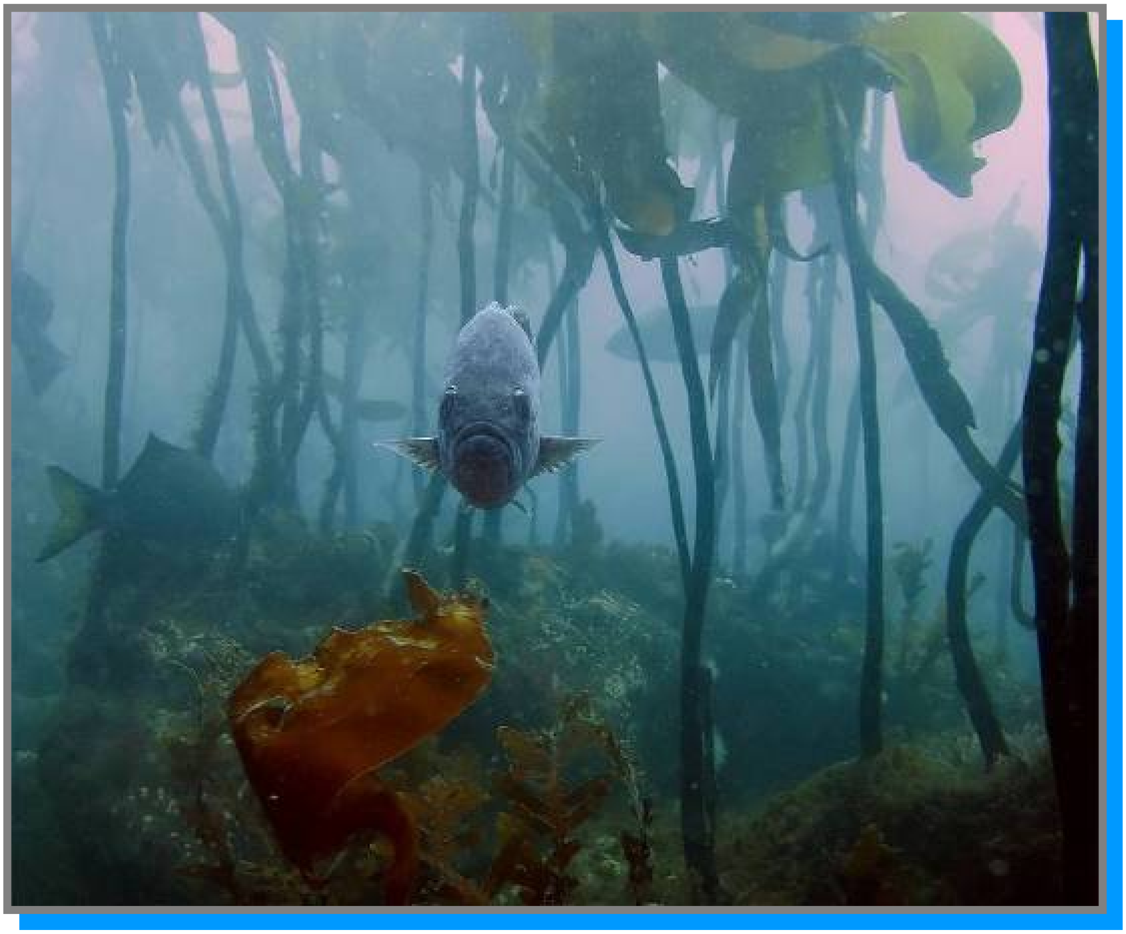
Oregon Marine Reserves
Ecological Monitoring Plan



2012

Marine Resources Program
Newport, Oregon

Acknowledgments:

Thank you to the Redfish Rocks and Otter Rock Marine Reserve Community Teams, biological working groups, local fishermen, divers and scientific experts for their time, hard work, and contribution to the development of the monitoring plan and to this document.

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Introduction

In 2008, the state of Oregon began a process to establish and implement a limited system of marine reserve sites within state waters. The Oregon Department of Fish and Wildlife (ODFW) is the lead agency responsible for implementation of Oregon's system of marine reserves. An important component of marine reserve implementation is monitoring and evaluation. In 2009, ODFW established a program focused on marine reserves implementation that includes staff responsible for the design and implementation of an ecological monitoring program that is to provide information for marine reserves evaluation and to be used in support of nearshore resource management.

The ecological monitoring program was developed by ODFW program staff, with assistance and collaboration from external scientists and marine reserve community team members. This document provides a description of the plans for monitoring of Oregon's system of marine reserves.

A. Monitoring Plan Purpose

The ecological monitoring program is designed for the long-term monitoring of Oregon's marine reserve system. This monitoring plan documents and describes the objectives, monitoring design, metrics, sampling activities, and data analyses that are all a part of the marine reserves ecological monitoring program. We hope that by documenting these objectives and activities we also will spur additional, complementary research that will be conducted by external entities to further assist in the marine reserves evaluation and add to our knowledge of the nearshore environment and resources.

Detailed methods, analyses and results, will be presented in biennial monitoring reports. We anticipate adaptations will be made as we learn from our monitoring activities and upon designation of any new marine reserve sites. An extensive review of the monitoring program and updates to the *Oregon Marine Reserves Ecological Monitoring Plan* will be conducted every five years, with assistance from external scientists and community members.

B. Marine Reserves: Oregon's Policy Guidance

Designation and implementation of Oregon's limited system of marine reserves is guided by the "Oregon Marine Reserve Policy Recommendations" developed and approved by the Ocean Policy Advisory Council (OPAC) in 2008. OPAC is a legislatively mandated body that advises the Governor, state agencies, and local governments on marine resource policy issues. The policy recommendations laid out by OPAC provided the starting point for development of the ecological monitoring program. The key definitions, goals, and objectives that provide overall guidance for the monitoring project are described below.

B.1. Marine Reserve Definition

The first policy recommendation that guides our monitoring program is the definition of a marine reserve. As established in the OPAC policy recommendations, Oregon defines a marine reserve as:

> . . . an area within Oregon's Territorial Sea or adjacent rocky intertidal area that is protected from all extractive activities, including the removal or disturbance of living and non-living marine resources, except as necessary for monitoring or research to evaluate reserve condition, effectiveness, or impact of stressors. (OPAC 2008)

B.2. Marine Reserve Goal

The goal of Oregon's marine reserves is to:

> Protect and sustain a system of fewer than ten marine reserves in Oregon's Territorial Sea to conserve marine habitats and biodiversity; provide a framework for scientific research and effectiveness monitoring; and avoid significant adverse social and economic impacts on ocean users and coastal communities.
>
> A system is a collection of individual sites that are representative of marine habitats and that are ecologically significant when taken as a whole. (OPAC 2008)

B.3. Marine Reserve Objectives

Marine reserve objectives, established in the OPAC policy recommendations, provide further guidance on planning and implementation of Oregon's system of marine reserve sites. Marine reserve objectives that direct the design of our ecological monitoring program include:

- Protect areas within Oregon's Territorial Sea that are important to the natural diversity and abundance of marine organisms, including areas of high biodiversity and special natural features.
- Protect key types of marine habitat in multiple locations along the coast to enhance resilience of nearshore ecosystems to natural and human-caused effects.
- Site fewer than ten marine reserves and design the system in ways that are compatible with the needs of ocean users and coastal communities. These marine reserves, individually or collectively, are to be large enough to allow scientific evaluation of ecological effects, but small enough to avoid significant adverse social and economic impacts on ocean users and coastal communities.
- Use the marine reserves as reference areas for conducting ongoing research and monitoring of reserve condition, effectiveness, and the effects of natural and human-induced stressors. Use the research and monitoring information in support of nearshore resource management and adaptive management of marine reserves.

