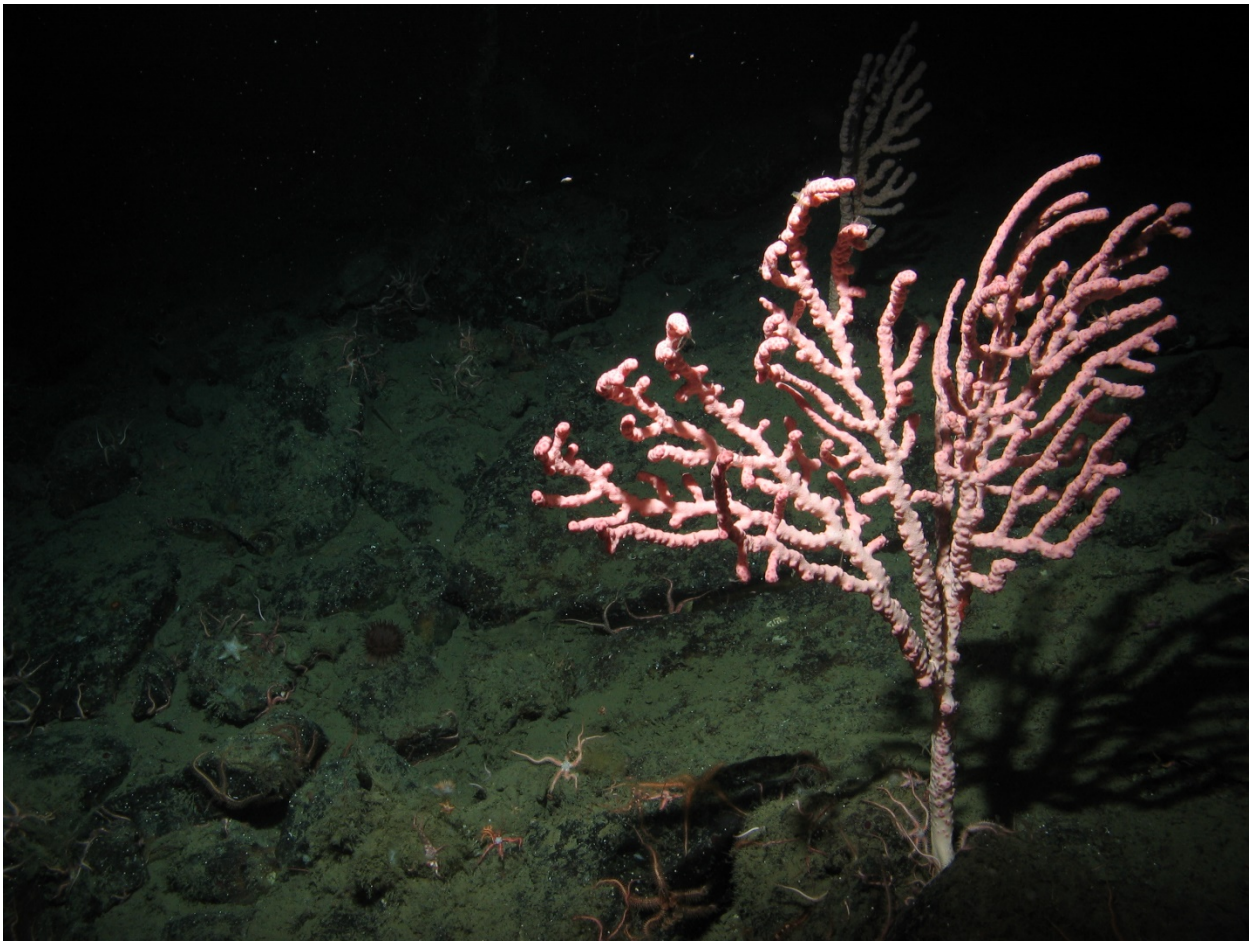
West Coast Deep-Sea Coral Initiative Science Plan (2018-2021)



Paragorgia sp. at the "Brush Patch" off Northern California (DSCRTP)

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Introduction

This Science Plan presents the objectives, proposed work-plan, and anticipated outcomes for the National Oceanic and Atmospheric Administration (NOAA) West Coast Deep-Sea Coral Initiative (WCDSCI) under the Deep Sea Coral Research and Technology Program (DSCRTP). The four-year Initiative (FY 2018-2021) is designed to work with partners to discover, map, characterize, explore, and conduct research on deepwater coral and sponge habitats in support of natural resource management off California, Oregon and Washington. The Science Plan was developed by a cross-NOAA steering committee with input from numerous partners and stakeholders. The Steering Committee will review the plan annually and provide ongoing guidance on implementation and budget. Out-year activities are subject to federal appropriations.

NOAA Deep Sea Coral Research and Technology Program: Mission and Objectives

NOAA established the DSCRTP under the authority of the Magnuson-Stevens Fishery Conservation and Management Act, as reauthorized in 2007. The goal of DSCRTP is to provide scientific information needed to manage, conserve, and protect DSCS ecosystems throughout the United States. These ecosystems create important biogenic habitats and support remarkably complex communities in deep waters around the globe, including off the U.S. West Coast (Clarke et al. 2017).

In carrying out their mission, DSCRTP supports multi-year regional fieldwork initiatives that produce new research along with analyses of historical data. To-date initiatives have been carried out in the South Atlantic (2009-2011), West Coast (2010-2012), Alaska (2012-2014), Northeast (2013-2015), Pacific Islands (2015-2017), and the greater Southeast (2016-2020) regions. Field work has included mapping, quantitative visual surveys and sample collection conducted in collaboration with regional fishery management councils, NMS, other federal agencies, academic partners, industries and non-government organizations (NGO) that collect and analyze information on DSCS location, biology, ecology, and potential anthropogenic impacts.

A national-level data management infrastructure supports these regional initiatives, allowing DSCRTP-supported data to be accessible by the public. In 2018, DSCRTP initiated the second regionally-led deep-sea coral research program on the U.S. West Coast, referred to as the West Coast Deep-Sea Coral Initiative (WCDSCI). WCDSCI's timeline (2018-2021), goals, priorities, and accomplishments to-date are described in the sections that follow.

Introduction to the West Coast Deep-Sea Coral Initiative (2018-2021)

Location and Biogeography of the U.S. West Coast Region

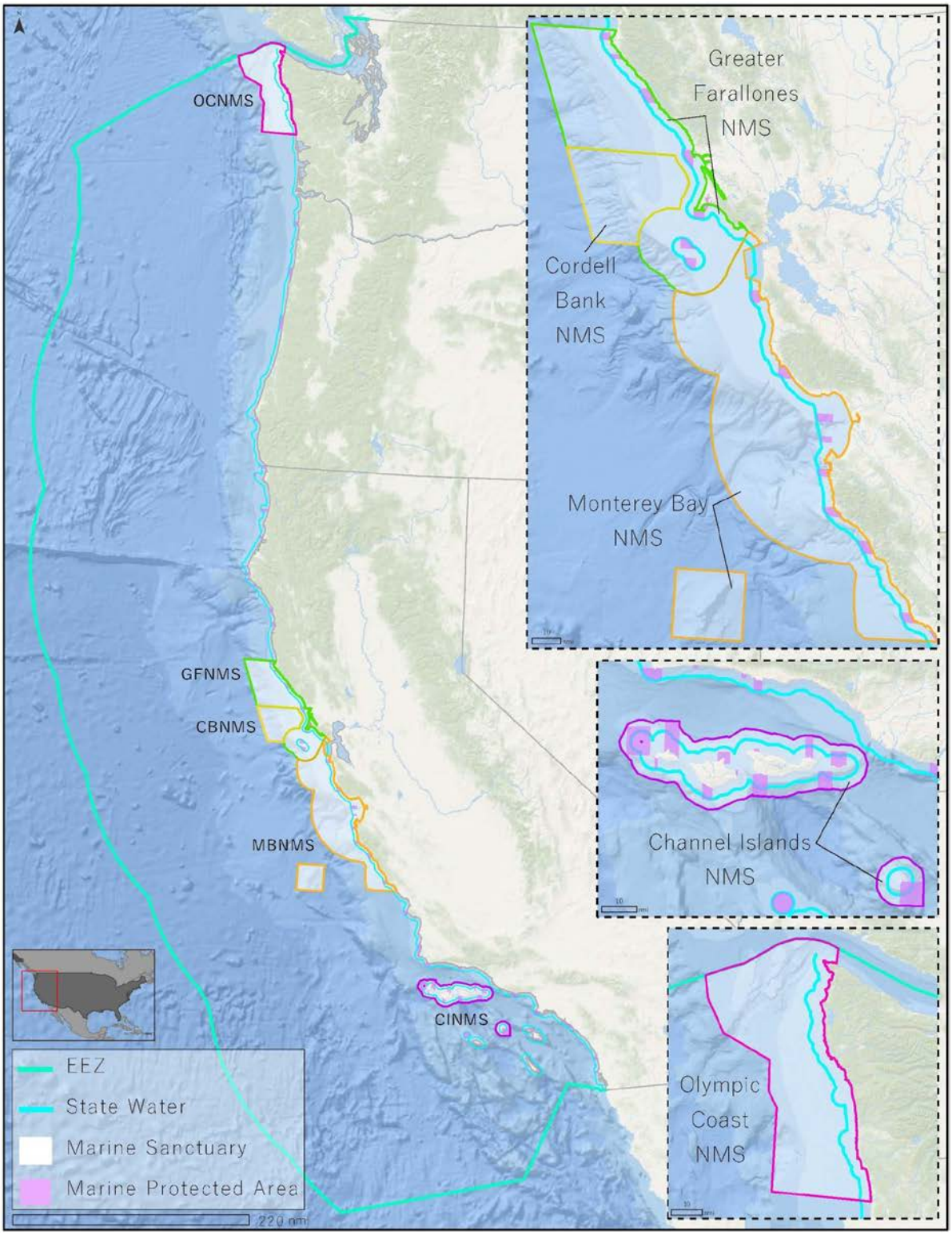
The U.S. Pacific Coast marine region encompasses the continental margin off the coasts of Washington, Oregon, and California, totaling 778,628 km^2 (Figure 1). The continental margin in this region is characterized by a relatively narrow (5-40 km) shelf and a steep continental slope, with the shelf break at approximately 200 m water depth. Other bathymetric features present off the West Coast include offshore islands, seamounts, oil and methane seeps, and submarine canyons. This marine region is wholly within the California Current Large Marine Ecosystem and includes two biogeographic provinces: the Oregonian province, which is a cold-temperate area in the north characterized by the southward flowing California Current, and the warm-temperate Californian province in the south, which is more heavily influenced by the northward flowing Davidson Current and Southern California Countercurrent. The two provinces converge near Point Conception in southern California, marking a major transition zone and biogeographic break where many species reach their northern or southern range limits. Frequent upwelling events are also characteristic of both west coast provinces, exposing the coastline to cold, nutrient rich, low pH, and oxygen depleted water during summer months when upwelling is strongest. The strength, duration, and timing of upwelling events are highly influenced by El Niño Southern Oscillations, Pacific Decadal Oscillations, as well as the local bathymetry (Fautin et al. 2010). The resulting variability in pulses of primary productivity creates a dynamic and complex marine environment along the West Coast. In recent years, however, typical upwelling patterns and other oceanographic processes have been disrupted, coincident with extreme weather events (e.g., marine heat waves and extended hypoxic events) with observed anomalies from the sea surface to at least 200 m in depth (Grantham et al. 2004; Harvey et al. 2017). Consequences of these anomalies are better understood for marine life such as marine mammals and fishery species than for marine life inhabiting the deep seafloor.

