Deep-sea Coral Research and Restoration

Workshop Summary

May 22 and May 31, 2023

Workshop Attendees

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Overview of the Purpose

Deep-sea coral (DSC) research is a relatively new scientific endeavor, to date focusing largely on mapping the location of different species of coral. However, these habitats are being impacted by human activities (e.g., by large marine debris and dispersed oil from spills) and mitigation for damages are being developed by NOAA. Methods to restore damaged DSC assemblages have been explored for some species and there is great interest in advancing our understanding of deep-sea coral biology and their associated faunal assemblages. For successful restoration and research concerning DSC, appropriately selected seafloor areas protected from human disturbances are needed. Experts participating in the workshop were asked about the best available information on the topic, including their professional judgment, as part of a planning exercise to determine locations for potential DSC research and restoration areas.

NOAA Office of National Marine Sanctuaries (ONMS) held workshops on May 22, 2023 and May 31, 2023 to receive input on the design of areas of sufficient size to outplant DSC, including sufficient spatial buffers adjacent to the DSC outplanting locations for regional propagules/ growth of additional DSC without disturbance to the seafloor, and are of sufficient size to answer community-level research questions related to understanding DSC communities at different depths.

The geographic focus for research areas is within Monterey Bay and Greater Farallones national marine sanctuaries (sanctuaries) at depths greater than 50 meters[1] for research based on known DSC habitat; and between 110 meters and 1340 meters for restoration based on currently available methodologies for DSC outplanting.

The feedback from the DSC research and restoration experts helped sanctuaries delineate areas to meet all of the following needs:

- Protect the areas from benthic fishing impacts in order to conduct long term research (defined as a minimum of 10 years[2]) and potential future outplanting;
- Pre-outplanting site selection, DSC collection, and processing for outplanting;
- DSC outplanting;
- Monitoring of restoration effectiveness; and
- Research on the density and diversity of DSC in the designated areas and other community-level research related to understanding DSC communities at different depths, such as DSC species and fish associations.

The first project is planned to start in 2025 and will be funded through a 2022 Draft Restoration Plan and NEPA Evaluation for the YFD-70 Dry Dock (YTD-70 Restoration Plan) authored by ONMS, which was released for public comment in December 2022 and closed March 15, 2023. The goal of the Restoration Plan is to restore resources, habitat, and biota to compensate for the impacts to DSC caused by a large, sunken dry dock. Additional restoration projects may be possible in the future and a better understanding of DSC communities at different depths is another important component.

The Process

The DSC subject matter experts were provided background on the original DSC selection criteria included in the 2022 YTD-70 Restoration Plan, which resulted in identifying appropriate locations for DSC restoration, as well as research areas. The criteria included the following:

- Depths that are suitable for translocation based on current methodologies (Boch et al., 2020) and within larger areas that have known DSC habitats. DSC suitable for translocation occur at depths between approximately 110-1340 meters (~360-4400 feet or ~60-735 fathoms) below sea level; areas deeper than 50 meters for research based on known DSC habitat.
- For translocation of DSC, hard substrate where DSC are known to historically or currently occur, and in locations that are protected from drilling, dredging, trawling, or seafloor disruption by sanctuary and other regulations.
- Enforceable areas.

[1] The deep sea coral range is defined from where the light is dim (around 150 feet or 50 meters deep) to more than 20,000 feet (6,000 meters) below the ocean's surface.

[2] As deep sea coral restoration is a new field, there is little information on the time frame over which we might expect to see different phases of success (e.g., survival, growth, propagation). However, a minimum of 10 years, but possibly longer is needed to allow these slow growing organisms to proliferate and grow and to allow for them to experience the range of ocean conditions that may occur over a decadal time scale and which would influence their growth and survival.

The experts were informed about the following NOAA ONMS planning:

- If relevant location imagery is not already available, the precise areas within an identified restoration site will be surveyed in the future to verify the suitability for restoration.
- If not available, environmental parameters such as oxygen, temperature, and depth will be measured before any translocations.
- If not available, video and still imagery will be captured to verify the substrate type and substrate samples will be collected.
- Multiple sites within a location may need to be surveyed to find an area of stable hard substrate, and at least two sites will be selected to maximize success and restoration impact.
- Transplant sites will be selected within depauperate areas of relatively flat terrain for maximum "coral pot[3]" stabilization.

