHab (2015). Backscatter measurements by seafloor-mapping sonars. Guidelines and Recommendations. http://geohab.org/wp-content/uploads/2018/09/BWSG-REPORT-MAY2015.pdf

Greenaway, S., Batts, A., and Riley, J. (2020). Are We Done Yet? An Empirical Estimator for Level of Effort for Seafloor Surveys - Including an Estimate for the Full Survey of U.S. Waters. *Marine Geodesy*, 43(2), 87-104. https://doi.org/10.1080/01490419.2019.1705449

Guimaraes, I.G. (2020). *Calibrating Broadband Multibeam Seabed Backscatter* [unpublished master's thesis]. Center for Coastal and Ocean Mapping, University of New Hampshire.

Sowers, D., Dijkstra, J. A., Masetti, G., Mayer, L. A., Mello, K., and Malik, M. A. (2019). Applying a Standardized Classification Scheme (CMECS) to Multibeam Sonar and ROV Video Data on Gosnold Seamount. In Harris, P.T. and Baker, E. (Eds.), *Seafloor Geomorphology as Benthic Habitat: GeoHab Atlas of Seafloor Geomorphic Features and Benthic Habitat* (2nd ed., p. 1076) Elsevier Inc.

Sowers, D., Masetti, G., Mayer, L. A., Johnson, P., Gardner, J. V., and Armstrong, A. A. (2020). Standardized Geomorphic Classification of Seafloor Within the United States Atlantic Canyons and Continental Margin, *Frontiers in Marine Science*, 7(9), 1-9. https://doi.org/10.3389/fmars.2020.00009

TABLE 1.1a:
SEAFLOOR CHARACTERIZATION DURING LARGE-SCALE (MANIFEST) MAPPING AND EXPLORATION

System	Frequency	Spatial Resolution	Data Type	Application
Multibeam Sonar	12 kHz *(All ocean depths)*	At 4,000-meter range: 70x140, 70x70, 35x70 meters 1x2, 1x1, 0.5x1 degrees	**Bathymetry**	Morphology, rugosity, physiographic features (seamounts, canyons, etc.), geologic settings, seafloor dynamics (bedforms, hazards, mass wasting), direct detection of resolvable human-made features
			Seafloor backscatter	Estimates of substrate type (hard, soft, rock, mud, etc.), cast shadows for large human-made objects
			Water column backscatter	Gas seeps (natural and human-made), human-made targets standing proud of seafloor, uncalibrated biological targets, low-resolution oceanographic features
	30 kHz *(Optimal from 200-2,500 meters water depth, and will detect seafloor beyond 6,000 meters water depth, but narrows swath)*	35x70, 35x35 meters 0.5x1, 0.5x0.5 degrees	**Bathymetry**	Morphology, rugosity, physiographic features (seamounts, canyons, etc.), geologic settings, seafloor dynamics (bedforms, hazards, mass wasting), direct detection of resolvable human-made features
			Seafloor backscatter	Estimates of substrate type (hard, soft, rock, mud, etc.), cast shadows for large human-made objects
			Water column backscatter	Gas seeps (natural and human-made), human-made targets standing proud of seafloor, uncalibrated biological targets, low-resolution oceanographic features
Fisheries Sonar	18-330 kHz	n/a	**Water column backscatter**	Quantitative determination of volume backscatter in water column, estimates of biomass, potential species identification, identification of physical oceanographic targets (pycnocline, internal waves, etc.)
Sub-bottom Profiler	1.5-15 kHz	~700 meters	**Sub-bottom reflectivity**	Recent geologic history and processes, insights into hazards (gas, faulting, etc.), potential to locate buried objects of suitable size and acoustic contrast, insight into seafloor type
Magnetometer	n/a	n/a	**Magnetic field direction, strength, or relative change**	Magnetic properties of seafloor or subsurface, identification of human-made objects (if within range)
Gravimeter	n/a	n/a	**Variations in Earth's gravitational field**	Variations in gravitational acceleration to indicate change in rock properties and absence of mass (if within range)
Underway Samples	n/a	n/a	**Near-surface water properties**	Productivity, oceanography, biomass, species presence/absence, ocean acificidication, climate studies, etc. (restricted to upper few meters of surface layer)
Coring, Drilling, Grab Samples	n/a	n/a	**Ground truthing**	Physical samples of bottom material (as deemed needed)
CTD	n/a	n/a	**Water column data**	Temperature, conductivity, density, turbidity

TABLE 1.1b:
SEAFLOOR CHARACTERIZATION DURING MEDIUM-SCALE (AUV-BASED) MAPPING AND EXPLORATION

System	Frequency	Spatial Resolution	Data Type	Application
Multibeam Sonar	200-400 kHz *(Within 100 meters of bottom)*	At 100-meter range: 1.75x1.75, 0.7x1.75 meters 1x1, 0.4x1 degrees	**Bathymetry**	Morphology, rugosity, fine scale features (vents, biological mounds, etc.), geologic settings, seafloor dynamics (bedforms, hazards, mass wasting), direct detection of resolvable human-made features
			Seafloor backscatter	Estimates of substrate type (hard, soft, rock, mud, etc.), potential identification of nodule fields and seafloor massive sulfides, cast shadows for large human-made objects
			Water column backscatter	Gas seeps (natural and human-made), human-made (cultural heritage) targets standing proud of seafloor, uncalibrated biological targets, vent fluids, gas flows
Sidescan Sonar *(When deployed on an AUV, SSS data is very similar to MBES backscatter data, though AUVs can be deployed with SSS and without using MBES)*	100-800 kHz	n/a	**Seafloor backscatter**	Detection of human-made objects (without depth information) *(Typically run 30-50 meters above bottom)*
Fisheries Sonar	18-330 kHz	n/a	**Water column backscatter**	Quantitative determination of volume backscatter in water column, estimates of biomass, potential species identification, identification of physical oceanographic targets (pycnocline, internal waves, etc.), gas flux
Sub-bottom Profiler	1.5-15 kHz	~17.5 meters	**Sub-bottom reflectivity**	Recent geologic history and processes, insight to hazards (gas, faulting, etc.), potential to locate buried objects of suitable size and acoustic contrast, insight into seafloor type
Magnetometer	n/a	n/a	**Magnetic field direction, strength, or relative change**	Magnetic properties of seafloor or subsurface, identification of human-made objects (if within range), identification of appropriate mineral deposits
Laser Line Scanner *(Typically need to be within 10 meters of bottom)*	532 nanometers (wavelength)	1-10 millimeters	**Near photo-like imagery (time of flight [micro DTM] in some systems)**	Very high resolution reconstructions of object shapes, imagery of features for direct identification and characterization, wider field of view than photo imagery
Still/Video Imagery *(Typically need to be within 8 meters of bottom)*	n/a	Sub-millimeter	**Videos and photos**	Direct visual identification of seafloor features (biology, geology, and cultural heritage)
Sampling *(Flow through systems, including eDNA, mass spectrometry, temperature, salinity, pressure, methane, CO_2, etc.)*	n/a	n/a	**Physical, chemical, and biological properties of water masses traversed**	Ecosystem, productivity, species distributions, eDNA, water properties, ocean chemistry, methane sources, vent communities, etc.

TABLE 1.1c:
SEAFLOOR CHARACTERIZATION DURING FINE-SCALE (ROV-BASED) MAPPING AND EXPLORATION

System	Frequency	Spatial Resolution	Data Type	Application
Multibeam Sonar	200-700 kHz *(Within 10 meters of bottom)*	At 10-meter range: 0.175x0.175, 0.7x0.175 meters 1x1, 0.4x1 degrees	**Bathymetry**	Morphology, rugosity, fine scale features (vents, biological mounds, etc.), geologic settings, seafloor dynamics (bedforms, hazards, mass wasting), direct detection of resolvable human-made features
			Seafloor backscatter	Estimates of substrate type (hard, soft, rock, mud, etc.), identification of nodule fields, cast shadows for large human-made objects
			Water column backscatter	Gas seeps (natural and human-made), human-made (cultural heritage) targets standing proud of seafloor, uncalibrated biological targets, vent fluids, gas flows
Sidescan Sonar	100-800 kHz	n/a	**Seafloor backscatter**	Detection of human-made objects (without depth information) *(Typically run 30-50 meters above bottom)*
Fisheries Sonar	18-330 kHz	n/a	**Water column backscatter**	Quantitative determination of volume backscatter in water column, estimates of biomass, potential species identification, identification of physical oceanographic targets (pycnocline, internal waves, etc.), gas flux
Sub-bottom Profiler	1.5-15 kHz	~17.5 meters	**Sub-bottom reflectivity**	Recent geologic history and processes, insight to hazards (gas, faulting, etc.), potential to locate buried objects of suitable size and acoustic contrast, insight into seafloor type
Magnetometer	n/a	n/a	**Magnetic field direction, strength, or relative change**	Magnetic properties of seafloor or subsurface, identification of appropriate mineral deposits, identification of human-made objects (if within range) *(Typically run with 30-meter line spacing, 6 meters above bottom for wrecks)*
Laser Line Scanner *(Typically need to be within 10 meters of bottom)*	532 nanometers (wavelength)	1-10 millimeters	**Near photo-like imagery (time of flight [micro DTM] in some systems)**	Very high resolution reconstructions of object shapes, imagery of features for direct identification and characterization, wider field of view than photo imagery
Still/Video Imagery *(Typically need to be within 8 meters of bottom)*	n/a	Sub-millimeter	**Videos and photos**	Direct visual identification of seafloor features (biology, geology, and cultural heritage)
Flow Through Systems	n/a	n/a	**Physical, chemical, and biological properties of water masses traversed**	Ecosystem, productivity, species distributions, eDNA, water properties, ocean chemistry, methane sources, vent communities, etc.
Drilling, Probing, Grab Samples	n/a	n/a	**Specimens of rocks, sediments, flora, and fauna**	Unambiguous characterization and critical ground truth for remotely sensed measurements

SECTION 2:
BIOLOGY CHARACTERIZATION BREAKOUT REPORT

INTRODUCTION

The primary goal of the biology characterization breakout group was to identify the strategies, tools, data priorities, and key partnerships needed to conduct baseline biological characterizations of deep-sea benthic environments across the U.S. EEZ in the Pacific. Discussions focused primarily on priorities for the characterization of deep-water (>200-meter depths) benthic biological communities; however, the group also emphasized that such characterizations need to be linked to efforts to characterize the overlying water column. The group was tasked with identifying how to prioritize exploration and characterization efforts, including how to identify priority geographic areas and specific methodologies needed to execute exploration activities. The expert community that provided input included representatives from various stakeholder groups actively working on deep-sea issues across the Pacific, including researchers and managers from government agencies, academic institutions, nongovernmental institutions, and the private sector. This report provides a summary of specific guidance identified as key for the successful exploration of deep-sea benthic habitats within the U.S. EEZ in the Pacific, as well as in adjacent international waters.

DEEP-SEA EXPLORATION OF BENTHIC HABITATS TO INFORM RESOURCE MANAGEMENT, PROTECTION, AND STEWARDSHIP

Deep-sea benthic habitats are largely unknown across the Pacific, yet these habitats represent one of the largest reservoirs of biodiversity on Earth, which also provide a myriad of other ecosystems services, including fisheries, carbon sequestration, nutrient cycling, cultural services, and more. The Pacific includes many island communities which are highly dependent on their ocean resources, including deep-water resources; therefore, such habitat information is critical to guide sustainable development throughout the Pacific region. Developing regulations for conservation and resource extraction, including bottom-fisheries, energy production, and seabed mining, requires information on the benthic communities found in the deep-water areas. Since human activities are increasingly expanding further offshore and into deeper habitats, it is imperative to obtain basic information on these habitats prior to extractive activities, so that the most special places can be conserved, as well as to provide baseline information against which future changes can be measured. While marine sanctuaries, marine monuments, and other MPAs often already have conservation measures in place, these are still important exploration targets, as most of their deep waters remain largely unexplored and provide places to test new management measures.

Since deep-sea benthic habitats include many important, fascinating, and often undescribed species, they captivate not only scientists, but also resource managers, policy makers, educators, cultural practitioners, and the public. Exploration thus provides a gateway to engage the broader community, which is essential not only to share information across disciplines and knowledge bases, but also for the continued support of deep-sea explorations. This work will inevitably include passage through international waters, thereby providing an opportunity to engage with stakeholders from other countries and intergovernmental organizations to make a meaningful global contribution. Specifically, there are many global initiatives and policies that will be developed or continue to develop in the coming years, including the U.N. Decade of Ocean Science for Sustainable Development, the Convention of Biological Diversity Post 2020 Framework, the Biodiversity Beyond National Jurisdiction agreement, and the ISA's deep-sea mining code, among others. By working across the Pacific, a deep-sea exploration program can therefore not only inform U.S. management actions, but also those of other involved and engaged countries.

INFORMATION NEEDS

Given that the vast majority of deep-sea benthic habitats in the Pacific are still virtually unknown, exploration will continue to focus on some of the most basic questions, namely what is there (e.g., species and habitats). Despite the recent efforts by NOAA OER's *CAPSTONE* expeditions, the Pacific still represents an enormous reservoir of undescribed species. Basic information on what deep-sea species are found throughout this region is still needed, and currently constrained by the limited ability to collect physical samples that must then be analyzed by taxonomic experts. Yet, even this very basic information can inform resource management and protection; as the colloquialism says, "you cannot manage what you do not understand."

Exploration for biological characterization should address the information needs for resource management and protection, with science driving management decisions. However, it is not possible to survey every square meter of seafloor visually. Therefore, predictive models are important tools for identifying sites for exploration, as well as to extrapolate information onto areas that have not yet been explored. These models require high-quality data sets with good spatial coverage, in order to improve their predictive capacity. These data can include observations and environmental data gathered at exploration sites, which can then be extrapolated to similar seafloor features and habitat types in broader regions. MPAs can provide important study sites, as these often have existing data, particularly in shallower waters, that can guide scientific explorations. These areas can also improve our understanding of the sensitivity of particular environments, as well as allow for the development of proxies for identifying sensitive habitats in adjacent locations. Exploration provides the information needed to identify new places and resources to protect, as well as how to conserve, existing ones effectively.

In order to characterize deep-sea biological communities, several data variables are essential to capture, including information on species identities, sizes, conditions, abundances, and distributions. Oceanographic and seafloor environmental characterization go hand-in-glove with biological characterization. Priority environmental variables include temperature, salinity, dissolved oxygen, fluorescence, turbidity, currents (speed and direction), total alkalinity, pH, and carbonate chemistry. Sound is a data variable that is largely unexplored in the deep sea, and therefore represents another opportunity for future exploration. Additionally, characterization should include identifying the locations of sensitive and highly aggregated benthic communities, as well as defining habitat requirements, environmental thresholds, and geographic distribution patterns of these communities.

Understanding connectivity on multiple levels (e.g., genetic, population, community, trophic, regional, vertical) will play a major role in exploration and characterization efforts. This also includes the important reliance of benthic communities on the water column above. Surface production fuels most benthic environments, yet we have little understanding of the source, quality, and variability of this food source. All this information will help to validate and improve predictive models of deep-sea communities, which, given the high cost of field surveys, are essential to characterize deep-sea habitats.

Engaging the public through education and outreach activities (e.g., ship tours, teachers at sea, telepresence, live feeds, and new approaches) provides avenues for them to gain confidence in science, as well as value these ecosystems, which are necessary to ensure effective implementation of future management actions. Engaging the public is essential for establishing the relevance to U.S. taxpayers, who are ultimately paying for deep-sea exploration in the U.S. EEZ. Thus, these exploration efforts will need to address the information needs of resource management and society at large, as well as involve these stakeholders in the exploration activities that are conducted.

EXPLORATION REQUIRES MULTIPLE TECHNOLOGIES

Understanding variability is critical for characterizing benthic communities; this requires identifying scales of variability, establishing consistent sampling and data standards, and ensuring appropriate replicate sampling to allow the information gathered to be broadly applicable. Options will include characterizing one or a few areas of interest in detail (e.g., seamounts, canyons, hydrothermal vents, chemosynthetic communities, deep-sea coral and sponge communities), and then testing whether those patterns can be generalized at similar features across the larger region. Specific tools and platforms that should be applied to capture variability include the wealth of submergence vehicles (e.g., ROVs, AUVs, HOVs), deployable instruments (e.g., drop cameras, benthic landers, CTDs), as well as ship-based equipment (e.g., echosounders, ADCPs), all of which are essential for acquiring data at the necessary spatial and temporal scales. Additionally, certain assets are more suited for specific types of exploration activities or for exploring specific habitats. For example, HOVs are still better at exploring steep topographies and strong current environments than ROVs or AUVs, and HOVs can also be used with other submersible technologies to survey and sample large seafloor areas in a more efficient manner. Additionally, some emerging technologies are not yet developed enough to be used for stand-alone characterizations (e.g., eDNA), and will need to be incorporated progressively and combined with traditional approaches that have endured the test of time (e.g., morphological taxonomy and video surveys). All available technologies should be engaged to enable holistic exploration across all deep-sea benthic environments.

In order to characterize these environments and their associated biological communities, *in situ* sample collections will continue to be essential, including water and seafloor samples (e.g., rocks, sediment) to provide environmental context. Representative biological specimens will also be required to provide vouchers for new species descriptions, to verify video identifications, and to constrain eDNA applications. Because offshore research has been plagued by the "taxonomic impediment", where there are few taxonomists with the critical expertise or available time, there is a clear need for taxonomists to execute this effort. Funding for taxonomic work should therefore be prioritized to remove existing bottlenecks and ensure timely identification of specimens. In addition, it is important to support long-term archival collections to maintain the collected specimens. This is true for geological and cultural collections, as well as biological.

New technologies that are demonstrating great promise include those used for recording ocean sound through passive acoustics. Hydrophones deployed on submergence vehicles or deep-sea landers can capture the ambient vibration and noise, recording the baseline soundscape (i.e., diversity of frequencies) of the seafloor and near-seafloor environment. This baseline can be used as a monitoring tool to track changes associated with increased human activity. There are also many opportunities to use active acoustics to explore and map life in the ocean and contribute to our understanding of biomass distribution, migrations, and more. Successful applications of soundscape technology and data processing will require engaging a diversity of experts from multiple disciplines, both within and outside the federal government, including international partners.

