MONITORING PLAN – ORGANISM INTERACTIONS

CONTACT: DAN HELLIN, OPERATIONS & LOGISTICS MANAGER, PACWAVE, P: 541-737-5452, DAN.HELLIN@OREGONSTATE.EDU

PRINCIPLE INVESTIGATOR: SARAH HENKEL, ASSISTANT PROFESSOR, HATFIELD MARINE SCIENCE AND DIRECTOR OF ENVIRONMENTAL RESEARCH, OSU, 541-867-0316, SARAH.HENKEL@OREGONSTATE.EDU (NOTE: STAFF CHANGES MAY OCCUR, BUT OSU FACULTY MEMBERS WILL LEAD THIS STUDY)

1. INTRODUCTION/OVERVIEW

1.1 Resources of Interest

The resources of interest are the demersal and water column organisms in and around the Project area, which is located south of Yaquina Bay on the central Oregon coast. The entire Project area is within designated critical habitat for green sturgeon and is Essential Fish Habitat (EFH) for groundfish, coastal pelagics, Pacific salmon, and highly migratory species. Benthic sampling around both PacWave South (formerly known as Pacific Marine Energy Center South Energy Test Site [PMEC-SETS] and PacWave North (formerly known as Pacific Marine Energy Center North Energy Test Site [PMEC-NETS]) indicate substrate composition on the mid to inner shelf along this section of the Oregon coast consists of medium to coarse sand with larger grain sizes found with increasing depth (Henkel 2014), switching again to smaller grain sizes on the western boundary of the PacWave South Project Site. Thus, while the habitat in the Project area is EFH, it also is highly common and abundant on the Oregon central coast. The groundfish assemblages in this area are typical for sedimentary (sand and/or mud) areas on the Oregon mid to inner shelf. Comparisons of beam trawl collections from PacWave North, and surveyed areas off Reedsport and north of Coos Bay showed that benthic species assemblages differed more by depth than they do by collection location. This indicates that the PacWave South area is likely not a unique area for benthic fish species in Oregon.

Additional resources of interest include fishery limiting species such as overfished, sensitive, threatened, endangered, or strategy species. ODFW identified Dungeness crab, salmonids, rockfish and forage fish as species groups of interest to ODFW management.

1.2 Potential Effects/Issue Summary

The subsea cables, subsea connectors, and anchors would result in both temporary and long-term alterations of benthic habitat in the Project area. Temporary disturbances may be recurring at various intervals over the 25-year term of the project if anchors and other bottom components are removed and re-installed for different devices under test.

The WECs and mooring lines in the water column may serve as fish attractants as they will provide shelter and colonization structures as have been observed on other structures in the sea (Claudet and Pelletier 2004, Wilhelmsson et al. 2006, Seaman 2007, Langhamer and Wilhelmsson 2009, Langhamer et al. 2009), particularly providing habitat for structure-oriented fishes, such as rockfish (Danner et al. 1994, Love and Yoklavich 2006). Components higher in the water column or near the surface may particularly attract juvenile fishes. Recruitment production of midwater habitat at oil platforms was 3.7 times as much as on natural reefs, possibly due to increased settlement opportunity (Claisse et al. 2014) and settlement stimulus provided by high vertical profile platform structure (Love et al. 2006). Similarly, most of the fish present at wind farms offshore Europe (i.e., Atlantic cod, pouting) are juveniles (Reubens et al. 2014). These effects may be limited to a small number of species as at the Lillgrund wind farm where no major effects on demersal fish diversity and abundance were detected as compared to reference areas (Bergström et al. 2013), although some common species were detected in higher densities near the foundations. A research question remains whether fish will just be re-distributed from nearby areas or if the increased habitat will result in increased local productivity (Pickering and Whitmarsh 1997, Brickhill et al. 2005). For some species groups, there is the potential for a negative effect on local populations if there is enhanced predation or fishing pressure due to the aggregation effect (Wilhelmsson 2012).

In addition to fishes, some benthic invertebrates may be attracted by the conversion of habitat or be affected by reduced fishing effort and/or changes in predation. Rock crabs may be attracted to structure as observed around oil platforms in southern California, although the effect varies by species. Using baited traps immediately underneath oil platforms versus 200 m away in soft sediment, for *Cancer antennarius* and *C. anthonyi* there was a positive effect of the platform on abundance, while for *C. productus* and *Loxorhynchus grandis*, there was no effect of location (Page et al. 1999). In regards to sex ratios, the proportion of male rock crabs at the reference stations was not different than 0.50, while the proportion of males trapped under the platform was 0.34 for *C. antennarius* and 0.10 for *C. productus*, indicating fewer males of these species utilizing the platform-associated habitat. Page et al. (1999) also tagged 780 crabs at the platforms. Recapture rates were low (0.9 – 3.1 %) for all species at the platforms, while local fishermen working up to 8 km away from the platforms returned 2.9 % of the *C. anthonyi* tags. This suggests that while rock crabs may be attracted to the structures, they still maintain large foraging/home ranges. Additionally, structure does not seem to be a barrier to crabs as remotely operated vehicle (ROV) surveys of a pair of 25.4 cm diameter, 46 km long gas pipelines crossing Georgia Straight (Vancouver Island Pipeline) taken at three intervals over the first 10 year period following construction showed box crab and red rock crab actively crossing the pipes, and crustaceans such as prawns and shrimp appeared to be strongly attracted to the habitat created by the pipe in soft sediment (Glaholt 2008).