B.4. Marine Protected Areas

Marine Protected Areas (MPAs), that allow certain specified extractive activities, are also included in Oregon's limited system. With regards to monitoring and evaluation of the marine reserve system, ODFW focuses only on those MPAs that are considered complementary to a marine reserve site. That is, the MPA must complement the marine reserve in its protection of species and habitats most likely to respond to prohibition of extractive activities. This may include when an MPA:

- Provides protection to fish and invertebrate species that are likely to benefit from, or show a response to, protection
- Provides a protective species buffer area to a marine reserve
- Provides an ecological corridor for fish species growth-related or seasonal movement
- Protects habitat forming and long lived invertebrate species from habitat destructive extractive activities or development

C. Marine Reserves Evaluation

A comprehensive evaluation of Oregon's marine reserves is to be conducted after the system of reserves has been in place for a minimum of 10-15 years after the prohibition of extractive activities have taken effect. This period will allow time for adequate data to be collected and for the detection of ecological responses to begin. The evaluation will focus on if, where, and to what degree each marine reserve site and the system as a whole are meeting the OPAC marine reserve goal and objectives. The evaluation will provide information so the state can determine if and how marine reserves should continue to be used as a nearshore resource management tool in the future.

The OPAC policy recommendations described above, in section B, provide three main themes that drive the design and execution of our ecological monitoring program:

- Using marine reserves as a tool to protect species, habitats, and biodiversity;
- Using marine reserves as a reference area to deduce natural from human-induced changes in the environment; and
- Evaluating the effectiveness of marine reserves as a management tool to achieve the protection and reference area purposes listed above.

Using marine reserves as reference areas and evaluating reserve effectiveness requires a program that:

- Examines species and habitats to determine change or variation over time, and
- Compares the marine reserve area with similar areas that are not in protected status to see if changes differ over time between the sites.

To assist the state's evaluation of marine reserve sites and the limited-system as a whole, long-term monitoring is designed to address the following aspects of the marine reserves evaluation:

- Determine the effectiveness of marine reserves in conserving certain species, habitats, biodiversity* or certain aspects of the ecosystem.
- Determine if marine reserves serve as ecological reference areas which allow us to deduce natural from human-induced changes to certain species, habitats, or certain aspects of the ecosystem and measure these changes over time.

- Determine if marine reserves increase our knowledge of Oregon’s nearshore environment and resources. Use this information to support nearshore resource management.
- Determine if size, configuration, location and prohibitions of marine reserve sites and associated MPAs, and the system as a whole, allow scientific evaluation of ecological effects.

* See Section II.E Biodiversity Note

Monitoring Program Design

The ecological monitoring program research questions, metrics, field sampling activities, and data analyses have all been designed in order to provide the information needed to meet the goal and objectives of the marine reserves evaluation. In this section we provide an overview of the monitoring program design.

A. Comparison Areas

Two of the core components of marine reserve monitoring are separating natural changes in species and habitats from human-caused changes, and determining if marine reserves are effective in conserving certain species and habitats. To accomplish this, the marine reserve needs to be compared before and after protective measures are put in place, and with areas that do not have the marine reserve protections. To this effect, each marine reserve will be paired to other areas that we refer to as **comparison areas** (i.e. scientific controls). Over the past couple decades this has been the approach of choice for scientifically rigorous and defensible studies for determining differences in a control vs. treatment area and has been applied to marine reserve monitoring elsewhere in the world (Michelie et al. 2004). Having only one marine reserve site and one comparison area is simply a comparison between two areas and consequently does not allow for differentiating natural from human-caused changes with any certainty. Therefore, more than one comparison area is to be paired to each marine reserve in an attempt to better achieve the goal of comparison. Given limited resources, one comparison area will be assigned as the **priority comparison area** for each marine reserve site.

To accomplish the comparison task, monitoring studies will be established to measure the same variables in marine reserves and their associated comparison area(s). Observing how these variables differ between the sites, when we compare multiple marine reserves with multiple comparison areas over time, will help us understand if differences might be caused by human factors and if the marine reserves are effective at conserving certain species and habitats.

Hereafter in the monitoring plan, we use the term **site** to refer to a **marine reserve** and its associated **comparison areas**.

A.1. Choosing Comparison Areas

Comparison areas are to be chosen based on similarity. Ideally, comparison areas will have similar habitats, dominant species, trophic structure and experience the same oceanographic conditions (i.e. similar currents, same water masses) at the same time as the marine reserve (Pande and Gardner 2009). Although no true replicate exists for a given marine reserve site, careful measures are to be taken to choose comparison areas as similar as possible to control for variation that could result from differences (e.g. habitat, oceanographic condition) and to avoid confounding of the results.

We will choose comparison areas based on similarities of substrate type, depth, species, oceanographic condition, and fishing pressure (Oregon Marine Reserve Monitoring Workshop Summary 2010). To identify comparison areas for each marine reserve, ODFW will use the best scientific information available (e.g. seafloor habitat maps, physical oceanographic information) and will work with commercial and charter fishermen, as well as researchers, who are familiar with the respective area to solicit input on habitat, species and fishing pressure within the reserve and nearby areas. In instances where a number of areas are identified as suitable for comparison, the comparison areas will be randomly chosen from among the areas identified as suitable.

Comparison areas will be placed at least 1,000 meters from the reserve, when possible. We are assuming that this level of separation between reserve and comparison area is adequate for the areas to be independent enough for statistical purposes. The need for the comparison area to experience the same oceanographic conditions (e.g. similar currents, same water mass) will dictate that the comparison area still be reasonably near to the marine reserve.

B. Research Questions

The following overarching questions provide general guidance for how we focus and structure our monitoring efforts:

- What is the oceanographic condition of each site? How does it change over time?
- What habitats exist within each site? How do they change over time?
- What algal, invertebrate, and fish species exist at each site?
  - How do species biometrics change over time?
  - How does biodiversity change over time?
- What are the species-habitat correlations at each site? How do they change over time?
- Does the prohibition of extractive activities change the community structure of the reserve?
- Are patterns or changes within the marine reserve consistent throughout the marine reserve system?

C. Sampling Design

Our sampling design is constructed from a system approach, with an encompassing goal of comparing within reserves to outside reserves across the system. Our monitoring is designed to:

- Characterize the habitat, oceanographic condition, and species that exist at each site
- Determine whether or not the marine reserve (prohibition of extractive activities) changes the environment over time
- Determine which components of the environment are affected
- Estimate the magnitude of the effects

This monitoring design requires that sampling account for:

- Differences in space
- Differences over time
- Differences between reserves and comparison areas, with concurrent sampling where possible

To meet these criteria, most of our sampling design for biological variables consist of comparing reserve and comparison areas by depth strata, and repeating these comparisons over time.