Advanced technologies, including AI and ML, will help tackle the enormous data sets and processing required to enable real-time decisions at sea and facilitate timely synthesis of large data sets post-expedition. Public access to streaming live video feeds also represents a powerful tool, not only to get more people interested in science, but also to engage the public in analyzing data. Along with the scientific experts, the public can help by providing detailed annotations and narratives of exploration activities. These activities are important for providing context and information transfer, not only to the public, but also to the scientists engaging from shore.

Finally, including other sectors that are not traditionally part of deep-sea explorations, such as artists, teachers, and the entertainment industry, will improve conveying the value of deep-sea exploration. The public can also provide input on best practices throughout the Pacific region, including culturally appropriate protocols for collecting and disseminating information.

PRIORITIZING SPECIFIC PLACES TO EXPLORE AND CHARACTERIZE

Given that the Pacific region is a vast area that requires basic exploration information, the biology characterization breakout group suggests avenues to help prioritize geographic areas and seafloor features. These suggestions include locating key areas that may be imminently impacted by certain human activities (including seabed mining and bottom fisheries), locations that may be vulnerable to disturbance as a result of underlying hazards (e.g., seafloor instability, landslide-prone areas), and regions that might be particularly susceptible to climate change impacts (such as decreased near-bottom oxygen concentrations, increased temperatures, shoaling aragonite saturation horizons, and/or methane release). Characterizing biological and ecological connections between the shelf and deep-sea areas will also be important, given that shelf areas are more accessible to people, particularly in the Pacific Islands, and therefore more susceptible to overexploitation. There are clear connections to be made among geology, geochemistry, benthic biology, and habitat characterization, which should be integrated when identifying interesting exploration features (e.g., using high resolution multibeam bathymetry to locate seamounts and seeps) and/or unique environments (e.g., using seafloor temperature anomalies to identify hydrothermal vents). For example, data derived from satellites, including surface productivity estimates, can help select productivity hotspots and underlying seafloor exploration targets.

Using a combination of tools and multidisciplinary expertise, including Traditional Knowledge and other knowledge bases outside the natural sciences, will help guide prioritization and site selection, including improving predictive models identifying where vulnerable communities are likely to occur. Homing in on specific priorities can also benefit from reframing exploration with specific scientific questions. Facilitating multidisciplinary exploration across broad areas will inspire collaboration and engagement by the broader community of experts.

Active margins in the Pacific United States, including the Aleutian Islands and the Cascadia margin, provide significant opportunities for key biological characterization activities, including chemosynthetic environments with associated hard-bottom coral and sponge communities, but also cross-cutting areas to explore and focus on human safety (seafloor hazards) and carbon cycling. These areas represent logical locations that will benefit from cross-agency federal partnerships; they will also facilitate broader scientific and public engagement, given the human interest and proximity to populated areas.

MPAs, marine sanctuaries, and marine monuments cover vast areas across the Pacific, yet remain largely unexplored. Knowing what biological resources are available within these areas, as well as how they are connected, is key to developing informed management directives. These areas also represent places that can be revisited and monitored over time, which should help address the variability question identified above.

The CCZ and the PCZ are areas of interest for future seabed mining. Many of these areas still lack baseline biological and habitat data, including those considered for mining, and adjacent areas where minerals are not a priority, but where there may be transboundary impacts and/or connectivity between communities. Many questions remain regarding potential impacts from deep-sea mining activities, from the reach and impact of water-column plumes to the direct impacts of substrate removal. CCZ seamounts are not planned to be mined, but are adjacent to planned mining areas. Therefore, these areas could be interesting exploration targets to address some data needs of mining operations, while also serving as sentinel sites where natural patterns can be studied in the absence of direct mining stressors.

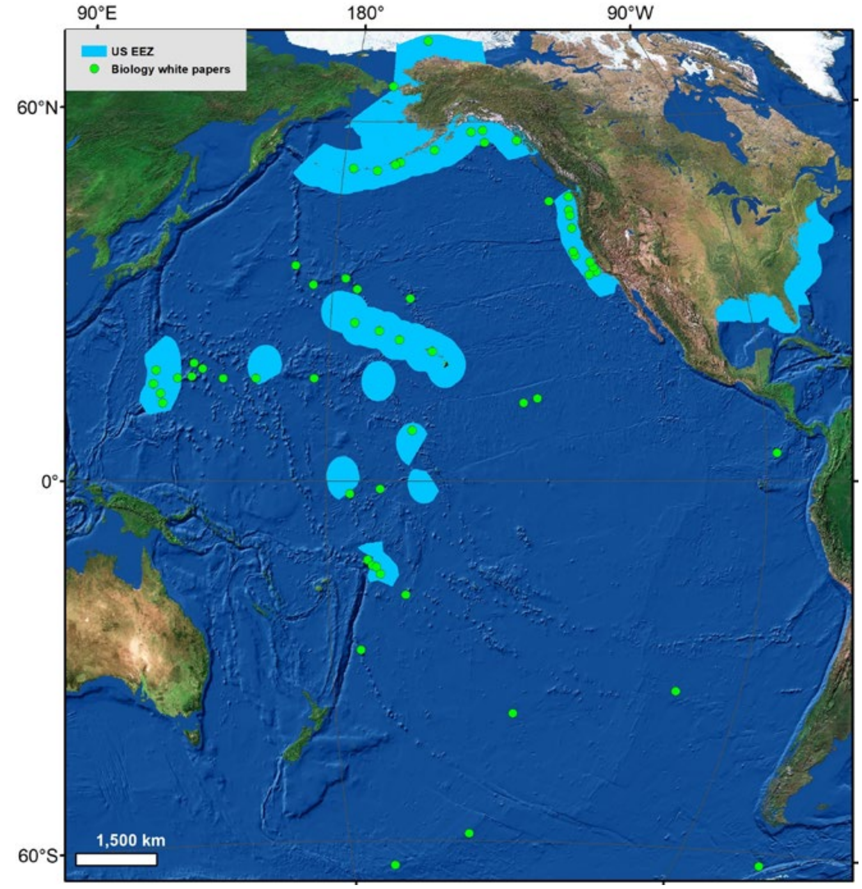


FIGURE 2.1: *Map showing the locations of priority areas for benthic biological characterization that were submitted in white papers ahead of this workshop. White papers with a benthic biological focus spanned across the Pacific, with concentrated clusters focusing on Central Pacific seamounts, Pacific marine monuments and sanctuaries, and the Aleutian and Cascadia margins.*

PARTNERSHIPS – EXPLORATION REQUIRES AN “ALL HANDS ON DECK” APPROACH

Successful efforts to explore seafloor biological communities within the Pacific region, including in the United States and adjacent international areas, hinge on engaging diverse groups of stakeholders within government, academia, philanthropy, and the private sector. Given the vast area that needs to be characterized and the diversity of systems within it, no one agency or institution can do this alone; it will “take a village” to execute this effort.

Importantly, in this regard, this workshop is well timed, given that implementing the specific outcomes will coincide with the initiation of the U.N. Decade of Ocean Science for Sustainable Development, with shared objectives of investigating our underexplored ocean and promoting a sustainable Blue Economy. Excellent and timely opportunities exist, consequently, for international as well as national collaborations in the Pacific Ocean. For biological exploration, SCOR Working Group 159 has just proposed a new decade-long program for deep-sea biology exploration, inspired by the 10-year anniversary of the conclusion of the Census of Marine Life. The proposed program envisages a global-scale network drawing upon multi-national resources organized at a regional ocean basin-scale. In that context, a new Pacific Ocean biological exploration initiative would be well placed to become a leading contributor and coordinator of activities pursuant to such an ambitious, decade-long, international initiative.

Given the logistical complexity of working in the Pacific Ocean, it is necessary to engage the public early to seek input on critical uncertainties, gather local information to help with logistical planning (e.g., weather patterns, required permits), and identify local resources that are available (e.g., people with specific technical skills). In order to ensure that partnerships with local communities are equitable, both benefiting from and supporting these efforts, it is important to engage these communities early and often, so that they are part of the decision-making process. One successful example involved soliciting native Hawaiian names for species discovered during recent NOAA OER missions within the Papahānaumokuākea Marine National Monument. This example illustrates how the investment of local wisdom can lead to positive outcomes, including the use of native languages for such names that will live on in perpetuity. Reaching out to the stakeholders and seeking their input throughout the planning, execution, and synthesis phases of exploration will ensure that a diversity of voices are included, and thus will be critical to success.

Examples of ways to engage local communities, scientists, and other stakeholders include holding workshops throughout the period of exploration. These venues serve as a mechanism to solicit input prior to campaign planning. Such workshops allow local scientists from broad disciplines to develop and participate in exploration plans. Workshops held following expeditions can also help disseminate important information to relevant stakeholders, as well as allow for adaptive planning for subsequent expeditions. Such workshops can also function as training avenues and thereby ensure that important information is transferred to the next generation of explorers. This is particularly important for taxonomic expertise, which is scarce for many deep-sea taxa.

Funding opportunities can provide other avenues to engage stakeholders, such as by including funding for training workshops, opportunities to test new technology, and developing outreach and engagement tools for information transfer to the public. Such funding provides a venue and a means both to engage the community of experts and encourage the broader scientific community to identify and investigate specific questions or areas of interest. Given the elevated costs of deep-sea exploration, focusing science efforts on those that have direct implications for resource management and policy is also critical. Finally, funding should also support the development of engagement tools, such as virtual reality applications to explore the deep sea, which could be made available in aquariums and museums, and apps that integrate livestreams and other information derived from telepresence-enabled expeditions.

Partners that were identified as particularly important to plan, execute, and report on deep-sea exploration in the Pacific include those from government, exploration organizations, academia, philanthropy, local educational organizations, nongovernmental organizations, intergovernmental organizations, industry, science networks, peer learning networks, and educational entertainment avenues (Figure 2.2). This is not meant to be a comprehensive list of all relevant entities that can make meaningful contributions, but rather serve as a starting point for identifying potential partners.

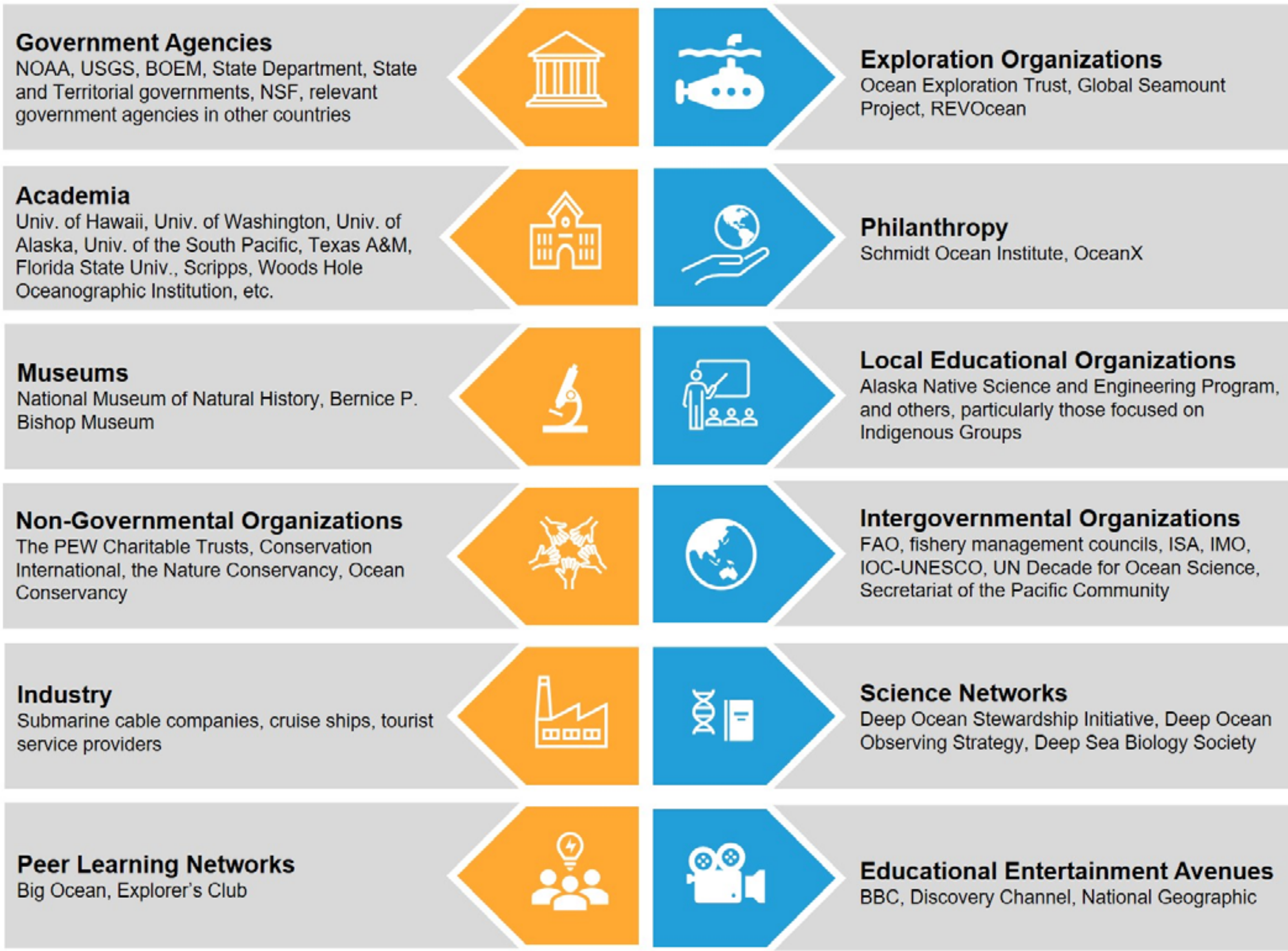


FIGURE 2.2: *Diagram showing the wide variety of partners that will be required in an "all hands on deck" approach to successfully execute a deep-sea exploration program in the Pacific.*

SECTION 3:
MARINE RESOURCES BREAKOUT REPORT

INTRODUCTION

While marine resources are often broadly interpreted as chemical, physical, geological, and biological (including genetic) materials that have economic value, the focus of this group was confined largely to geological resources, including energy (e.g., oil, gas, methane hydrates) and minerals (e.g., polymetallic nodules, cobalt-rich ferromanganese crusts, polymetallic sulfide deposits). The inclusion of offshore wind is a primary exception.

The traditional definition of a geological resource requires that it possess an economic potential. We realize that many people use the term "resource" more loosely, including those that may not be economical and/or technically feasible to extract. We use the more traditional, restrictive definition in this report.

While the broader intent of the workshop is to interface resource and habitat-related exploration priorities, the marine resources breakout discussion focused only on resource identification and characterization as applicable to exploration. Primary motivations for this approach are to: 1) identify how resources are driving the economic and national security discussions, planning, and decisions under the context of building a sustainable Blue Economy; 2) bring resource-specific exploration efforts to the forefront, as this topic has only rarely been discussed in past exploration workshops; and 3) provide information to enhance the value of exploration efforts for resource understanding in order to support implementation of U.S. national strategies.

Based on these inputs, the following commonalities emerge with respect to energy and mineral exploration priorities:

1. Given the enormous area of the Pacific Ocean and the lack of relevant energy and mineral data, focusing resource and habitat exploration in areas of highest expected economic potential should be the most immediate priority.
2. The regions for marine minerals are expansive within the U.S. Pacific EEZ and adjacent international waters, and include coarsely mapped regions for polymetallic nodules, polymetallic sulfides, and cobalt-rich ferromanganese crusts. The extant USGS offshore mineral maps should be verified, with purposeful exploration expeditions to identify and characterize those resources.
3. There is at present more information and data available for energy resources, as compared to mineral resources, in the U.S. Pacific EEZ.
4. Responsible extraction of any nonrenewable critical minerals and/or energy requires robust mapping and site characterization to inform resource-value and ecosystem management priorities, including habitat characterization. In addition to the seafloor and subsurface, studies of the water column must be included as part of the overall habitat characterization effort.
5. Exploration must be supplemented with systematic sampling and include activities such as coring, high-resolution imaging, and precision location of samples to characterize accurately the extent of the resource(s) and the ecosystems within which they reside. Establishment of a standard set of methods and data-sharing principles for exploration and characterization work will advance a systematic understanding of the resources.
6. Given the expanse of the region and complexities associated with extractive activities, public-private partnerships to identify specific resources best suited for extraction are needed. However, the lack of a legal framework for private investment in exploration and characterization work for such resources remains an impediment.
7. Mineral resource exploration and characterization requires the support of an informed and engaged public, including local Indigenous groups. Exploration can be a vehicle for engaging the public in understanding and valuing the deep sea and its resources.

EXPLORATION TO INFORM UNDERSTANDING OF U.S. ENERGY AND MINERAL RESOURCES

The economic and national security implications of energy and mineral resources is a bipartisan issue. Congress and the Administration – including NOAA – acknowledge the very limited understanding of resources within U.S. waters and state that addressing the information gaps across the U.S. EEZ is a high priority. Responsible management requires the identification and characterization of these resources and associated habitat(s), ecosystems, and other resources (e.g., biological, microbial, cultural, etc.).

Traditional NOAA OER-funded energy and mineral resource-related efforts (as well as the white paper submissions for this workshop) largely focus on habitat characterization. Resource management agencies, like NOAA and BOEM, then use the habitat-related information to inform environmental analyses, such as those required by NEPA and Section 106 of the NHPA. A greater focus by the ocean exploration community on providing resource-relevant information would help scientists and managers to answer fundamental questions regarding mineral and energy resources; where is the resource, what is its composition, and what is its valuation per legislative mandates (e.g., Outer Continental Shelf Lands Act)?

Providing meaningful resource-specific information requires coordination among multiple agencies (science, technology, and management) and science/research organizations for site surveys, sampling, and data-sharing protocols and procedures. Such coordination would ensure the broadest utility of exploration efforts as implementation of a national ocean exploration strategy is developed and executed. Initial baseline information that would typically be collected in early exploration campaigns also has value to industry groups that may use or extract these resources, and can inform more responsible methods and/or facilitate partnerships that could benefit longer term resource management.