Regional Management of DSCS

To date, physical disturbance from bottom-tending fishing gear has been one of the largest chronic threats to DSCS. The Pacific Fishery Management Council (PFMC) and NOAA have been protecting DSCS, both directly and indirectly, through groundfish fishery management measures. DSCS are among the habitat types that benefit from the network of essential fish habitat conservation areas (EFHCAs) that prohibit bottom trawling and, in some cases, other types of fishing gear in contact with the seafloor. The EFHCA network presently contains 10,225 km^2 of hard and mixed substrate, including areas where DSCS are known to occur.

DSCS and other benthic habitats are also indirectly protected by bottom-trawl closures designed to minimize bycatch of overfished species, such as trawl rockfish conservation areas (RCAs)

Figure 1: Map of the U.S. West Coast, the study area of the regional DSCRTP supported initiative**.**



and cowcod conservation areas (CCAs). The RCA is a large-scale closed area extending along the entire length of the U.S. West Coast, covering 13,071 km^2. The RCA contains approximately 1,079 km^2 of hard and mixed substrate that includes numerous observations of DSCS. The two CCAs cover 13,315 km^2, and contain 995 km^2 of hard and mixed substrate, also with numerous observations of DSCS.

How much DSCS habitat resides within the bottom-trawl closed areas is not clear based on the general lack of high resolution mapping and visual survey data in the region. However, the different types of fishery management closures, some of which overlap, cover approximately 375,000 km^2.

Most recently, Amendment 28 to the Groundfish Fishery Management Plan (FMP) was approved by the PFMC in April 2018, and when implemented, will modify the suite of EFHCAs and eliminate (i.e., reopen to bottom-contact fishing) the trawl RCA off Oregon and California. No changes were proposed for federal waters off Washington State as part of Amendment 28. This PFMC action was informed by data in NOAA's National Database of Deep-Sea Corals and Sponges (current version 20190418-0; Hourigan et al. 2015) as well as input from the fishing industry. New essential fish habitat closures will cover approximately 33,670 km^2, and approximately 7,770 km^2 will be reopened to bottom trawling. Approximately 228 km^2 of hard substrate will be reopened to trawling, while another 2,033 km^2 of hard substrate will be closed to bottom trawling. The areas that will be reopened have been closed to bottom trawling for the past 12-16 years and present a unique opportunity to study the recovery potential of DSCS. Amendment 28 will also close all waters deeper than 3,500 m to bottom-contact gear. Although comprehensive substrate data are unavailable for this large area of the U.S. exclusive economic zone, numerous observations of DSCS have been recorded throughout.

In addition to protections that accrue from the fisheries management processes described above, NOAA has also provided protections to DSCS through establishment and management of five national marine sanctuaries (NMS) on the West Coast. West coast sanctuaries afford protections for more than 38,850 km^2 of seafloor habitats and communities encompassed by sanctuary boundaries, each of which includes DSCS habitat: Channel Islands NMS (CINMS), Monterey Bay NMS (MBNMS), Greater Farallones NMS (GFNMS), Cordell Bank NMS (CBNMS), and Olympic Coast NMS (OCNMS). Although NMS do not regulate fishing activities, sanctuary regulations prohibit alteration of submerged lands and other types of human uses that could potentially harm DSCS habitat, such as oil and gas exploration/extraction, and permit others that may break sanctuary regulations but contribute to research, monitoring, and management of sanctuary resources. Each of the five sanctuaries are guided by specific management plans tailored to address site-specific issues, and each brings unique perspectives to seafloor and DSCS protection efforts. Generally, resource protection specialists across sites focus on mitigating impacts to the seafloor from marine accidents and groundings, anchoring, marine debris, and research activities through permitting processes. Some California national marine sanctuaries are also heavily engaged in addressing concerns related to bottom-contact fishing activities, and staff at these sites regularly collaborate with fishers, conservationists,

managers, and other interested parties through the formal processes of the PFMC. Some sites also have special management zones within their boundaries to further protect particularly sensitive DSCS habitat.

Over time, the reach of national marine sanctuary protections has increased through boundary modifications. For example, in November 2008, the boundaries of MBNMS were expanded by 2,007 km^2 to include Davidson Seamount, one of the largest known seamounts in U.S. waters that was found to harbor hundreds of species of deep ocean organisms (including many DSCS) and several species new to science. In 2015, the boundaries of both GFNMS and CBNMS were expanded by 3,320 km^2 and 1,370 km^2, respectively. Expansion areas include significant portions of the continental shelf and a number of submarine canyons that are highly likely to include significant DSCS living resources.

Threats to DSCS

Current and ongoing threats to DSCS along the U.S. West Coast generally stem from human activities that may have direct or indirect impacts to deep-sea habitat. Direct threats include seafloor disturbances that stem from activities such as fishing using bottom-contact gear, anchoring or mooring, marine accidents, groundings or other emergencies, installation of submarine telecommunication cables, as well as research that may disturb sensitive areas of the seafloor. The potential for new offshore industries in support of the nation's blue economy, such as aquaculture, renewable energy, or mining, represent important economic opportunities that will require baseline data to inform management and mitigation of potential impacts to these ecosystems. Indirect threats include human activities that induce changes in climate and in ocean conditions, such as ocean acidification, hypoxia, and temperature anomalies like marine heat waves. These indirect issues are assumed to continue to disrupt ocean conditions, particularly in the northern extent of this geography. For a more thorough discussion of potential threats to DSCS on the West Coast, see Clarke et al. (2017).

Past Research

The first coordinated campaign to study deep-sea corals on the U.S. West Coast was initiated in 2010 with the support of DSCRTP. Priorities for the 2010 initiative were defined in a workshop similar to the one described below (Caldow et al. 2019). The goals of the first Initiative were to determine the distribution and abundance of DSCS along the West Coast; to collect, identify, and describe unknown species of DSCS; and to examine the relationship between fish and DSCS to better understand whether DSCS act as essential fish habitat (EFH). Over 100 annotated visual surveys for coral, sponges, and habitat type were conducted along the entire West Coast as part of these efforts. More than 50% of these sites were previously unexplored. These data have been used by the PFMC during EFH decision-making processes, and have informed sanctuary boundary expansion analyses and sanctuary condition reports. Thousands of data records have been submitted to the National Database and are being used to

model habitat suitability for DSCS by the Bureau of Ocean Energy Management (BOEM) and NOAA. These data have also enabled new analyses related to understanding anthropogenic and environmental disturbances on coral and sponge assemblages (Yoklavich et al. 2018) and on octocoral reproduction (Feehan and Waller 2015). In addition, many specimens of DSCS and associated organisms were collected to confirm taxonomic identifications and for genetic, reproductive, and stable isotope analyses. This work also resulted in several new species descriptions.

WCDSCI Structure, Timeline, and Accomplishments to Date

The second regionally-led deep-sea coral research initiative on the West Coast supports DSCS research, conservation, and management for 4 years, starting in fiscal year (FY) 2018. Year 1 (2018) served as a ramp-up year to accommodate preparation and planning for the following field-intensive years (2019-2020) when the majority of research expeditions will occur. The last year (2021) will serve as a wrap-up year to conclude outstanding tasks, such as submitting data records to the National Database or finalizing manuscripts for publication.

During the 2018 ramp-up year, WCDSCI co-leads Elizabeth Clarke (Northwest Fisheries Science Center, or NWFSC) and Chris Caldow (CINMS) formed a NOAA-led steering committee with representatives from the National Marine Fisheries Service (NMFS), Office of National Marine Sanctuaries (ONMS), National Centers for Coastal Ocean Science (NCCOS), Office of Exploration and Research (OER), and DSCRTP. Following the formation of a steering committee, CINMS and NMFS organized and hosted a priority scoping workshop that captured a wide variety of perspectives from regional experts on the most pressing research and management needs relevant to the West Coast. The results from this Research Priorities Workshop (Caldow et al. 2019), which are outlined below, have heavily shaped the science priorities and activities outlined in this Plan. In addition to drafting the workshop report and beginning to prepare the Science Plan in 2018, WCDSCI also supported two DSCS cruises that visited many of the priority areas identified during the Research Priorities Workshop, thereby taking advantage of early opportunities to collect DSCS data and address critical management needs.

A sponge garden on Daisy Bank off the coast of Oregon (DSCRTP)

Thematic Foci

The Research Priorities Workshop held in April 2018 was instrumental in establishing the overarching science and management priorities that will guide WCDSCI activities over the next several years. In total, 41 experts from NOAA (NWFSC, Southwest Fisheries Science Center or SWFSC, Alaska Fisheries Science Center or AFSC, NMFS West Coast Regional Office, ONMS, NCCOS, and OER), PFMC, BOEM, U.S. Geological Survey (USGS), Fisheries and Oceans Canada (DFO), Ocean Exploration Trust (OET), Quileute Tribe, Makah Tribe, Northwest Indian Fisheries Commission, academic institutions, and NGOs participated in group sessions to identify deep-sea coral survey and product related priorities along the West Coast. Attendees were divided into small groups focused on the following topics: (1) mapping; (2) visual surveys and research questions; (3) modeling; (4) species identification, genetics, and connectivity; (5) human impacts; and (6) education and outreach products. Detailed recommendations on each of these themes are in Appendix A, but a brief summary is given here in the following sections. The activities outlined in this Science Plan were developed by the WCDSCI Steering Committee

based on the recommendations from the Research Priorities Workshop, their feasibility, intersection with NOAA goals, and were prioritized based on available funding.