Adult Dungeness crabs are opportunistic, carnivorous feeders that primarily consume bivalves, fish, and shrimp as well as other small invertebrates by excavating prey from the sediment (Rasmuson 2013; Gotshall 2005). As such, they may be attracted to areas of sediment disturbance and/or structure that could provide feeding opportunities. During video reconnaissance at the 76 cm diameter, 1.5 km long Bazan Bay pipeline in Canada, Dungeness crab were observed feeding on epiphytic algae growing on the pipe exterior, actively crossing the pipe, buried in substrate immediately adjacent to the pipe, as well as in sediments up to the outer limit of the 15 m sample transect length perpendicular to the pipeline (Glaholt 2008). While we are not aware of studies that have directly tested Dungeness crab attraction to structure relative to soft-sediment habitats in the NE Pacific, a number of tagging studies have been carried out in the region to assess Dungeness crab movement patterns. These studies can be used to assess the potential for crabs to range in and out of the Project Site. The smallest estimates of movement are reported from Fritz Cove, Alaska. Estimated movement ranged from 2.13 to 7.24 km for males and 0.38 to 4.23 km for females, although no female crabs left the bay, which necessarily limited their potential range (Stone and O'Clair 2001, 2002). In British Columbia, Smith & Jamieson (1991) estimated that after one year of random dispersal, in the absence of geographical boundaries, 95% of males and females would be within radii of 9.5 and 13.9 km, respectively, of the point where they were one year previous. In a California study of females 54% of recovered crabs had moved more than 2 km away of the original release sites (~1 year later) while one crab was recovered 80 km away (with other recoveries at various distances in between; Diamond and Hankin 1985). In Oregon, Waldon (1958) conducted a tagging study of adult males and found crabs travelled an average of 15.3 km in an average of 80 days from the time of release to recapture with some distances exceeding 92 km. Similarly, Hildenbrand et al. (2011) found adult males tagged off Reedsport, Oregon, travelled an average of 18.6 km with a maximum of 90.7 km between release and recapture locations. It's important to note that distances observed in the mark-recapture studies represent minimum distances the crabs may have travelled, as the crabs may have made any number of movements between the times of release and recapture.

Besides the deployed structure itself, shell mounds are a feature of the sea floor around offshore oil platforms in California (Page et al. 1999) and wind turbines in Europe (Hiscock et al. 2002) where structures are colonized by fouling organisms, which then fall or are scraped off the devices as part of regular maintenance. In California, sea stars and *Pandalus* shrimp dominated shell mound megafauna, with rock crab and Dungeness crab observed on shell mounds around platforms (Goddard & Love 2010). Thus, if similar mounds form beneath WECs and their moorings at PacWave South there is the potential for other megafaunal invertebrates (in addition to Dungeness crabs) to show differing distributions or abundances compared to pre-installation conditions or reference areas. However, it is uncertain whether these features will develop at PacWave South as the duration of WEC deployment and thus potential for fouling community succession as well as the need for at-sea cleaning are unknown. A study of the fouling communities on the Ocean Sentinel anchors and surface floats marking them (neither of which were coated with anti-fouling paint) found very little biomass on the anchors (primarily small balanoid barnacles, percent cover ranging from 2 % to 80 %) while on the buoys at least 50% of the subsurface halves were covered with turf algae, gooseneck barnacles, and mussels (Mendoza thesis, in prep.)

2. NEED FOR INFORMATION

Available literature leads us to expect a new community will form on and to some degree around deployed structures (Claisse et al. 2014), but what that community will be composed of and how long it will take to form remains unknown. Published information is available to characterize fish assemblage and marine life that currently occupy waters of the Pacific Ocean off of Newport at similar depths as SETS (see section 3.3.3 of the PDEA). However, some gaps remain in terms of spatial and temporal trends or distribution of fish within the water column. The new community associated with WEC testing at PacWave South could have both positive and negative effects on existing local populations of marine species. The state maintains a high level of interest in how important resources and uses may be impacted, and considers it paramount that they are considered when the siting and authorizing of marine renewable energy projects is conducted (DLCD 2015).

Published literature indicates great variability in taxon- and age-specific responses of fishes to the deployment of differently designed artificial reefs (Hueckel et al. 1989, Bohnsack, et al. 1991, Baine 2001; Claudet and Pelletier 2004) as well as structures of offshore renewable energy devices (e.g. Wilhelmsson et al. 2006, Seaman 2007, Langhamer and Wilhelmsson 2009, Langhamer et al. 2009, Bergström et al. 2013). Thus, we expect that different WECs (and their associated mooring systems) deployed at PacWave South could have different levels of “attractiveness” to organisms in the vicinity. In addition, the time of year of WEC deployment may have an effect on the species attracted due to differences in migration or recruitment of fishes. An ROV survey conducted in September 2012 around the WetNZ device 25 days after WEC deployment at PacWave North did not show any fish around the WEC, the Ocean Sentinel, or any of the anchors, aside from the occasional flatfish disturbed from the sediment. The lack of observations using the ROV may be due to the season, the time of day the surveys were conducted, the length of time devices had been in the water, or due to the behavior of the species (avoiding the ROV). When we conducted an ROV inspection of the Ocean Sentinel anchors in May 2015, we observed juvenile rockfish schooling just above one of the anchors indicating ROV presence may not be driving whether or not fish are observed. Similarly, ROV observations of the 10-meter-diameter Ocean Power Technology anchor documented “large schools” of black rockfish as well as lingcod and potentially other fish as well as motile invertebrates (e.g. Dungeness crab, sea stars) associated with the structure (OPT 2014; OPT 2016). Conducting twice-yearly surveys of deployed structure multiple times after they are installed will help us determine if the difference in fish observed in September 2012 versus May 2015 was due to seasonal differences (e.g., timing of settlement of juveniles) or fish finding and being attracted to the structure after it had been deployed for some time.

The fouling communities on the Ocean Sentinel anchors and surface floats were documented after over 2 years of deployment at NETS, following removal in November 2015. The Ocean Sentinel surface floats had considerably more biomass than the anchors, including large gooseneck barnacles, mussels, and seaweed (Figure 1). The anchors out of the water showed very little accumulation of biomass (Figure 2): mostly Balanoid barnacles, a small number of chitons (molluscs), bryozoans, and a single anemone across all three anchors after over 2 years of deployment. There was evidence of anchor movement that may have affected development of the attached surface community. After 23 months installed in water depths similar to the proposed SETS project, in-water observations of the 10-meter-diameter Ocean Power Technology anchor documented an “established community” including attached invertebrates (e.g. plumose anemones) (OPT 2014; OPT 2016). The potential for ecologically significant shifts in community composition at PacWave South due to biofouling is unknown and there is potential for broader scale changes with longer-duration tests incorporating multiple anchors and mooring systems. However, this may be offset by the potential for more frequent removal of WECs, surface floats, and anchors, resulting in less time to support biomass accumulation.

Management interests in monitoring fishery (including crab) resources at SETS are primarily driven by ODFW’s expressed need to understand how stocks interact with installed devices and if fishing activity potentially enhanced or constrained by facility installation could result in localized changes to abundances or distributions. ODFW may use information gathered from this study to inform fishery management decisions relating to use of the project area or nearby areas.