Useful models do exist for federal agency collaboration, such as a planned 2021 tri-agency (NOAA OER, USGS, and BOEM) expedition investigating polymetallic sulfides in offshore California and Oregon. This USGS-led expedition is explicitly designed to increase information to support both resource and habitat characterization. The project is likely the most resource-relevant mineral- or energy-related exploration effort that has ever involved NOAA OER, and is a good example of how exploration can better inform our understanding of marine resources.

This breakout report further synthesizes and distills community input into information items that should inform early stages of exploration planning for mineral resources. Community input used for this report is derived from a variety of sources, including white papers submitted for this workshop, white papers from OET's 2014 *Telepresence-Enabled Exploration of the Eastern Pacific Ocean* workshop, and the marine resources-focused group discussion for this workshop, with representation from industry, the federal government, academia, nonprofits, and private oceanographic research organizations.

INFORMATION NEEDS: RELEVANCE OF EXPLORATION TO MARINE RESOURCE MANAGEMENT

Finding, assessing, and managing marine resources requires specialized tools and techniques, which span the spectrum from low-resolution site surveys through highly advanced studies of specific areas for the purpose of evaluating the composition, distribution, and quality of a particular resource.

FIGURE 3.1: *Simplified process depiction of the progression from exploration to a detailed energy or mineral resource assessment. The categories are intended to differentiate between traditional NOAA OER-funded exploration and the information required by industry and partners to conduct energy and mineral resource characterizations and resource assessments. This is not intended as a recommendation that NOAA OER conduct resource characterization and/or resource assessments; rather, that NOAA OER considers how it can design and fund exploration efforts that can better inform subsequent marine resources work.*

“Exploration” is generally defined as a preliminary assessment of an area’s physical, chemical, and biological characteristics. This “baseline characterization” includes a combination of ship and submersible operations. The work often includes collecting a limited number of biological and physical samples. NOAA OER-funded exploration is not usually focused on energy and mineral resources, but can collect information that will be valuable to future resource-related decisions. Given U.S. environmental regulations, information collected through exploration relevant to resource management may be about the potential resource itself or the surrounding environment in which the resource is located. Prior ocean exploration efforts were not intended to characterize or assess the resource itself, but such efforts could be expanded in the future to characterize such resources in tandem with habitat characterization.

Energy and mineral “resource characterization” is conducting laboratory and data analysis using samples collected systematically, for the express purpose of identifying the extent and type of a resource. This provides general estimates of the resource potential, including quality and quantity. Resource characterization studies are largely funded and conducted by industry, as well as a limited number of federal agencies, including USGS and BOEM. While NOAA OER does not conduct energy or mineral resource characterization, activities could be designed (e.g., targeted sampling of specific resources) in a way to provide meaningful information to enhance these follow-on activities.

Energy and mineral “resource assessment” involves creating a detailed analysis focused on the valuation of a resource, which is more rigorous than a characterization. These are primarily conducted by industry with a proprietary interest, but a subset of data may have to be shared with a relevant federal agency with stewardship responsibilities. While some ocean exploration efforts may provide data that are ultimately used with this effort, conducting a resource assessment is currently beyond the scope of NOAA OER interests.

CRITICAL MARINE MINERALS

Critical minerals are often discussed collectively and not individually. Providing meaningful input on priorities requires considering each major group of offshore mineral deposits and the regional differences in their composition (e.g., polymetallic nodules, cobalt-rich ferromanganese crusts, polymetallic sulfide deposits) separately. Only very limited information is available about any of these major resource groups within the U.S. EEZ. Of the existing information, much is hypothetical and not sufficiently tested, validated, or sampled. For instance, extant USGS resource maps have been generated with the best available data, but these maps are often interpreted only as a demonstration of a resource’s existence and distribution. These are hypothesis-driven geographic estimates that need to be tested and validated with sampling campaigns. Exploration efforts are one tool that can contribute to the testing, validation, and improvement of these maps.

Using exploration to test such maps systematically will encourage the scientific community, and the public, to rethink where we explore. Often, ocean exploration is focused on “hot spots” of biological activity fueled by unique geography, like seamounts, or relatively abundant chemical energy resources, like hydrothermal vents and cold seeps, with more limited focus on less dynamic abyssal plains and inactive vent deposits. Though these unexplored areas may have less biological activity per unit area, they still support unique ecosystems that need to be explored and characterized. Moreover, these may be where critical mineral deposits with the greatest economic potential are found.

No single federal agency currently has the resources to conduct complete or nearly complete marine mineral resource exploration, characterization, or assessment efforts. As a result, we have a gap in the process from exploration to characterization that is not being addressed. Exploration can provide critical information to help understand these resources. However, exploration alone is not enough. Conducting a robust characterization and assessment that adequately documents resources within the U.S. EEZ requires substantial follow-up efforts well beyond the scope of any standard ocean exploration effort. Unless these follow-on efforts are also adequately funded and implemented, we will continue to have only cursory knowledge of marine resources within the U.S. EEZ.

CRITICAL MINERALS – DATA AVAILABILITY, COLLECTION, SHARING, AND BARRIERS

Data are limited on Pacific marine mineral resources, given the expanse of the basin and the excessive depths at which these resources are found. Efforts require appropriate equipment and funding that has traditionally only supported limited mission objectives. A few of the resources and limitations that were discussed by this breakout group include the following (see accompanying Table 3.1):

- Cobalt-rich ferromanganese crusts occur on rock surfaces at depths of 400-7,000 meters, typically associated with older seamounts. Crust thickness is one of the key pieces of information needed to adequately assess their economic value and gauge potential commercial interest. These crusts are a challenge to measure *in situ*, typically requiring sample collection. While NOAA OER and OET have collected numerous crust samples using NOAA Ship *Okeanos Explorer* and E/V *Nautilus*, and have made those materials publicly available through NSF sample repositories, such activities are only an initial step towards what is needed for a systematic effort to characterize these resources. For example, the collected crusts are often on pieces of rubble that are easily accessible, and it is unclear how representative these may be of the bulk crust on any seamount.
- Polymetallic nodules occur on sediment-covered abyssal plains characterized by low sediment flux at depths of 3,500-6,500 meters. They mainly occur on the seafloor surface. Knowledge of nodule extent and content within the U.S. EEZ is poor, primarily due to few samples.
- Polymetallic sulfides occur along 89,000 kilometers of ocean plate boundaries, spreading centers, arcs, and back-arcs. The dimensions of these deposits and extent of inactive sulfides – where the primary resource interest lies – are poorly known. Adequately characterizing this resource requires subsurface work not typically funded or executed through NOAA OER activities.

Type	Resource Information Needs	Suggested Tools	High Priority Regions Based on Economic Potential	Additional Recommended Areas
Polymetallic Nodules	Presence/absence, extent, abundance, composition, surrounding environment and fauna	Box core, free fall grab, video, AUV, ROV	Jarvis Island, Wake Atoll, Kingman Reef and Palmyra Atoll, Johnston Atoll, Howland Island, Baker Island, American Samoa, Commonwealth of the Northern Mariana Islands	CCZ (outside U.S. EEZ), Hawaiian Islands
Ferromanganese Crusts	Presence/absence, thickness, extent, composition, surrounding environment and fauna	ROV, AUV, video, dredge	Magellan seamounts east of the Mariana arc, northern Kingman and Palmyra seamounts	Lili'uokalani Ridge and seamounts, seamounts offshore California, Northwestern Hawaiian Islands, Johnston Atoll, Wake Island
Seafloor Massive Sulfides	Surface and below seafloor extent, composition, surrounding environment and fauna	ROV, AUV, video, coring, drilling, electromagnetics	Mariana arc and back-arc basin, Gorda Ridge	Aleutian arc, American Samoa, Pacific-Antarctic Rise (outside U.S. EEZ)

TABLE 3.1: *Breakdown of priority information needs, suggested tools, and geographic regions by major deep-ocean mineral type. Tools are focused on what is needed for characterization of the resource. Resource geographic priorities are recommended based on USGS maps and industry recommendations of locations with the highest economic potential within the U.S. EEZ. Additional areas for exploration are listed separately and include areas in international waters and areas with lower or no expected economic potential. Though not included on this table, phosphorite deposits in the Southern California Bight were a priority for exploration noted in white paper submissions.*

Advancing mineral resource exploration and characterization will require consolidating and compiling baseline environmental information and providing such data in the public domain. This is a challenge, and improvements need to be made to assimilate all relevant information that can help agencies meet stewardship requirements, and help to align and coordinate future collaborative research efforts, whether by government agencies, private sector, nongovernment organizations, and/or combinations thereof. Such data assimilation and management require funding and infrastructure not currently available.

Existing regulations are also a barrier. Currently, industry efforts to identify and extract critical marine minerals are largely focused in international waters. Industry does not substantially invest in U.S. waters. This is largely because no clear permitting frameworks exist for securing exclusive extraction rights to an exploration area and for commercializing seafloor mineral resources. Without these frameworks, industry is likely to remain reluctant to invest substantially in U.S. EEZ exploration activities and partnerships in the Pacific. From a national perspective, if the regulatory issues can be resolved, industry might increase their investment in characterizing these minerals in the U.S. EEZ and provide baseline information regarding associated ecosystems. Resolving permitting and leasing challenges provides opportunities to accelerate and facilitate data collection and sharing.

ENERGY RESOURCES

NOAA OER's longstanding work to support domestic energy information needs has traditionally focused on characterizing habitats (e.g., deep-water coral and seep communities) in the vicinity of prospective development, in partnership with BOEM and USGS. However, NOAA OER has recently joined with inter- and intra-agency partners to help inform potential offshore wind development in the Pacific.

Off the U.S. West Coast, and particularly in the vicinity of the Cascadia margin (U.S. Pacific Northwest), there is also overlap in the geographic areas of interest related to offshore wind development, recently discovered water-column anomalies indicative of seafloor gas hydrates, as well as high-priority marine geohazard work. This confluence of interests and the similarity of tools and technologies needed for site surveys provide the foundation for an evolution in the traditional interagency habitat characterization model, as discussed in the partnerships section below.

Oil and gas activities in the U.S. Pacific EEZ are currently limited to southern California and Cook Inlet in Alaska. (Any potential activity off the North Slope of Alaska [i.e., the U.S. Arctic] was beyond the geographic scope of this discussion.) There are 23 offshore platforms and 32 active leases in federal waters off southern California. These are generally located between Long Beach and Santa Barbara. The current 2017-2022 National Outer Continental Shelf Leasing Program includes new leasing in Cook Inlet, but does not include any new leasing off the West Coast. There are substantial hydrocarbon resources in Alaska, as well as central and southern California, that are well beyond the footprint of current development. Decommissioning planning is actively underway for multiple platforms off of southern California. Currently, there is no new oil and gas development planned for the West Coast.

Offshore wind development, specifically floating wind, off the U.S. West Coast and Hawai'i is in the federal planning process (Table 3.2). Interagency ocean exploration-related activities to support habitat characterization of areas in the vicinity of potential wind farm development are already underway, but more can and should be done. At present, there are several areas under consideration for potential future leasing, including two locations off O'ahu, Hawai'i; two off Morro Bay in central California; and one off the coast of Eureka in northern California. BOEM and the state of Oregon have recently restarted discussions to determine the level of interest in potential wind farm development offshore southern Oregon. It is currently unknown which – if any – of these areas will move to the leasing and ultimately development stages. Interagency ocean exploration-related activities to support habitat characterization of areas in the vicinity of potential wind farm development are already underway, but more will need to be done.

There is limited ongoing work in the Pacific to pursue gas hydrates as an energy source. Similar to what was observed on the Atlantic margin, recent multibeam bathymetric mapping off the West Coast has identified hundreds of water-column anomalies. These anomalies have been very useful in locating methane seeps at the seafloor and sensitive biological communities warranting further exploration. While this is very important preliminary information, the methods used by resource management agencies to characterize hydrate resources (e.g., boreholes, seismic) are well outside of the scope of previously funded NOAA OER efforts. Consequently, hydrate resource characterization was not explicitly addressed during this breakout discussion.

Energy Type	Ocean Exploration-Relevant Resource Information Needs	Suggested Tools for Habitat Work	Priority Regions for Habitat Information Included in White Paper Submissions
Oil and Gas	n/a - Requires deep subsurface work (e.g., seismic)	Multibeam, ROV, AUV, CHIRP sonar	Southern and Central California; Alaska: Bering Strait, Gulf of Alaska, Queen Charlotte Fault
Offshore Wind	n/a - Resource is above sea level	Multibeam, ROV, AUV, CHIRP sonar, piston coring	Southern Oregon to Northern California: Coos Bay to Mendocino Ridge; Central California: Monterey Bay to Point Conception; Hawaiʻi: Offshore Oʻahu
Gas Hydrates	n/a - Typically requires deep subsurface work (e.g., seismic, borehole)	Multibeam, ROV, AUV, CHIRP sonar	U.S. West Coast (incl. Cascadia margin); Alaska: Bering Strait, Aleutian Islands, Gulf of Alaska, Queen Charlotte Fault

TABLE 3.2: *Breakdown of priority information needs, suggested tools, and geographic regions by major energy type. Characterization of actual energy resources is not considered particularly applicable to the discussion of ocean exploration. However, exploration of deep-water habitat in the vicinity of oil/gas resources or where wind development is considered is certainly applicable. Water column mapping does provide preliminary information that can help to inform location of gas hydrates on the seafloor. Tools are focused on what is needed for habitat characterization in the vicinity of the resource. Priority geographic areas are listed for habitat characterization.*

PARTNERSHIPS

Mapping and characterizing marine mineral resources in the U.S. Pacific EEZ and beyond will require public-private partnerships. The expanse of the region itself cannot be mapped or characterized by a single entity. The tri-agency efforts described earlier to be conducted off the U.S. West Coast in 2021 provide one successful project-specific model that includes substantial industry and academic involvement. In just the last few years, those three agencies and MBARI have been developing a more fluid and nimbler model to enhance collaboration, specifically off the U.S. West Coast. This project, called *EXPRESS*, is an adaptive multiagency public-private partnership between NOAA, USGS, BOEM, MBARI, and University of Southern California Sea Grant that should be considered as one potential model for the implementation of the NOMEC Strategy. Both traditional and adaptive models should be considered as part of any robust Pacific Ocean exploration effort. Identifying more effective ways to incorporate various sustainable Blue Economy sectors – technology, philanthropic, and energy – will provide additional potential.

Nonetheless, public-private and interagency partnerships are not simple. Effective partnerships require time and effort; partners must be willing to convene around one or a few common goals and potentially sacrifice or set aside other goals. Developing effective win-win partnerships requires no fewer than five things: Trust, Communication, Homework, Accepting Reality, and Attitude (Kendall, 2019).

Communication, as a key partnership element, is critical. Regarding communication, the United States currently lacks formal communication venues for partners to come together, instead having to rely on cross-initiative and cross-discipline forums, such as this workshop, that are facilitated by neutral, science-based, and community-focused convening groups to bring together these different audiences.

Mineral characterization that informs extraction can be a sensitive topic which often limits the types of partnerships that can or should be formed. While industry can be a controversial partner, it can also help form bridges between groups. In meeting the goals of a U.S. Pacific mapping strategy, and eventually those set forth in a national ocean exploration strategy, private industry must have a seat at the table. The sustainability, resources, and tools that can be brought from industry are significant.

Specific to mapping and characterizing marine minerals, private industry and philanthropic organizations can be an accelerator for national efforts. Their expertise, knowledge, and resources can help achieve the first priority identified by the marine resources breakout group – that marine mineral baselines must be established in the U.S. Pacific EEZ. Exploration – in all forms and across all types of partners – can help to meet this priority goal.

Achieving the right partnerships will enable NOAA OER to connect priorities to potential partner organizations while scaling the efforts needed to map and characterize marine minerals in the Pacific.

Data collected from private industry can help to supplement NOAA OER planning efforts by minimizing the amount of survey efforts in shallower sections beyond the shelf-edge of the U.S. EEZ. Cooperative efforts between private industry and government agencies will not only increase seafloor data collection, but also help to inform responsible development. For example, early interagency-funded projects executed by industry and academia in the Gulf of Mexico have provided information that ultimately led to expansion of protective buffer zones around hard-bottom habitats. Survey work by industry has also resulted in the discovery of shipwrecks and other items of historical and national significance there. The tools, technologies, and techniques used by industry are just as applicable to characterizing habitat in the vicinity of offshore wind development.

A number of interagency committees related to mapping, exploration, and critical minerals provide important venues to keep others aware of new and emerging resource-related interests and projects. While these meetings cannot replace the importance of direct interpersonal communication with individual scientists and managers, they can be an effective tool for broadly sharing high level information across multiple agencies.

The general public and local Indigenous groups must also be viewed as an important partner in these efforts. In particular, the general public in island regions that host mineral resources needs to be actively engaged in discussions, baseline characterization, and data sharing in a manner that compliments their existing understanding of the resources and habitats of their regions. This also allows scientists and managers to understand the importance of those resources to local communities through the lens of Traditional Knowledge. The Department of Interior Office of Insular Affairs could aid NOAA OER in building these relationships, and the communication assets of NOAA OER, such as live-streaming ROV dives, can be a great enabler of this effort.

REFERENCES

Kendall, J. (2019, December 7). Partnerships & Strategic Priorities: Reflections from Ocean Exploration. *LinkedIn*. https://www.linkedin.com/pulse/partnerships-strategic-priorities-reflections-from-ocean-kendall/

SECTION 4:
WATER COLUMN CHARACTERIZATION BREAKOUT REPORT

DATA GAPS

Key Question: What characteristics/attributes are not commonly measured or observed by the ocean exploration enterprise?