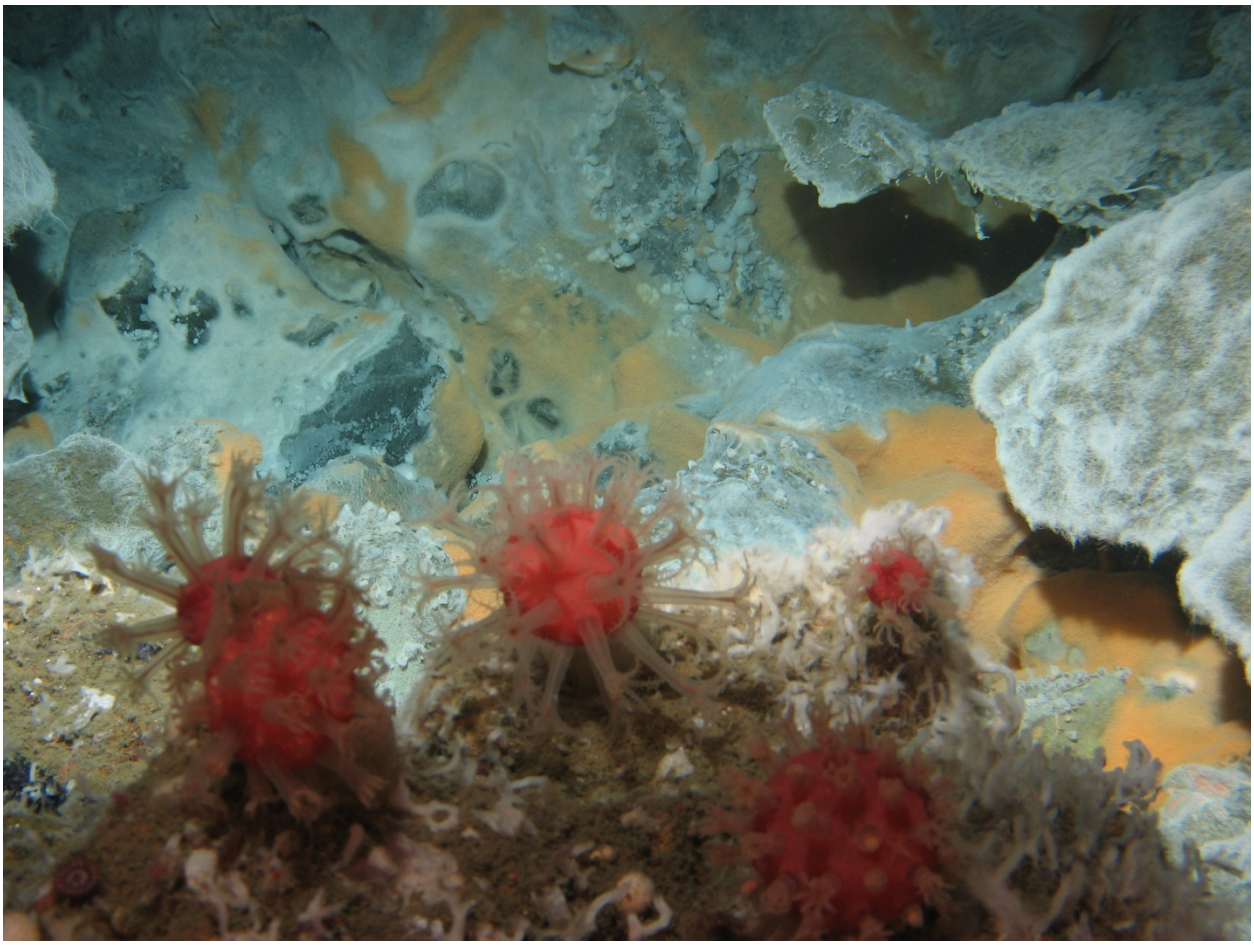
Summary of Major Place-Based Research Priorities

Overall, three major themes emerged from the Research Priorities Workshop discussions, each directly or indirectly tied to geographic locations. An emphasis was put on the following:

1. Gather baseline information from areas subject to fishing regulation changes prior to the implementation of Amendment 28 to the Pacific Coast Groundfish Fishery Management Plan.
2. Improve our understanding of known DSCS bycatch “hot spots”.
3. Explore and assess DSCS resources within NOAA National Marine Sanctuaries with emphasis on areas of sanctuary resource protection and management concerns

Summary of Priorities by Research Topic

Critical management issues, research questions, prioritized geographic locations, and outreach materials that were identified as priorities are described in more detail in Appendix A. In brief, potential priority areas were identified for the collection of multibeam bathymetry data, which are necessary to determine if an area is likely to support DSCS communities and important to safely plan remotely operated vehicle (ROV) or autonomous underwater vehicle (AUV) surveys (Appendix A.1). Participants also made a series of recommendations to improve and optimize the use of visual surveys to evaluate abundance, distribution, genetics, habitat associations, disturbances from human activities, and other key aspects of DSCS communities (Appendix A.2). Research priorities for predictive habitat modeling include incorporating important predictor variables and advancing innovative methodologies (Appendix A.3). Genetic research informs identification and connectivity studies and should be included in ongoing DSCS work on the West Coast. A preliminary list of target species for connectivity studies was compiled at the Research Priorities Workshop (Appendix A.4). DSCS are not immune to human impacts and careful consideration should be made to study effects of warming, acidification, deoxygenation, bycatch, and other impacts on DSCS communities, particularly through long-term monitoring and comparative approaches (Appendix A.5). Finally, participants brainstormed a range of ideas to share the work of WCDSCI with the public including lesson plans, story maps, museum partnerships, and the use of social media (Appendix A.6). Ultimately, the priority projects and products included in the WCDSCI Science Plan represent a subset of the many suggested by workshop participants. For a comprehensive overview of the Research Priorities Workshop, see Caldow et al. 2019.



Mushroom Corals (*Heteropolypus ritteri*) near a methane seep off Northern California (DSCRTP)

Work Plan to Address WCDSCI Priorities

The initiative will strive to collect information that addresses the shared priorities of agencies involved in the management of DSCS ecosystems on the West Coast, namely PFMC, NMFS, the five NMS, and four Coastal Treaty Tribes living on Washington State's Olympic Coast, and these organizations will be consulted regularly throughout the 4-year initiative. The main activities planned are described in the following sections. Whenever possible, WCDSCI will strive to address additional research and management needs described in the Research Priorities Workshop report, either through partnerships or potential leveraging opportunities.

To address the above goals, the planned activities supported by DSCRTP are outlined below, and mainly consist of (1) field expeditions on NOAA research ships and sanctuary vessels to collect visual survey, mapping and environmental data in fished and unfished areas, (2) the analysis of newly gathered information as well as historic data, (3) the advancement of predictive modeling efforts, (4) the continuation and advancement of genetic and taxonomic analyses, and (5) the development of both data and education/outreach products. A summary of planned field expeditions is provided in Table 1, while planned data and outreach products are detailed in Table 2.

Initiative Management

The WCDSCI management team is divided into four parts: DSCRTP, initiative leads, coordinators, and the Steering Committee. Representation from NOAA DSCRTP ensures that the initiative stays on target with national goals and objectives, is responsive to program mandates as well as to Congress, and (together with the West Coast Regional Office) is inclusive of PFMC and other relevant fishery management efforts. Second, initiative leadership is divided between NWFSC and ONMS. The co-leads are responsible for raising funding and awareness to support the initiative, building partnerships, ensuring effective and efficient use of resources, and ensuring products developed are on target with regional and national needs. The co-leads are also responsible for the selection of the next two management components (coordinators and the Steering Committee). The coordinators work to enhance connectivity across other regional initiatives as well as with headquarters. They lead project information gathering, workshop planning, Science Plan development, and report writing, as well as assist with vessel time requests, sample processing, and outreach. The Steering Committee is chiefly responsible for leading research priority and wrap-up workshops, writing the Science Plan, and making budgetary recommendations. In addition, each member of the Steering Committee is responsible for coordinating within their home office, channeling broader input, and identifying opportunities for partnership and leverage.

Funding Uncertainties & Contingencies

The Science Plan serves as a framework for additional study of these important deep-sea habitats. NOAA's DSCRTP strongly encourages identifying other potentially significant leveraging opportunities not listed below that may be achieved through additional partnerships or collaborations. Some activities are also contingent on the award of future ship time on NOAA research vessels, which is presently uncertain but has been estimated here based on past experience. Given that future ship time is unknown and that multiple proposals were submitted across NOAA offices to increase the likelihood of acquiring days at sea (DAS) to support WCDSCI research, it is possible that more ship time may awarded to WCDSCI collaborators or principal investigators (PI) than the budget can support. In this case, the Steering Committee will discuss the available options and choose to support the highest priority field missions. In the event that additional resources become available or anticipated ship time is not provided by NOAA, funds may be reallocated to other priority efforts vetted by the Steering Committee. This Plan is the result of an effort to balance new data acquisition and the analysis of historic data, however, there are more historic data sets than the balanced budget could support. Therefore, the list of prioritized contingency projects is mainly comprised of these historical data sets which will be considered first for funding should resources become available (see Table 3 for a list of the west coast data rescue needs).

Field Expeditions

Research expeditions will occur primarily on NOAA and NOAA-partner (e.g., E/V Nautilus) research ships and smaller sanctuary vessels. Research cruises planned with confirmed/awarded ship time are detailed below and summarized in Table 1. However, since ship time has yet to be awarded for FY 2020, cruises proposed for the second year of field activities are tentative and represent the best possible estimate of potential DAS on multiple vessels. Depending on the availability of vessels and staff, the following activities may occur during field missions: seafloor mapping, visual surveys via ROV and/or AUV, specimen sampling and preservation, and collection of supplemental environmental information. Also, whenever possible, field expeditions will be enhanced with small projects and experiments to address additional research priorities highlighted during the Research Priorities Workshop.

Leveraging Opportunities

Seeking common goals with other agencies within and external to NOAA can be an efficient way to address shared research priorities, integrate expertise and technology, and accomplish more than agencies acting independently. One example of an inter-agency collaboration in which WCDSCI is engaged is the EXpanding Pacific Research and Exploration of Submerged Systems (EXPRESS) campaign. The EXPRESS campaign targets data collection in deep water areas off California, Oregon, and Washington and seeks to expand collaboration among federal entities such as BOEM, USGS, the Office of Coast Survey (OCS), OER, NMFS, OET, and ONMS. The main goal of the campaign is to align resources and efforts to generate geospatially explicit habitat information in deep water ecosystems to support resource management decisions while also supporting the U.S. government's mission of growing commerce. Coordinated efforts to acquire ship time under the EXPRESS campaign were successful in 2019 and will be employed again for ship time in 2020 to address mutual deep-sea related research priorities. Another active collaboration that addresses deep-sea research needs is the partnership between OER, OET, and ONMS. OET's exploration vessel (E/V) *Nautilus* has explored each of the five west coast NMS on previous missions as well as other deep-sea areas from Mexico to Canada. The *Nautilus* is equipped with sophisticated mapping instrumentation, a set of paired deep-sea (>1000 m) ROVs, and a telepresence communication system that allows scientists from across the world to contribute to the mission in real time. In 2019, the *Nautilus* will be working within three west coast NMS, through grant funds administered by ONMS, conducting work that directly complements WCDSCI science and outreach goals.