Our sampling design has three tiers, with each tier laying a foundation for the next:

- Site Characterization
- Systematic Rapid Assessment
- Detailed Assessment

C.1. Site Characterization

To put our research questions in context, before the prohibition of extractive activities take effect, monitoring will begin with a general characterization of the site describing the habitats, oceanographic condition, and species present. To accomplish this we will employ several steps:

- A literature review
- A synthesis of past studies and data
- Oceanographic sampling
- A systematic rapid assessment of habitats and species presence

In general, we anticipate site characterization to be conducted over the course of two complete field seasons, with the majority of sampling carried out between April and October, when the swell is smaller for logistical and safety reasons. We anticipate that the majority of the site characterization will happen in the first two years with the exception of continual assessment of oceanographic condition over time.

The metrics derived from site characterization will include:

- Oceanographic condition: temperature, salinity, chlorophyll, dissolved oxygen, and light
- Habitats: depth, relief, substrate type, and biogenic features
- Focal species: presence and abundance

C.2. Systematic Rapid Assessment

We will use the best available data on substrate type and depth collected from the extensive hydrographic mapping survey recently conducted in Oregon state waters, led by the Active Tectonics and Seafloor Mapping Lab at Oregon State University (further described in section III.B.). In general and specifically for areas that have not been mapped, we will augment these data with local knowledge from fishermen, scientific experts, and local divers to delineate hard bottom areas and areas of unconsolidated sediment. A systematic point grid will be applied to the marine reserve and comparison areas. We will use a video lander (further described in Section III.D.) and standard vessel sounding equipment to sample on the grid to define (ground-truth) bottom type and depth, as well as document fish and invertebrate species presence and abundance. We will then analyze the systematic grid to generate habitat maps based on bottom type and depth regime for the site. Once the habitat areas are defined, sampling tools and methodologies will be assigned and implemented in the more detailed assessment. The systematic rapid assessment will be conducted in the first two years prior to the prohibition of extractive activities and will produce information on:

- Habitats: depth, relief, substrate type, and biogenic features
- Focal species: presence, distribution, and abundance

C.3. Detailed Assessments

Both before and after the prohibition of extractive activities takes effect, we will use a stratified random sampling design to conduct more detailed assessments of the marine reserve sites and comparison areas. The detailed assessments will gather data for more specific metrics to further help us answer our research questions.

The metrics examined by the detailed assessments include:

- Oceanographic condition: temperature, salinity, chlorophyll, dissolved oxygen, and light
- Habitats: depth, relief, substrate type, and biogenic features
- Focal species: presence, distribution, abundance, density, and size

All biological sampling methods implemented and species examined will be additive to start obtaining a measure of biodiversity. All data will be further analyzed for species-habitat correlations.

Our detailed assessments are to be carried out over the long-term, and form the basis for our long-term monitoring effort. As we implement and begin to learn from our monitoring, we will develop appropriate timescales for each monitoring activity. Many monitoring activities will not require annual sampling, and will likely be on a longer timescale such as every two years or every five years. As the timescales are determined, they will be incorporated into the monitoring plan. Future monitoring activities, or work conducted by external entities, may focus on additional metrics to further help us answer our research questions. Some suggested areas of study are outlined in Section V.

We will use stratified random sampling in our detailed assessments for biological response variables. At each site, sampling is to occur within the marine reserve and the associated comparison areas. Sampling efforts will be focused on two general bottom types: 1) hard bottom, and 2) unconsolidated sediment. These data are not comparable across the two bottom types, rather they are additive and used together as part of our comprehensive assessment of habitat, species biometrics, and biodiversity for the site. Within a given bottom type, sampling is stratified by depth, and random sampling points are assigned per strata. Additional post-hoc stratification may be applied for physical and biogenic features such as relief and kelp, as the analyses dictate.

For each bottom type, a variety of sampling tools and methods have been developed to collect data. The sampling tools and methods are generally described in Section III. All sampling methods are to be properly replicated and balanced, to the degree possible, within the marine reserve and comparison areas and across depth strata. Methodologies implemented are to be as similar as possible at all sites and will only be altered when water depth or another logistical concern deems the method impracticable. Methodologies used at the sites will be documented in further detail in the biennial monitoring reports.

D. Focal Species

While efforts will be made to identify and enumerate all species sampled; limitations of the sampling gear and limited time, staff, and funds dictate that reporting and analysis be focused on a select group of species for each site. These focal species are to be chosen based on their ecological or economic importance, and their potential to show a response, or change, within the marine reserves.

The list of focal species will include both species common among all sites and species unique to a site. To select focal species, we will begin by generating a list of species likely to occur within the area. The list will be vetted and modified based on input from local fishermen, local divers, and scientific experts. Economically important species include species targeted by commercial or recreational fisheries. Ecologically important species include those that are habitat forming, critical primary producers, keystone species, trophically important, and rare or endangered species. Since we are looking to evaluate marine reserve effectiveness and examine natural versus human-induced changes, and the primary change at marine reserves is the prohibition of extractive activities, the highest priority response variables are those that will measure change in harvested species. Harvested species most likely to show a biological response to the marine reserve are those species with smaller adult home ranges. These species are the highest priority to sample and analyze. There are also likely to be secondary effects on non-harvested species in the marine reserve sites, due to the changes in abundance of previously harvested species and other factors. These secondary effects may result in altered species abundances due to predator-prey relationships, competition, or other ecological interactions. Examining these changes will be a secondary sampling and analysis priority. Other species to be included in our monitoring are those that already will be sampled by the methods used for sampling the higher priority species. This includes the larger conspicuous demersal fish, benthic invertebrates and algae. All methods which collect data on species presence will contribute to an overall measurement of biodiversity.

E. Biodiversity Note

As described in Section I.C, one aspect of marine reserves evaluation that our long-term monitoring program is designed to address is the effectiveness of marine reserves in conserving biodiversity. Although it is not feasible to measure all components of biodiversity, we can measure certain components. As described by Feest (2006), no one single index of biodiversity quality is adequate to fully describe the biodiversity of a given area. Feest recommends a range of indices be calculated for a given site so that its biodiversity can be compared through time and between areas, which is the approach we have adopted.

The components of biodiversity we can readily measure and assess through our biological and habitat sampling include:

- Number of species
- Species densities
- Habitat types
- Habitat complexity

From these components we will be able to calculate a range of biodiversity indices that cumulatively will help us understand biodiversity at sites for both hard bottom and unconsolidated sediment environments.

Monitoring Activities

Sampling activities and methods have been chosen based on their effectiveness for sampling within given habitat types and to derive specific metrics. The methods are integrated to collect a baseline/T_0 and long-term data set to generate algal, invertebrate and fish species biometrics and for us to characterize the general ecology and oceanography of the site.