The oceanic water column is recognized as comprising most of Earth's biosphere (Ramirez-Llodra et al., 2010; Ingels et al., 2016). Despite this, the deep pelagic realm has not received the efforts needed to understand or characterize it (Figure 4.1). Since the 2017 *From Surface to Seafloor* workshop (Netburn, 2018), which outlined a framework for water column characterization, little progress has been made. A potential national ocean exploration program should promote expeditions focused on the water column. Without such dedicated efforts, water-column exploration is treated as an "add on," using equipment designed for other purposes. In the event of inevitable scheduling problems due to weather or equipment issues, water-column investigations are typically the first to be cancelled.

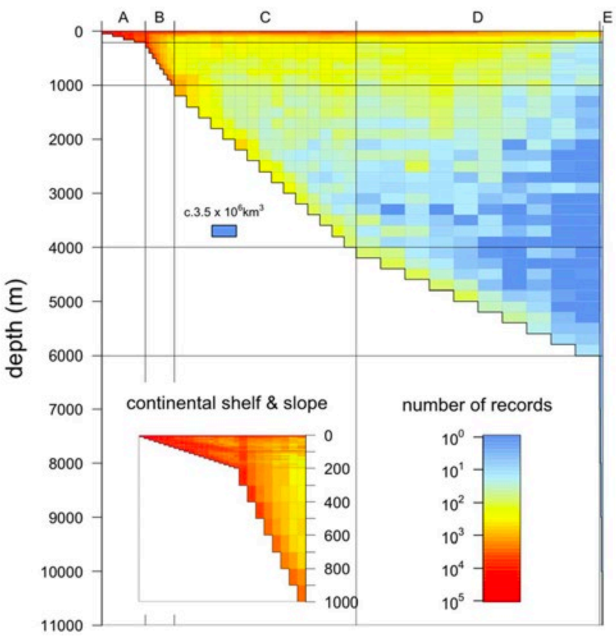
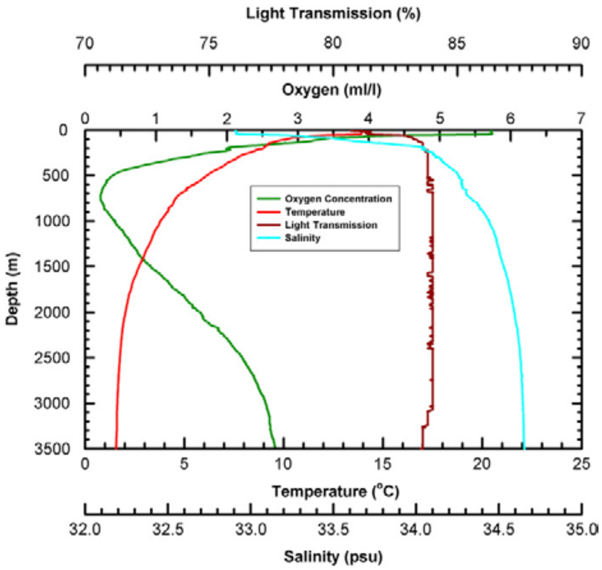
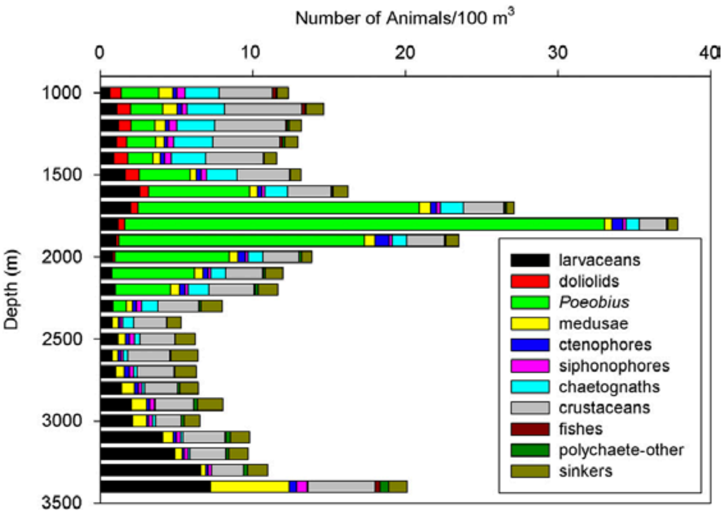


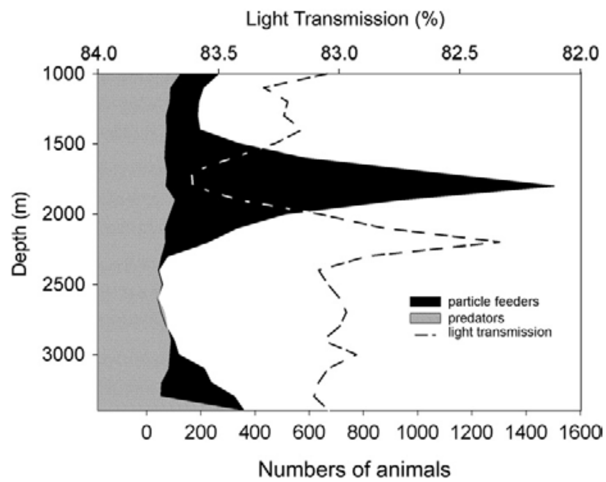
FIGURE 4.1: *Global distribution of marine biodiversity records in the Ocean Biogeographic Information System showing the lack of water-column data (Webb et al., 2010.)*

To characterize the water column, information requirements are broad: biological, physical, and chemical characteristics need to be measured (Figure 4.2). Basic characteristics, such as vertical profiles of water temperature, salinity, and dissolved oxygen, are often collected on ascent or descent during ROV missions. However, the four-dimensional nature of the water column necessitates a more robust and standardized approach.

FIGURE 4.2: *One of the few places globally where the deep water column has been well characterized is Monterey Canyon (offshore California). These graphics, from Robison et al. (2010), show the vertical distribution of bathypelagic animal groups and the transmission of light at depths of 1,000-3,500 meters, based on data accumulated from 15 oblique ROV transects, as well as a typical profile of physical parameters (temperature, salinity, and dissolved oxygen). Note the oxygen-minimum layer in the mesopelagic zone (200-1,000 meters).*







There is a need for specialized sensors. For example, pH is an important baseline environmental indicator in a changing ocean. Other specialized sensors (e.g., measuring dissolved methane, pollutants, microbes, or turbidity) might be necessary. Ocean currents, including at small scales (e.g., turbulent mixing), are often not characterized by ocean exploration platforms, but are critical to understanding both natural and anthropogenic processes, such as pathways for particulate and dissolved materials, from gametes to pollutants. Such information can help assess environmental risk from human activities, including deep-sea mining or oil and gas extraction, while aiding our understanding of ecosystem connectivity.

Biological characteristics of the water column are difficult to measure and observe. However, accurate characterization of the biological properties is foundational to understanding baseline ecosystem patterns, as well as human impacts. Measuring the biodiversity of the water column, from microbes to cetaceans (i.e., a census of marine life focused on the midwater), is a challenge requiring dedicated expeditions using multiple appropriate techniques and strategies. Whereas midwater eDNA and metagenomic analyses show promise as emerging technologies to improve efficiency of biodiversity characterization, reliably identified archival specimens of organisms must also be collected to build an operationally useful reference genetic database. Proof of concept for midwater eDNA requires validation with these sampling and associated genetic techniques.

STRATEGIES, METHODS, AND TOOLS

Key Questions: How should a potential national ocean exploration program measure physical oceanography and water-quality properties to characterize water-column ecosystems? How can we characterize and observe pelagic organisms and their activities? Should observations and collecting be standardized?

There is such a dearth of information on the water column globally that the water column breakout participants do not think a systematic characterization is possible initially. Rather, there is still much to be learned to refine strategies and techniques that may eventually become standard.

Many tools and strategies exist for midwater characterization, but few have been applied to NOAA OER expeditions. A key takeaway is that no one tool is enough. Rather, a robust characterization of the water column requires the application of complementary tools and techniques. The broad spectrum of data required is part of the reason why a single platform or tool is insufficient. Each tool "sees" only a part of the total oceanographic/ecological picture; instead, multimode sampling and sensing, when utilized concurrently, reveals the selectivity and limitations of single modes. These tools should be applied to maximize efficiency and integration, as the task of exploring the water column is immense.

Technologies traditionally used for ocean exploration are insufficient for adequate water column characterization. For example, ROVs introduce bright lights and loud noise, which are known both to attract and repel certain active biota. Therefore, specialized cameras and light systems should be developed, tested, and utilized for midwater imaging. "Wire-walking" technologies, taking advantage of an ROV cable, could continuously profile the midwater while the ROV is operating deeper, and provide short-term time-series data sets. Autonomous systems provide freedom to explore in space and over time. This four-dimensional freedom, utilizing autonomous vehicles with specialized midwater sensors, also frees the ship to gather other data.

Autonomous platforms (e.g., floats, gliders, vehicles) are force-multipliers that should be used to gather data in the water column in areas chosen for higher-density data collections. A nested approach for using later generation technologies based on analysis of preexisting or low-cost (time/effort) technologies can increase use-efficiency and impact. Human-intensive methods (e.g., nets and ROVs) are necessary for targeted exploration, cross-comparison of techniques, and when the information from these approaches cannot be replaced (e.g., developing baselines, which are necessarily quantitative).

Important technological hurdles must be overcome to develop a multifaceted expedition strategy for the water column. Data storage and/or transfer capabilities and power capacity on autonomous platforms should be improved to allow increased mission length and sophistication of sensors. Valuable data, such as water-column acoustic backscatter, are often not collected by autonomous vehicles due to storage capacity issues. Similarly, multi-frequency and broadband acoustic sensors have large power requirements, thus limiting the range/efficiency of autonomous systems.

Data extraction via AI and ML is critical to improve rapid decision making and allow researchers to synthesize the large volumes of data needed to characterize large volumes of water quickly and efficiently. Determining when to use ship-based vs. cloud- or shore-based resources for this synthesis will likely continue to evolve, as computing and satellite technologies improve. What analyses can be done by computers (AI or ML) vs. humans to make the best decisions for asset utilization?

PARTNERSHIPS

Key Questions: What existing partnerships can be leveraged to facilitate exploration? What new partnerships would enable further or more effective exploration? How would a national ocean exploration program advance data collection and characterization? What aspects of a potential national program would be most beneficial compared to separate regionally managed programs?

Water column characterization should be conducted with coordinated, collaborative partnerships, which have different strengths. For example, collaboration between traditional academic or fisheries vessels, with berths to support large science teams and capabilities for towed nets, and ships, which have technical teams and capabilities aided by telepresence, would allow scientists the opportunity to work towards more complete characterization of discrete areas of the Pacific. In addition, large ocean observing data sets, such as those from Argo or glider fleets, or satellites, should be used to guide site selection for focused water column characterization. These data sets can provide important context and help refine an expedition plan. Targeted joint expeditions would help further refine tools and methods needed to define successful achievement of water-column exploration goals and objectives.

A series of expeditions should be envisioned to focus on the water column. Initial expeditions could develop and test methods and tools to determine the most effective and efficient ways to combine, utilize, and process data. NASA is likely to remain a relevant partner, similar to the past NOAA OER co-sponsored *SUBSEA* mission, which helped share ideas across organizations and develop new paradigms for exploration that are effective on all ocean worlds.

Private philanthropists are also investing in water-column exploration, leading to the development of new tools that could be part of a comprehensive midwater program. Development of these tools for broad use will take coordinated effort, working with researchers, to test new platforms at sea and to verify that the data, observations, and collections are useful. Ocean exploration programs should aim to determine which platforms are robust and which sensors make the greatest contributions to water-column discoveries. This goal will require partnerships that are funded, coordinated, and iterative to be successful. For example, the philanthropic-academic collaboration of the *Ocean Twilight Zone* project at WHOI has proven to be an effective approach for engaging scientists and the public in exploration of the mesopelagic water column from 200-1,000 meters.

Engaging the public as an ally through citizen-science efforts and/or educational outreach is an important component of a successful ocean exploration program looking to gain broad support for work in the water column. While telepresence-broadcast water-column dives might not be appealing to the public, new technology that incorporates data visualizations can help inform the public of the importance of, and threats to, this vast set of ecosystems. Additionally, highlight videos of water column-dwelling organisms, such as the *Deepstaria jellyfish*, *Halitrephes jellyfish*, and gulper eels observed on past NOAA OER-supported missions, are often very popular. As we explore areas around remote Pacific Islands, local community/public engagement should be part of all phases of expeditions. Collaboration with Indigenous populations should be encouraged to develop plans that incorporate Traditional Knowledge, cultural links, and curiosity about local waters.

REGIONAL PRIORITIES

Key Questions: What is the relevance/importance water column characterization to a sustainable Blue Economy? Identify priority geographic regions for exploration that are critical in both the Pacific Ocean and globally.

Aside from being the largest ecosystem on Earth, the water column is very dynamic and does not adhere to geopolitical boundaries. Therefore, its exploration and characterization are daunting. Within broadly defined areas (e.g., ocean basins), depth layers, rather than specific geographical locations, may be more important in forming an exploration strategy. Other than relatively small trench areas, the huge bathypelagic zone (1,000-4,000 meters) is the least studied of all parts of the water column, due to difficulties of adapting current techniques and tools. Efforts should be made to meet these challenges. The boundary between the mesopelagic (200-1,000 meters) and bathypelagic is an area that remains particularly underexplored, yet this interface experiences wide variations in properties which are expected to be altered by a changing climate, like oxygen concentration and nutrient availability. Developing an understanding of these layers now is essential for predicting how they will continue to change in the future, for effective ocean management.

The decision on where to conduct water-column exploration may be driven by phenomena or temporally relevant events. The oxygen-minimum zone, regardless of geographical location, should be targeted for water-column studies, because climate change models predict that oxygen-minimum zones should both intensify and expand. Consequently, understanding how these oxygen-minimum zones are changing and impacting both the water column and underlying benthos over time is critical to predicting the future of our oceans and our planet. Collecting quantitative baseline data before new anthropogenic activities are introduced to an area should be a focus to facilitate a sustainable Blue Economy. For example, the need to understand the water column is pressing in areas where deep-sea mining, petroleum extraction, or fisheries are developing or expanding, so that we have a baseline characterization of this environment prior to any anthropogenic impact.

Finally, just as "Ewing Stations" were ways of systematically exploring the seafloor during early oceanographic voyages, regularly scheduled water-column surveys, including transects at fixed depths in addition to targeted phenomena (e.g., oxygen-minimum zones), are crucial for gathering baseline information needed to develop a more informed plan for deep-sea water column characterization. While past focus on biomass-rich depths might have been of particular interest – to understand the dynamics of aspects of specialized environments (e.g., above seeps and vents or the deep-scattering layer) – the water column characterization breakout group agrees that better understanding all depths of the water column, regardless of biomass, is important because so little is known. Such surveys should be conducted in as many areas as possible, regardless of underlying benthic features that may be of interest for other ocean exploration goals.

REFERENCES

Ingels, J., Clarke, M.R., Vecchione, M., Perez, J.A.A., Levin, L.A., Priede, I.G., Sutton, T., Rowdon, A.A., Smith, C.R., Yasuhara, M., Sweetman, A.K., Soltwedel, T., Santos, R., Narayanaswamy, B.E., Ruhl, H.R., Fujikura, K., Zettler, L.A., Jones, D.O.B., Gates, A.R., Snelgrove, P., Bernal, P., and Van Gaever, S. (2016). Chapter 36 F, Open Ocean Deep Sea. In Inniss, L. and A. Simcock (joint coordinators), *First Global Integrated Marine Assessment, World Ocean Assessment I*. United Nations, New York.

Netburn, A.N. (Ed.) (2018). *From Surface to Seafloor: Exploration of the Water Column* Workshop Report [2017, March 3-4]. NOAA Office of Ocean Exploration and Research. NOAA Technical Memorandum OAR OER; 003. https://doi.org/10.25923/rnjx-vn79

National Research Council (2018). *Discovering the Deep Blue Sea: Research, Innovation, Social Engagement*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25027

NOAA Ocean Exploration Advisory Working Group Summary Workshop Report: Planning the Maiden Voyage of the *Okeanos Explorer*. Washington, D.C., 10-11 May 2007.

Ramirez-Llodra, E., Brandt, A., Danovaro, R., De Mol, B., Escobar, E., German, C.R., Levin, L.A., Martinez Arbizu, P., Menot, L., Buhl-Mortensen, P., Narayanaswamy, B.E., Smith, C.R., Tittensor, D.P., Tyler,P.A., Vanreusel, A., and Vecchione, M. (2010). Deep, diverse and definitely different: unique attributes of the world's largest ecosystem. *Biogeosciences*, 7, 2851–2899. doi: 10.5194/bg-7-2851-2010

Robison, B.H., Sherlock, R.E., and Reisenbichler, K.R. (2010). The bathypelagic community of Monterey Canyon. *Deep-Sea Research Part II: Tropical Studies in Oceanography*, 57(6), 1551-1556. doi: 10.1016/j.dsr2.2010.02.021

Webb, T.J., Bergh, E.V., and O'Dor, R. (2010). Biodiversity's Big Wet Secret: The Global Distribution of Marine Biological Records Reveals Chronic Under-Exploration of the Deep Pelagic Ocean. *PLoS ONE*, 5(8). doi: 10.1371/journal.pone.0010223

Workshop to Identify National Ocean Exploration Priorities in the Pacific, White paper submissions, March 2020. Consortium for Ocean Leadership and NOAA Office of Ocean Exploration and Research.

Workshop on Telepresence Enabled Exploration of the Caribbean Region (Workshop summary & White paper submissions), Miami, Florida, 15-18 November 2012. Ocean Exploration Trust. https://nautiluslive.org/sites/default/files/documents/2020-05/2012CaribbeanWhitePapers.pdf

Workshop on Telepresence Enabled Exploration of the Eastern Pacific (Workshop summary & white paper submissions). San Francisco, CA., 11-13 December 2014. Ocean Exploration Trust. https://nautiluslive.org/sites/default/files/documents/2020-05/2014EasternPacificWorkshopWhitePapers_21Nov.pdf

SECTION 5: CULTURAL HERITAGE BREAKOUT REPORT

DEFINING THE TOPIC: HUMAN BOUNDARIES

Cultural heritage is an aspect of ocean mapping and characterization that spans all areas of the overall ocean exploration effort. Cultural heritage also underscores the ethos of exploration. The next 10 years could be a decade of momentous discovery. Those discoveries, in the ocean and on the seabed, will mean different things to different people. One important aspect highlighted during this workshop was that recent examples of racial injustice in the United States have galvanized the public, leading to strident calls for increased awareness and the need for change. In general, there is a need for greater DE&I in marine sciences. The ocean exploration community must actively seek out the participation and expertise of voices which are historically underrepresented in marine science, particularly with regard to Indigenous communities who have ancestral ties to the Pacific. Therefore, it will be important to listen and include their information, in their voice, to supplement the substantive information and overall process as much as possible.