The use of video tools to observe organisms present in the project area has distinct advantages over other methods of assessment. While traditional survey methods of hook-and-line, trawling, and or crab pots allow for higher taxonomic resolution and biometric data on individuals (ex. sex, weight), they fail to provide either behavioral information of precise habitat utilization and/or actual interactions with the device. Capture methods also often result in the take (or killing) of the sampled organisms. Video techniques do allow for direct observations of the organisms in the habitat and provide better taxonomic resolution than hydroacoustic survey methods. Videos also provide a long-term archive of information that can be reviewed in the future to revisit existing research questions or investigate new questions. These video records additionally may be valuable in terms of identifying entangled gear and other debris and/or maintenance issues on the WECs and/or mooring systems before they become larger problems.

3. GOALS/OBJECTIVES

The overall goal of this organism interaction monitoring plan is 1) to track changes to pelagic and demersal fish and invertebrates (particularly Dungeness crab) that might be (a) attracted to the installed components or (b) affected due to the potential for reduced fishing pressure, and 2) to track biofouling on the anchors/devices. The information will be provided by the licensee to ODFW for the agency's use in managing ocean and coastal resources.

3.1 Study Objective

The presence of Project components will introduce hard substrate previously unavailable in the project area. We expect these components to be colonized by fouling organisms over time, as well as to potentially attract mobile invertebrates and fish to the area. The objectives of the organism interaction monitoring are to assess differences in the timing, abundance, and size classes of fish and invertebrate species or species groups that colonize or associate with different types of project structures on the bottom and in the water column.

4. DATA COLLECTION AND ANALYSIS

4.1 Methods & Equipment

An ROV will be used for monitoring of biofouling, structure-oriented fish, and distribution of organisms surrounding installed components in the test berth area. The ROV will have forward and downward facing video cameras with live feed to the support vessel. The ROV also will be equipped with a Tritech Gemini multibeam imaging sonar to evaluate whether there are fish beyond the camera's visual field that may avoid the ROV. The ROV will have a pair of lasers at a fixed width to assist with sizing organisms. A single pre-installation (pre-WEC installation) survey will be conducted in the spring/early summer period before the first devices are deployed at PacWave South, as described in Section 4.2.1 below, to obtain pre-installation abundances of benthic and lower water column organisms at the test site as well as gain insight on visibility/detectability of seafloor organisms at the test site. Once WECs are deployed, sub-surface components and the surrounding seafloor will be surveyed using videographic observations from ROVs at the frequency described in Section 4.2.1, below. While on the vessel, the live video feeds will be watched in real time by a dedicated observer and notes will be taken regarding ocean and seafloor conditions and organisms seen. Any derelict gear observed while at sea will be reported as detailed in the Entanglement Mitigation Measure, and appropriate actions will be taken according to the terms of the Mitigation Measure. Additionally, any derelict gear observed during processing of the video in the lab will be compared to at-sea observations and any additional observations will be reported and acted upon per the terms of the Mitigation Measure. Each organismal community to be monitored is described in more detail below.

4.1.1 Structure-associated, water-column fishes

Each sub-surface component type (both WECs in the water column with associated moorings and anchors on the bottom) will be observed for mobile, water-column organisms associated with the structure. To accomplish this, the ROV will partially circle the subsurface components from decreasing distances towards the device to assess the number and species of fish visible in each swath. A similar approach was determined to be effective for assessing fish communities on submerged oil and gas platforms (Ajemian et al. 2015). We will drop the ROV in the water ~25 m away (using a range-finder on the surface) from the WEC (on the downstream side). The ROV will be flown to the first position: 10 m below the surface, 20 m away from the WEC, where it will be held stationary with the camera facing up-current for a 1 minute period [a modified stationary point count (SPC)]. After the stationary observation, the ROV will navigate along a continuous horizontal rove partially around the structure from near one mooring line to near the next. Then we will instruct the ROV to move closer (e.g., to ~10 m away), do a SPC followed by a semi-circular swath, then move ~1-2 m from the WEC to do a SPC followed by a semi-circular swath. At no point would we attempt to maneuver the ROV across or under the mooring lines. Thus, if a WEC is on a three point mooring, the semi-circular swaths would cover an arc of just under 120°, as illustrated in Figure 3. If the draft of the WEC under observation does not extend to 10 m below the surface, we will attempt to conduct the WEC observations as near to the base of the WEC/surface of the water as possible with the caveat that operations closer to the surface make navigation and station keeping for the SPCs more challenging. Then we will instruct the ROV to dive to a position ~20 m away from the expected position of an anchor, 1-2 m above the bottom. Then SPCs and semi-circular swaths will be conducted moving toward the anchor. We would then transit along the sea floor to the second anchor, conducing SPCs with semi-circular swaths as we approach.

This navigational task will be accomplished using a commercial AUV navigation system on the ROV combined with the open-source Robot Operating System (ROS) in an integration developed by the Hollinger lab at Oregon State University (Lawrance et al. 2016). In brief, the system allows for autonomous station keeping as well as traveling between known positions. In 2016 field trials, the ROV was able to reach and traverse between waypoints to within approximately 1 m with respect to the internal navigation determination. Once the position of the WEC is known (after deployment) we will develop dive plans for the ROV that will include the paths of the roves.

If multiple sub-surface components of the same type are deployed in a berth, we will attempt to sample at least two of the same type. For example, if a WEC is on a 3-point mooring (3 anchors), then we anticipate we likely will be able to survey the two anchors on the downstream side of the WEC, as it is preferable to maneuver the ROV against the prevailing current rather than go with the flow and potentially be swept into the object of interest. If multiple WECs are deployed within a berth the configuration of the array will affect how many of the individual WECs/anchors can be surveyed; however, our goal will be to get at least three observations of each WEC and anchor types.

Although we do not expect a high likelihood of observing mid-water fish in reference areas, as we are descending for the reference band transects (described below), we will pause at 10 m below surface and do an SPC (with multibeam imaging sonar) before continuing the descent to the seafloor.