FY 2018

Cordell Bank, Greater Farallones, and Monterey Bay NMS, NOAA Ship *Shimada*

Although the initiative did not request ship time in 2018, the Steering Committee did commit funds to help support a DSCS cruise on the NOAA Ship *Bell M. Shimada (Shimada)* in August

2018 for 12 DAS. The *Shimada* conducted visual surveys in CBNMS, GFNMS, and MBNMS with an ROV funded in part by the WCDSCI. The data will be analyzed for deep-sea coral and sponge presence, absence, and abundance as well as for fish size and abundance.

FY 2019

EXPRESS DSCS Cruise, NOAA Ship *Shimada*

As part of the EXPRESS campaign, SWFSC, NWFSC, and ONMS were each awarded 10 DAS aboard NOAA Ship *Shimada,* together providing 30 DAS to support DSCS research. The sea days were combined into a single expedition that was jointly planned by NOAA, BOEM, and USGS and occurred October 9 - November 8, 2018. During the cruise, 15 sites were studied in offshore waters from Newport, Oregon to San Diego, California. Thirty-seven ROV dives, including 150 timed transects, and 24 AUV dives were completed. The majority of the dives were conducted in previously unexplored sites. Geological, biological, and water chemistry samples were collected, and specific sites for model validation were also visited. Forty-one coral samples and 54 sponge samples were collected for genetic and taxonomic identification and isotope analysis. Water chemistry samples were collected for vertical profiles of nutrients (n=104), major/minor elements (n=104), water isotopes (n=87), alkalinity (n=91), pH (n=91), and dissolved inorganic carbon (n=49). These measurements will provide a spatial gradient of water column properties that influence DSCS habitat, including nutrient availability and aragonite saturation state. Twenty-seven of the water chemistry samples were collected near corals to enable environmental DNA analysis.

Olympic Coast NMS, NOAA Ship *Shimada*

OCNMS was awarded 7 DAS by the NOAA Fleet Council to support a research cruise to investigate DSCS communities within the sanctuary in September 2019. Because PFMC Amendment 28 does not open, close, or otherwise alter any EFH or RCA that fall within the sanctuary (due to overlap of the sanctuary with the treaty-protected fishing areas of Washington State's four Coastal Treaty Tribes), that thematic focus area, which is of great interest elsewhere in the region, does not apply to this sanctuary. Thus, further characterization of sensitive hard bottom habitats, including within the existing Olympic 2 EFH area, is expected to be a primary goal of the expedition. A detailed cruise plan will be developed in cooperation with WCDSCI Steering Committee members to achieve the broader goals of the initiative while addressing specific OCNMS concerns.

EXPRESS Mapping Cruise, NOAA Ship *Rainier*

Building on the momentum and progress generated to date by the collaborative, multi-agency EXPRESS campaign, collaborators are again hoping to secure 15 additional DAS of NOAA Ship time on NOAA Ship *Rainier* in summer 2019 to conduct targeted high-resolution mapping of

deep water (>50 m) seafloor areas that may harbor significant living marine resources including DSCS species. A formal process is underway for identifying geographic priorities for seafloor mapping and establishing consensus on those priorities. Results will guide mapping efforts undertaken through the EXPRESS campaign and provide opportunities for further engagement, consistent with each agency's unique mission and capabilities.

Channel Islands NMS, R/V *Shearwater*

In FY 2019, a seven-day mission aboard the research vessel (R/V) *Shearwater* will focus on surveying uncharacterized regions within CINMS. High resolution seafloor mapping data collected in CINMS since 2014 has led to the identification of several unexplored yet unique and potentially biologically significant features. As a result, this cruise will focus on: 1) characterizing newly identified seafloor features, and 2) exploring areas near San Miguel Island that cross the biogeographic transition zone into cooler waters. A third objective will be to revisit the Footprint Marine Reserve, an area of particularly high coral cover known to harbor an abundance of fish. A detailed cruise plan will be developed in cooperation with WCDSCI Steering Committee members to achieve the broader goals of the initiative while addressing specific CINMS management priorities.

Proposed for FY 2020

Cordell Bank, Greater Farallones, and Monterey Bay NMS, E/V *Nautilus*

For more than a decade, NOAA OER has supported OET operations, and other NOAA programs have additionally developed productive and collaborative relationships with them. OET's exploration vessel, E/V *Nautilus*, has been an important asset for exploring deep seafloor areas of west coast NMS over the past few years, and provides an opportunity for scientists ashore to participate in real-time. In 2019, OET was awarded approximately $2 million through a major ONMS funding opportunity to explore and document the deep-sea oceanography, marine habitats, cultural sites, and living and non-living resources in and around NMS while using telepresence to engage the general public as well as formal and informal educators. With this support, cruises are expected to occur in west coast sanctuaries throughout the duration of the WCDSCI. These expeditions will enhance DSCS research by providing additional opportunities for fieldwork, ROV visual surveys, and public outreach via the ship's telepresence system. In early FY 2020 (October 2019), the *Nautilus* expedition season is expected to include approximately 17 days of mapping and visual survey work in CBNMS and GFNMS in central California. Due to significant technical difficulties experienced during an expedition to MBNMS at the end of the 2018 expedition schedule (early FY 2019), OET has expressed an intention to allocate additional DAS to MBNMS as part of the FY 2020 (October 2019) expedition.

EXPRESS DSCS Cruise, NOAA Ship *Shimada/Lasker*

In October 2019 (early FY 2020), WCDSCI will support an expedition of up to 30 DAS along the U.S. West Coast aboard either NOAA Ship *Shimada* or *Reuben Lasker* (*Lasker*). The cruise will be a collaborative effort among researchers from NMFS (NWFSC and SWFSC), ONMS, OER, USGS, and BOEM, and conducted as part of the EXPRESS campaign. The main focus of this FY 2020 expedition will be to conduct quantitative visual surveys of DSCS and fishes using an AUV and ROV, with an emphasis on characterizing previously-unexplored areas through collection of new baseline data; revisiting previously surveyed sites; collecting samples for species validation, identification, and connectivity studies; groundtruthing DSCS habitat suitability model outputs; and mapping high-value portions of the seafloor. Although specific survey locations have not been selected, the majority of work is expected to happen within Amendment 28 modification areas that were not surveyed in FY 2019, areas of priority to EXPRESS collaborators including USGS and BOEM, and/or high coral bycatch, areas of interest identified from the Spatial Prioritization Tool (see Collaboration Facilitation Tools), and sites within NMS boundaries.

Cordell Bank, Greater Farallones, and Monterey Bay NMS, R/V *Fulmar*

Initiative funds have been allocated in FY 2020 for approximately 7 days of ROV surveys using the sanctuary vessel, R/V *Fulmar*, to benefit one or more of the central California NMS: MBNMS, GFNMS, and CBNMS. Allocation of support for work on the R/V *Fulmar* is to be determined and will be used to try to balance the overall portfolio of fieldwork activities and ensure that all west coast NMS sites have the chance to conduct new surveys and collect new data in FY 2019 and FY 2020.

Channel Islands and Olympic Coast NMS, E/V *Nautilus*

Through the same competitive ONMS telepresence grant awarded to OET, OET will continue to partner with NMS in FY 2020 and is anticipating to conduct additional mapping and ROV visual survey efforts from the E/V *Nautilus.* Primary activities are expected to occur in OCNMS and CINMS, and may include modest effort within MBNMS.

Video Annotations and Image Analysis of Data

DSCS and fish data will be collected from the video and still imagery recorded from each cruise. For consistency, all video and image annotation from all cruises will be completed by experts using similar methodology. Video annotators will consult on difficult to identify species. Images will be annotated by NOAA (NWFSC, SWFSC, NMS, NCCOS) and contracted experts (with guidance from NOAA experts) in DSCS and fish identification and image analysis. The general plan for image analysis is to identify and enumerate all DSCS and fishes observed during transect times. All DSCS 10 cm and larger in height will be measured (when possible) using

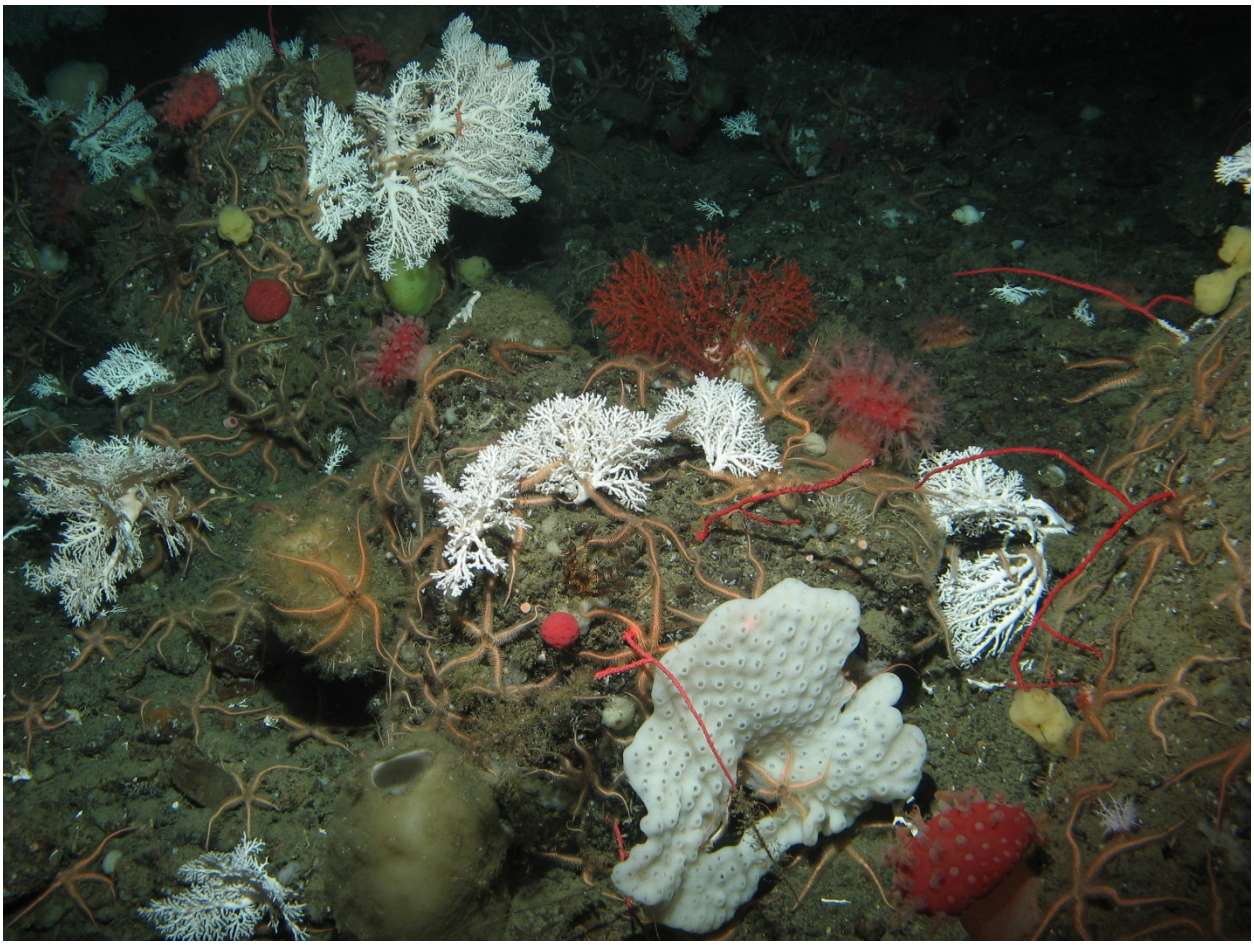
either stereo camera imaging software or scaling laser spots visible in the video or still image (these spots are 10-20 cm wide depending on the survey vehicle used). All fishes will be identified to the lowest practical level of taxonomic resolution and their total length measured (for fishes 10 cm and greater). Seafloor habitat classification will be completed for all transects. Once the data are collected and checked for accuracy, DSCS observation records will be uploaded to the National Database. Additional analyses may be conducted for individual data sets (e.g., the FY19 R/V *Shearwater* cruise) in order to add value to the data and answer other key research questions.