Cultural heritage in the Pacific comprises a wide and diverse span of peoples and activities and is much more than the sum of historical maritime artifacts. For centuries, Indigenous communities have created interdependent, kincentric ecological relationships with the Pacific Ocean and used the ocean for transportation. Through time, these experiences have culminated in a wealth of Traditional Knowledge about the ocean that is not always evident to, acknowledged by, or embraced by the conventional scientific community. One definition of Traditional Knowledge, *used by BOEM*, is: “a body of evolving practical knowledge based on observations and personal experience of local residents over an extensive, multi-generational time period.” The sea is tied to a profound cultural meaning for Indigenous peoples around the Pacific Rim and associated island nations. Sea life and species have cultural meaning, as does the landscape of the sea, even that which is seemingly not “visible.” The perspectives of Indigenous peoples need to be heard and incorporated into the ethos of not only why the conventional scientific community “discovers,” but also how it “discovers.” Marine science must also acknowledge that there is diversity in Indigenous culture and belief, and that a “one size fits all” approach will not meet the need for consultation and involvement with Indigenous peoples. Identification of local Indigenous leaders and advanced consultation should be considered standard parts of advanced planning efforts for any such mission. Ongoing and continuous involvement links to an understanding that future ocean exploration should not adhere to the conventions and mistakes of past imperialistic “exploration and discovery” in the Pacific.

Another key point is that ocean exploration by 2030 may likely find areas and sites of exceptional cultural significance associated with the human migration to the Americas during the last glacial maximum period, ~20,000 years ago. Sea level rise drowned the landscape through which migrations took place, and with it, sites where people settled close to shore, in coastal valleys, and in sea caves where remnants of these features may still be found up to 140 meters below present day coastline. Locating these types of sites in order to avoid impacts from offshore energy development is a priority for agencies such as BOEM. The highest probability for discovering submerged pre-contact sites will be in Beringia (Alaska), the areas around the Olympic Peninsula (Washington), Heceta Bank (Oregon), and off the Farallones and surrounding the Channel Islands (California). Overall, the collection of sub-bottom data in water depths less than 140 meters along the U.S. West Coast could provide useful information for refining our model of submerged landforms and their potential for heritage information.

Finally, as cultural heritage is human-based, a key aspect of the human experience is storytelling. Storytelling engages audiences, informs the public, and encourages cooperation and support. Planning for outreach and ways to communicate should be actively considered at the beginning of, and throughout, every ocean exploration mission in the Pacific; it is more than just thinking about how to share various bits of photo/video on social media post-expedition. One way to accomplish this is by inviting diverse storytellers on *all* ocean exploration missions – more live, more behind-the-scenes, and documentation with storytelling and oral traditions in mind.

DATA PRIORITIES

What are the data requirements that define "characterization", existing capabilities available to collect needed data, and potential/new capabilities that can further enable collection of needed data?

All ocean exploration mapping should have the ability to recognize and/or document previously unidentified cultural heritage sites. Minimum preparation should include coordination with an archaeologist/cultural resources specialist who has expertise/familiarity with the mission area. During a mission, an officer on board should serve as a liaison for any cultural heritage issues. That person should be familiar with potential sensitivities related to cultural heritage sites, such as the need to restrict the release of location information or potential for the presence of human remains at a site. A key point is that the long extant "Doctors on Call" protocols are good and should be followed, if suspected targets are known or encountered. A "call sheet" can be developed for specific types of sites, regions, and cultural contexts for all missions to draw upon, using the "on call" protocols. If any characterization is to be done, archaeologists should be available during dives, whether that is on board or via telepresence. Cultural heritage experts are generally available, they have good relationships with communities and many relevant organizations, and they add value to all expeditions through the power of human connection and storytelling. The cultural heritage breakout group strongly supports the provision of telepresence for all missions, including more use of fly-away systems for partners on vessels large and small.

In terms of detecting cultural resources, hull-mounted multibeam sonar is limited primarily to delineating large, steel-hulled shipwrecks. Ships the size of oil tankers can be found with multibeam sonar (e.g., EM302) down to a depth of only ~600 meters. Therefore, large scale, deep-water mapping is not likely to locate any specific cultural resources. However, such mapping can provide important bathymetric data to help inform landscape studies and paleo-shorelines (in the Bering Sea, for example), upon which more fine scaled data can be collected. Sub-bottom surveys would be useful along the eastern Pacific, in water depths less than 140 meters. For cultural resources, sonar surveys should be able to detect discrete targets 0.5 meters in length at maximum range. While these survey parameters are not typically done during oceanographic surveys, for areas of high cultural potential, we recommend following extant *BOEM guidelines*.

Magnetometers and sub-bottom profilers are typically run at 30-meter line spacing, with magnetometers at a maximum altitude of six meters above the seafloor. This is to ensure that magnetic or buried targets are detected on multiple profiles. Sidescan sonar can be used for medium and fine scale surveys. Sidescan sonar is heavily used for cultural heritage surveys and is even more usable now by integration with AUVs (particularly deep-water AUVs). These tools have been essential in recent discoveries, such as for the USS *Indianapolis*, USS *Nevada*, and USS *Lexington*. Sidescan sonar data can also be used to document seafloor landscapes and anthropogenic impacts, such as trawling impacts on the seafloor.

Standard mapping at a 300-meter elevation will register most modern metal-hulled shipwrecks, even those which have broken apart. Interpretation is key, especially with input and analysis by experts who can assess for probable wreck sites. Other types of submerged sites can also be detected, including aircraft and older, more degraded wooden-hulled wrecks, but their status as cultural sites may not always be apparent. Even then, at 300 meters of elevation, such sites may not be recognized if they are disarticulated or degraded.

For areas where there is a higher priority or a greater probability of finding significant cultural heritage targets, the ability to resolve 0.5-meter objects on the seafloor is preferred. The cultural heritage breakout group would like to emphasize the effectiveness of AUV/UUV systems in surveys. They can be particularly effective in surveys where aircraft wrecks are expected, as the sensors need to be as close to the bottom as possible to get the resolution needed. Ideal altitudes for this type of survey are 30-50 meters above the seafloor. Programmable AUV dives can fly closer than 100 meters above the seabed to find "faint" resolution targets. These can and would include shipwrecks from the 19th Century and earlier, where the wood structure of a wreck may not have survived as a visible entity. A significant 19th Century shipwreck, the Blake Ridge Wreck in the Atlantic, for example, has little vertical resolution and might not appear to be a wreck unless surveyed at distances of less than 100 meters. An HOV survey delineated its anchor chain and a pile of brick from the crew's galley, which presented in patterns more commonly associated with cultural remains.

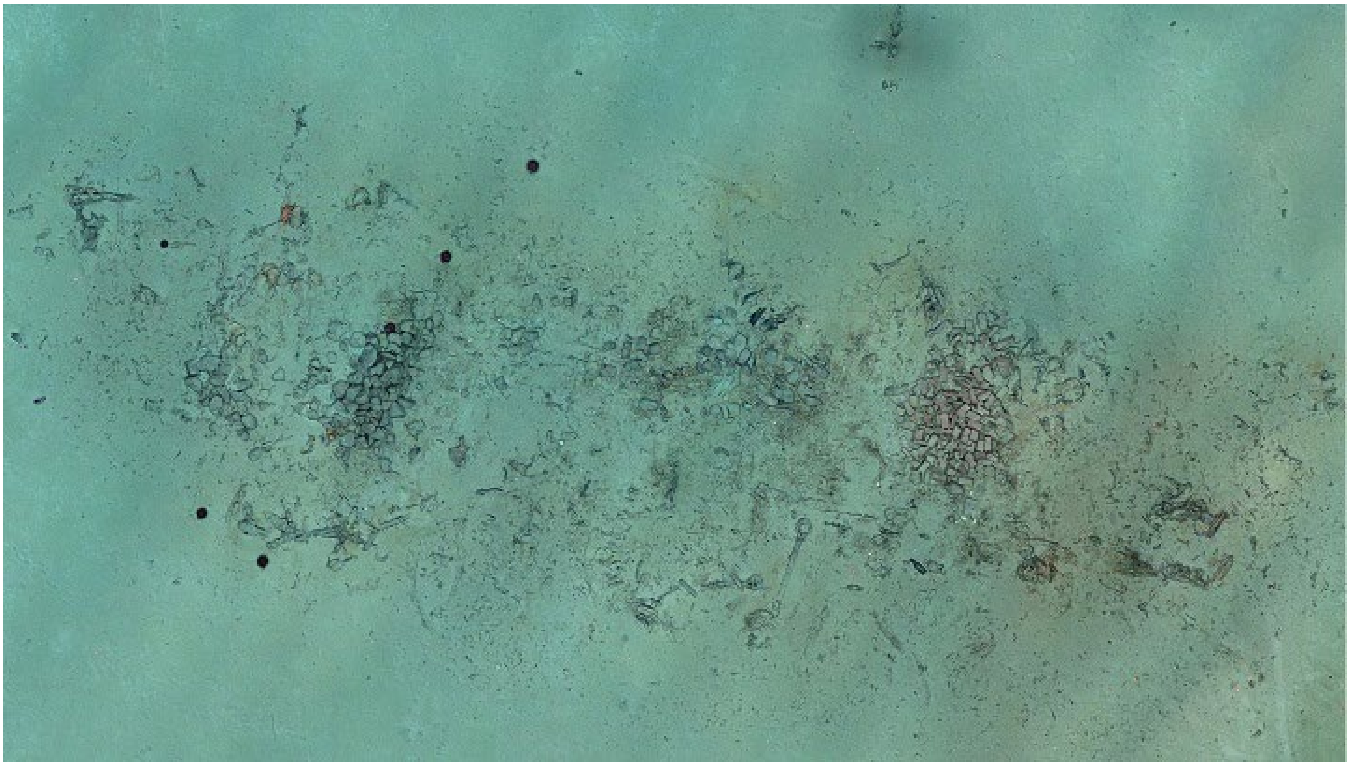


FIGURE 5.1: *The Blake Ridge Wreck, c. 1840, was discovered on an Alvin dive, and subsequently ROV-mapped at close range by NOAA Ship* Okeanos Explorer *and processed by BOEM.*

Using AI to monitor surveys, along with predictive modeling, can also help define probable cultural targets. Coral growth on cultural targets may obscure detail, but an expert eye or AI-processed data might still provide the essential pattern recognition needed to identify a cultural site. For submerged early human migration and settlement sites, site predictive modeling can discern likely high-quality target areas on ancient shorelines, in coves, or at river mouths and estuaries, as well as areas with sea caves that are now submerged. Characterization of these types of sites can include coring, sampling, and using small, sensor-equipped ROVs and AUVs to enter and assess submerged sea caves and cenotes.

What new data are needed for cultural heritage? What are the gaps in existing data?

The fundamental data gap is an inventory of located and characterized cultural heritage sites that span the full range of human activity in the Pacific. The potential for rewriting the history of human migration into the Americas is becoming more recognized as a scientific priority, with much work being done in California and Oregon by a variety of researchers with universities and the government, the latter most notably by BOEM. The high potential for finding sites, data, and rewriting our understanding of the past from the drowned landscape of ~10,000 years ago is vast and provides an exceptional opportunity to capture global attention on a NASA-style scale of outreach. Data on the location and survey of historic properties are also needed for federal agency compliance with NHPA, particularly in MPAs, and with WWII wrecks that may also be a threat to the marine environment, related natural resources, and sustainable Blue Economy jobs such as fisheries and ecotourism.

PARTNERSHIPS

What existing partnerships can be leveraged to facilitate exploration?

Discovering our cultural heritage through ocean exploration has a growing public audience. Year after year, exploration of RMS *Titanic* has won massive audiences. Interest is building in the stories of the Pacific; among others, these include how people migrated from Asia to America; how Polynesians purposefully navigated across vast waters using the waves, winds, and stars; how sailors ventured across the Pacific to establish trade links to Asia and to hunt the whales that provided oil to keep the lamps lit at home; how aviators forged skyways across the Pacific; and how sailors and airmen fought for mastery of the Pacific in WWII. National Geographic has funded research and reporting on potentially polluting WWII wrecks in the Pacific in the past, and WWII cultural heritage sites continue to be topics of interest to the Secretariat of the Pacific Regional Environment Programme, the Major Projects Foundation, The Ocean Foundation, and members of the IUCN World Congress. New exploration and discoveries can supply these stories to an eager audience and facilitate a sustainable Blue Economy. The general public has an appetite for stories of how people have ventured into the unknown to find facts that help to explain the mystery of life on this planet, including facts that alert us to future risks. Some members of the audience will wonder how their ancestors traveled from Asia to America. Some will want to know the circumstances in which family members fought and perhaps died during WWII in the Pacific. Others will be interested in information about the threats to the marine environment and how to facilitate the growth of our economic interests across the Pacific. All may want to hear well-told stories of how the United States is reinventing its calling as a nation of explorers.

New partnerships and relevance/importance to a sustainable Blue Economy.

The cultural heritage breakout group would like to bring our audience “on board” to the fullest extent possible. Many explorers are great storytellers. Exploration is an adventure story. How can we bring the audience along on the adventure? The other aspect, as noted, is to improve upon existing relationships and build new ones in ocean exploration and mapping through inclusivity, diversity, and respect for Indigenous cultures. One opportunity is through developing opportunities to work with Historically Black and Tribal Colleges and Universities, as noted in Executive Order 13592 in 2011. The human story gives us an opportunity to discuss inclusivity and engagement. We can carefully and cleverly make sure that the next generation is engaged and diverse. Broadcasting the stories can engage media partners and sharing platforms; these missions can inspire next-generation technologies and partnerships to invest in ocean exploration through the selling power of human stories. Engaging nonprofits and social media helps to spread our message. Other key groups include organizations trying to characterize sites that are hazardous legacies. Engaging with scholars and others seeking to expand knowledge of earlier seafaring and its material record is another key. The group suggests including the DPAA for sites where military casualties may be discovered. In mapping and characterizing, ocean exploration will find wrecks that at one time represented our enemies, though are now our friends (e.g., Japan). Working with these national partners can help enhance good diplomatic relations. As we respect others’ remains, we would expect them to do the same with ours. NOAA has demonstrated such international leadership, showing sensitivity with former enemies and allies and keeping lines of communication open.

GEOGRAPHIC PRIORITIES

Identify priority geographic regions for exploration that are critical for this topic in both the Pacific Ocean and globally.

Aspects of cultural heritage should be a part of pre- and ongoing mission planning, regardless of where mapping and characterization take place. For example, ships transiting to the Marianas region can pass by Wake Island where significant WWII wrecks (such as the Japanese destroyers *Hayate* and *Kisaragi*) remain undiscovered between two and thirty miles offshore. Ships transiting from Hawai‘i to American Samoa can pass by the recorded loss areas of other significant ships, or follow the established “track lines” for early oceanic sail and steamship routes that transited the Pacific. In order to combine and highlight the previously noted significant research directions, areas, and concerns, the cultural heritage breakout group proposes six signature missions which also build upon and support the goals of characterizing the seafloor, benthic biology habitat, and nearby marine resources. They could also include water-column analysis, since many of these wrecks have the potential to be threats to the marine environment and a sustainable Blue Economy. Each of these missions could also support and enhance opportunities to work with Indigenous communities:

- *The Battle of Midway*. This mission would map thousands of square kilometers of unmapped seabed in the U.S. EEZ. The goal is not only to locate the ships, but also aircraft, lost in this pivotal WWII aerial battle. Out of the hundreds of wrecked warplanes, some may be substantially intact with crew inside. This would be a ground-breaking multidisciplinary, multi-agency, and external partner mission that would build on the signature missions of Robert Ballard, Paul Allen and Robert Kraft, and David Jourdan. This mission could be effectively and efficiently accomplished with coordinated AUV surveys and ROV follow up, and with telepresence would capture global attention and interest. The model utilized by Vulcan in the Pacific on R/V *Petrel* has shown high productivity and results, with minimum staffing, and can be applied here. The mission may also assist in the compliance of NHPA, help to address threats to the marine environment from potentially polluting wrecks, and facilitate a sustainable Blue Economy. There are potentially polluting wrecks that are a threat to the marine environment and the Papahānaumokuākea Marine National Monument that are identified by NOAA, but have not been located, and should therefore be a priority.
- The Flying boat *Samoan Clipper* (NC16734) (Figure 5.2). The most significant early aircraft loss in the Pacific region, this pioneering Pan American Airways plane went down in 1938, some 12 miles off the north coast of Tutuila, while on approach for an emergency landing at Pago Pago harbor. Chief pilot Edwin C. Musick, who surveyed and inaugurated the first commercial transpacific air route just two years before, was killed in the tragedy with his entire crew. Intensive archival research directed by Russ Matthews has yielded a wealth of solid evidence pinpointing the likely crash site, while a recent (July 2019) expedition further refined the search area. A comprehensive AUV survey to map these previously unexplored sections of the American Samoa EEZ holds a high probability for a new and momentous discovery. A mission to write the final chapter to *Samoan Clipper*'s powerful story would be vigorously supported by nonprofit and media partners, promising tremendous levels of public engagement as well.