Here we have asked more focused questions, to help us concentrate our monitoring activities in order to answer our overarching research questions. We have focused our studies into four ecological themes: 1) oceanographic assessment, 2) seafloor mapping, 3) visual surveys, and 4) extractive surveys.

In this section, the term **site** refers to a **marine reserve** and its associated **comparison areas**.

A. Oceanographic Assessment

Research question:
What is the oceanographic condition of each site? How does it change over time?

Focused questions:
What are the light, temperature, chlorophyll, dissolved oxygen and salinity levels?
Is the reserve experiencing different water masses than its associated comparison areas?
What are the seasonal levels of the variables?

Metrics derived:
Temperature, salinity, chlorophyll, dissolved oxygen and light

To assess the oceanographic variables and processes within the sites we will use two primary tools, moorings and benthic oceanographic platforms (BOPs). High sea conditions combined with shallow water in the reserve areas makes maintaining moorings throughout the winter months risky. BOPs largely overcome this problem because they are bolted to rock on the seafloor, but have additional logistical challenges because they can only be serviced by divers. Using a combination of these two tools will enable us to acquire year round collection of select oceanographic variables, with a more thorough examination in the summer months.

A.1. In Situ Oceanographic Measurements

A.1.a. Moorings

Moorings are modeled after those developed and used by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) group at Oregon State University. Moorings will be implemented so that data are comparable to that of PISCO.

Moorings will be deployed in April and retrieved in October. One main mooring is to be placed within the reserve and a complimentary temperature mooring is to be placed in the priority comparison area.

Both moorings are to be anchored in 15-20 meters of water in unconsolidated sediment. The main mooring will measure light, conductivity, temperature, chlorophyll and dissolved oxygen at 14 meters depth every 15 minutes. Additional temperature loggers are to be placed on the main mooring at 1 and 14 meters depth measuring every two minutes. The temperature mooring in the priority comparison area is to house a temperature logger at 1 and 14 meters depth. Given the resources available, we are only able to measure temperature in the comparison area. We understand that both temperature and salinity, which define density, are the true indicators of a water mass. Temperature will be used as a proxy to determine if the marine reserve and associated comparison area are experiencing different water masses. If water masses differ there is likely to be a temperature signature. While measuring temperature alone will not allow us to define all properties of the water mass, temperature will serve as the water mass signature and should tell us if the water masses differ between the reserve and comparison area.

Data collected from these instruments in the reserve will allow us to measure variation in light, conductivity, temperature, chlorophyll and dissolved oxygen over time and assess small scale shifts in water masses throughout the summer. Additional data collected from the comparison areas will allow us to compare temperature regimes within and outside the reserve.

A.1.b. Benthic Oceanographic Platforms (BOPs)

Benthic oceanographic platforms (BOPs) are designed to be anchored to rock substrate on the seafloor and assess select oceanographic variables in the reserve and comparison areas throughout the year. They consist of a stainless steel plate with mounting brackets for oceanographic instruments,. Sand inundation and swell exposure will be considered during the placement of the platform before it is drilled into the rock substrate. Depending on the sensors added to the platform, the BOP may measure a wide array of variables including temperature, light, salinity, dissolved oxygen, and chlorophyll. Sensor choice will depend on available resources and any site specific requirements or constraints.

A.2. Analyses and Reporting

Mooring and BOP temperature, salinity, chlorophyll, dissolved oxygen and light data will be plotted and assessed through time series analysis. Average values will be computed for all variables on a one, six, 12 and 24 hour time scale. These methods and data collected will generate an overall description of the oceanographic condition of the site. Temperature levels will be assessed and compared by depth and between the reserve and comparison areas.

B. Seafloor Mapping

Research question:
What habitats exist within each site? How do they change over time?

Focused question:
Is there a difference in habitat type, depth stratification or habitat and depth percent composition between the marine reserve and the associated comparison areas?

Metrics derived:
Depth, relief, substrate type, habitat classification

Between 2009 and 2011, the Active Tectonics and Seafloor Mapping Lab (AT&SML) at Oregon State University conducted an extensive hydrographic survey using multibeam sonar within Oregon's state waters. The survey was conducted with funding from the Oregon Department of State Lands and in cooperation with the National Oceanographic and Atmospheric Administration's National Ocean Service. The survey mapped approximately 48% of Oregon's territorial seafloor, including about 80% of the rocky habitat in Oregon's state waters (Goldfinger, personal communication).

ODFW worked in coordination with AT&SML to identify and prioritize areas for high-resolution sonar mapping, including potential marine reserve sites and comparison areas. The hydrographic surveys, using multibeam sonar, were conducted at priority areas in areas deeper than 15 meters. At each site, grab samples were collected on a 2 km grid and within areas exhibiting unique sonar imagery patterns. These samples serve as ground-truth or reference data for habitat classification.

As part of the larger seafloor mapping effort and marine reserves monitoring, ODFW will collect video imagery data using Remotely Operated Vehicle (ROV), video sled and video lander survey tools within marine reserve sites and comparison areas. The imagery data will be used to ground-truth habitat classifications for the portions of sites that have been surveyed using multibeam sonar. For areas that have not been surveyed using multibeam sonar, due to water depth or other logistical reasons, video imagery habitat data will be used to classify and map habitats. More information on the visual surveys to be conducted by ODFW can be found in Section III.C.

The multibeam surveys produce image mosaics of bathymetry (water depth) and backscatter intensity, from which seabed hardness will be inferred. Bathymetry images are further processed to derive rugosity (bathymetry roughness). Finally, habitat classifications will be derived from analysis of all available imagery and reference datasets for marine reserve sites and comparison areas.

C. Visual Surveys

Research questions:
- What habitats exist within each site? How do they change over time?
- What algal, invertebrate, and fish species exist at each site?
- How do species biometrics change over time?
- What is the biodiversity of the site?
- What are the species-habitat correlations at each site?
- How do theses variables and ecosystem states vary over time?

Focused questions:

Habitat:
- What types of seafloor habitat exist at the site?
- What is the percent composition of depth and relief?

Algal:
- What algal species are present?
- What is the percent cover of focal species?

Invertebrates:
- What species are present?
- What is the abundance, distribution, and density of focal species?

Fish:
- What species are present?
- What is the abundance, distribution, and density of focal species?

Metrics derived:
- Algal, invertebrate, and fish abundance, distribution, and density
- Species- habitat correlations and biodiversity indices

We will use a suite of visual survey tools that will allow us to collect data for fish, invertebrate and algal species and on seafloor surficial physical attributes. Bottom type and depth dictate which type of visual survey and equipment are to be used to collect these data. Video lander, remotely operated vehicle (ROV) and SCUBA divers will be used to conduct visual surveys in hard bottom areas. Video sled, video lander and ROV will be used to conduct visual surveys in unconsolidated sediment (i.e. sand, mud).

We acknowledge there are limitations and inherent sampling biases associated with different visual survey tools in detecting organisms. Water visibility, currents and sea state can also affect the quality of the data collected. Fish behavior such as avoidance, attraction and movement create challenges to collecting an unbiased sample. We also note that some visual surveys, such as those conducted by ROV, have not shown to be adequate for surveying cryptic and smaller organisms well. All survey methods (e.g., trawls) have their own inherent biases; therefore, the important points are to understand and minimize these biases to the maximum extent practicable, and to acknowledge their existence and influence on any conclusions drawn. Attention will be paid to these biases in our data collection, processing and analysis.