FY19-FY20 Seafloor Mapping Data Analysis

Multibeam bathymetry and associated backscatter data will be collected throughout the study region as part of the WCDSCI as well as the associated EXPRESS campaign. These new data acquisitions will be compiled together with readily accessible pre-existing data sets originating from partners including: NOAA, USGS, Oregon State University, California State Monterey Bay and Fugro. Footprints of each data set along with metadata will be uploaded to the NOAA Office of Coast Survey Integrated Ocean and Coastal Mapping Program's Seasketch website at the University of California, Santa Barbara. Metadata will include year of acquisition, horizontal resolution, presence of associated backscatter, and contact information for the data. Datasets collected will be integrated into coastwide products that can then be utilized for site selection and species distribution modeling.

Important Information for WCDSCI Collaborators/Principal Investigators

It is crucial to note that any field mission supported (in full or part) by WCDSCI is done so with the expectation and understanding that the cruise-lead or chief scientist will ensure that the required data products are budgeted for and contributed to the DSCRTP's National Database, with the type of products dependent upon the level of support. The data team, Matt Dornback (matt.dornback@noaa.gov) and Robert McGuinn (robert.mcguinn@noaa.gov), will connect with cruise-leads in advance of the field work, during cruise planning, to provide guidance and facilitate the collection of data. The data team will also offer guidance post-cruise to facilitate database submissions. Documentation detailing data requirements is also available online (i.e. Fieldwork Data and Reporting Guidance, Checklist and Timeline for Science Team Data Deliverables).



Octocorals, hydrocorals and sponges on Mendocino Ridge, CA (DSCRTP)

Products

Standard DSCRTP Products

Observation Records and Site Characterization Reports

PIs funded through WCDSCI are required to submit standard products to DSCRTP, including georeferenced location and species records for DSCS and a site characterization summarizing DSCS and fish resources within a location. To facilitate and streamline the development and submission of standard products, PIs will be connected with DSCRTP data team staff during cruise planning in an effort to streamline data collection, records formatting, and submission of DSCS observations to the National Database online portal. Where possible, ancillary observations, such as fish-habitat associations, assessments of DSCS health or condition, and measurement of physical/chemical properties of the ocean will be summarized and reported to DSCRTP.

Wrap-up Workshop and Final Report

A wrap-up workshop will be organized in the final year of WCDSCI (FY 2021). This workshop will allow WCDSCI participants to reflect on the successes and challenges of the initiative, report on the status of outstanding tasks or database submissions, and summarize initiative accomplishments. A final report will be submitted to DSCRTP.

Historical Data Analyses

Mining or 'rescuing' previously collected survey datasets through retrospective image and video analysis can provide enhanced DSCS occurrence data (i.e., presence/absence, quantitative measures of area surveyed, and coral number, condition, and size). The following projects involve analyzing data sets collected in years previous to the WCDSCI.

Southern California Bight ROV Dives

NOAA NCCOS will conduct a retrospective video analysis of select surveys previously conducted in the Southern California Bight. Analysis will focus on benthic characterization of hard and soft bottom areas 50-350 m deep within CINMS, with special attention to quantification of coral and sponge densities and identification of coral gardens. The analysis will produce a large number of new high-quality observation records and information (e.g., presence/absence, abundance, condition, colony size) for the National Database. The image analysis will focus on surveys conducted since 2015 by OET, NCCOS, ONMS, and Marine Applied Research and Exploration (MARE). The new data will also support the development of enhanced habitat suitability models (see Modeling section).

Coral and Fish Association Analyses

Studies on fish associations with DSCS have demonstrated mixed results. Studies off Alaska (Krieger and Wing 2002; Stone 2006) found high numbers of fish associating with corals and sponges, while studies in other areas found many fewer fish (Tissot et al. 2006; Yoklavich et al. 2013). The goal of this FY 2020 project is to investigate the corals as habitat for groundfishes along the West Coast using existing data sets, primarily an extensive, long-term manned submersible and ROV data set collected in southern and central California. These data were collected over 19 years (1992-2011) by SWFSC scientists using a variety of survey vehicles (Delta submersible, DeepWorker and Dual DeepWorker submersibles, SWFSC Phantom ROV, and the Kraken II ROV). Fish densities, lengths, diversity, and assemblage structure will be compared among similar seafloor habitat types with varying amounts and types of corals. Comparisons will be made within and between southern and central California study sites to assess the amount of spatial variability in fish-coral associations. Successful completion of this project will result in quantitative estimates of the relative importance of corals as habitat for a variety of commercially and ecologically significant groundfishes and the spatial consistency of

these associations. If funding allows for the continuation of this project into 2021, the scope of the project will expand to include existing DSCS surveys from Oregon, Washington, and Alaska.

Table 1. Field expeditions supported by the Deep Sea Coral Research and Technology Program (DSCRTP) planned for the West Coast Deep-Sea Coral Initiative (WCDSCI).

Vessel	Science Lead	Dates	Region	Operations	DSCRTP Support
FY2018					
NOAA Ship *Shimada*	Danielle Lipski/ Jan Roletto	July 28-Aug. 10, 2018	GFNMS, CBNMS, MBNMS	DSCS Surveys	ROV (<600 m), data analysis
FY2019					
NOAA Ship *Shimada*	Elizabeth Clarke/Tom Laidig/Chris Caldow	Oct. 9 – Nov. 8, 2018	Many locations from Oregon to CINMS	DSCS Surveys	ROV (<600 m), science support, data analysis
NOAA Ship *Shimada*	Jenny Waddell	Sept. 10-16, 2019	OCNMS	DSCS Surveys	ROV (<600 m), science support, data analysis
NOAA Ship *Rainier*	Chris Caldow/ Elizabeth Clarke	Summer/Fall 2019, 23 DAS	TBD	Mapping	Science support, data analysis
R/V *Shearwater*	Peter Etnoyer/ Chris Caldow/ John O'Sullivan	June 3-13, 2019	CINMS	DSCS Surveys	Ship time, ROV (<600 m), science support, data analysis
FY2020					
E/V *Nautilus*	Danielle Lipski/ Jan Roletto	Oct. 2019	GFNMS, CBNMS	DSCS Surveys (up to 1000 m)	Science support, data analysis
NOAA Ship *Shimada* or *Lasker*	Elizabeth Clarke/Tom Laidig/Chris Caldow	TBD, 20-30 DAS	West Coast, TBD pending ports and DAS	DSCS Surveys	ROV, science support, data analysis
R/V *Fulmar*	Dani Lipski/Jan Roletto/Andrew DeVogelaere	TBD, 7 DAS	Central CA NMS	DSCS Surveys	Ship time, ROV, science support, data analysis
E/V *Nautilus*	Chris Caldow/ Jenny Waddell/ Andrew DeVogelaere	TBD, May – Nov. 2020	OCNMS, CINMS, maybe MBNMS	DSCS Surveys (up to 1000 m)	Science support, data analysis

Genetics, Connectivity, and Taxonomy

Species Identification and DNA Barcoding

Understanding species distribution and connectivity is an important component of conservation and management. Clear species identification is necessary to establish species distribution and boundaries, and to improve species distribution models. Much work on the West Coast to date has focused on establishing and updating the current comprehensive coral species list for the U.S. West Coast as well as clarification of species records in the National Database. These efforts included traditional morphological methods, as well as developing and applying molecular barcodes and vouchers to clarify species identification. Taxonomic uncertainty remains, and additional work is needed to better resolve existing species. This will include collection, identification and sequencing of additional individuals and genetic markers; application of high-throughput, genome-wide techniques such as RAD sequencing; as well morphological methods including scanning electron microscopy and consultation with morphological taxonomists.

Much of the taxonomic work on the West Coast to date has focused on corals; work in deep-sea sponges is in early stages. This initiative will address the need for increased taxonomic identification work in sponges, by increasing collections, and applying morphological and genetic methods for identification to sponges collected coast wide.

In both corals and sponges, new species are being discovered and described, both through revision of existing taxonomy and addition of previously unknown species. Throughout this initiative work, researchers will continue to update the existing species lists for the West Coast, add additional coral species and haplotypes to the existing molecular barcode set and will begin creating a voucher collection for sponges, with accompanying molecular barcodes to aid in sponge identification. The resulting sequences and identifications available through national databases including the DSCRTP National Database and Genbank. The molecular barcode collections will also be crucial to the environmental DNA (eDNA) research activities (see below) providing reference datasets for identification.

Population Connectivity Studies

Beyond identification of species and species distribution, understanding connectivity between populations is key for conservation and management. To date, little work has been applied to understanding the connectivity of DSCS populations. To date, a single study has been carried out on the U.S. West Coast (Everett et al. 2016). Deep-sea corals have a variety of life history traits that may affect their connectivity and population structure. Over the course of this initiative, studies in population connectivity will be carried out on a diverse panel of coral species, selected to include a diverse group of families and life history traits. Additionally, as our collection of sponges grows, and our ability to clearly identify them develops, these studies may be applied in sponges as well. This work will be published in peer-reviewed journals, and the molecular markers developed in the course of these efforts may have additional downstream

applications such as species identification, landscape genetics, and identifying specific traits and loci associated with environmental factors.

eDNA Analysis

Environmental DNA analysis can be an important component of survey efforts, allowing detection of species that may be challenging or impossible to detect with more conventional sampling methods (Everett and Park 2018; Kelly et al. 2017; Thomsen et al. 2016). Since 2016, OET has made collecting eDNA samples in coral and sponge communities one of their standard objectives during ROV dives from E/V *Nautilus*. Samples of eDNA from the 2016 season were used to profile diverse communities of octocorals along the West Coast (Everett and Park 2018). eDNA samples from the 2017 and 2018 collection seasons are being processed at NWFSC for octocorals, fish, sponges, black and scleractinian corals. Samples from these collections include eDNA collected from NMS, as well as from the DFO Canadian seamounts expedition promoting collaborative work between the two agencies. Additional eDNA samples will be collected during 2019 and 2020 expeditions, and analyzed for their coral, fish and sponge communities. Sequences will be deposited in the NCBI Short Read Archive and community data will also be submitted to the National Database, along with corresponding images. Data collected from these studies may help address other questions targeted in the Science Plan, such as the ecosystem function of deep-sea corals and their use by fish communities.