FIGURE 5.2: Samoan Clipper *in Pago Pago (Pan Am Historical Foundation).*

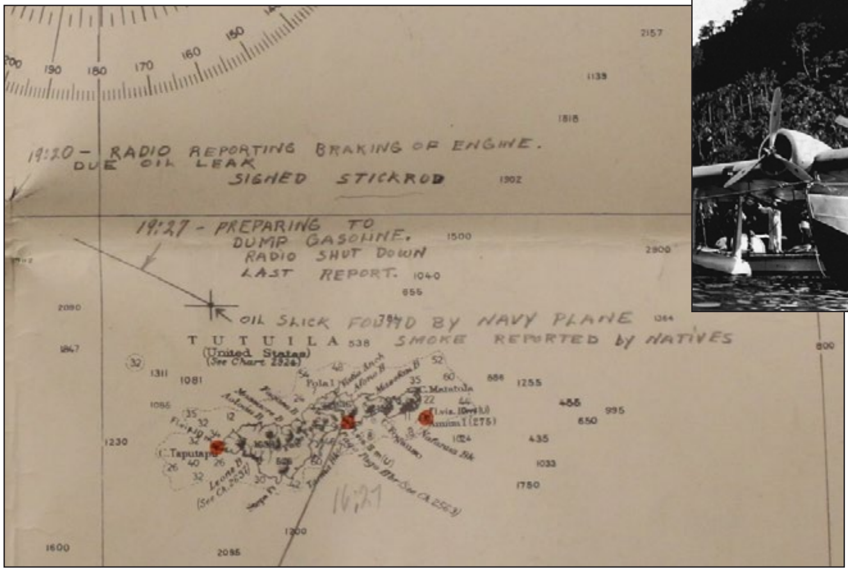


FIGURE 5.3: *Detail of period Pan American search map (University of Miami Libraries).*

- The iconic battleship USS *Pennsylvania* (BB-38). A super-dreadnought commissioned on the eve of WWI, this ship sailed with distinction for 30 years including WWII service that spanned the entire Pacific campaign, from the surprise attack on Pearl Harbor to the climactic battle for Okinawa, and finally ended as a target vessel for the atomic bomb tests at Bikini Atoll. *Pennsylvania* was ultimately scuttled intact just off Kwajalein in the Marshall Islands, where its likely wreck location was recently mapped in a multibeam survey by NOAA Ship *Okeanos Explorer*. The wreck carries enormous potential for a signature ROV characterization mission, including pollution potential assessment, planned and executed in conjunction with media partners.
- The waters off the Northern Mariana Islands. Known to ancient islander and Asian mariners, colonial Spanish seafarers, and site of later era wrecks, including WWII ships and aircraft. Known B-29 crash sites off Tinian and Saipan can open a window into these types of sites, as well as assess them for DPAA. Recent work by East Carolina University on WWII sites in these islands has included substantial Indigenous consultation and engagement.
- The "*Kelp Highway*." This mission, which would complement ocean exploration expeditions in deep water, will seek evidence of early human migrations into the Americas following the now-drowned coastline at the 100-meter depth level and shallower in the U.S. EEZ, from Beringia (Alaska) to Baja California. This would be a set of expeditions that, building on existing and planned scholarship and initiatives, and engaged in vital sustainable Blue Economy mapping and characterization, seeks to unlock the drowned stories of ancient America. Alaska and Beringia are the highest priority, as this is the trek taken by early humans via a land and sea bridge. This signature mission would engage and cooperate with Indigenous peoples, not only along the Pacific Coast of the United States, but also with others in the Americas.
- USS *Stewart* (DD-224). This is the uniquely compelling story of one ship that sailed under two opposing flags in the Pacific conflict. Launched just after the end of the WWI, the old destroyer *Stewart* saw early WWII action as part of embattled multi-national American-British-Dutch-Australian forces until damaged, abandoned and captured by the Japanese. Refloated and refurbished, this ship was pressed into service with the Imperial Japanese Navy as *Patrol Boat No. 102* for the remainder of the war. Discovered in a Tokyo backwater after Victory in Europe (VE) Day, *Stewart* was recommissioned and returned to the United States under tow to be sunk as a target vessel. The precise location of the ship was recently rediscovered by archival researcher Lonnie Schorer inside the boundaries of Cordell Bank National Marine Sanctuary. A mission could stage with relative ease from nearby San Francisco and deploy an AUV to survey the *Stewart* scuttling position, while simultaneously mapping and characterizing Bodega Canyon.

SECTION 6:
DE&I IN THE PACIFIC – PANEL DISCUSSION SUMMARY

PANEL OVERVIEW AND KEY FINDINGS

To share experiences and to learn from each other as we explore the confluence of diverse systems of knowledge, and open new pathways to understanding and mutual trust.

Panelists:

Papali‘i Dr. Tusi Avegalio – Pacific Business Center Program, University of Hawai‘i
Dr. Wendy F. Smythe – University of Minnesota Duluth
Kahu M. Kalani Souza – University of Hawai‘i FEMA NDPTC Community Outreach Specialist/Olohana Foundation
Kahu Ramsay Taum – Life Enhancement Institute of the Pacific

Moderator:

Dr. Genene Fisher – NOAA OER

Co-organizers:

Catalina Martinez – NOAA OER
Dr. Dominique Rissolo – University of California, San Diego

Facilitator:

Bill Thomas – NOAA Office for Coastal Management

FIGURE 6.1: *A screenshot from the virtual panel discussion. This image includes Kalani Souza (top left), Genene Fisher (top center), Ramsay Taum (top right), Bill Thomas (bottom left), Tusi Avegalio (bottom center), and Wendy Smythe (bottom right).*

A workshop focused on ocean exploration in the Pacific, and specifically regarding partnerships, would not be complete without active awareness of the cultural context in which ocean exploration is often conducted. An essential part of DE&I in this region is incorporating the voices and lived experiences of Indigenous communities. Recognizing the unique and numerous Pacific communities as partners and stakeholders enhances the overall impact of the ocean exploration enterprise through wider public support, a more diverse workforce and community of practitioners, and incorporation of Traditional Knowledge systems throughout the process. The NOMEC Strategy also points to the value of enhancing inclusion in ocean exploration, highlighting this as a national priority and imperative.

As all five of this workshop's topical breakout groups identified Indigenous communities as important partners in the Pacific, a session during the closing plenary served as an opportunity to hear from a select group of cultural practitioners and leaders from this region. These esteemed individuals were invited to participate in a free-form discussion on how organizations engaged in ocean exploration should approach Indigenous communities and offer guidance for relationship building. Ultimately, this exercise serves to inform broader partnership formation and development in advance of and during exploration in the Pacific, and potentially beyond, should a true national ocean exploration program take shape.

Some of the key lessons from this session are:

- Language and proper communication are important. Be sure to ask community leaders about local protocols and preferred terminology before fully engaging with communities in the Pacific.
- Conducting ocean exploration impacts the people who live in the area. Be cognizant of this and be respectful. Organizations engaged in exploration should start by asking them: *How can we contribute to your community in a positive and meaningful way?*
- Strive for relational rather than transactional interactions. For example, partnerships with local and/or Indigenous communities are often pursued because of requirements for funding – that is transactional. Focus instead on building relationships by talking about the environment and the communities themselves.
- Be willing to put in the time and effort required to build and sustain these relationships.
- Consultation is important, but collaboration should be the goal. Convergence of Traditional Knowledge and conventional scientific knowledge is also an important goal.
- Embrace Traditional Knowledge systems as equivalent and complementary bases for science. Traditional Knowledge should be considered and clearly articulated during every step of the scientific and decision-making process (Kendall et al., 2017):
    1. In designing, planning, and conducting science.
    2. Apply information from Traditional Knowledge systems at the earliest opportunities.
    3. Use Traditional Knowledge in environmental impacts assessments.
    4. Consult with Indigenous leaders at key decision points.
    5. Apply Traditional Knowledge at programmatic decision levels.
- If Traditional Knowledge from a specific community is going to be used, incorporated, or applied, that community should first be approached to ensure:
    1. Sharing the knowledge is appropriate considering intellectual property and ownership by certain individuals, families, and/or communities.
    2. The knowledge is interpreted as intended.

The following section presents personal thoughts and reflections from the organizers, panelists, and workshop participants following this panel discussion, in their own words. For more background information on the panelists, please see their biographies in *Appendix C*. A full video recording of the session is available on the *COL website*.

PANEL REFLECTIONS

A Statement from Dr. Dominique Rissolo – Panel Co-organizer

The desire to explore knows no cultural or social boundaries. For thousands of years, our oceans were explored by the greatest diversity of peoples, and the future of our oceans relies on the talent, drive, creativity, and expertise of all those connected to the sea. Surrounding us is a corpus of knowledge and insight that predates entrenched and pervasive European paradigms by millennia.

The great Polynesian explorers developed and employed a range of wayfinding skills far more diverse, nuanced, and sophisticated than could ever have been imagined by their European contemporaries – ways of understanding the ocean that continue to serve Pacific navigators today and have much to contribute to other ocean science communities. Indeed, such multigenerational mastery involves ways of reading and interpreting ocean phenomena that have traditionally been omitted or excluded from the modern ocean exploration enterprise. An openness to learn and to share goes beyond the moral and ethical imperative of inclusivity and can functionally enrich and expand our national program of ocean exploration.

Since the earliest peopling of the American continents and the farthest reaches of the vast Pacific, knowledge about the ocean and ocean systems was passed on orally, via storytelling and song as well as performative expression and mentoring. Literally thousands of years of cumulative ecological and technological knowledge – fundamentally derived from the processes of exploration, observation, and experimentation – were transferred from one generation to the next. Many adaptations, like those that enabled peoples of present-day Alaska and their ancestors to thrive in their ocean world, can hardly be improved upon today.

I join my colleagues as a listener and a learner, and I am grateful to have had this opportunity.

A Statement from Catalina Martinez – Panel Co-organizer

As we consider various approaches for ocean exploration in the Pacific, it is clear that we need to learn directly from Indigenous scholars and cultural practitioners from the Pacific Island Nations and Alaskan communities where research ships will be operating. Although working in these areas is not new, our hope is that we can learn to approach our engagement in these special regions differently than we have in the past. As a start, it is important to:

- Discuss opportunities for inclusive and equitable collaborations and operations in the Pacific.
- Reimagine engagement through a “relational” rather than “transactional” lens.
- Consider new ways to diversify teams, collaborators, and the workforce.
- Share effective practices to incorporate diversity, equity, and inclusion in all activities.

These are points that motivated the development of this panel discussion. After a few weeks of reaching out to various partners, and with the specific assistance of our esteemed NOAA colleague in Hawaiʻi, Bill Thomas, we were able to assemble a powerful group of panelists who generously shared their wisdom, thoughts, and ideas during this engaging discussion.

Reflecting back on our experience together, I believe we far exceeded our initial concepts for this session and gained tremendous insight into how to navigate the world differently going forward. Hopefully, the workshop participants can now reimagine how to engage and build relationships, build in new considerations when assembling teams and developing opportunities, broaden their perspectives about acquiring and sharing data, ask different questions, and apply equal value to Traditional Knowledge systems and different ways of knowing. If we are intentional about how and why we make particular choices and decisions, we can and will make significant impacts. As our brilliant panelist Kalani Souza shared during the discussion, “Now that you know better, you can do better and be better.” Kalani also expressed the notion that “we are all Indigenous Island Earthlings!” If we can embrace Kalani’s worldview, regardless of where we come from geographically, we are all related.

With that said, we have much to learn. As this is an ongoing journey, please know we are all in this together. I am thankful for the opportunity to co-organize such a wonderful session. To our amazing panelists, I am eternally grateful.

Reflections by Dr. Wendy F. Smythe – Panelist

- **JEDI:** Justice, Equity, Diversity, and Inclusion are all separate terms with specific meaning. The below listed concepts may be novel to those from mainstream society; however, these are truths in the world of those from culturally diverse communities. We must continually learn about "mainstream" culture, and it is expected that we do so, otherwise we have no chance of success in academic careers.
  - Engaging in JEDI should be *normalized* as part of our everyday life both personal and professional.
    - Hearing about "DE&I fatigue" lately is shocking and offensive. These initiatives have been around for a while; however, the movement for real change, meaningful change, and change now has only been at the forefront since the public murder of George Floyd on May 25, 2020. This fatigue is only a few months old for those who don't have to think about DE&I every day. Keep in mind, your colleagues from diverse cultures have to think about it every day of our lives.
  - When working *with* diverse populations or communities, colleagues, students, or in territories of diverse communities such as Native American, Alaska Native, and Pacific Islander, it is just as important to research with the intent to learn their cultural protocols, customs, and ways of knowing as the effort put into a specific research project.
  - JEDI is a life-long learning process; there are no one-time interventions that can provide all the information and knowledge necessary to engage with diverse people or communities.
    - There is no such thing as cultural competence, as we will never truly experience or understand what others from a diverse group experience on a daily basis or what members of oppressed groups have experienced or continue to experience.
  - Engaging in JEDI should not be driven by statements from international or national professional societies, agencies, organizations, or governments. As researchers, we have the knowledge to know and understand our *personal* responsibility to learn about and advocate for JEDI, the diverse communities we wish to work with, and to do so with the utmost respect and ethics. In the same manner you would want a researcher working with you.
  - Understand that **historical trauma** is real and alive in diverse communities. It didn't happen hundreds of years ago, but in *your* lifetime. Specifically:
    - Native boarding schools did not end until 1973.
    - Native ceremonies were illegal until 1978.
    - Speaking Native languages was illegal until 1972.
- **Words Matter:** How you describe a diverse group often involves the term "minority," setting up a hierarchy and presenting one or a group as less than, even if subconsciously. We are people and we deserve the same respect we give to others. We have to find equitable ways/terms for describing and/or introducing our colleagues, this of course will take time and I am sure there are individual preferences, but we can and should begin to consider the ways in which we engage with and consider one another. Possible terms include "underrepresented scholars," "marginalized scholars," "cultural practitioners," etc.
  - The way in which a member from a diverse community is introduced or talked about again can set up an unspoken indicator that the "Native faculty" member only has their racial/ethnic identity to offer rather than scholarship, or that one did not earn their title or position, rather it was "given" to them as a "diversity" initiative.
    - Consider how you would feel being introduced as a "white faculty member." Not so great, huh?
- **Identity:** One's identity can be tricky. How does one identify? Having more than 570 tribes within the United States, identity is, and can be, fluid. Best practice may be to ask. Some terms commonly used:
  - Alaska Native, peoples who have resided in Alaska since time immemorial.

  - Native American and/or American Indian, again this depends on personal preference and refers to tribal members from the continental United States.
    - American Indian is the legal term in which the United States recognizes all tribal nations and tribal members. However, not all Native people consider themselves "Indians."
  - Indigenous, in the United States, refers to not only Alaska Native, American Indian, Native American, but also Pacific Islanders, Black populations that were in the United States prior to colonization, and Mexican populations. We know there are Indigenous populations globally, and here I am focusing on the United States.
- **Knowledge Systems:** Disregarding Traditional Knowledge/Traditional Ecological Knowledge/Indigenous ways of knowing goes against the very nature of science. If we are to be good scientists or scholars, it is our responsibility to learn about and acknowledge that there are more knowledge systems than just conventional science and that these knowledge systems are valid and grounded in tens of thousands of years of inquiry.
- **Relationality and Trust Building:** Acknowledge and understand that collaboration with Indigenous communities or on/in Indigenous territories first requires trust-building to establish meaningful and mutually respectful relationships, and that there is a relationship that we hold with not only one another as humans, but also with the air, land, water, and all beings.
- **Ethics of Discovery:** Remember that knowledge acquired from Indigenous communities, collaborators, cultural practitioners, or Traditional Knowledge systems must be acknowledged. Too often Traditional Knowledge is repackaged and disseminated as a "discovery" without acknowledging the source of that knowledge (this also ties into trust-building). In addition, building those meaningful relationships where the researcher is learning from the community or cultural mentor will allow for interpretation of Traditional Knowledge to be disseminated with permission and with the intended meaning, and not through one's own worldview.
- **Power Sharing:** A concept typically not considered in science is the concept of "power sharing." This is perpetuated in academia due to the need to accomplish to gain job security through tenure or notoriety through publication/discovery. Power sharing is: 1) acknowledging Traditional Knowledge sources and collaborators, and 2) providing a voice for cultural practitioners or community members (mentors) to participate in manuscript development, speaking events, development of research materials and/or proposals.
- **Mistakes:** Currently there is a lot of meaningful work being done to bring awareness of JEDI; however, many of these trainings/meeting/initiatives are ended with the sentiment that "we are trying but we will make mistakes." This provides a disclaimer for superficial efforts. This sentiment is no longer acceptable, the United States has had more than 400 years to make these mistakes and to learn from them, so there is no more time for mistakes. As scientists, we never engage in research with this sentiment, so why then do we engage with each other this way?

As our brother Ramsay Taum said during the panel discussion, "You can no longer say you don't know, because now you do. You no longer have ignorance to blame because now you are informed."

Reflections by Papaliʻi Dr. Tusi Avegalio – Panelist

The Feagaiga (Covenant) with Mother Earth

The wisdom passed down by our ancestors tells us that all humans have two mothers and two fathers; the two mothers are our biological birth mother and, *Papa*, our Earth Mother. In Polynesia, a newborn's umbilical cord is wrapped in *Tī* leaves and ritually buried in the sacred ground. The physical act of burial ritually conducted by elders symbolically connects the newborn to *Papa,* or Earth Mother.

Today, the modern meaning of *fanua* in Sāmoa is "land". Its original and ancient meaning is "placenta" or "afterbirth". *ʻEleʻele* today means "dirt" and *palapala* is "mud". The original and ancient meaning of both words is "blood". *Maʻa* today means "stone", but its original meaning comes from the word *fatu maʻa*, which means "heart".

The very language of ancient Polynesia discerns the earth as living and as Mother that birthed all life and material from the progenitor of the heavens, *Tagaloa Lagi*.

All elders of Polynesia are revered as the living stewards of the seeds of our living covenant to *Papa* the Earth Mother. It is believed that the life tree within our elders bears and carries the seeds of the living covenant that is passed on to each generation by breathing it into each new life.

Holding the newborn, the grandmother or senior elder conducts a ceremonial prayer over the infant that ends by breathing into the nose and mouth of the child. In that manner, the spiritual seeds of the covenant are planted within the lungs of the child. The *mana*, or spiritual energy carried by the breath of the elder, enters the child and flows throughout with the child's every breath carrying the seeds of the covenant to the extremities. In time, the body of the infant and covenant grow into a living oneness. The covenant and infant become one and the same.