4.1.2 Biofouling

Focal observations of major sub-surface components (e.g., WEC, anchor) will be made following the closest swath survey conducted on each component as described above. As practical, multiple (2-3) observations on different faces of the same component type will be made. If there are multiple components of the same type (e.g., anchors), at least two anchors (those on the down-current side of a WEC) will be observed in each berth as described above. Additional anchors may be observed as possible. During the focal inspection, the ROV operator will perform a slow pan of the structure of interest, primarily using the forward camera to observe the structure. During anchor observations, the downward camera will be used to observe scour and organisms in the sediment adjacent to the anchors.

4.1.3 Benthic fishes and invertebrates

The ROV will conduct band transect surveys within the individual test berths in use among the bottom-mounted components on the seafloor. We will conduct 3 transects each at least 100 m long within each berth. This will enable standardized abundance estimates of benthic fishes and invertebrates at and between the different bottom-mounted components.

Band transect surveys also will be conducted at pre-determined reference areas outside of the PacWave South Project Site to determine the density of benthic fishes and invertebrates that would be expected in the area in the absence of the installation. We will conduct 6 reference transects each at least 100 m long outside of the Project Site: two north and two south of the Project Site at depths that match the test berths as well as two inshore of the Project Site, which will necessarily be shallower.

Additionally, although the cables will be buried for nearly the entire length, one of the cable routes will be surveyed as part of each semi-annual ROV cruise. (Thus each of the five cables will be surveyed every 2.5 years.) This will include the unburied portions near the sub-sea connector as well as the buried route back towards shore. We will follow the expected route based on GPS coordinates as well as use all reasonably available tools to orient along the cable.

4.1.4 Video processing

Trained personnel will process collected videos in the laboratory. Videos from the forward-looking and downward-looking cameras will be viewed simultaneously on stacked monitors. The forward-looking versus the downward-looking cameras will be the quantification view depending on the type of observation, as described below. If time codes are recorded onto the audio track of the video footage, a time code wedge will be used to record the time (on the video) of each organism observation, which can be useful for re-finding species of interest on the footage during data analysis.

For the semi-circular swath observations, all organisms encountered on each rove, swath, and SPC will be identified to the lowest possible taxonomic level and enumerated. Because the start/stop time will be logged for each individual rove, swath, and SPC, we will be able to compare the numbers of individuals observed during each survey component. Fishes will be classified as juveniles, sub-adults, or adults (as appropriate for the species), based on size determined using the lasers. Crab and seastar sizes will be estimated using the lasers. We anticipate that with each view of the subsurface components (at different distances), we will count some organisms that had been observed and counted in the previous view. Thus, at each SPC and over the course of the encircling rove, we will determine the maxN (the maximum number of fish for a given species) within the field of view, a commonly used metric (e.g., Merritt et al. 2011; Cappo et al. 2004; Cappo et al. 2007; Harvey et al. 2007) and note observed behavior. (This metric is sometimes referred to as MinCount because it represents the minimum number of individuals for a particular species during a dive; Ellis and DeMartinie 1995, Watson et al. 2005, Willis et al. 2000). As feasible, we will use the distance travelled over the bottom to convert numbers of each species observed in the water column on the rove to standardized abundances. If we are not able to determine distance travelled, organism counts will be standardized by survey time using the start and stop time of each rove and SPC. As the ROV is transiting from the WEC to the anchors, any fish and/or schools of fish will be documented and reported. However, we do not intend to quantify densities of organisms detected in these "off transect" observations. Upon the approaches to the anchor, in addition to quantification of organisms, we will review the footage to look for evidence of scour. Since we will be conducting slow swaths at three distances, if we detect scour in close proximity to the anchors using this video tool, we will be able to delineate the extent at least relative to the three distances. If we detect scour at all visual survey distances and suspect the extent is broader, we anticipate it would then be detected by the within-berth band transects if they are conducted in the direction of the scour and, if very wide-spread, by sediment analysis of the box core grabs, which begin at 50 m away from the anchor.

For each of the Project component focal observations, the percent cover of fouling on the component will be determined. All organisms will be identified to the lowest possible taxonomic level. We anticipate for the initial observations, total percent cover or perhaps percent cover of film/invertebrates/algae will be the lowest possible taxonomic level. As the community develops, we may be able to distinguish general classes of fouling organisms (e.g., sponges, ascidians, barnacles, bryozoans, mussels), and the percent cover of each will be determined. As the community further matures, fouling species may be distinguished. Additionally, mobile organisms such as seastars, anemones, and crabs observed on the structures will be identified and sizes estimated using the lasers. A challenge to using video techniques for assessing biofouling can occur if you have many canopy-forming and sub-canopy species, making it difficult to observe, let alone identify, all the organisms on a surface. We do not anticipate this will be an issue for assessing biofouling on the anchors as they will be at ~70 m, well below the photic zone, and we did not observe or collect algae on the Ocean Sentinel anchors which were deployed for over two years in shallower waters. Canopy-forming invertebrates such as anemones or those with lots of interstitial spaces such as mussels can present similar challenges for quantifying smaller organisms. However, as described above, we did not observe these species on the Ocean Sentinel anchors at NETS. The extent of biofouling on anchors will vary based on anchor type, complexity of the structure, duration of installation, and height above the seafloor where the potential for abrasion is highest. We recognize that the WECs themselves could support growth of larger organisms (e.g., algae, gooseneck barnacles, mussels; Figure 1) as we collected from the Ocean Sentinel floats, although the algae on the floats was small turf algae, and the floats were not coated with anti-fouling paint.

For the band transects (pre-test, between device components, and reference transects) standard analysis procedures will be used (e.g., Tissot 2008). Along each transect, the substratum type will be classified (mud/sand/coarse sand/shell hash) and the presence of "litterfall" will be delineated, and all organisms larger than 5 cm will be identified and enumerated. (If we observe large aggregations of small individuals that cannot be enumerated, we will report their occurrence but will not attempt to quantify them.) Benthic epifauna, some endofauna taxa showing recognizable body parts above the sediment, and fish will be identified to the lowest possible taxonomic level and enumerated. We will use the distance travelled over the bottom to convert numbers of each species observed along the transect to standardized abundances. If we are not able to determine distance travelled, organism counts will be standardized by survey time using the start and stop time of each transect. Fishes will be classified as juveniles, sub-adults, or adults (as appropriate for the species), and crab and seastar sizes will be estimated using the lasers. When interesting behaviors are observed (e.g., crabs feeding on litterfall), they will be documented and reported. Again, this footage also may be used for quantification of the spatial extent of scour.