Modeling

Modeling Workshop

Predictive modeling of deep-sea coral distributions provides a cost-effective means of identifying potential DSCS habitat within large areas to inform management and future data collection (Guinotte et al. 2017); as such, predictive modeling of DSCS was identified as a priority activity during the WCDSCI Research Priorities Workshop. A technical workshop will be convened to define best practices for deep-sea coral distribution modeling that can guide future modeling efforts and data collection aimed at improving and validating model predictions. Attendees will include representatives of organizations actively involved in U.S. deep-sea coral research, modeling, and management, particularly on the West Coast. Specific topics to be discussed include: 1) alternative modeling techniques (e.g., presence-only, presence-absence, density, or integrated); 2) data formats required by these techniques; 3) quantifying and reporting uncertainty in model predictions; 4) methods for validating model predictions; 5) sampling design of surveys and data collection to inform and validate models; 6) temporal models and data requirements. Modeling Workshop conclusions will be documented in a manuscript for submission to a peer-reviewed scientific journal. Conclusions will help inform investments in future modeling projects and improve the design of future DSCS surveys. More generally, the conclusions of the workshop will be of interest to a wide range of U.S. and international deep-sea

coral researchers and managers, and may be relevant to the research and management of other taxa (e.g., other benthic organisms).

Advancing Predictive Habitat and Distribution Modeling

Many previous regional models of deep-sea coral distributions in U.S. waters used occurrence data and employed 'presence-only' modeling methods (Bauer et al. 2016; Bryan and Metaxas 2007; Etnoyer et al. 2018; Georgian et al. 2014; Guinotte and Davies 2014), which entail challenges and limitations to inference. The current Pacific Cross-shelf Habitat Suitability Modeling project, funded by BOEM and conducted by NCCOS, is the most recent example for the West Coast. This project will advance methodology for predictive modelling of deep-sea coral habitat by exploring and comparing alternative techniques that may include presence-absence data, density data, integration of multiple data types (e.g., presence-only, presence-absence, and density), and/or joint species distributions. These alternative techniques, which will be discussed in detail at the Modeling Workshop (see priority #1 in previous paragraph), are more demanding in terms of data requirements, so this project would focus on a smaller geographic area(s) for which sufficient data are available. Ideally, comprehensive datasets for key environmental predictor variables (e.g., high-resolution bathymetry, backscatter, bottom currents, and ocean chemistry such as organic carbon) would also be available or could be developed during the project. Results of this project will be new, and hopefully augmented, predictions of the habitat and distributions of deep-sea coral species in the study area(s). Results will shed light on how predictions are affected by the data types considered, potentially improving inferences from existing regional presence-only models. This project has synergies with the Modeling Workshop (see Modeling section), which could guide the choice of modeling techniques to explore, and historical data (see Historical Data section), which could provide the types of survey data required for analysis.

Collaboration Facilitation Tools

Spatial Prioritization Tool

Given the diverse list of WCDSCI partners, there is a strong interest and need to identify spatial priorities using a transparent and quantitative process. Refining spatial priorities identified at the Research Priorities Workshop is an important step, and would help WCDSCI more effectively leverage partner assets and maximize the limited resources available to explore deep-sea communities. In this project, NCCOS will use a well-established spatial framework and tool to help the WCDSCI Steering Committee develop a spatial prioritization plan for seafloor mapping and visual surveys of deep-sea communities. Over the past several years, NCCOS has developed and refined this framework, and, along with local partners, has successfully applied it to multiple regions throughout the United States. A stand-alone ArcGIS application allows various parts of the spatial prioritization process to be customized (e.g., method used, user

access, product types, etc.) on the basis of specific needs and questions relevant to the users and region of interest.

For WCDSCI, NCCOS will build on past efforts and leverage ongoing projects along the West Coast. In particular, NCCOS will adopt the Washington seafloor mapping spatial prioritization process used in 2015 and 2018 (Battista et al. 2017), and revise it while including California and Oregon. NCCOS will include datasets in this updated prioritization portal that have already been compiled for the BOEM-funded Pacific Cross-shelf Habitat Suitability Modeling and Pacific Marine Bird Modeling projects. Other relevant, readily-available datasets (e.g., existing deep-sea coral records from the National Database, EFH, bycatch areas, and habitat areas of particular concern) will be ingested into the prioritization portal from existing data warehouses (e.g., NWFSC FRAM) or if provided as readily available data by DSCRTP partners. Marine areas will be divided into discrete locations to be selected and attributed by respondents. Prioritization participants were identified from the list of Research Priorities Workshop attendees and EXPRESS partners. This participant list was refined and finalized in consultation with the WCDSCI Steering Committee. This spatial prioritization framework and process will provide WCDSCI an opportunity to strengthen its partner base, to transparently and quantitatively identify clear spatial priorities to inform its Science Plan, and to continue to efficiently leverage resources across federal and non-federal agencies. In addition, the compilation of datasets in the prioritization tool will be a valuable resource for other WCDSCI activities.

Target Species List

Obtaining biological specimens is a limiting factor in a number of DSCS studies that range from taxonomy and connectivity to diet and age. In order to facilitate targeted sampling to meet the needs of the deep-sea coral research community, a list of specific taxa, both corals and sponges, has been assembled. This list will be maintained and updated throughout the initiative and beyond. The goal of this document is to both facilitate sample collection for target groups, and also facilitate sample sharing and collaboration in the DSCS research community, which may help prevent overcollection of sensitive targets, by serving as a central hub for species of interest. The species target list includes the following information: species of interest, researcher(s) interested in particular taxon/taxa, and a general note of the type of research being conducted, as well as any special collection instructions. This document has been shared among individuals in the DSCS research community and will be provided for all sampling cruises conducted as part of this initiative. The list is being maintained by Meredith Everett at NOAA NWFSC (Meredith.Everett@noaa.gov) and researchers interested in contributing to or accessing the list should contact her.

Species Identification Guide for West Coast Corals, Sponges, and Fishes

One highly-desirable product identified at the Research Priorities Workshop is a comprehensive species identification guide for west coast corals, sponges, and fishes. While a number of guides exist to help with identification of eastern Pacific deep-sea fish species, few resources are available for corals and sponges. Using the comprehensive coral species list assembled for the 2017 DSCRTP State of Deep-Sea Coral and Sponge Ecosystems of the United States Report and work begun by Curt Whitmire (NWFSC), WCDSCI will create a DSCS species guide and update identification materials used by the NOAA Fisheries observer program. This guide will include photos of each described species, both *in situ* and *ex situ* (i.e., museum specimens or bycaught individuals) wherever possible. Species descriptions will be assembled from existing literature to highlight characteristics that are critical for differentiating similar species, and identify taxa for which there is ongoing taxonomic uncertainty. Where taxa lack a good taxonomic definition, but are nonetheless frequently observed, representative photos, along with any distinguishing information such as observed habitat and any limited taxonomic information will be included. The guide, which will be available online and as a printed resource, will be designed to allow for easy updates on an annual basis.

As with corals, few resources exist to assist in the identification of west coast deep-sea sponges. The SWFSC team maintains an in-house species guide used for identification of species in video and photo transects, which includes a number of sponges identified by taxonomists, and Monterey Bay National Marine Sanctuary Foundation has published *The Sponges of California* (Lee et al. 2007). However, clarification of sponge taxonomy on the West Coast is ongoing, with regular detection of novel and cryptic species and collection of sponges for genetic analysis (see Genetic Products section), and there is need for a comprehensive, regularly updated species list for the region. A new sponge guide will update the list of known species and their descriptions, and include *in situ* as well as specimen photos. This guide will also be available as an online resource and will be designed to allow for easy updates on an annual basis as species descriptions change or are added.

Outreach and Education Tools and Opportunities

Photomosaics to supplement NMS Online Curricula

Researchers will create highly detailed 3-dimensional (3D) seamless mosaics by combining smaller overlapping images (photomosaics). Ideally, depending on logistics, weather, and ship time, a photomosaic will be created for each of the five west coast NMS and at other important DSCS locations outside sanctuary boundaries. These products would greatly enhance the existing West Coast National Marine Sanctuaries Deep Sea Coral Curriculum, and photomosaics could be incorporated into the curriculum to help students visualize remote seafloor communities. Completed photomosaics may also be used in other online materials and products, such as story maps, to inspire and educate a variety of audiences.

SeaSketch Educational Portal

SeaSketch is a powerful data visualization tool that can be used by students to examine and solve real world problems. A regional geodatabase would provide the backbone for student lessons. For this project, teachers will be encouraged to use SeaSketch to view and display the National Database's coral and sponge observations along with other open source data layers (e.g., EFH, protected areas, predicted habitat suitability model outputs for various DSCS species, and so on) to challenge students to address hypothetical management issues. Using SeaSketch, the audience would have an enhanced ability to interact and ask questions about various data layers, and students can propose evidence-based solutions to local issues related to habitat conservation, ocean acidification or other resource issues affecting the West Coast. The Seasketch DSCS module will complement and enhance the West Coast National Marine Sanctuaries Deep Sea Coral Curriculum, and its integration will be guided by education and outreach staff from west coast NMS sites.

3D Printed DSCS

3D printed coral and other specimens provide a way for audiences to interact with and safely handle coral and sponge replicas, helping them connect with and understand the importance and value of deep-sea coral communities. The west coast NMS education team has already created 3D plankton models that have been popular in teacher workshops and public outreach events. It is estimated that the sanctuary education and outreach teams in the region will produce six different 3D models of DSCS species to share among west coast sites during public outreach and education events.

Infographics

To ensure WCDSCI develops materials to serve the overarching mission goals of providing managers and stakeholders digestible information to influence decision making, the initiative will also support the development and dissemination of two infographics. The purpose of infographics will be to convey information about DSCS ecosystems in a way that makes them easily read, understood, and remembered. The content or conceptual design will be determined during the initiative to meet the needs of multiple agencies participating in WCDSCI. Suggested examples include a timeline comparing coral and human life histories to better portray the chronic nature of disturbance and recovery of DSCS, an elaboration of the pathway from research to management decisions to protect DSCS, and an illustration of genetic connectivity between west coast populations of DSCS.

Table 2. Projects and products supported by the Deep Sea Coral Research and Technology Program during the West Coast Deep-Sea Coral Initiative.