Hence, every child is and must be treated as a living covenant and a reminder to all, of the promise between human and Earth Mother. As a living covenant, it is the responsibility of all in the village to nurture and cultivate each child with *Alofa* (Love), until the fruits of maturity are expressed through actions of respect and love that reaffirm the covenant in all humans with *Papa*. The basis of the covenant is the reaffirmation of love, respect, and actions that are consonant with the health, wellness, harmony, beauty, balance, and sustainability of *Papa* and *Tagaloa*'s gifts of life to *Tagata Māoʻi* (genuine or native human being in Sāmoan, the Hawaiian term *Kanaka Maoli* has an identical meaning).

It is the collective responsibility of all adults of the village (i.e., human society) to nurture and cultivate the health, wellbeing, and wellness of all children as repositories of the ancient promise. The seed of the covenant, when it matures, produces the fruits of *Alofa* (Love) and *Faʻaaloalo* (Respect), which are the basis for harmony between humans and the universe, humans and nature, human and fellow human, and human and self. It is only when all four harmonies are consonant with each other that there is true balance, harmony, and peace on Earth.

Papa's health, wellness, beauty and life are dependent on the harvest of love and respect produced by the covenant. With the symbolic connection created by the burial of the umbilical cord in the earth, human fate is inextricably bound to the fate of *Papa*. If *Papa* is well, humans will be well. If *Papa* is ill, humans will become sick. If *Papa* is dying, humans will die.

CHANT OF THE COVENANT

(Derived from a speech delivered in ancient Sāmoa)

THE WHALES HAVE LOST THEIR WAY…
THE SEA TERN THAT CHOOSES ONE MATE FOR LIFE; FLIES ALONE…
THE CORAL IS BURNED BY THE SUN…
THE WINDS CARRY THE SALT OF YOUR TEARS.

ALL ARE REMINDERS; THAT WE HAVE MISPLACED OUR FEAGAIGA (COVENANT) WITH OUR MOTHER EARTH.

WE HAVE MISPLACED OUR FEAGAIGA (COVENANT) BY HOLDING IT ALOFT WHERE THE BIRDS OF SELF-INTEREST AND PRIDE HAVE PECKED ON IT; WE HAVE PLACED IT UPON THE GROUND WHERE CREATURES OF GREED, PROFIT AND EXPLOITATION HAVE CRAWLED OVER IT; WE HAVE HELD IT IN OUR TREMBLING HANDS WITH TIMIDITY WHERE IT HAS HARDENED WITH THE MOLD OF CREATURES THAT HIDE FROM THE LIGHT OF THE SUN.

WE THANK THE GREAT WINDS FOR REMINDING US THAT THE FEAGAIGA (COVENANT) IS SOMETHING THAT ONE DOES NOT HOLD UP IN THE AIR, LAY UPON THE GROUND OR HOLD IN ONES HAND; THAT A FEAGAIGA'S (COVENANT) LIFE IS NOT POSSIBLE OUTSIDE OF OUR OWN.

WE WILL PLACE OUR FEAGAIGA (COVENANT) BETWEEN OUR HEARTS AND OUR LUNGS SO THAT, SO LONG AS OUR HEART BEATS AND OUR LUNGS BREATHE
OUR FEAGAIGA (COVENANT) LIVES.

SO LONG AS WE LIVE, OUR COVENANT WILL LIVE; SO THAT WE WILL SEE TO YOUR HEALTH, YOUR WELLNESS AND YOUR BEAUTY.

WE WILL HELP THE WHALE TO FIND ITS WAY; THE SEA TERN TO FIND ITS MATE, THE WAVES TO COMFORT THE CORAL, AND THE WINDS TO CARRY THE MESSAGE OF LIFE.

RETURN TO YOUR DWELLINGS, LANDS, AND ISLANDS AND BREATH LIFE IN ALL THAT YOU DO; ALOFA, ALOFA, ALOFA IA TE OE.

Reflections by Kahu M. Kalani Souza – Panelist

Diversity, equity, and inclusion. The integration of Indigenous and modern knowledge systems. The move from reductionist lineal systems of thinking to spherical, crystalline, interactive structures as functional design. The dismantling of the Doctrine of Discovery, replacing the transactional with the relational; the Doctrine of Relationship as it were. Far from being easy conversations to undertake, this landscape is ripe with critical disaster potential from a social justice perspective. And yet…

Into this very domain we did explore, the leadership, researchers, staff and observers, panelists and participants alike. Did we do a fair job? Task complete? Like the ocean floor below us, we have much to uncover. So much more territory to map. To witness engaging community, Indigenous leaders, scholars and scientists from all walks of life, people who serve; we may yet reveal to the human experience the unmet portions of our relational contracts.

Knowing full well that while seeming to separate us, truly in the deep the ocean connects us. Understanding our relationships – like understanding the ocean – is the nexus of our needs, our desires, and our capacity to survive.

A Statement from Bill Thomas – Panel Facilitator

In my introduction of the panelists and the discussion, I mentioned the importance of protocol, prayers, and people as we seek to engage with Indigenous communities in the Pacific. Fundamentally, it's all about relationships – engaging with humility, respect for moral and ethical authority, and reciprocation. But the panel, more than talking about these fundamentals, described living these in a way that was "reflexive" rather than "reflected". None had to think about the lens through which they view issues nor the reason for their relational approach to issues that are at the intersection of environmental and social justice. This is what they've learned through their families who have passed to them the ancestral knowledge, ways of knowing, and ways of being. They do what they do without having to think about it because this is what their families have been doing for generations. Treating every element of the systems that we live within like family, with the respect that would be accorded to any family member, opens the door for having that deep understanding of all that surrounds us – actually all that are *connected* to us. Doc Tusi, Wendy Smythe, Kalani Souza and Ramsay Taum spoke to these points from their lens. And, in the end, Ramsay brought this all home with his explanation of the deeper meaning – the significance – of the word *Hawai'i* and how it guides us in our daily lives…

The word *Hā* – the breath of life – is the first breath that we take when we come into this world and the last thing that we give back when we leave. We never really "own" those breaths in between the first and the last. The *Wai* – the water that we drink that's in each of us. It's the spiritual water that guides us daily – the water that leaves our body with each breath that enters the atmosphere and then returns as rain that connects all of us to each other and to everything. It is the *I* – the spiritual force or the creative energy that some attribute to our gods, the cosmos or to nature. It allows us to recognize one another before we introduce our names or our background. The *Hā*, the *Wai*, and the *I* is the "mission statement" that guides us and tells us to care for the air, the water, and the spirits. Watch what you eat and serve others, and watch how you treat your friends and your place. Our *kuleana* – our responsibility – in our home, *Hawai'i*, is to do just that. To care for the air, the water, and the spirits; for ourselves and for others; for the present as well as for the future, as we honor our ancestors in the past. This captures it all. And I have the honor of working with these people and others like them on a regular basis. How much better can that be?

Select Comments and Questions from Workshop Participants

During the panel discussion, workshop participants and observers provided feedback via the live chat log and a Google Form. Select questions were relayed to our panelists, and many observations and experiences were shared with all. Below are a few examples (edited for length and clarity).

One anonymous contributor to the Google Form raised an issue that was touched upon in earlier conversations with our panelists. It concerned the emphasis of NOAA OER and its partners on deep-water environments and warrants further consideration as relationship building begins: *"If assets and resources are focused on collecting data farther offshore, how might NOAA OER and others engage with communities who have identified nearshore priorities?"*

Dr. Russell Hopcroft (University of Alaska Fairbanks) brought up an interesting point with respect to raising expectations: *"If only one in ten science proposals are funded, how do you engage a community when the probability that nothing will materialize is high (and you have no advance funding for that engagement)?"* As a reply, Dr. James Kendall (BOEM Alaska Region) recommended: *"…build[ing] bridges with researchers already with contacts in communities."* Dr. Erik Cordes (Temple University) added: *"You make connections and collaborations in the same way that you would develop a team for a proposal. Everyone understands that funding is not guaranteed."*

The panel saw resonance with the notion of stewardship. Dr. David Butterfield (NOAA PMEL) reminded everyone that: *"The purpose of our exploration and research has to fit the NOAA mission of stewardship above all else. Understanding how the whole system works and communicating it."*

Some participants wondered how stewardship aligns with the push for a sustainable Blue Economy. Dr. Amy Baco-Taylor (Florida State University) asked: *"How do we bring the message of regeneration and restoration of a tired ocean to people who are pushing to take more?"* David Butterfield agreed: *"The Blue Economy can't be based on extraction, or taking, it has to be built on a healthy ocean and sustainable practices."*

With respect to the international community, RADM Jonathan White, USN (ret.) from COL asked: *"Is the [United Nations Decade of Ocean Science for Sustainable Development] doing enough around transformational inclusionary thinking and acting? Without such, I fear [the U.N. Decade] will be much less successful than it otherwise could be. Perhaps U.S.-led ocean exploration, especially in the Pacific, could advance this framework in the dramatic manner that is needed."*

During the panel discussion, James Kendall contributed insight from his personal experiences working in Alaska: *"…maybe we just need to remember, or develop, a new perspective; the community does not need a seat at the table; rather, it is 'their table', and 'we' should be asking for a seat."*

REFERENCES

Kendall, J. J., Brooks, J. J., Campbell, C., Wedemeyer, K. L., Coon, C. C., Warren, S. E., Auad, G., Thurston, D. K., Cluck, R. E., Mann, F. E., Randall, S. A., Storzer, M.A., Johnston, D.W., Meyer-Pietruszka, D., and Haller, M.L. (2017). Use of traditional knowledge by the United States Bureau of Ocean Energy Management to support resource management. *Czech Polar Reports*, 7(2), 151-163.

CONCLUSION

The *Workshop to Identify National Ocean Exploration Priorities in the Pacific* has taken advantage of a unique set of circumstances to carry out an extended discussion on the potential and the promise of ongoing and future ocean exploration activities in the Pacific. The workshop was originally planned as a traditional in-person workshop to be held in March-April 2020, but instead evolved into a series of virtual events in response to the COVID-19 pandemic. However, hosting virtually afforded the opportunity to invite a longer list of participants than that of an in-person workshop, which resulted in very robust feedback. The content of this report represents this broad sharing of expertise during the workshop by individuals from across government, academia, industry, and other private organizations.

This workshop helps to set the stage for the work that NOAA OER and others, both in partnership and independently, are going to conduct in the Pacific. The workshop will also be helpful in informing the planning and implementation of ocean-focused U.S. national strategies, such as the NOMEC Strategy, and for mobilizing the global ocean exploration community in support of national and international strategies and opportunities, such as the U.N. Decade of Ocean Science for Sustainable Development.

This report provides expedition strategists a well-thought out set of priorities and considerations for detailed planning activities, such as dedicated “flagship” ocean exploration missions in the Pacific and potential ConOps workshops. The findings support the need for collaborative, national-scale ocean exploration to fill vast (and sometimes four-dimensional) information gaps and identify opportunities for ocean exploration to have greater impact in supporting a sustainable Blue Economy. Partnerships are essential, but they will require effort and may require tradeoffs and lifting of barriers (e.g., legal) that limit private engagement in exploration activities. Ongoing venues for cross-sectoral dialogue and sharing of needs will be critical to meeting the priorities outlined in this report. Finally, as pointed out by cultural practitioners and across all the breakout groups, ocean exploration must involve from the outset relationship building and the sustained involvement of Indigenous communities as partners in this vast, largely unexplored region.

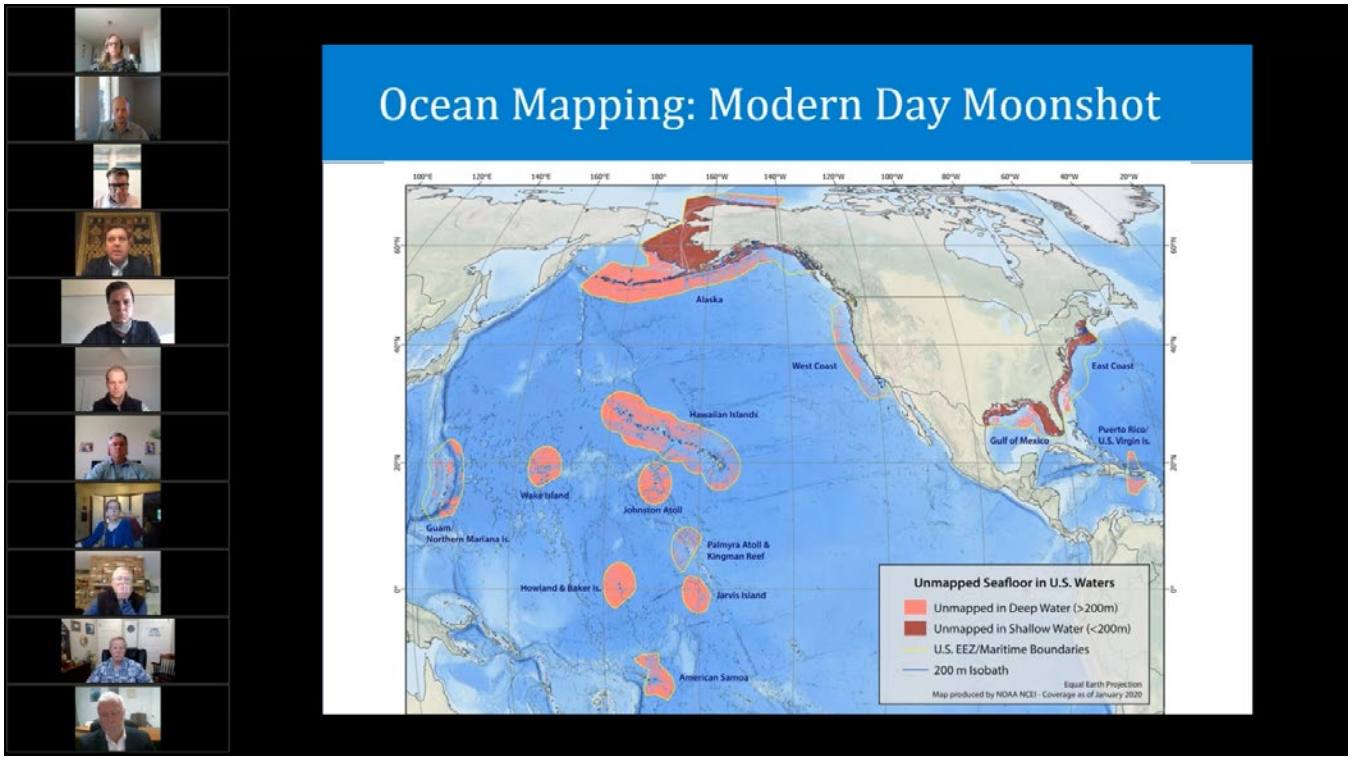


FIGURE ii: *A screenshot from the virtual closing plenary meeting on September 21, 2020.*

APPENDIX A:
WORKSHOP SCHEDULE AND AGENDAS

SCHEDULE OF VIRTUAL EVENTS

Opening Plenary – July 10, 2020

Cultural Heritage Breakout Sessions – July 22 & 24, 2020

Seafloor Characterization Breakout Sessions – July 28 & 29, 2020

Marine Resources Breakout Sessions – July 30 & 31, 2020

Water Column Characterization Breakout Sessions – August 7 & 11, 2020

Biology Characterization Breakout Sessions – August 10 & 13, 2020

Closing Plenary – September 21 & 22, 2020

OPENING PLENARY AGENDA

July 10, 2020 (1:00-4:45pm EDT)

1:00pm Opening Remarks by RADM Jonathan White, USN (ret.) – President & CEO – COL

1:10pm Remarks by RDML Timothy Gallaudet, USN (ret.) – Assistant Secretary of Commerce for Oceans and Atmosphere, Deputy Administrator – NOAA

1:30pm Introduction to the Workshop by Dr. James A. Austin – Workshop Moderator – NOAA OER

1:45pm Remarks by Dr. Alan Leonardi – Director – NOAA OER

2:00pm Workshop Objectives Q&A

2:15pm Break

2:30pm Introduction to the Breakout Topics

- Cultural Heritage: Dr. James Delgado – SEARCH, Inc.
- Seafloor Characterization: David Millar – Fugro
- Biology Characterization: Dr. Amanda Demopoulos – USGS
- Water Column Characterization: Dr. Michael Vecchione – NOAA Fisheries
- Marine Resources: Jeremy Potter – BOEM

3:45pm Break

4:00pm Breakout Objectives Q&A

4:15pm Inclusive and Equitable Partnerships in the Pacific and Beyond – Dr. James A. Austin – NOAA OER

4:30pm Workshop Timeline and Concluding Remarks by Moderator & COL Staff

4:45pm Meeting Adjourn

CLOSING PLENARY AGENDA

Day 1: September 21, 2020 (1:00-5:30pm EDT)

1:00pm	Welcome, Housekeeping, and Opening Remarks by RADM Jonathan White, USN (ret.) – President & CEO – COL
1:05pm	Introduction and Day 1 Objectives by Dr. James A. Austin – Workshop Moderator – NOAA OER
1:15pm	Workshop Remarks and Ocean Exploration Updates by Dr. Alan Leonardi – Director – NOAA OER
1:35pm	Presentation on the Blue Economy by John Kreider – Chair – NOAA Science Advisory Board & NOAA OEAB Blue Economy Subcommittee
2:00pm	Break
2:10pm	Cultural Heritage Breakout Summary and Discussion/Q&A
2:55pm	Seafloor Characterization Breakout Summary and Discussion/Q&A
3:40pm	Break
3:55pm	Biology Characterization Breakout Summary and Discussion/Q&A
4:40pm	Marine Resources Breakout Summary and Discussion/Q&A
5:25pm	Day 1 Closing Remarks by Dr. James A. Austin – Workshop Moderator – NOAA OER
5:30pm	Meeting Adjourn

Day 2: September 22, 2020 (1:00-5:00pm EDT)