4.1.5 Sonar processing

The use of the multibeam imaging sonar will allow us to estimate the presence of fish that may disperse beyond the field of view before the ROV gets close enough to see them on the optical camera. A suite of metrics may be used to quantify variability of pelagic nekton biomass detected by the multibeam sonar including density, aggregation, center of mass, and dispersion, which have been used to describe a wide range of aquatic organism distribution attributes (Urmy et al. 2012). These metrics, as appropriate, will be compared among structure types. Acoustic images will be analyzed as described below in 4.4.2, and compared to optical information to determine if fish may be avoiding the ROV. However, acoustic images will likely be insufficient in detail to identify species.

4.2 Schedule & Frequency

4.2.1 Within Site

A single pre-installation ROV survey (pre-WEC installation) will be conducted as early as technically feasible (e.g. ocean conditions conducive to effective monitoring) without jeopardizing human safety, property and the environment in the spring (mid-March to mid-June) prior to our first anticipated testing client. During this survey, we will carry out the survey described in section 4.1.3 – the seafloor band transects. For this survey, we will survey transects at 6 locations outside of the Project Site (the Reference transects) as well as 6 transects randomly placed inside the Project Site. Before diving for each set of transects, we will pause at 10 m below the surface to do a SPC, as described at the end of 4.1.1 above.

Seasonal ROV surveys will be conducted twice per year targeting spring (mid-March to mid-June) and fall seasons (late August to late October) with a minimum of 3 months between data gathering events that meet the objectives of this plan. Spring surveys will be conducted as early in the season as technically feasible to minimize risk of entanglement as described in mitigation measure 3. This schedule likely will result in any new installation being surveyed within three months of deployment (as we anticipate summer deployments that would be observed by the fall survey). During those semi-annual surveys, all test berths with WECs installed in them will be surveyed. If multiple structures of the same type are installed in a single berth (e.g., > 3 anchors of the same type) a subset of those structures may be observed on each survey. Semi-annual surveys will continue for at least three years of deployed WECs and anchors.

After three years of semi-annual surveys, if no devices are under test, any hardware remaining in the water will be surveyed once every three years. If survey results indicate consistent and predictable species associations over time (i.e., no significant differences observed in species diversity, density/ maxN, or total number of fish observed in spring versus fall on the multiple WEC, anchor or mooring types/configurations), then for the next 7 years ROV surveys for the purposes of organism interaction monitoring will be conducted annually when WECs are present. After 10 years of ROV surveys, the licensee will consult with the AMC regarding the frequency/need of continued organism interaction ROV surveys. This timeline is based on documented observations where colonization of an artificial reef showed fluctuations in species abundance within the first two years, but after two years most of the species that dominated or characterized the reef after five years had already settled (Hiscock et al. 2010). Of course, the situation at PacWave South may differ since the same structures may not be in place for a continuous three years, so the “stabilization” of species recruitment observed by Hiscock et al. after two years may not be observed at PacWave South.

4.2.2 Cable Route

For biological purposes, one of the cable routes will be surveyed as part of each ROV cruise, including the “pre-WEC installation” survey. Thus, with five cables, each one will be surveyed once after the first 2.5 years of semi-annual sampling and each will be surveyed at least a second and possibly a third time by the end of the 10 years of ROV surveys. This schedule is based on the assumption that all seafloor cables will be entirely and continuously buried, and does not preclude additional observations that may or may not occur for maintenance purposes. If installation or post-construction survey of the cables indicates unburied segments, the licensee will consult with the AMC regarding the appropriate frequency of organism interaction ROV surveys.

4.3 Constraints & Limitations

A constraint in developing this monitoring plan is the variability associated with the Project as a test center. To overcome that, we have written this study to be applicable to deployments of various size, number, and location of device components, the distance between them, and the number and type of mooring hardware associated with the Project components of interest. The major constraints of any ocean-going field project are weather conditions and vessel availability. However, we are confident we can successfully conduct surveys sometime in the mid-March to June window and again in the August to October window.

The ability to implement ROV surveys is subject to weather and safety constraints. OSU will notify the AMC within 10 days of the close of each seasonal window (end of June/October) if it seems likely we will not be able to complete the sampling within that window to discuss whether sampling should be attempted in the next month or deferred until the following season. Furthermore, any inability to perform this study within the time period or spatial extent described here would be communicated to members of the AMC within 10 days from the date determined by OSU that it is unable to complete the tasks identified in this plan, and a contingency plan would be developed and submitted to the AMC within 30 days after notification.

4.4 Analysis

4.4.1 Analysis of video observations

For the SPCs and semi-circular swath surveys, the maxN of different species as well as total number of fish observed and overall diversity will be compared along distances from the structure and among structure types. Within species, we will investigate if different size classes are present associated with the WEC (at 10 m below the surface) versus at the anchors (1-2 m above bottom) or at varying distances away from the structures and/or among structure types.

For the focal observations, percent cover or density (as appropriate) of different biofouling organisms (as identifiable) will be determined and compared among structure types (using either faces of the structure or multiples of the same structure type as replicates). The diversity of fouling organisms also will be compared among structure types. If structures are left in place over long periods of time (perhaps anchors that are re-used) we will (eventually) develop histograms to display the arrival, growth, and succession of major colonizing species.

For the band transects, data will be analyzed as described in Hemery and Henkel (2016). In short, multivariate analysis will be conducted to assess the similarities and/or differences in the organisms along position on transect (distance from a structure), within versus outside the site, and in association with any particular substratum type. We also will conduct univariate analyses on total diversity and abundance against these factors. For particular fish species and Dungeness crabs, we will investigate if different densities and/or size classes are present by comparing size and density distributions before versus after installation of project components, in varying distances away from the structures, among structure types, or within versus outside of the Project Site. Berth-specific visual surveys will allow us to determine if different structures are differentially attractive (versus a baited capture survey where we might catch organisms in one berth that were utilizing habitat in another berth). We also will compare detections of fish using the imaging sonar on the band transects within the Project Site to the reference ROV band transects conducted outside the Project Site.