C.1. Lander and Sled: Habitat and Biota Surveys

Initial explorations of habitat types for the systematic rapid assessment are conducted using a video lander. To safely explore and help determine the appropriate tool to sample for abundance and diversity of species in a given area, the video lander is deployed on a point grid system. Once bottom type is grossly classified as either hard bottom or unconsolidated sediment, the video lander is utilized for more intensive sampling of hard bottom areas while a video sled is used for unconsolidated sediment areas in a stratified random sampling detailed assessment.

C.1.a. Video Lander

Video landers have been used in a variety of ways to explore habitats, characterize fish populations, and observe fish behaviors (Priede et al, 1994; Cappo et al, 2003; Kaimmer, 1999). A lander is any device that is lowered to the seafloor, either by free-falling or using an umbilical tether, which then performs specific sampling tasks such as collecting video images or physical data.

Our video lander consists of a frame constructed of aluminum, with breakaway mild steel sections in case of fouling in rock, and is equipped with an autonomous video system (Figure 1). The video system is composed of a low-light color camera, paired with an LED light, used to capture underwater video. Parallel lasers with 10-cm spacing are used to estimate scale in captured images. Video is recorded onto a mini-DV tape. An appropriate length of floating buoy-line and three crab floats are attached to the lander. Vessel and drop site positional data are collected using a GPS chart-plotter connected to a laptop running navigational software.

Figure 1. Video lander.

All video "drops" occur during daylight hours, starting one hour after sunrise and ending no later than one hour before sunset. This avoids confounding our data with imagery collected during crepuscular periods and the possible change of fish behavior as light levels rise or fall. Bottom time is sufficient to examine and classify substrate, as well as capture information about any faunal species present. Work off Cape Perpetua with a video lander by ODFW biologists suggests using a bottom-time of four minutes, after which the maximum number of fish in view, as well as the species diversity, tends to remain constant (Matt Blume, ODFW, personal communication).

For each lander drop, the collected video segment will be examined for viewing properties (visibility, lander behavior, obstruction, etc.), substrate type, as well as algae, invertebrate and fish species present. Selected sessile macroinvertbrates are identified to taxa and enumerated. All identifiable fish species are counted as a maximum count in view for a given species (*Max N*). The count is recorded as a maximum in order to overcome the problem of fish entering and leaving the view (Priede et al, 1990). Macroinvertebrates and fish species presence and maximum abundance is determined and species habitat correlations are assessed.

C.1.b. Video Sled

Large areas of seafloor bottom with homogenous features and low relief, such as sand and mud, can be covered most efficiently by towed video equipment (Butler et al, 1991). We will define habitat areas using local knowledge, backscatter and multibeam data and/or video lander imagery. Based on these data, we will identify areas of unconsolidated sediment as potential areas to sample with the video sled. Video sleds are inexpensive and have been successfully used for surveying flat bottomed areas for both fish and invertebrate assessments, with little damage to substrate and sessile organisms (Spencer et al, 2005). Video data will be collected for habitat classification and for enumeration of benthic faunal species.

The video sled system consists of several parts, including a sled frame, two independent video systems, towline and bridle, two dropper chains and a topside recording system with umbilical cable from the sled (Figure 2). The first video system is the autonomous underwater video system or “tube” system and provides for high quality video to be collected for laboratory analysis. The second video system delivers a live video image to the boat showing what the sled is coming toward, as well as the behavior and status of the sled frame, for navigational purposes. This is a simple system and is of lower image quality. Both systems use time-code generators that are synched to an onboard GPS unit collecting location data, so that the video can be accurately geo-referenced (Tissot, 2008). These two systems work in concert to allow for safe towing through appropriate habitat areas while capturing high quality video.

Figure 2. Video sled.

The detailed assessment uses a stratified random sample design to determine the sled start tow locations. The vessel tows the sled in a given direction dictated by current conditions with the intention of covering a 700 – 1,000 m transect (20 to 30 minutes). Once the appropriate on-bottom time has elapsed or inappropriate habitat is encountered the sled is hauled back aboard.

Each video sled transect collected is divided up into sections and examined for viewing properties, substrate type, fish species and select macroinvertebrates. Select sessile macroinvertebrates are identified to taxa and abundance is determined. Fish are identified to species, binned by size and enumerated as able. Species presence, distribution, and abundance is determined and species habitat correlations are assessed.

C.2. SCUBA: Habitat and Biota Surveys

Scientific divers will be contracted to conduct dive surveys in rocky reef portions of sites, within the 5-20 m depth range, using sampling protocols developed and employed by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) adapted and tailored to meet the needs of Oregon’s research questions and nearshore environment (PISCO protocols available online). SCUBA surveys will be conducted in late summer/early fall when visibility is good and the swell is relatively small.

To assure adequate sampling of habitat and species, dive transects will be stratified across depth zones and vertically throughout the water column. Each transect will be 30 m long x 2 m tall x 2 m wide. Each 30 meter transect will be randomly placed within a depth strata of 5, 10, 15 and 20 meters.

Two teams of divers will be utilized: a fish survey team and a benthic survey team. The fish survey team will conduct surveys along the benthos and mid water column at 5, 10, 15 and 20 meter depth contours enumerating all fish and identifying to species when able. All young of the year (YOY) rockfish will be grouped into one of two categories, *Pteropodus* or *Sebastosomus* and enumerated. The benthic survey team is to use two sampling methods; the swath methodology and the uniform point contact methodology along the bottom at 5, 10, and 20 meters depth. The goal of the benthic transects is to classify habitat and quantify the density or cover of algae and invertebrates along each transect line. Benthic survey divers have three main objectives: 1) classify habitat, 2) identify and enumerate individual conspicuous, solitary or mobile invertebrates, and 3) enumerate and identify brown and green algae to the lowest taxonomic level possible and red algae grouped by morphological characteristics.

Fish species present, density, and species-habitat correlations are to be analyzed and determined for each depth zone and water column strata. Algal and invertebrate species present and density or cover estimates are to be determined for each depth zone.

C.3. Remote Operated Vehicle (ROV): Habitat and Biota Surveys

Remotely operated underwater vehicles (ROVs) are unoccupied, highly maneuverable and operated by a person aboard a vessel. They are linked to the ship by an umbilical cable which includes a group of cables that carry electrical power, video and data signals back and forth between the operator and the vehicle. We will use the Department's Phantom HD2+2 ROV (Deep Ocean Engineering) to conduct habitat and biota visual surveys at sites. A more detailed description of the Phantom HD2+2 ROV used in these surveys will be included in our monitoring reports. Here we provide a general overview of how our ROV surveys will be conducted.