The experts were provided access to maps of the five selected areas of interest through the NOAA Geo Platform that included the following information:

- No trawl Essential Fish Habitat (EFH) Conservation Areas
- Bathymetry
- Substratum type
- Presence of DSC
- Explored transects
- Habitat suitability probability distribution and known locations from remotely operated vehicle (ROV) surveys of adult yelloweye rockfish.
    - National Marine Fisheries Service West Coast bottom survey catch and bycatch by effort 2003-2010
- Fishing effort and coral bycatch
    - Relative intensity of commercial bottom trawling before gear modifications and no-trawl EFH Conservation Areas (Jan 2002-June 2006)
    - West Coast groundfish observer program coral and sponge bycatch by effort (Jan 2002-June 2006)

The experts were then each given access to a drawing tool where they could draw a shape and explain the rationale behind the shape. This information was captured in the tool, but the experts did not see designs or shapes from other experts. The project team from NOAA ONMS reviewed all of the drawings subsequent to the workshops, which provided the basis for the final designs.

[3] "Coral pot" is defined as the container that stabilizes the translocated coral branch. It could be made of materials such as cement or natural rock.

Discussion Summary

The following research and restoration questions were considered about the characteristics of each area, and when each expert reviewed the data in the NOAA GeoPlatform:

1. Knowing that the science for determining propagule dispersal and growth is limited, what is currently known about DSC dispersal distance, and what factors should be considered in determining the size of an area to be protected from benthic habitat disturbance? How much area around the outplanting sites is appropriate to protect?
2. What factors could be important in determining the size of a protection/restoration area (e.g., habitat type, habitat diversity, predator densities, ocean currents)? Would depth and currents change the size and if so, how?
3. The target depth for mitigation sites is 110-1340 meters (~360-4400 feet or ~60-735 fathoms) below sea level. If outplanting occurs at the shallower depths, how likely is it to facilitate dispersal of DSC to deeper depths?
4. The expected methodology is to target areas of hard substrate where DSC have historically or currently occurred; however, relatively flat terrain is likely needed for effective stabilization of "coral pots." What geographic areas are appropriate to allow for both rocky habitat and flat terrain?
5. The precise areas within an identified restoration site will be surveyed using an ROV to verify the suitability of restoration. How should an area be surveyed to properly characterize it for final, precise area identification?
6. Environmental conditions will be measured using a conductivity, temperature, and depth ("CTD") sensor on the ROV. Are there specific targets for conductivity and temperature that are critical for maximizing success? Are there other important considerations that should be included in the criteria such as turbidity, oxygen, and currents?
7. What additional answers would you need to have optimal confidence in selecting DSC restoration and protection areas?

- The working group discussed the availability and suitability of coral species for restoration (outplanting). The discussion focused on species at different depths and included bamboo corals, *Corallium* sp., *Swiftia* sp., *Callistephanus* sp., *Keratoisis* sp., *Isidella* sp., and a black coral *Lillipathes* sp. *Isidella tentaculum* was included in translocation studies.
- There was general agreement that DSC communities differ greatly between 200 meters and 1300 meters, and therefore different research questions may be addressed at these different depth zones.
- The group discussed the change in the rollers and footropes of the trawl gear in 2005. Before the change, large roller gear (large tires) could access areas that are not accessible now, and so some of the places that are not considered trawlable now were previously trawled. At some locations there has been some documented recovery.
- The group discussed the need to have nearby control area(s) and the associated monitoring that should occur. There was a recent publication showing translocated DSC do better if the source corals have similar depth and environmental conditions, which should be considered when choosing locations. It is important to understand what DSC species are available and

where. The criteria used to define suitable control areas for restoration efforts was discussed briefly, but not resolved.