Visual surveys also allow for behavioral observations, rather than just whether organisms are captured more inside or outside of a particular area (which can be influenced by attraction to bait). For example, with visual surveys we can assess whether crabs are burying near an anchor, using it as additional shelter, or if they are foraging on the organisms growing on the anchors. We will be able to observe whether the density of buried crabs changes in conjunction with sediment changes (if changes in sediment are observed) with increasing distance away from an anchor or inside versus outside the project area. We also will determine and report the ratio of Dungeness crab to rock crab at varying distances away from the structures and/or among structure types.

4.4.2 Analysis of sonar observations

The number of targets in the acoustic images will be compared among structure types, and we will attempt to assign the acoustic targets to a species group. The use of the multibeam imaging sonar will allow us to estimate the presence of fish that may disperse beyond the field of view before the ROV gets close enough to see them on the optical camera. We will compare and report the number of targets (individual fish) or aggregations (schools of fish) detected acoustically using the sonar with the numbers of fish/schools of fish detected visually using the cameras and determine the percent of acoustically-detected targets that were not detected using the visual tools.

5. RESULTS

For the semi-circular swath surveys, we will summarize findings including the total number of fish observed and the relative abundances of different fish species at different distances for the floating (WECs) and bottom (anchor) structures. By comparing the relative abundance of fish across the different distances away from the floating structures, we will be able to describe the spatial pattern of any fish attraction effect and how far it extends. Comparisons among WEC/anchor types will inform us if differently shaped/sized components have different levels of attractiveness or attract different species. A species list including number of individuals and life stages of each species observed during each survey, as well as over time, will be provided.

The results of the focal observations for biofouling will include graphical representation of percent cover and/or density (as appropriate for the organism type) on different components. A species list including number of individuals and life stages of each species observed during each survey, as well as over time, will be provided.

For the band transects, we will report the densities of organisms along the in-berth transects as compared to the reference transects. We will report the densities of organisms as a function of distance away from structures. We will report the results of all multivariate and univariate analyses described above. Again, if we observe large aggregations of small individuals that cannot be enumerated, we will report their occurrence. A species list including number of individuals and life stages of each species observed during each survey, as well as over time, will be provided.

6. REPORTING

Once the activities under this plan commence, they will be reported annually in OSU's Annual Report, which will be filed with FERC and provided to the AMC. The annual reporting will include the components described below; it will also identify any relevant new information considered in the findings or future monitoring.

6.1 Monitoring Summary

OSU will summarize all activities undertaken in implementing the monitoring plan, including a table with monitoring dates and locations if appropriate. In the unlikely event that OSU must deviate from this plan for reasons outside of its control (e.g., delayed sampling due to adverse weather conditions that pose risk to human safety) it will describe any deviations from the monitoring plan as reported to the AMC and discuss implications of any such deviations.

6.2 Results & Conclusions

The AMC will discuss the monitoring results and any significant findings or conclusions. The AMC will be given the opportunity to provide feedback on the study results prior to any official filing, and if they exist, OSU will describe any disagreements over characterization of results in its final report.

6.3 Future Monitoring

OSU will describe in each Annual Report monitoring activities that are planned for the next reporting period. OSU will provide any proposed modifications to the monitoring plan and rationale for the changes to the AMC.

7. References

Ajemian, M.J., J.J. Wertz, B. Shipley-Lozano, G.W. Stunz. 2015. Rapid assessment of fish communities on submerged oil and gas platform reefs using remotely operated vehicles. Fisheries Research. 167: 143-155.

Baine, M. 2001. Artificial reefs: a review of their design, application, management and performance. Ocean & Coastal Management. 44(3-4) 241-259.

Bergström, L., F. Sundqvist, U. Bergström. 2013. Effects of an offshore wind farm on temporal and spatial patterns in the demersal fish community. Mar Ecol Prog Ser. 485: 199-210.

Boehlert, G.W, G.R. McMurray, and C.E. Tortorici (eds). 2008. Ecological Effects of Wave Energy Development in the Pacific Northwest. NOAA Technical Memorandum NMFS-F/SPO-92.Northwest Fisheries Science Center. Seattle, WA. October 11-12, 2007.

Bohnsack, J.A., Johnson, D.L., Ambrose, R.F. 1991. Ecology of artificial reef habitats and fishes. In: Seaman, W., Sprague, L.M. (Eds.), Artificial Habitats for Marine and Freshwater Fisheries. Academic Press Inc., San Diego, California, pp. 61–84.

Brickhill M.J., Lee S.Y., Connolly R.M. 2005. Fishes associated with artificial reefs: attributing changes to attraction or production using novel approaches. J Fish Biol 67:53−71.

Cappo M., P. Speare, G. De'ath. 2004 Comparison of baited remote underwater video stations (BRUVS) and prawn (shrimp) trawls for assessments of fish biodiversity in inter-reefal areas of the Great Barrier Reef Marine Park, J. Exp. Mar. Biol. Ecol., 302:123-152.

Cappo M., G. De'ath, P. Speare. 2007. Inter-reef vertebrate communities of the Great Barrier Marine Park determined by baited remote underwater video stations, Mar. Ecol. Prog. Ser., 350:209-221.

Claisse, Jeremy T., D.J. Pondella II, M. Love, L.A. Zahn, C.M. Williams, J.P. Williams, A.S. Bull. 2014. Oil Platforms off California are among the most productive marine fish habitats globally. Proceedings of the National Academy of Sciences 111 (43), 15462-15467.

Claudet J. and D. Pelletier. 2004. Marine protected areas and artificial reefs: a review of the interactions between management and scientific studies. Aquatic Living Resources 17:129−138.

Danner, E.M., T. C. Wilson, and R.E. Schlotterbeck. 1994. Comparison of rockfish recruitment of nearshore artificial and natural reefs off the coast of central California. Bulletin of Marine Science 55:333-343.

DeMartini, E. E., D. A. Roberts, and T. W. Anderson. 1989. Contrasting patterns of fish density and abundance at an artificial rock reef and a cobble-bottom kelp forest. Bulletin of Marine Science 44:881-892.

Department of Land Conservation and Development, Oregon Coastal Management Program. 2015. State of Oregon Geographic Location Description. Analysis of Reasonably Foreseeable Effects of Federal Actions Related to Marine Renewable Energy Projects on Resources and Uses Occurring within the Federal Waters of the Oregon Ocean Stewardship Area. Available Online https://www.oregon.gov/LCD/OCMP/docs/Public_Notice/GLD_final.pdf

Diamond, N. and D. G. Hankin. 1985. Movements of adult female Dungeness crabs (*Cancer magister*) in northern California based on tag recoveries. Canadian Journal of Fisheries and Aquatic Sciences 42:919-926.