Project	Lead	Dates
Standard		
Cruise Reports	Cruise Principal Investigator(s)	Various
Site Characterizations	Cruise Principal Investigator(s)	Various
Record Submissions to National Database	Cruise Principal Investigator(s)	Various
Final Report	Chris Caldow (CINMS), Liz Clarke (NWFSC)	2021
Wrap-up Workshop	Chris Caldow (CINMS), Liz Clarke (NWFSC)	2021
Historical Data Analyses		
Southern California Bight ROV Dives	Peter Etnoyer (NCCOS)	2015-2018
ROV Dives in OCNMS	Jenny Waddell (OCNMS)	August-September 2017
Southern California Bight Submersible Dives	Tom Laidig (SWFSC)	1998-2008
Coral and Fish Association Analyses	Tom Laidig (SWFSC)	1992-2014
Genetics		
Species Identification and Population Connectivity Studies	Meredith Everett (NWFSC)	Various
eDNA Studies	Meredith Everett (NWFSC)	Various
Modeling		
Modeling Workshop	Arliss Winship (NCCOS)	Feb. 19-20, 2019
Advancing Predictive Habitat and Distribution Models	Arliss Winship (NCCOS)	2020
Collaboration Facilitation Tools		
Spatial Prioritization Tool	Bryan Costa (NCCOS)	2019
Target Species List	Meredith Everett (NWFSC)	2018-ongoing
Species Identification Guide for West Coast DSCS and Fishes	Meredith Everett (NWFSC)	2019-2021
Education and Outreach Tools and Opportunities		
Photomosaics	Lizzie Duncan (CINMS)	2020-2021
SeaSketch Educational Portal	Lizzie Duncan (CINMS)	2019-2020
3D Printed DSCS	Lizzie Duncan (CINMS)	2020-2021
Infographics	Lizzie Duncan (CINMS)	2020

Table 3. Other potential projects to be prioritized by the steering committee as funding becomes available throughout the West Coast Deep-Sea Coral Initiative.

Data Rescue Projects								
PI	**Ship/ID**	**Location(s)**	**Dates**	**ROV/ Auv**	**Num. of Dives**	**Hours of video**	**Transect or exploratory**	**Analysis**
Jan Roletto	*Nautilus*	GFNMS, northern MBNMS	Aug 2016	Herc & Arg	9	75	Both	Corals, Sponges, Fish
Jan Roletto	Shimada	GFNMS, northern MBNMS: Cochrane Bank, Deep Reef, Pescadero Reef, and Pigeon Point Reef	Aug 2018	Beagle		27	Both	Corals, Sponges, Fish
Jenny Waddell	Nautilus (NA086)	OCNMS	Aug/Sept2017	Herc & Arg	16	160	Exploratory	Corals, Sponges, Fish
Chad King	Nautilus	MBNMS	Oct 2018	Herc & Arg		42	Exploratory	Corals, Sponges, Fish
Milton Love/ Mary Yoklavich	Many	Southern California	1995-2008	Delta	various	280	Transects	Corals, Sponges,
Peter Etnoyer	Shearwater (SW180X)	Southern California	2018	Beagle	18	21 (bottom time)	Transects (52)	Corals, Fish
Peter Etnoyer	Shimada (BS1705)	Southern California	2017	Beagle & AUV	15	26 (bottom time)	Transects (45)	Corals, Fish
Bob Ballard/ Julie Bursek	Nautilus (NA083)	Southern California	2017	Herc & Arg				
Peter Etnoyer	Nautilus (NA074)	Point Conception	2016	Herc & Arg	18	27 (bottom time)	Transects (15)	Corals, Sponges, Fish
Lisa Levin/ Peter Girguis	Nautilus (NA066)	Southern California	2015	Herc & Arg	13	175 (bottom time)	Exploratory	Corals, Sponges, Fish
Tom Laidig	Nautilus (NA83)	Southern California	2017	Herc & Arg	2	10 hours on bottom	Both	Corals, Sponges, Fish

Other Proposed Projects		
PI	**Research Theme**	**Project Description**
James Thorson	Modeling	Comparison of presence-only and presence-absence deep-sea coral and sponge models with multiple modes of data to inform and advance predictive modeling capabilities

References

Battista, T., K. Buja, J. Christensen, J. Hennessey, and K. Lassiter. 2017. Prioritizing seafloor mapping for Washington's Pacific coast. Sensors 17(4).

Bauer, L., M. Poti, B. M. Costa, D. Wagner, F. Parrish, M. Donovan, and B. Kinlan. 2016. Chapter 3: Benthic habitats and corals. *in* B. M. Costa, and M. S. Kendall, editors. Marine biogeographic assessment of the main Hawaiian Islands. Bureau of Ocean Energy Management and National Oceanic and Atmospheric Administration, OCS Study BOEM 2016-035 and NOAA Technical Memorandum NOS NCCOS 214. pp. 57-136.

Bryan, T. L., and A. Metaxas. 2007. Predicting suitable habitat for deep-water gorgonian corals on the Atlantic and Pacific Continental Margins of North America. Marine Ecology Progress Series 330:113-126.

Caldow, C., M. E. Clarke, H. M. Coleman, E. Duncan, M. V. Everett, T. F. Hourigan, T. E. Laidig, A. N. Netburn, J. H. Stadler, J. Waddell, and A. J. Winship. 2019. Deep-sea Coral Research and Technology Program. Research priorities workshop report for the DSCRTP West Coast Research Initiative, 2018-2021, https://deepseacoraldata.noaa.gov/library/workshop-report-dscrtp-west-coast-2018-2021.

Clarke, M. E., C. E. Whitmire, and M. M. Yoklavich. 2017. State of deep-sea coral and sponge ecosystems of the U.S. West Coast. *in* T. F. Hourigan, P. J. Etnoyer, and S. D. Cairns, editors. The State of Deep-Sea Coral and Sponge Ecosystems of the United States. National Oceanic and Atmospheric Administration, NOAA Technical Memorandum NMFS-OHC-4. pp. 112-155.

Etnoyer, P. J., D. Wagner, H. A. Fowle, M. Poti, B. Kinlan, S. E. Georgian, and E. E. Cordes. 2018. Models of habitat suitability, size, and age-class structure for the deep-sea black coral *Leiopathes glaberrima* in the Gulf of Mexico. Deep-Sea Research Part Ii-Topical Studies in Oceanography 150:218-228.

Everett, M. V., and L. K. Park. 2018. Exploring deep-water coral communities using environmental DNA. Deep-Sea Research Part Ii-Topical Studies in Oceanography 150:229-241.

Everett, M. V., L. K. Park, E. A. Berntson, A. E. Elz, C. E. Whitmire, A. A. Keller, and M. E. Clarke. 2016. Large-scale genotyping-by-sequencing indicates high levels of gene flow in the deep-sea octocoral *Swiftia simplex* (Nutting 1909) on the West Coast of the United States. Plos One 11(10).

Fautin, D., P. Dalton, L. S. Incze, J. A. C. Leong, C. Pautzke, A. Rosenberg, P. Sandifer, G. Sedberry, J. W. Tunnell, I. Abbott, R. E. Brainard, M. Brodeur, L. G. Eldredge, M. Feldman, F. Moretzsohn, P. S. Vroom, M. Wainstein, and N. Wolff. 2010. An overview of marine biodiversity in United States waters. Plos One 5(8).

Feehan, K. A., and R. G. Waller. 2015. Notes on reproduction of eight species of Eastern Pacific cold-water octocorals. Journal of the Marine Biological Association of the United Kingdom 95(4):691-696.

Georgian, S. E., W. Shedd, and E. E. Cordes. 2014. High-resolution ecological niche modelling of the cold-water coral *Lophelia pertusa* in the Gulf of Mexico. Marine Ecology Progress Series 506:145-U454.

Grantham, B. A., F. Chan, K. J. Nielsen, D. S. Fox, J. A. Barth, A. Huyer, J. Lubchenco, and B. A. Menge. 2004. Upwelling-driven nearshore hypoxia signals ecosystem and oceanographic changes in the northeast Pacific. Nature 429(6993):749-754.

Guinotte, J. M., and A. J. Davies. 2014. Predicted deep-sea coral habitat suitability for the US West Coast. Plos One 9(4).

Guinotte, J. M., S. E. Georgian, B. Kinlan, M. Poti, and A. J. Davies. 2017. Predictive habitat modeling for deep-sea corals in U.S. waters. *in* T. F. Hourigan, P. J. Etnoyer, and S. D. Cairns, editors. The state of deep-sea coral and sponge ecosystems of the United States. National Oceanic and Atmospheric Administration., NOAA Technical Memorandum NMFS-OHC-4. pp. 211-235.

Harvey, C. J., N. Garfield, G. D. Williams, K. S. Andrews, C. Barceló, K. A. Barnas, S. J. Bograd, R. D. Brodeur, B. J. Burke, J. M. Cope, L. deWitt, J. C. Field, J. L. Fisher, C. M. Greene, T. P. Good, E. L. Hazen, D. S. Holland, M. G. Jacox, S. Kasperski, S. Kim, A. W. Leising, S. R. Melin, C. A. Morgan, S. H. Munsch, K. C. Norman, W. T. Peterson, M. R. Poe, J. F. Samhouri, I. Schroeder, W. J. Sydeman, J. Thayer, A. R. Thompson, N. Tolimieri, A. N. Varney, B. K. Wells, T. H. Williams, and J. E. Zamon. 2017. Ecosystem status report of the California Current for 2017 : a summary of ecosystem indicators compiled by the California Current Integrated Ecosystem Assessment Team (CCIEA). National Oceanic and Atmospheric Administration, NOAA Technical Memorandum NMFS-NWFSC 139.

Hourigan, T. F., P. J. Etnoyer, R. P. McGuinn, C. E. Whitmire, D. S. Dorfman, M. Dornback, S. L. Cross, and D. E. Sallis. 2015. An introduction to NOAA's National Database for Deep-Sea Corals and Sponges. National Oceanic and Atmospheric Administration, NOAA Technical Memorandum NOS NCCOS 191. pp. 1-27.

Kelly, R. P., C. J. Closek, J. L. O'Donnell, J. E. Kralj, A. O. Shelton, and J. F. Samhouri. 2017. Genetic and manual survey methods yield different and complementary views of an ecosystem. Frontiers in Marine Science 3.

Krieger, K. J., and B. L. Wing. 2002. Megafauna associations with deepwater corals *(Primnoa* spp.) in the Gulf of Alaska. Hydrobiologia 471:83-90.

Lee, W. L., D. W. Elvin, and H. M. Reiswig. 2007. The sponges of California: A guide and key to the marine sponges of California. Monterey Bay Sanctuary Foundation, Monterey, CA, USA.

Stone, R. P. 2006. Coral habitat in the Aleutian Islands of Alaska: depth distribution, fine-scale species associations, and fisheries interactions. Coral Reefs 25(2):229-238.

Thomsen, P. F., P. R. Møller, E. E. Sigsgaard, S. W. Knudsen, O. A. Jørgensen, and E. Willerslev. 2016. Environmental DNA from seawater samples correlate with trawl catches of subarctic, deepwater fishes. Plos One 11(11):e0165252.