- How to measure successful outplanting and passive versus active restoration was discussed. There are two types of successes: the first is if the outplants live; the second is if the outplants live and provide recruits to the area.
- There was a discussion about the value in collecting environmental DNA (eDNA). Specifically, communities at 200 meters will have different assemblage than at 1300 meters. We can assess biodiversity before taking tissue samples. There are coast-wide eDNA samples from the NOAA Deep Sea Coral Research and Technology program and that data can be made available.
- There is a recent publication that the translocated DSC do better if the source corals have similar depth and environmental conditions (Boch et al., 2019). That should be a factor to consider along with what DSC are available at similar depths.
- The experts suggested the ONMS team consult with the Monterey Bay Aquarium about their deep-sea coral husbandry and what they have observed in their tanks/exhibits.
- Some individual species have not been successfully propagated in reproductive experiments. There are plans to assess the coral populations in the areas selected.
- There was a discussion related to the fact that more ROV surveys result in the ability to more likely to find source corals. In the Gulf of Mexico, finding source corals for restoration projects was initially a concern, but subsequently were found via ROV surveys. The central California region should develop criteria to focus where we can do the most work.
- There was a discussion about coral reproduction modes (some are broadcast spawners and others are brooders) and that the substrate type will be a factor. Experts recommended we look at where a DSC population might be up or downstream from a restoration site, look at DSC feeding seasonality for the timing of the restoration, and consider harvesting coral when there is more productivity, such as during upwelling, so they have a higher survival rate.
- There were questions related to predation on DSC and relevant observations. Certain sea stars and sea slugs have been observed feeding on some DSC. However, there are some DSC that have physical and/or chemical defenses so it's useful to know about the biology of the area and to review available imagery. Some things to consider: at the oxygen minimum zone depth, relevant impacts of climate change on DSC might be less about ocean acidification, but more hypoxia zones and water turbidity might be a factor.
- The Bureau of Ocean Energy Management funded habitat suitability model layers were suggested as potential data layers to review. National Centers for Coastal Ocean Science created map packages of the inputs as well as outputs that could be informative for this process. They modeled corals and sponges, as well as other benthic macrofauna, up to 1200 meters.
- Population connectivity is a really important question. If source corals are from 20 km away, or even 50 or 100 km away, connectivity is probably pretty high. To avoid problems with genetic or phenotypic variability, there is a suggestion to collect DSC as close as possible to a nearby source population.
- Research on DSC recovery after fishing is important. For example, NOAA Fisheries is analyzing data taken in 2005 versus 2018 and 2019 to compare differences.

The following highlights key points discussed regarding the potential for DSC research and restoration at the five areas:

1. *Sur Ridge*
   Sur Ridge is the deepest overall location of the five areas, ranging from 820-1560 meters. DSC communities have been researched more extensively in this area compared to other areas and it is a location where outplanting has been successful. Since July 2014, eight groups of various corals have been successfully translocated in the northern portion of Sur Ridge proper. The successful translocations, alive for almost a decade include: *Lillipathes* sp., *Isidella tentaculum*, *Keratoisis* sp., *Swiftia kofoidi*, and *Corallium* sp. The bamboo transplants are producing visible eggs. Sur Ridge has thousands of DSC and can be a donor site for DSC at deeper depths. Donor colonies from Sur Ridge have demonstrated survival when being transported, but have not been transported as far north at Greater Farallones National Marine Sanctuary. Areas of Sur Ridge were trawled 1997-2003, including trawling to the west and to the south of the ridge. Protecting Sur Ridge from benthic habitat impacts is important because it includes the research equipment by Monterey Bay Aquarium Research Institute (MBARI), and the work planned there, which are expected for the long-term.

2. *Año Nuevo-Ascension Canyon Complex*
   Two separate canyons together make up the Año Nuevo-Ascension Canyon Complex, and the depth of the canyons ranges down to approximately 1770 meters, although suggested options ranged from 480-1460 meters. The upper and lower canyon areas are very different from one another. This is the second deepest area of the five locations, and both the upper and lower canyon areas are deeper than the sites to the north. There were discussions about how these are not "active" canyons, which is key to conducting research and restoration as it means the canyons are more stable and there is less sediment flow which can impede coral growth. Sometimes DSC recruits when water is not so turbid. The upper canyon may have too significant of a slope, which may indicate this is not a good location for DSC outplanting. In an active canyon, DSC can get covered by sediment. There may be some sediment flowing in the lower area of the canyons. Video imagery from Delta submersible dives for DSC and sponges indicate almost exclusively sponges, as there is a 360 meter limit for depth from that data. There was concern expressed about the upper part of the canyon complexes (shallower depths) not being suitable for DSC restoration and that the areas to focus on are at the lower parts of the canyons that indicate hard substrate and have observed corals. For example, bamboo corals do not occur at shallow depths, even in near-pristine locations. So, we would not want to take bamboo corals from deeper depths, lower in the canyon and transplant them out up at the canyon head, as they will not do well there.

3. *Cochrane Bank/Fanny Shoals*
   This is the shallowest of all the sites ranging from 60-160 meters. Mostly cobbly habitat and mixed substrate (high and low relief) were observed, some previously trawled and potentially impacted by other historic benthic fishing. Biologists would like to see how the shallower DSC grows vs deeper areas. There is a lot of research value to this area. This area

lies in a stratification layer of the California coastal zone with distinct layers of water. There is an oxygen minimum zone at ~85m here. This is possibly why black coral has been observed in this area, as it was found at 91m near the highest (shallowest) part of the Cochrane Bank feature (Etnoyer et al., 2014). How the area is affected by California current and should be considered as part of DSC research and restoration. It could be a passive restoration site to see how many corals recruit and grow, or if the black coral is propagating and if so, where. The escarpment or Cordell Bank could serve as potential areas for source corals, specifically the Red Whip Gorgonian (*Chromoplexaura marki*). Note that observations were from still images (vs video transects) via an ROV.