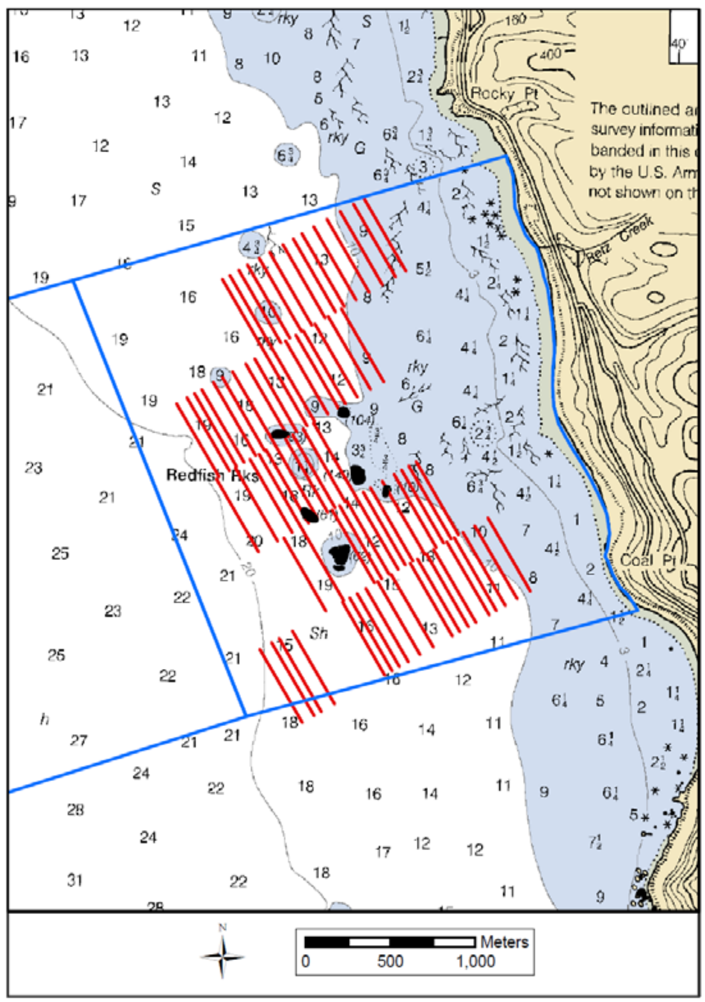

Figure 4. Potential ROV survey transects (red lines) placed within the marine reserve (framed in blue).

ROV surveys will target rocky reef habitat in depths greater than 20 meters and have a simple random sampling design. The following description of how survey transects will be chosen is illustrated in Figure 4. Potential sampling transects will be identified by first orienting parallel, adjacent 500 meter-wide "swaths" that are approximately perpendicular to the shore, depth contours, and the prevailing incident wind direction during the fall season. Then, potential transects will be placed perpendicular to the long axis of the swath and horizontally spaced 10 meters apart. Potential transects that do not intersect rocky substrate will be eliminated outright from further consideration. Based on the planar area of rocky substrate within each swath relative to other swaths, the number of potential transects to choose within each swath will be weighted proportionally. We will randomize the transect identifiers within each swath and evaluate them for further consideration (i.e. length of transect actually over rocky substrate, depth zone of interest, and no shallower than -20 m, in priority order based on the randomization, up to the number designated from the weighting. This process will be repeated for each swath area. In order to disperse sampling within an area and to reduce the chance of spatially autocorrelated data, we determined that all transects within a given swath should be ≥ 50 m apart (note however that this criteria will not be applied among adjacent swaths). All potential final transects for an area will then be assigned a random priority order for sampling during fieldwork.

We will use strip transects that are 500 meters in length with a variable transect width of 1-4 meters depending on visibility and ROV elevation off the bottom. A transect length of 500 m was chosen to strike a balance between maximizing sample size, sample unit size, and overhead time and cost of deploying the ROV. This transect length should prove more than adequate for post-hoc sub sampling of "sub-transects", which will be the actual statistical sampling unit. Using data from ROV surveys in California and Oregon, Karpov et al. (2010) determined that 50 m^2 (e.g., 25 m length x 2 m width) sub-transects afforded the best statistical power for detecting a difference in fish densities.

The ROV survey will acquire continuous video coverage along each transect, except when obscured by visibility or other factors (e.g., topography-induced blind spots, loss of bottom contact). Every second of ROV video will have an associated time and geographic position, along with accessory telemetry data (e.g., height of ROV above the bottom, camera tilt, pitch and roll).

The methods for video review of fish and habitat will be based on those described in the biennial monitoring reports. Video is reviewed in the lab for habitat and fish metrics and will be synchronized by time, allowing for individual observations during video review to be geo-referenced. Habitat type will be determined along the ROV transects. We will count and identify fish to the highest taxonomic resolution (species, usually), and estimate the length for a subset of species. Fish counts will be converted to fish density (# individuals/100 m^2). Due to problems with identifying small organisms in video footage, all young of the year rockfish will be grouped into a single category. Video will be sub-sampled for invertebrate review. Invertebrates will be identified to the highest taxonomic resolution practicable. Density will be calculated for invertebrate species of interest that are solitary (i.e. not colonial) and relatively abundant (e.g., habitat forming species such as *Metridium* anemones, *Gorgonocephalus* basket stars).

D. Extractive Surveys

Research questions:
- Does the prohibition of extractive activities change the community structure of the reserve?
- What algal, invertebrate, and fish species exist at each site?
- How do species biometrics change over time?
- How does biodiversity change over time?

Focused questions:
- What is the density and length frequency of sea urchins within the reserve and associated comparison areas prior to closure?
- What is the benthic biodiversity?
- Does this biodiversity index differ by depth, relief?
- What focal fish species, size, age and sex are being caught in the reserve and associated comparison areas?
- How does fish species composition, age structure and size change over time in response to the reserve?

Metrics derived:
- Habitat classification
- Urchin density
- Focal fish species composition, size, sex and age structure.
- Biodiversity index for invertebrate community on rock habitat

D.1. Red Sea Urchin (*Strongylocentrotus fransiscanus*) Surveys

Harvest refugia (e.g. marine reserves) are known to have a positive effect on population levels of long lived, high site fidelity animals such as red sea urchins (Quinn, 1993). Red sea urchins live in aggregations and depend on close proximity for successful fertilization as they spawn via broadcasting their gametes. As sea urchin densities increase, the probability of successful fertilization increases. As densities decrease, the reverse is true. To this effect, sea urchins in high density aggregations are the source groups most important to the success and persistence of the population. This population density concept is known as the Allee effect (Allee, 1931) for which sea urchins are an oft referred example.

Creation of harvest refugia is expected to increase local urchin densities and therefore larval output, which could improve the long term viability of red urchins in areas adjacent to reserves. Given the importance of the red sea urchin in the trophic structure of the ecosystem at some marine reserve sites, combined with the distinct effect of the fishery, we are interested in describing changes in density, population structure and dispersion.

These surveys could be instrumental in informing fisheries management and marine reserves evaluation by providing: 1) evaluation of the effects of the urchin fishery on urchin populations, 2) baseline for populations of primary kelp grazers known to affect kelp biomass, and 3) degree to which reserves function as a larval source for urchins compared to fished areas. These surveys of density and population structure will be directly applied to aid the understanding of the response of red sea urchins to the creation of harvest refugia.