Ellis, D. M., and E. E. Demartini. 1995. Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, *Pristipomoides filamentosus*, and other Hawaiian insular shelf fishes. Fishery Bulletin 93:67-77.

Glaholt, R.D. 2008. Investigation of the Potential Effects of Marine Pipelines on Dungeness Crab Movement and Benthic Ecology. Pages 679-692 In J.W. Goodrich-Mahoney, L.P. Abrahamson, J.L. Ballard and S.M. Tikalsky (Editors), Environment Concerns in Rights-of-Way Management 8th International Symposium.

Gotshall, Daniel W. 2005. Guide to Marine Invertebrates: Alaska to Baja California, 2nd Edition Revised. Sea Challengers. CA.

Harvey E.S., M. Cappo, J.J. Butler, N. Hall, G.A. Kendrick. 2007. Bait attraction affects the performance of remote underwater video stations in assessment of demersal fish community structure, Mar. Ecol. Prog. Ser., 350:245-254.

Hemery, L.G. and S.K. Henkel. 2016. Patterns of benthic mega-invertebrate communities and habitat associations in temperate continental shelf waters: a reassessment. Biodiversity and Conservation. 25(9), 1761-1772. DOI: 10.1007/s10531-016-1158-y

Hiscock K., Sharrock S., Highfield J., Snelling D. 2010. Colonization of an artificial reef in south-west England-ex-HMS 'Scylla'. J. Mar. Biol. Assoc. UK 90:69-94

Hiscock K., Tyler-Walters H., Jones H. 2002. High level environmental screening study for offshore wind farm developments – marine habitats and species project, Report from the Marine Biological Association to The Department of Trade and Industry New & Renewable Energy Programme.

Hueckel, G.J., and R.M. Buckley. 1987. The influence of prey communities on fish species assemblages on artificial reefs in Puget Sound, Washington. Environmental Biology of Fishes 19:195-214.

Langhamer, O. and D. Wilhelmsson. 2009. Colonisation of fish and crabs of wave energy foundations and the effects of manufactured holes - a field experiment. Marine Environmental Research 68:151-157.

Langhamer, O., D. Wilhelmsson, J. Engström. 2009. Artificial reef effect and fouling impacts on offshore wave power foundations and buoys — a pilot study. Estuar. Coast Shelf Sci. 82:426–432

Lawrence, N.R.J., T. Somers, D. Jones, S. McCammon, G. Hollinger. 2016. Ocean Deployment and Testing of a Semi-Autonomous Underwater Vehicle. Available at: http://research.engr.oregonstate.edu/rdml/sites/research.engr.oregonstate.edu.rdml/files/ocean-deployment-testing.pdf

Love, M.S., and M. Yoklavich. 2006. Deep rock habitats. Pages 253–268 in L. G. Allen, D. J. Pondella II, and M. H. Horn (Editors), The Ecology of Marine Fishes, California and Adjacent Waters. University of California Press, Berkeley and Los Angeles, California.

Love, M., D.M. Schroeder, W. Lenarz, A. MacCall, A.S. Bull, L. Thorsteinson. 2006. Potential use of offshore marine structures in rebuilding an overfished rockfish species, bocaccio (*Sebastes paucispinis*). Fish. Bull. 104:383-390.

Merritt D., M.K. Donovan, C. Kelley, L. Waterhouse, M. Parke, K. Wong, J.C. Drazen. 2011. BotCam: a baited camera system for nonextractive monitoring of bottomfish species. Fish. Bull. 109:56-67.

Normandeau, Inc., T. Tricas, and A. Gill. 2011. Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09.

ODFW, 2014. Oregon Dungeness Crab Research and Monitoring Plan. ODFW Marine Resources Program. Available online http://www.dfw.state.or.us/MRP/shellfish/commercial/crab/docs/ODFW_DungenessCrabResearchMonitoringPlan_updated20 14_Final_081414.pdf

Ocean Power Technologies (OPT), Inc. 2014. Reedsport OPT Wave Park Project Final Decommissioning Plan. Available online http://www.ferc.gov/docs-filing/elibrary.asp Docket Number P-12713. Accession Number 20140725-5141

Ocean Power Technologies (OPT), Inc. 2016. Reedsport OPT Wave Park Site Clearance Approvals. Letter from OPT to the Federal Energy Regulatory Commission. Available online http://www.ferc.gov/docs-filing/elibrary.asp Docket Number P-12713. Accession Number 20160720-5141.

Page, H.M., J.E. Dugan, D.S. Dugan, J.B. Richards, D.M. Hubbard. 1999. Effects of an offshore oil platform on the distribution and abundance of commercially important crab species. Marine Ecology Progress Series. 185: 47-57.

Pickering, H. and D. Whitmarsh. 1997. Artificial reefs and fisheries exploitation: a review of the 'attraction versus production' debate, the influence of design and its significance for policy. Fish Res 31:39−59

Popper, A.N., A.D. Hawkins, R. Fay, D. Mann, S. Bartol, Th. Carlson, S. Coombs, W.T. Ellison, R. Gentry, M.B. Halvorsen, S. Lokkeborg, P. Rogers, B.L. Southall, D.G. Zeddies, W.N. Tavolga. 2014. Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. New York: Springer. 73 pp.

Rasmuson, L.K. 2013. The Biology, Ecology, and Fishery of the Dungeness crab, *Cancer magister*. In Michael Lesser, editor: Advances in Marine Biology, Vol. 65, Burlington: Academic Press, pp. 95-148.

Reubens, J.T., S. Degraer, M. Vincx. 2014. The ecology of benthopelagic fishes at offshore wind farms: a synthesis of 4 years of research. Hydrobiologia 727: 121-136.

Seaman, W. 2007. Artificial habitats and the restoration of degraded marine ecosystems and fisheries. Hydrobiologia 580:143−155.

Stone, R.P., and C. E. O'Clair. 2001. Seasonal movements and distribution of Dungeness crabs *Cancer magister* in a glacial southeastern Alaska estuary. Marine Ecology Progress Series 214:167-176.

