Oregon Marine Reserves

Ecological Monitoring Report

2010-2011

2014

Marine Resources Program
Newport, Oregon

Acknowledgments:

Thanks to Chris Aiello, Jim Burke (Oregon Coast Aquarium), Dr. Mark Carr (UCSC), Tim Foley, Dr. Gayle Hansen (OSU), Steven Hatfield, Jeff and Mark Lottis, Dr. Kristen Milligan (OSU - PISCO), and Mark Roberts for their collaborative efforts to help collect the baseline data for Redfish Rocks and Otter Rocks Marine Reserve.

Contributors:

Dr. Brittany Huntington, Keith Matteson, Neal McIntosh, Katherine Pierson, Alix Laferriere, Cristen Don, David Fox, Chris Eardley, Kelsey Adkisson, Annie Pollard, Mike Donnellan, Scott Groth

Oregon Department of Fish and Wildlife
Marine Resources Program
2040 SE Marine Science Drive
Newport, OR 97365
(541) 867-7701 x 227

www.dfw.state.or.us/MRP/

www.oregonocean.info/marinereserves

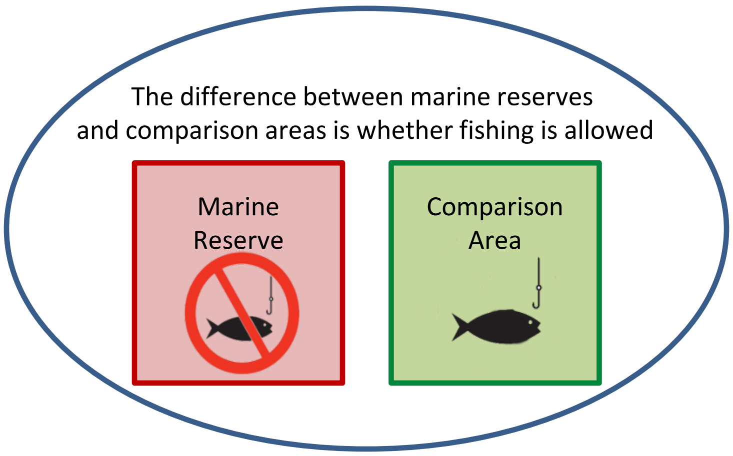
ODFW Marine Reserves Program

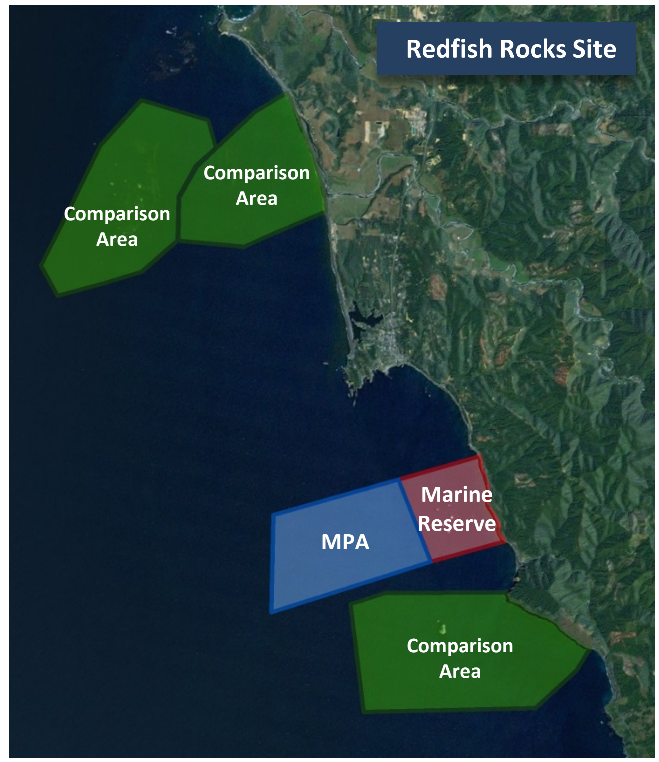
Comparison Areas – tools for understanding changes over time

In 2012, Oregon completed designation of five marine reserve sites within its state waters to advance scientific research and conserve habitats and biodiversity. Oregon Department of Fish & Wildlife is responsible for overseeing the management and monitoring of Oregon's marine reserves.