At Redfish Rocks, in an effort to explore fishery viability, red sea urchin surveys were performed in 1984, then again in 1992, after initial exploitation via the fishery. Comparison to past work presents problems, such discontinuous survey methods. However, current surveys were performed in a more standardized and well described manor. It is our goal to conduct urchin surveys in marine reserves and associated comparison areas, where commercial urchin harvest has occurred, to document a baseline before closure and obtain a post fishery condition.

Commercial urchin divers will be contracted to conduct the surveys. Areas of commercial urchin harvest will be identified within a site and random transect starting points will be assigned within. Standard urchin transect sampling methods will be used (Richmond, 1996). This includes laying out a 40 meter belt transect, with a 1 meter width on either side of the transect. Transect lines will be divided into sixteen, 5 m x 1 m quadrats, by divers swimming 5 meters with a 1 meter length of PVC pipe on either side of the transect line. Divers will swim simultaneously on either side of the transect line, enumerating and collecting all urchins within each quadrat. One diver will also capture video for habitat classification.

At the surface, ODFW staff will measure urchin test diameter, then return urchins to the area. Video is to be reviewed in the laboratory and habitats classified. Urchin density and length frequency distribution is to be calculated and analyzed.

D.2. Focused Benthic Surveys

All of our biological and habitat sampling will provide data that cumulatively will help us understand biodiversity at sites. As described in Feest (2006), no one index of biodiversity quality is adequate to fully describe the biodiversity of a given area. Feest recommends a range of indices be calculated for a given site so that its biodiversity can be compared through time and between areas. To derive a range of biodiversity indices, we will be measuring and assessing number of species, species densities, habitat types, and habitat complexity at each site. Contributing to this effort, we will conduct focused benthic surveys for small algal species and sessile invertebrates in rocky subtidal areas of sites, at depths between 7-20 meters.

Figure 3. Airlift powered by Hookah.

The focused benthic surveys will be carried out using SCUBA divers. These surveys will be conducted separately from the SCUBA habitat and biota surveys, described earlier in this chapter (section C.2.). Our focused benthic surveys will use a stratified random sampling design. We will randomly place transect starting locations, in the reserve and priority comparison area, a priori using GIS in the laboratory. In the field, SCUBA divers will place 30 m transects at the selected starting locations on randomly assigned azimuths within two depth strata (15 m and 20 m). We will use a nested quadrat design: one, 1 m x 1 m quadrat with four, 0.25 m x 0.25 m quadrants nested within. We chose this nested quadrat design because the 0.25 m x 0.25 m quadrat size is commonly used, is more efficient than larger quadrats, and is likely appropriate for most macroinvertebrates and macroalgae (Dayton 2008; Pringle

1994; Medina et al. 2004), while the larger quadrat is more appropriate for the larger organisms, such as *Picnopodia* and *Metridium*.

In the field, once on location, divers will swim out 30 meters of transect tape and collected video in a 1 m swath on each side of the transect line. One, 1 m x 1 m quadrat will be placed at the 10, 20 and 30 meter marks along the transect. Large macroinvertebrates, such as *Pycnopodia spp.*, *Metridium spp.*, and *Nereocytis* stipes will be enumerated and recorded within the whole quadrat. Then, a 0.25 m x 0.25 m quadrant will be randomly selected from within the larger quadrat for extractive sampling. The divers will use paint scrapers to remove everything from the quadrant and an airlift powered by Hookah (Figure 3) to vacuum-collect all materials into a fine mesh bag. One diver will scrape at the surface of the substrate while the other uses the airlift. The contents of the bags will be taken to the lab, grossly separated into algal and invertebrate containers and fixed in either five and or ten percent formalin, respectively. Algae will be indentified to the lowest taxonomic group possible and biomass (weight/m^2) will be determined. Invertebrates will be identified to the lowest taxonomic group possible and enumerated.

Ideal sample size varies with the abundance and aggregation of target species, and no single sampling design will be ideal for all species expected to be present. Our degree of replication will fall within the ranges recommended in other biodiversity studies (Dayton 2008; Bartsch et al. 1993; Halse et al. 2002). Since our goal is to collect densities of most, if not all, of the species present we will choose the largest sample size we can with our allotted resources.

We will calculate species richness, Shannon-Wiener, Simpson’s and Berger-Parker biodiversity indices as well as the species value index and density for each species (Feest 2006). To assess community structure, we will run a multivariate community analysis using PRIMER which will cluster groups of quadrats which have similar species assemblages. The PRIMER program SIMPER will be used to determine which species are primarily responsible for this clustering. Correlations between environmental factors (depth, relief community structure) will be calculated using the PRIMER program BIO-ENV (for a more detailed description see Clark and Warwick 1994).

D.3. Hook and Line Fish Survey

Commercially and recreationally harvested bottomfish species with small home ranges are expected to change in abundance, size, and age within marine reserves as a direct result of closure to harvest. Abundances of fish species relative to each other may change over time as well, as fishing tends to target different species at different rates.

Video lander, video sled, ROV, and SCUBA techniques will contribute data on changes in abundance, and, to a lesser extent, changes in size composition of formerly extracted fish species. However, these visual methods have a limited capacity to accurately estimate fish lengths and are incapable of determining other metrics such as weight, sex, age, and breeding condition. Also, species that tend to hide in holes or under rocks may not be seen by divers or video equipment. Length and weight data collected by ODFW port samplers prior to closure of marine reserves is valuable for describing the upper end of the size-frequency distribution of each species of harvested fish. However, small fish are almost always released. It is important to construct size-frequency distributions which include young fish cohorts so that we can adequately determine whether changes in fish size over time is due to changes in recruitment of young, recruitment of adult fish, or decreased mortality. Therefore, baseline fishery-independent surveys will be conducted at select marine reserve sites to describe the size-frequency distribution of certain fish species within each reserve. Subsequent re-sampling will be used to determine potential changes in size and age structure post-closure.

Fish species that are commonly harvested and exhibit small home ranges will be targeted for these surveys as these are the most likely to experience a detectible change in relative abundance and size in response to the closures. In addition, species regularly found within each reserve will be selected as target species, in order to achieve adequate samples sizes to compare changes in size distribution between the reserves and their associated comparison areas. The array of target fish species will likely be different for each marine reserve due in part to depth and habitat differences between sites. Targeted species may include: kelp greenling, lingcod, cabezon, black, blue, China and quillback rockfish. This selection is based on the prevalence of these species in ODFW market samples and from ODFW interviews of recreational and commercial fishermen at reserve sites. Canary and yelloweye rockfish are protected species, and will not be specifically targeted. However, bycatch of these species will be measured for length and weight before release.