4. *The Football*
   Depth ranges at the Football are 190-280 meters. Species of interest for outplanting is *Swiftia* sp., which are a habitat-forming species that are found here. Could transplant *Swiftia* based on depth. There is a bubblegum coral that occurs this shallow. A nearby rocky habitat that has hundreds of these DSC and could be a source. There is interest in the "flat rocky" area for restoration. There is interest in the connectivity between this area and the area offshore Pt. Arena. Depth range can span several species of DSC. The area has low relief rock, and areas of layered rock areas where fish will hide. It is a unique place in terms of experimenting with translocation/outplanting. This predicted habitat is pretty accurate.

5. *Offshore of Point Arena Area*
   The depths are similar to "The Football" and range from 160-590 meters. There is interest in the connectivity between this area and "The Football." This area has seen the most changes in fishing impacts. The Essential Fish Habitat Conservation Area that prohibited trawling were reduced and data was collected in areas previously protected and areas that remain protected from bottom trawling. There are a lot of DSC in the area that was opened. At the bend, there may be good habitat, and the north may be more mud draped. The south has less mud draping. There are potentially source DSC to the west. In many locations there is low relief rock mixed with mud veneer. Small areas of high relief rock to the east. There are DSC, but they are small and spread out. There are research questions related to how disturbance may impact DSC. According to Expanding Pacific Research and Exploration of Submerged Systems (EXPRESS), other ROV surveys to the north had higher density of DSC observed. Rock should be interpreted cautiously. An interesting fact about this area (eastern end of it) at the high relief rock, is that some large yellow eye and cowcod were observed. Could be beneficial to think about fish associations and of overall management as a research question. This is too far away from Sur Ridge to transport unless there are tanks onboard that could allow them to be moved longer distances. *Swiftia* outplanting here may be possible. This is not a bamboo coral habitat. We know more about how to keep them alive. Starting in 2006 or after, the observer program has been freezing a lot of corals. We may have these specimens in the freezer.

Wrap Up

- The upper three (Point Arena areas and The Football) are good because they are close, and of similar depth. North Point Arena could be used as a control, and outplant to the south.
- We could evaluate an area that is sediment draped and an area that is not.
- We would want at least three controls to have statistical variance. We need to think of how we want to analyze data before we identify a control.
- We need to better understand potential impacts of wind energy. Although it is outside of the sanctuaries, there will be more areas of wind energy. Keep the wind energy area planning in mind.
- Note that we may get the DSC up to a size that causes them to fall over. However, they still are propagating.
- If we can protect some areas of the deep sea, we can answer a lot of research questions for future funding for projects.
- We need more information on the reproductive biology (e.g., seasonality, reproductive traits) and recruitment success of targeted species.
- While population connectivity is an important question, it might be a better approach to prioritize collections and outplanting in the same general area to avoid unknown stress on transplants (e.g., genetic/phenotypic variants that are unsuitable for the translocation site/depth).
- More field research is needed to locate, identify, collect, and quantify DSC populations (would address several, if not all, of the expressed needs listed above).

Additional Questions that Could be Answered from the Selected Areas

- What additional answers would you need to have optimal confidence in selecting DSC restoration and protection areas?
- Where are potential donor/source coral populations located to inform and prioritize nearby restoration?
- Questions related to DSC handling - how far away can donor/source corals be transplanted (duration on the vessel)? What handling protocols increase their chance of survival post-transplant (Monterey Bay Aquarium)?

Factors that might be considered (including many already listed):

- Depth: deeper is more expensive and technically more difficult
- Oxygen (~depth): may target higher oxygen depths within the depth range suitable for the target species
- Substratum: hard bottom (and steep, rugose, un-sedimented areas nearby)
- Turbidity: DSC abundance is lower in Monterey Canyon than Sur Ridge/Davidson - this lower abundance could be driven by many factors, however turbidity may be stressful for many DSC (and may be why densities are low in that area). Tolerance to turbidity may vary considerably among DSC, so choose species wisely.
    - For this reason, maybe canyons (near Ascension) are riskier transplant sites.
- Flow: important, but maybe not that variable among potential sites

- Productivity: considering the productivity of an area and seasonality to select the most productivity times and locations for the work
- Temperature and pH: largely invariant among potential sites at similar depths

Next Steps

Participants were asked to independently draw polygons of areas and were not provided access to other submissions. ONMS will look at submissions in aggregate to help focus the areas. ONMS will be designing areas that will be proposed to the Pacific Fishery Management Council as part of a scoping document to consider management that prevents benthic impacts.

References

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