What are Comparison Areas?

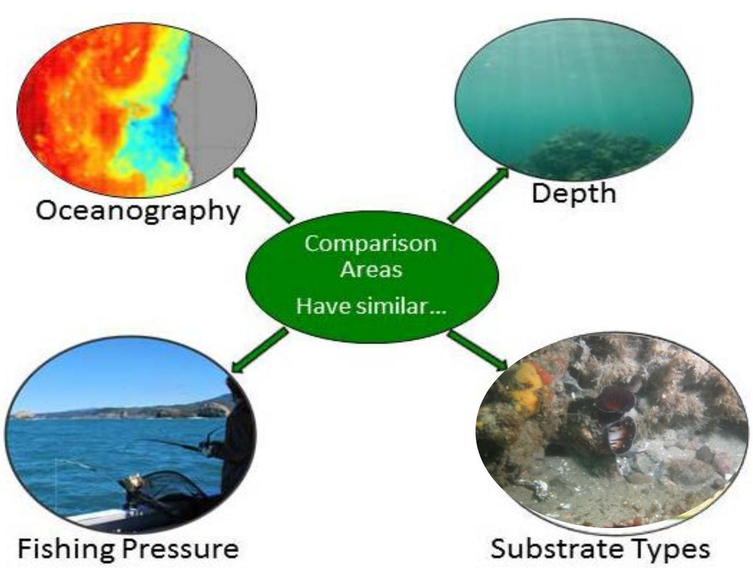
Comparison areas are monitoring sites, in close proximity to the marine reserve, that remain open to fishing. Long –term monitoring will be conducted identically in both the reserve and comparison areas so that we can understand whether the changes we are seeing in the marine community (fish and invertebrate species) are from environmental variation or from the marine reserve protections.





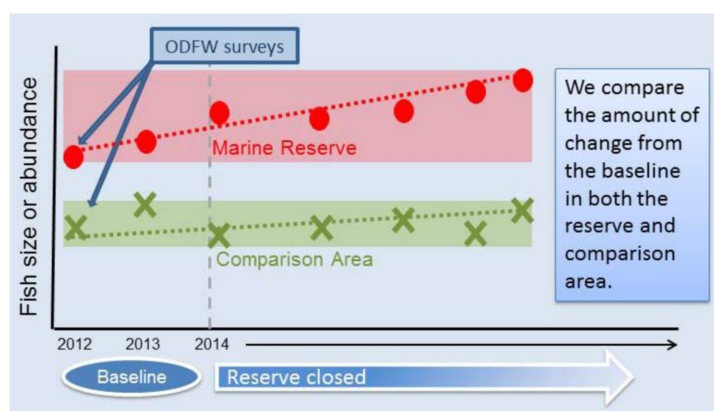
How do we choose Comparison Areas?

Ideally, a comparison area would be identical to the marine reserve in all ways except that it remains open to fishing. In reality, it is impossible to find two areas that are perfectly identical. Instead, we find areas as similar as possible and select more than one comparison area per reserve. We look to find comparison areas that have similar ocean conditions, habitats, and fishing pressure as the marine reserve.



Where do we start? Baseline …

Prior to the prohibition of fishing, we sample in the reserve (red) and the comparison areas (green) to quantify the initial conditions of these areas. This allows us to identify differences that already exist between the areas.

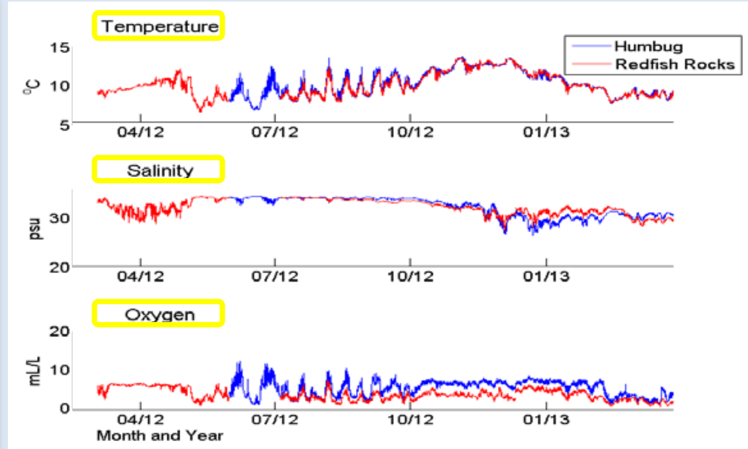


What's next? Understanding changes over time …

From our baseline, we are now tracking the changes occurring in the reserve and in the comparison areas over time. This allows us to isolate reserve effects from natural variations. We are looking for changes in species composition, size, and abundance.