1:00pm	Welcome, Housekeeping, and Day 2 Objectives by Dr. James A. Austin – Workshop Moderator – NOAA OER
1:05pm	Water Column Characterization Breakout Summary and Discussion/Q&A
1:50pm	Break
2:00pm	*DE&I in the Pacific* Panel Discussion – Dr. Genene Fisher – Panel Moderator – NOAA OER
3:30pm	Break
3:45pm	Workshop Priorities, Outcomes, and Final Report Discussion – Dr. James A. Austin – Workshop Moderator – NOAA OER
4:55pm	Final Closing Remarks by RADM Jonathan White, USN (ret.) – President & CEO – COL
5:00pm	Meeting Adjourn

APPENDIX B:
WORKSHOP PARTICIPANT LIST

BIOLOGY CHARACTERIZATION BREAKOUT GROUP

Diva Amon . . . . Natural History Museum, London
Amy Baco-Taylor . . . . Florida State University
Erik Cordes . . . . Temple University
Amanda Demopoulos . . . . USGS Wetland and Aquatic Research Center
Peter Edwards. . . . . Pew Charitable Trust
Steve Gittings . . . . NOAA Office of National Marine Sanctuaries
David Itano . . . . Western Pacific Regional Fishery Management Council
Randall Kosaki. . . . . Papahānaumokuākea Marine National Monument
Lisa Levin . . . . Scripps Institution of Oceanography
Shirley Pomponi . . . . Florida Atlantic University
Daniel Wagner. . . . . Conservation International

CULTURAL HERITAGE BREAKOUT GROUP

David Ball . . . . BOEM Pacific Region
Rick Brennan . . . . NOAA Office of Coast Survey
James Delgado . . . . SEARCH, Inc.
Cameron Hume . . . . NOAA OEAB
Robert Kraft . . . . Vulcan, Inc.
Megan Lickliter-Mundon . . . . Beacon Heritage
Russell Matthews . . . . Air/Sea Heritage Foundation
Robert Neyland . . . . Naval History and Heritage Command
Matthew Piscitelli . . . . SEARCH, Inc.
Ole Varmer . . . . The Ocean Foundation

MARINE RESOURCES BREAKOUT GROUP

Robert Ballard . . . . Ocean Exploration Trust
Amy Gartman . . . . USGS Pacific Coastal and Marine Science Center
James Kendall. . . . . BOEM Alaska Region
Brian Kennedy. . . . . Boston University
Beth Orcutt . . . . Bigelow Laboratory for Ocean Sciences
Ruth Perry . . . . Shell Exploration & Production Company
Jeremy Potter . . . . BOEM Pacific Region
Christopher Scholin . . . . MBARI
Hans Smit . . . . Ocean Minerals LLC
Janet Watt . . . . USGS Pacific Coastal and Marine Science Center

SEAFLOOR CHARACTERIZATION BREAKOUT GROUP

David Butterfield . . . . University of Washington
Megan Carr . . . . BOEM Alaska Region
Vicki Ferrini . . . . Lamont-Doherty Earth Observatory
Sebastien de Halleux . . . . Saildrone, Inc.
Larry Mayer . . . . University of New Hampshire CCOM/JHC
Laurie Meyer. . . . . Ocean Minerals LLC
David Millar . . . . Fugro
Kira Mizell . . . . USGS Pacific Coastal and Marine Science Center
Kim Picard . . . . Geoscience Australia
Robert Pockalny . . . . University of Rhode Island
Mattie Rodrigue . . . . OceanX
Dorsey Wanless . . . . Boise State University
Amanda Williams . . . . U.S. Department of State

WATER COLUMN CHARACTERIZATION BREAKOUT GROUP

Kelly Benoit-Bird . . . . MBARI
Brian Connon . . . . USM Hydrographic Science Research Center
Alice Doyle . . . . UNOLS
Christopher German . . . . WHOI
Donglai Gong . . . . Virginia Institute of Marine Science
Russell Hopcroft . . . . University of Alaska Fairbanks
Eric King . . . . Schmidt Ocean Institute
Wade Ladner . . . . Naval Oceanographic Office
Nicole Raineault . . . . Ocean Exploration Trust
Tracey Sutton . . . . Nova Southeastern University
Michael Vecchione. . . . . NOAA Fisheries and National Museum of Natural History

APPENDIX C:
DE&I IN THE PACIFIC – PANELIST BIOGRAPHIES

Papali‘i Dr. Tusi Avegalio is the Director of the Pacific Business Center Program and former Executive Director of the Honolulu Minority Business Enterprise Center at the Shidler College of Business Administration, University of Hawai‘i at Mānoa. Dr. Tusi has the unique distinction of being a recognized business, economic, and community development expert of Oceania; an academic; and is a ranking Pacific traditional leader from the Sāmoan Islands. He was bestowed the title of Papali‘i in 1980 as a senior heir to the Mālietoa warrior king line of Sāmoa in Sapapali‘i village in the island of Savai‘i. He is the first Pacific Islander born and raised in Oceania to serve on the University of Hawai‘i College of Business Administration faculty as a business professor, starting in 1989. Dr. Tusi has worked extensively throughout the Pacific in collaboration with traditional leaders and village councils of Micronesia, Melanesia, and Polynesia. He was raised in a social-cultural context that views Earth as an organic living entity; rooted in regeneration, symbiosis, and synergy, a perspective that also embraces man’s kincentric relationship to nature based on balance, harmony, *Alofa* (Love), and respect. That perspective helps to reconcile the conventional mechanistic perspectives led by the industrial/machine paradigm with the organic/living paradigm of Indigenous Oceania, a perspective he feels are the keys to effectively addressing Pacific and global challenges that takes the best of both worlds and creates a third option with value added.

Dr. Wendy F. Smythe is Alaska Native Haida from Hydaburg, Alaska. Her Haida name is K’ah Skaahluwaa (laughing lady), from the Xáadas (Haida) clan of Sdast’ aas (Fish egg house). Dr. Smythe is an Assistant Professor at the University of Minnesota Duluth (UMD) with a joint appointment in the Departments of American Indian Studies and Earth & Environmental Sciences. Prior to joining UMD, she served as an American Association for the Advancement of Science, Science & Technology Policy Fellow, hosted by the National Science Foundation, working across the Directorates for Education & Human Resources and Geoscience in the Division of Earth Science Systems. Dr. Smythe is a research geoscientist whose research focus is on examining microbial diversity, biogeochemistry, and biomineralization in metalliferous groundwater and marine ecosystems from deep-sea hydrothermal volcanoes to hydrothermal springs in southeast Alaska and Yellowstone National Park, and in examining environmental health and its impacts on Indigenous first foods. She is an Assistant Editor for the Journal of Geoscience Education. Dr. Smythe has partnered with her tribal community for over a decade, coupling Traditional Knowledge with geoscience to create culturally aligned K-12 science curriculum. She serves on the Board of Directors for the tribal nonprofit, Xáadas Kil Kuyáas Foundation, a 501(c)3 whose mission is to promote, preserve, and perpetuate the Northern Haida language. Through her work, she seeks to increase the number of Native American and Alaska Native students represented in STEM disciplines to increase diversity and innovation, and to empower the next generation of Native leaders.

Kahu M. Kalani Souza is the Founding and current Director of the Olohana Foundation, a nonprofit based on Hawaiʻi's Big Island since 2008. Olohana focuses on building community capacity, cohesiveness, resilience, and emergency preparedness around food, energy, water, and knowledge systems. He is an esteemed *Kahu*, or keeper of wisdom and Hawaiian Elder, who advocates for the weaving of traditional wisdom and cultural values with modern science, knowledge, and technology. Recognized locally, nationally, and internationally, he is a renowned practitioner of *Aloha* and cross-cultural facilitator of Hawaiian spirituality. He is a mentor and resource who has lectured extensively on social justice through conflict resolution at the Spark Matsunaga Center for Peace and at the University of Hawaiʻi at Mānoa in the Department of Urban and Regional Planning. His native roots allow him a unique perspective of the collision of two worlds – one steeped in traditional culture and the other a juggernaut of new morality and changing economic and political persuasion. He serves as a Cultural Competency Consultant for the NOAA Pacific Services Center and as a Coastal Community Resilience Trainer with FEMA Consortium member, the National Disaster Preparedness Training Center at the University of Hawaiʻi. Kalani was awarded the *Aloha Global Ku Award* at the Hawaiʻi Global Breadfruit Summit in 2016 for his advocacy of low glycemic, gluten free, and high plant protein breadfruit to fight global diabetes, obesity, heart disease, and renal disease. Oceania leads the world with those health scourges.

Kahu Ramsay Taum is recognized locally, nationally, and internationally for transformational leadership in sustainability, cultural, and place-based values integration into contemporary business models. Kahu Taum advocates team building, strategic partnerships, community brilliance, and creative thinking. He is a recognized cultural resource, sought-after keynote speaker, lecturer, trainer, and facilitator. He is especially effective working with Hawaiʻi's industries where he integrates Native Hawaiian cultural values and principles into contemporary business. Mentored and trained by respected *kūpuna* (elders), he is a practitioner and instructor of several Native Hawaiian practices: hoʻoponopono (stress release and mediation), lomi haha (body alignment), and Kaihewalu Lua (Hawaiian combat/battle art). He graduated from The Kamehameha Schools, attended the United States Air Force Academy at Colorado Springs, and earned a B.S. degree in public administration from the University of Southern California. His eclectic background and experience in business, government, and community service makes him a valuable asset in the public and private sectors, and has been instrumental in for-profit and nonprofit businesses. In 2009, Kahu Taum was recognized and honored by the University of Hawaiʻi as a *Star of Oceania*, an honor presented every three years to extraordinary individuals of Oceania for their work and service-related contributions to raising greater awareness of Oceania and its people to the nation, region, and world.

APPENDIX D:
LINKS TO WHITE PAPERS, PRESENTATION SLIDES, VIDEO RECORDINGS, AND OTHER WORKSHOP MATERIALS

- **Link to the COL Website.** This is the primary page for the *Workshop to Identify National Ocean Exploration Priorities in the Pacific*. All presentation slides, video recordings, agendas, as well as other background information from the workshop are available here:

  https://oceanleadership.org/ocean-exploration/

- **Link to the 2014 White Papers.** These white papers were submitted in advance of OET's 2014 workshop on *Telepresence-Enabled Exploration of the Eastern Pacific Ocean*. Participants of the 2020 workshop were encouraged to review these:

  PDF: *https://oceanleadership.org/wp-content/uploads/2020/07/2014EasternPacificWorkshopWhitePapers_21Nov.pdf*

- **Links to the 2020 White Papers.** These white papers were submitted in advance of the *Workshop to Identify National Ocean Exploration Priorities in the Pacific*:

  PDF: *https://oceanleadership.org/wp-content/uploads/2020/04/OE-Workshop-White-Papers.pdf*

  ArcGIS Online Map: *https://services7.arcgis.com/2bxwn493gUBN0otH/arcgis/rest/services/OE_Pacific_Priorities_Workshop_White_Papers_(2020)_view/FeatureServer*

APPENDIX E:
LIST OF 2020 WHITE PAPERS

The Northern Line Seamounts: Opportunities for New Exploration of Deep-water Communities in the Pacific Prime Mineral Crust Zone
Steven Auscavitch (Temple University)

NOAA Ocean Exploration Cooperative Institute: Exploration Vessel Nautilus Pacific Field Proposal 2021-2023
Robert Ballard (Ocean Exploration Trust)

Seep and Hydrothermal Vent Exploration at the Alaska Margin through Multibeam Mapping, Targeted Sampling, Plume Mapping, and Geochemical Analysis
Jeffrey Beeson (NOAA Pacific Marine Environmental Laboratory)

Pacific Wrecks of World War II: Submerged Landscape of an Aerial War
Michael Brennan (SEARCH, Inc.)

Shipwrecks of the Cold War: The Target Ships from Operation Crossroads
Michael Brennan (SEARCH, Inc.)

Exploring Earthquake Hazards, Environmental History, and Seabed Ecosystems along the Aleutian Subduction Zone and Queen Charlotte Fault, Southern and Southeastern Alaska
Danny Brothers (USGS Pacific Coastal and Marine Science Center)

Exploration Priorities in the National Marine Sanctuary of American Samoa
Valerie Brown (National Marine Sanctuary of American Samoa)

Collaboration for Exploring Offshore Alaska: Leveraging Current Projects for Value Added Seafloor Mapping and Characterization
Kelley Brumley (Fugro)

Systematic Exploration of the Mariana Region
David Butterfield (NOAA Pacific Marine Environmental Laboratory)

Targeted Seafloor Mineral Science and Mapping in the Arctic and Aleutian Arc Large Marine Ecosystems
Megan Carr (BOEM Alaska Region)

Biodiversity and Connectivity along a Costa Rican Mountain Range from Offshore to the Mainland
Jorge Cortés (Universidad de Costa Rica)

Maritime Heritage of Alaska
James Delgado (SEARCH, Inc.)

Submerged Landscapes, Human Coastal Migration, and Early Maritime Adaptations
James Delgado (SEARCH, Inc.)

Cascadia Margin Cold Seeps: Subduction Zone Fluids, Gas Hydrates, and Chemosynthetic Habitats
Amanda Demopoulos (USGS Wetland and Aquatic Research Center)

Mapping, Exploration, and Characterization of the California Continental Margin and Associated Features from the California-Oregon Border to Ensenada, Mexico
Amanda Demopoulos (USGS Wetland and Aquatic Research Center)

Guam and Commonwealth of Northern Mariana Islands Critical Marine Minerals
Alden Denny (BOEM Marine Minerals Division)

Exploration of Mesopelagic Boundary Layer Communities and Near Island Aggregations of Micronekton
Jeffrey Drazen (University of Hawai‘i at Mānoa) and Michael Vecchione (NOAA Fisheries and National Museum of Natural History)

Exploration of Seafloor and Midwater Communities in the Clarion Clipperton Zone
Jeffrey Drazen (University of Hawai‘i at Mānoa)

Alaska/Aleutian Subduction Zone
Vicki Ferrini (Lamont-Doherty Earth Observatory)

Juan de Fuca Plate
Vicki Ferrini (Lamont-Doherty Earth Observatory)

Baseline Data Collection: Gorda Ridge through Blanco Fracture Zone
Amy Gartman (USGS Pacific Coastal and Marine Science Center)

Polymetallic-Nodule-bearing Abyssal Plains and Associated Ecosystems in the Western Pacific Ocean
Amy Gartman (USGS Pacific Coastal and Marine Science Center)

Unknown But Not Unknowable: The South Pacific Basin
Christopher German (WHOI)

Exploring the Deep Reaches of West Coast National Marine Sanctuaries
Steve Gittings (NOAA Office of National Marine Sanctuaries)

The Bering Strait: A Rapidly-Changing Subpolar Environment with Underexplored Potential
Jacqueline Goordial (Lamont-Doherty Earth Observatory)

Exploration of Deep Waters of the Aleutian Islands: America’s Last Marine Frontier
Russell Hopcroft (University of Alaska Fairbanks)

Unexplored Seamounts in the Gulf of Alaska
Katrin Iken (University of Alaska Fairbanks)

Deep Bottomfish Habitat Characterization of American Samoa, Guam and the Commonwealth of the Northern Mariana Islands (CNMI)
David Itano (Western Pacific Regional Fishery Management Council)

Monitoring the Condition and Rate of Recovery of Fishery Resources of the Emperor Seamounts Useful for Management
David Itano (Western Pacific Regional Fishery Management Council)

Hess Rise, Liliuokalani Ridge, and Musicians’ Seamounts
Brian Kennedy (Boston University)

Biodiversity of Seamounts in the Papahānaumokuākea Marine National Monument
Randall Kosaki (Papahānaumokuākea Marine National Monument)

Characterizing the Ecosystems Associated with Mineral Deposits (Phosphorites and Polymetallic Crusts) in the North Pacific Ocean
Lisa Levin (Scripps Institution of Oceanography)

Aviation's Lost Pioneers: Pan American Airways Samoan Clipper (NC16734)
Russell Matthews (SEARCH, Inc.)

Marine Minerals and Associated Ecosystems in the Northwest Pacific Ocean
Kira Mizell (USGS Pacific Coastal and Marine Science Center)

Liliuokalani Ridge Seamounts: Mineral Crusts, Benthic Habitat, and Ecosystem Services in an Un-mapped and Unexplored Region of the US EEZ and International Waters
Beth Orcutt (Bigelow Laboratory for Ocean Sciences)

The Pacific-Antarctic Rise: An Uncharacterized Mid-Ocean Ridge
Beth Orcutt (Bigelow Laboratory for Ocean Sciences)

Aleutian Trench/Arc System
Robert Pockalny (University of Rhode Island)

Central Pacific Abyssal Channel
Robert Pockalny (University of Rhode Island)

Niue Trough
Robert Pockalny (University of Rhode Island)

BOEM West Coast and Hawaii Ocean Mapping, Exploration, and Characterization Priorities
Jeremy Potter (BOEM Pacific Region)

'EXPRESS': An Ongoing U.S. West Coast Campaign and Potential 'Cell' in Broader Pacific Effort
Jeremy Potter (BOEM Pacific Region)

Augmenting Sample Size for Depth, Feature, and Region from CAPSTONE 2015-2017 Efforts
Randi Rotjan and Brian Kennedy (Boston University)

Phoenix Islands Protected Area (PIPA) and Howland and Baker Unit of PRIMNM
Randi Rotjan (Boston University)

Exploration of High Seas Coral Reefs in the North Central Pacific
Daniel Wagner (Conservation International)

Systematic Deepwater Mapping along the Cascadia Subduction Zone Critical for Exploration and Hazard Science
Janet Watt (USGS Pacific Coastal and Marine Science Center)

This page intentionally left blank.

Ocean Exploration

Published November 2020. This report was compiled and edited by Katie Fillingham, Daniel Rogers, and Kristen Yarincik, with immense authorship support from Dr. James A. Austin, Jr. and the Breakout Co-Leads. A special thanks to Abby Ackerman and Jason Mallett for their essential roles in editing and graphic design.

CONSORTIUM FOR Ocean Leadership