Tissot, B. N., M. M. Yoklavich, M. S. Love, K. York, and M. Amend. 2006. Benthic invertebrates that form habitat on deep banks off southern California, with special reference to deep sea coral. Fishery Bulletin 104(2):167-181.

Yoklavich, M. M., T. E. Laidig, K. Graiff, M. E. Clarke, and C. E. Whitmire. 2018. Incidence of disturbance and damage to deep-sea corals and sponges in areas of high trawl bycatch near the California and Oregon border. Deep-Sea Research Part Ii-Topical Studies in Oceanography 150:156-163.

Yoklavich, M. M., T. E. Laidig, A. Taylor, D. L. Watters, L. Krigsman, and M. S. Love. 2013. A Characterization of the Christmas tree black coral (*Antipathes dendrochristos*) community on three seamounts in the Southern California Bight from a survey using a manned submersible. A report to NOAA Deep-Sea Coral Research and Technology Program, https://deepseacoraldata.noaa.gov/library/hidden-reef-footprint-and-piggy-bank-site-characterization-2010.

Appendix A. Thematic Foci

1. Mapping

Gathering bathymetry and seafloor habitat information was a critical first step in determining which areas are likely to support DSCS habitat since hard bottom geology is a prerequisite to support many of these species. Knowing where hard bottom habitat persists is critical to planning exploration and site characterizations via ROV and/or AUV. However, critical data gaps still exist for high quality mapping data despite relatively recent acquisitions thanks in part to formation of the Southern California Seafloor Mapping Initiative, EXPRESS campaign, and Washington State Seafloor Mapping Spatial Prioritization effort. Participants in the 2018 Research Priorities Workshop prioritized three main goals in relation to gathering mapping information on the West Coast as a part of WCDSCI:

- Identify rocky habitats.
- Collect higher resolution backscatter data in areas mapped prior to 2005 and apply a more quantitative approach for characterizing habitat type.
- Map areas that are currently under, or are being considered for protection.

The mapping break-out groups also identified general spatial priorities in which to generate those mapping data. The top ranked spatial priorities included: areas proposed for protection modifications under the adoption of Amendment 28 to the Groundfish FMP, Santa Lucia Bank, the northern Channel Islands, several Southern California offshore banks, Hydrate Ridge, and areas with historically high accounts of DSCS bycatch in the southern Oregon and northern California areas.

There are two points to note regarding mapping prioritization efforts (the first point applies to visual survey priorities as well) that were highlighted by Research Priorities Workshop attendees. First, this effort represented an initial rough cut of potential priority locations and will require further spatial refinement to be valuable for planning purposes. Prioritization would also benefit from additional input by entities that were unable to attend the workshop in-person, a source of bias noted in the workshop report. Second, the northern outer Washington coast had a number of priority areas in close spatial proximity, including OCNMS, EFH and biogenic area closures, and the usual and accustomed fishing areas of Washington's four coastal treaty tribes. However, a mapping prioritization effort has already been conducted in this area and a more in-depth discussion of those results can be found in Battista et al. (2017).

2. Visual Surveys

Deep-sea coral and sponge visual surveys along the West Coast have been conducted using ROVs, AUVs, submersibles, and drop and towed cameras. In the past, surveys have mainly focused on abundance and distribution of DSCS along the coast from California to Washington. In addition to discussing what data should be collected using visual surveys, the WCDSCI Research Priorities Workshop also recorded the highest priority locations where these

surveys should occur. The nine primary research and visual survey priority ideas are listed below.

- Conduct DSCS surveys in EFH determined areas that will be newly opened or closed due to the adoption of Amendment 28.
- Understand fish and coral/sponge associations more clearly to determine the importance of corals and sponges as EFH.
- Collect physical oceanographic data and pair with coral/sponge distributions.
- Find a central repository for DSCS survey data; a separate, local clearinghouse of DSCS information on west coast projects.
- Explore automated image processing to speed analyses of video and still images.
- Establish a common survey design for conducting transects.
- Prioritize visual surveys and sampling that would benefit other projects (e.g., sampling to validate models and seafloor mapping data).
- Use visual surveys and sample collection to characterize genetic diversity along the West Coast and across oceans, as well as for improving the taxonomic resolution of DSCS species.
- Conduct visual surveys in previously unsurveyed locations to improve understanding of the distribution and abundance of DSCS.

The top-ranked spatial priority captured in this break-out session was the collection of locations chosen for designation changes as EFH or RCA by Amendment 28 to the Pacific Coast Groundfish FMP. Following this, Juan de Fuca Canyon (northern Washington), areas of high DSCS bycatch by trawl fisheries (northern California and southern Oregon), a potential offshore wind energy area (north of Point Conception, California), and Sverdrup Bank (western edge of the Southern California Bight) were the next highest-ranking areas to survey.

3. Modeling

The NOAA DSCRTP report 'The State of Deep-Sea Coral and Sponge Ecosystems of the United States' has a chapter by Guinotte et al. (2017) reviewing predictive habitat modeling, hereinafter simply referred to as modeling, for deep-sea corals in U.S. waters. As discussed in that chapter, modeling of deep-sea corals is an active area of research, providing a cost-effective means of identifying potential deep-sea coral habitat over large areas that can inform management. Several past and current studies have conducted modeling of deep-sea corals in waters off Washington, Oregon, and/or California (e.g., Bryan and Metaxas 2007, Huff et al. 2013, Guinotte and Davies 2014, current BOEM-funded Pacific Cross-shelf Habitat Suitability Modeling project).

The objective of this break-out session was to discuss research priorities for modeling-related work as part of WCDSCI. While this break-out session did not conduct voting on priorities, several main priorities were identified:

- Inclusion of important predictor variables (e.g., bottom substrate and habitat features, total organic carbon, aragonite saturation state, presence of other species).

- ❖ Advancement of modeling methodology (e.g., presence-absence, density, integrated, multi-species, dynamic models).
- ❖ Model validation and sampling design for that purpose.
- ❖ Engagement with management to facilitate use of model products.

4. Species Identification, Genetics and Connectivity

Genetic studies play an important role in the understanding of deep-sea corals on the U.S. West Coast. Genetic and genomic methods are being used to confirm species identifications and improve taxonomy, an important component for monitoring species distributions and for habitat suitability modeling. In addition to identification value, understanding genetics and connectivity within species is also important for conservation and management. Identifying patterns of connectivity can inform selection of regions needing protection, as well as planning recovery efforts. To date on the West Coast, research has focused on genetic identification of species, either with direct sampling via ROV surveys, from fisheries bycatch, or through eDNA survey efforts. In this region, there has also been a single connectivity study on the *Swiftia simplex* (Everett et al. 2016). This study developed and applied a novel panel of single nucleotide polymorphism (SNP) markers, demonstrating that this species forms a single population along the whole U.S. West Coast. However, studies of other species and regions have also found that specific species can be highly regional, emphasizing the need for connectivity studies in multiple groups of interest within a region. WCDSCI Research Priorities Workshop participants outlined research objectives and priorities that related to several categories:

- ❖ Collect additional samples of DSCS for genetic work. There was an emphasis on the need for collection in relatively understudied groups, additional sponge collections, as well as for all species across a greater range of depths.
- ❖ Prioritize sample collection and collaboration by creating and widely sharing a "target list" of species.
- ❖ Improve collaboration between groups to prioritize and share collected samples, including internationally with Mexico and Canada.
- ❖ Conduct additional studies/collections to characterize DSCS connectivity along the West Coast. These studies should cross a variety of taxa and life histories.
- ❖ Incorporate genetics in future efforts to advance DSCS models.
- ❖ Continue to improve studies (develop common nomenclature, additional genetic markers, refine eDNA methods, etc.) and use collections to further resolve DSCS taxonomy.

Spatially, this group highlighted the importance of both collecting samples broadly to understand coastwide distribution and connectivity of DSCS, as well as specifically targeting regions near natural breaks, or biogeographic boundaries, to help better understand and delineate these boundaries as they relate DSCS.

5. Human Impacts

Although deep-sea ecosystems are remote and seemingly beyond the reach of humans, visual surveys have revealed that DSCS are indeed affected by human activities. DSCS are especially threatened by bottom fishing, changes in climate such as increasing temperatures and ocean acidity, marine pollution, drilling and cable laying, and marine accidents such as oil spills and the loss of containers from cargo ships. Managers need a better understanding of the activities impacting DSCS (in addition to bottom fishing), the responses of DSCS to those disturbances, and the recovery potential of DSCS once an activity has ceased. WCDSCI Research Priorities Workshop participants recommended research priorities spanning a wide range of subjects related to human impacts that also ranged in specificity. The topics discussed most during break-out sessions focused broadly on potential fishing impacts and DSCS monitoring including the following:

- Better define areas of high DSCS bycatch, or "hot spots," off the West Coast.
- Collect baseline data within areas proposed for protection modifications to assess potential fishing impacts on, and recovery of, DSCS communities.
- Identify areas that are relatively undisturbed by human activity ("refuges"), and determine how to quantify "pristineness."
- Determine the frequency and intensity of other fishing gear impacts on DSCS communities.
- Initiate long-term monitoring such as conducting consistent surveys through time to monitor human influences.
- Understand and monitor DSCS responses to ocean acidification, hypoxic events, and warming.
- Incorporate advanced technology into monitoring strategies (photomosaics, machine learning for image analysis, etc.).

Spatially, NMS were named as priorities since each of the five west coast sites contains DSCS and typically contains a relatively high concentration of fine-scale data (mapping and/or biological) that could supplement DSCS information. In addition, there is typically high human use within sanctuaries, with both commercial and recreational activities occurring throughout.

6. Education and Outreach

Research Priorities Workshop participants discussed potential opportunities, outlets, and tools to help develop and distribute data products and other informative material related to WCDSCI. Participants were encouraged to think creatively about how to make WCDSCI research results more accessible, engaging, and digestible to other scientists, managers, stakeholders, students, and the general public. Below is a summarized list of products participants felt might effectively communicate deep-sea science to a variety of audiences:

- A species identification guide for corals, sponges, and fishes for the West Coast.
- A "Species Target List" to prioritize specimen collection and inventory existing collections.

- A West Coast Regional Database for spatially explicit data sets.
- Updated National Marine Sanctuary Condition Reports and Sanctuary Integrated Monitoring Network webpages.
- New content and lesson plans to expand the existing NMS deep-sea coral online curriculum.
- Make use of photomosaics, 3D printing, story maps and other new communication tools and technology.
- Partner with institutions that curate public signage, such as aquariums, visitor centers, and museums, and collaborate on content that includes WCDSCI and/or DSCRTP.
- Social and traditional media content/posts, and telepresence experiences for various groups (academic, club, volunteer, etc.).

Generally, all groups emphasized the importance of setting outreach and education goals for sharing information and stories about WCDSCI's purpose, goals, and outcomes.