Age data are very useful in describing patterns in growth, survival, recruitment and reproductive output. We might see increase in mean age of rockfish over time in the reserves due to decreased mortality from fishing. This is ecologically significant because rockfish are exponentially more fecund as they get larger, and some species of older rockfish have been shown to produce offspring which have higher growth rates and higher survival rates than young rockfish (Berkeley et al. 2004). Detecting a change in age distribution over time requires lethal extraction of samples on the order of 150-200 individuals. Destructive sampling of large numbers of long-lived, ecologically significant rockfish species from small marine reserves could compromise important reserve objectives. Therefore, we will only collect age distributions for black rockfish and kelp greenling, which are more abundant than all other near-shore bottom-fish species. As fecundity in rockfish is also very strongly correlated with length and weight (Eldridge et al. 1991), fisheries-independent surveys will use these metrics allowing for non-destructive sampling methods for all other species. Also, research is underway to determine a non-lethal ageing method for rockfish species. Species, length, weight, fin rays in lingcod (for ageing) and when possible, sex and reproductive state will be collected, and then fish will be released, using appropriate barotrauma amelioration techniques.

Fish sampling will be done in each marine reserve and in one or both of the respective comparison areas. Growth rates of rockfish have been shown to be different between neighboring reefs (Troy Buell, ODFW staff personal communication) probably due to differences in productivity or density dependent growth. To limit variation within our samples and increase the likelihood of detecting a reserve effect on size distribution over time, we will delineate and sample index areas in the marine reserves and their corresponding comparison areas. Each reserve and comparison area will have three or more index reef structures. Index areas will be chosen that have adequate rocky structure, high fish abundance and diversity, a range in depths, and accessibility. Power analysis will be used to determine the N needed for each species to detect a 5% or a 10% increase in fork length (one-tailed t-test) or to change in fork length (two-tailed t-test). We will use commercial fishery sample data, collected at nearby ports from 2004-2009, to determine the current mean size and standard deviations. We will use the highest and lowest of these values as our target sample size range. (Note: the variances found in the market data are likely to be lower than the actual natural fork length variance within the reserve. This is due to the fact that commercial fishermen do not retain small size classes, and often release gravid females.)

Both hook and line and cable gear long-line are commonly used to catch rockfish. Suzanna Stoike, while studying Port Orford rockfish, observed cable long-lining to capture a more diverse array of rockfish species and suggested we use both methods to ensure the capture of all common species. We will use both hook and line and cable gear from chartered vessels. Our hook and line gear will consist 6 oz. diamond jig, and will target kelp greenling, lingcod, and rockfish. Each cable gear set-up will consist of a 2 m long braided steel wire, weighted on both ends, with five baited circle hooks, and will target cabezon, lingcod, and China rockfish.

Initial sampling will occur before the closure during the spring and summer, with repeated efforts made every five years. Lethal sampling of black rockfish and kelp greenling will occur once every 5-10 years, to minimize researcher induced mortality rates. In our analysis, we will use size-frequency distributions, mean size, and the proportion of fish over an arbitrarily chosen large size to assess the effect of marine reserve on fish sizes. Additionally, for black rockfish and kelp greenling, we will be analyzing age distributions and relative growth rates (from otoliths). For both gear types we will be collecting GPS points for every fish caught, which can be paired with our habitat survey data to estimate absolute abundances of fish within the reserves. We will use CPUE to estimate relative abundance for each species. As there are gear selectivity issues with any gear, data from each gear type will be treated separately in our analysis.

Analytical Framework

Several approaches will be used to integrate and analyze all data collected to establish the baseline and produce a site characterization and desired products. The desired products are: oceanographic condition, habitat maps, species presence, species relative or absolute density/abundance, biodiversity indices, and species habitat correlations. These products will be analyzed and produced for each combination of bottom type, depth zone and site.
All metrics will be compared between a reserve and its complementary comparison areas, as well as across the system of reserves. Given the high variation typical of most biological field data and the desire to minimize the chances of a Type II statistical error (i.e. not rejecting the null hypothesis when it is in fact false), we are setting the alpha statistical significance level at 0.1 (beta=0.9) a priori (Mapstone, 1996).

We will use multiple data sets, including those derived from seafloor mapping, video lander, video sled, SCUBA and ROV to refine and add value to existing habitat maps for each site. Select species presence and abundance levels will be mapped as well. The maps will visually describe the geographic boundaries of key habitat types and depict species abundance levels. This somewhat qualitative method of communicating our results provides a site characterization of habitat types and species present, also enabling comparisons of the similarities, differences and relationships within the reserve versus the comparison areas.

We will use appropriate parametric, non-parametric and multivariate statistical tests to compare species presence, abundance levels and distribution within and among bottom type and depth strata and within reserve versus comparison areas. Not all species encountered in our methods will be statistically analyzed but will be prioritized, starting with extracted focal species and then non-extracted focal species. For algae, invertebrate and fish we will strive to identify the habitat and oceanographic variables that might correlate with species distributions. Multivariate statistical analysis methods, such as ordination and multiple stepwise logistical regressions will be employed to enable us to identify the most important of our measured environmental variables that may be affecting species distribution.

Additional Monitoring Activities

Due to limited resources we are unable to conduct studies year round and or examine all variables that we would like. We would however like to examine additional variables; aspects of community function and or utilize additional methodologies in the marine reserves. We recommend the following studies for future funding and or scientific researchers to pursue. We strongly encourage researchers to contact the department for discussion and potential collaboration.

- Rocky intertidal studies
- Assess pH levels
- Current measurements
- Circulation pattern studies
- Remotely sensed data (satellite, high-frequency, land based radar) for current speed and direction, sea surface temperature and sea surface chlorophyll levels
- Phytoplankton and Zooplankton sampling
- Harmful Algal Bloom (HAB) sampling
- Larval transport analysis
- Additional focused biodiversity studies
- Sea bird studies
- Marine mammal studies
- Additional acoustic tagging studies
- Boundary studies
- Genetics
- Age structure
- Otolith microchemistry
- Trophic cascades
- Assess nitrate, phosphate and silicate levels
- Independent fishery study through a cooperative and collaborative fisheries approach
- Abundance and fecundity of pigeon guillemots
- Measurements of production: growth rate, feeding activity, nursery areas

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Appendix

Some of the other studies or surveys that have been conducted recently that complement or contribute to our marine reserves monitoring efforts are touched upon in this appendix.

Bull Kelp (*Nereocystis luetkeana*) Survey

Kelp bed surveys have periodically been conducted off Oregon, going back as far as the late 19^{th} century. More frequent surveys, on the order of every five to 10 years would allow us to make long-term comparisons in change over time in protected areas and across the state as a whole, that could be used to inform nearshore resource management. The comparison of kelp biomass of now versus the future may be indications of changing ocean conditions including storms and/or potential shifts in trophic cascades in response to a marine reserve or to anthropogenic change such as ocean acidification or climate change.

In 2010 a survey was conducted to calculate the surface and sub-surface biomass of bull kelp *(Nereocystis luetkeana)* off Oregon. The majority of kelp beds occur between the California border and Depoe Bay, Oregon, with minor amounts of kelp occurring north to Cape Falcon. Aerial digital multi-spectral imagery of kelp beds were collected and analyzed. Geo-referenced mosaics were generated from the imagery to analyze surface and sub-surface kelp canopy presence and biomass. Aerial imagery was ground-truthed with field methods that estimate kelp bed density and individual plant weights.

2012

Marine Resources Program
Newport, Oregon