Stone, R. P., and C.E. O'Clair. 2002. Behavior of female Dungeness crabs, *Cancer magister*, in a glacial southeast Alaska estuary: Homing, brooding-site fidelity, seasonal movements, and habitat use. Journal of Crustacean Biology 22:481-492.

Tissot, B.N. 2008 Video analysis, experimental design, and database management of submersible-based habitat studies. In: Reynolds JR, Greene HG (Eds) Marine habitat mapping technology for Alaska. Alaska Sea Grant, Fairbanks, AK, p 157-167.

Urmy, S.S., J.K. Horne, D.H. Barbee. 2012. Measuring the vertical distributional variability of pelagic fauna in Monterey Bay, ICES Journal of Marine Science. 69: 184–196. doi:10.1093/icesjms/fsr205.

Waldron, K.D. 1958. The fishery and biology of the Dungeness crab (*Cancer magister* Dana) in Oregon waters. Fish Commission of Oregon Report No. 24.

Watson, D. L., E. S. Harvey, M. J. Anderson, and G. A. Kendrick. 2005. A comparison of temperate reef fish assemblages recorded by three underwater stereo-video techniques. Marine Biology 148:415-425.

Wilhelmsson, D. 2012. Effects of altered habitats and fishing practices in wind and wave farms. Proc. Oregon Mar. Renewable Energy Environ. Sci. Conf., Nov 28–29, 2012, Corvallis, OR.

Wilhelmsson, D., Malm, T., Ohman, M.C., 2006. The influence of offshore windpower on demersal fish. ICES Journal of Marine Science 63, 775-784

Willis, T. J., R. B. Millar, and R. C. Babcock. 2000. Detection of spatial variability in relative density of fishes: comparison of visual census, angling, and baited underwater video. Marine Ecology Progress Series 198:249-260.

Figures

Figure 1. Photo quadrats taken from the Ocean Sentinel surface floats after over two years of deployment. The photo on the left is the quadrat that had the least percent cover and the photo on the right had the most percent cover of all 6 quadrates (2 on each of the 3 floats).

Figure 2. Photo quadrats taken from the Ocean Sentinel anchors after over two years of deployment. The photo on the left is a side of the anchor and the photo on the right is the top of the same anchor.

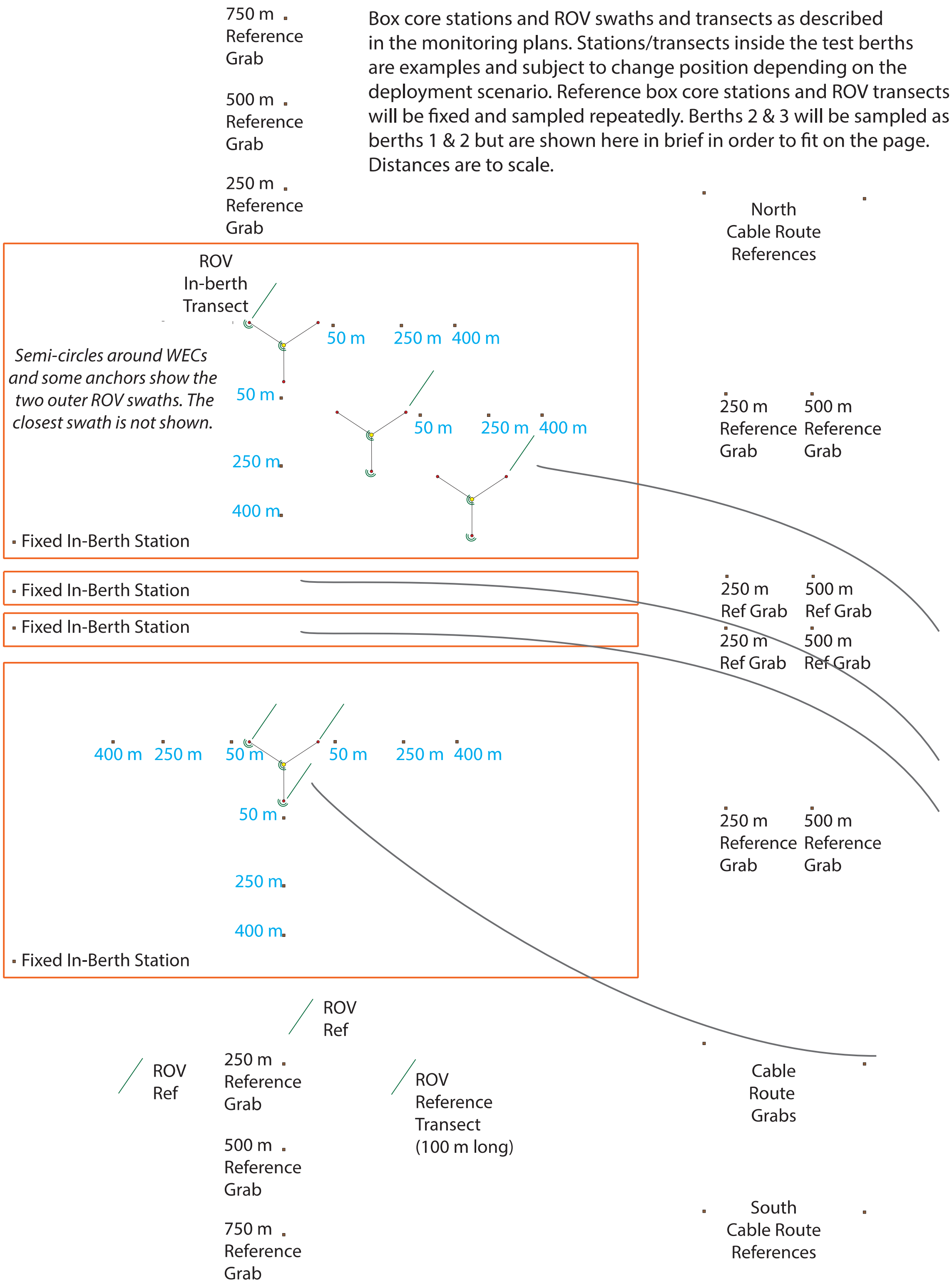

Figure 3. Benthic and organism interaction monitoring schematic. Within berth station distances are relative to the project component . Reference grab distances are relative to the site boundaries.