Do the comparison areas have similar ocean conditions as the marine reserve?

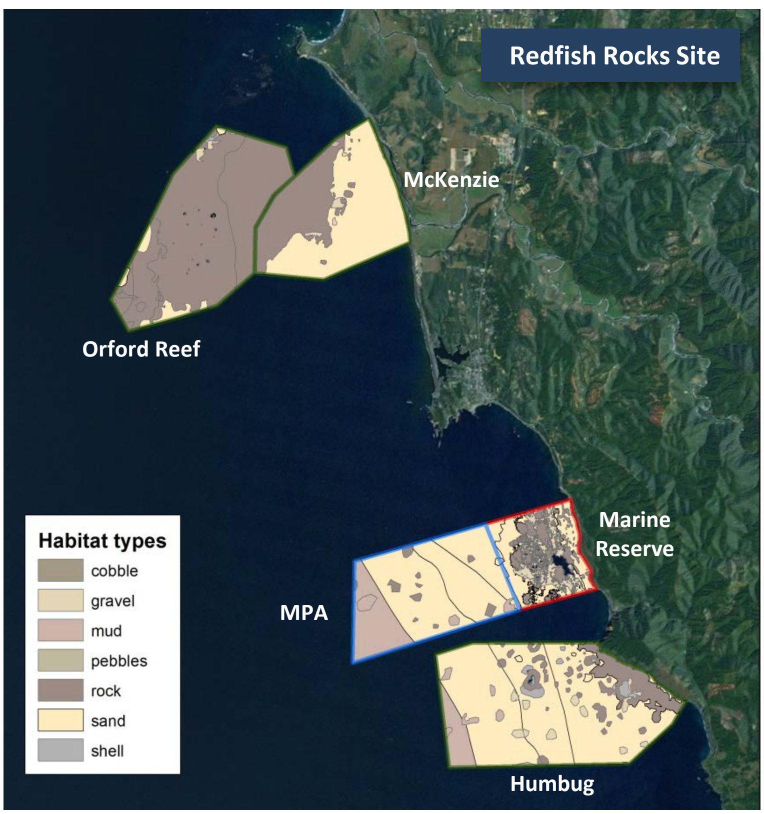
Oceanographic instrument (CTD) bolted to the ocean floor collecting data at Redfish Rocks.



Temperature, salinity, and oxygen measured April 2012 - January 2013. Marine reserve in red; comparison area in blue.

Ocean conditions were very similar between the marine reserve and the comparison area suggesting that Humbug is a good comparison area to the reserve.

Do the comparison areas have similar habitat and fishing pressure as the Redfish Rocks marine reserve?



During our baseline assessments, we found Humbug Comparison Area to have very similar ocean conditions, proportions of habitats, and fishing pressure to the marine reserve. Also, we found similar habitats at Orford Reef and McKenzie Comparison Areas to the marine reserve. However, these two areas have more fishing pressure than the reserve experienced prior to protection. We therefore are using Humbug as our primary comparison area and Orford Reef and McKenzie as secondary comparison areas.

Comparison Areas: Facts and Myths

MYTH: Comparison areas are meant to catch fish that swim out of the reserve

Actually, comparison areas are meant only to be a scientific control to detect change over time.

FACT: A reserve can have more than one comparison area

Yes, since no area is a perfect match to the marine reserve, more than one comparison area is usually selected.

MYTH: Comparison areas are meant to catch larval fish that originated from the reserve

Actually, comparison areas are meant only to be a scientific control to detect change over time.

FACT: Fishing is allowed in comparison areas

Yes, be sure to consult all current fishing regulations before fishing in a comparison area.

For more information from ODFW

Website:
www.oregonocean.info/marinereserves
E-mail us:
odfw.marinereserves@state.or.us

Join our email list and receive updates:
http://listsmart.osl.state.or.us/mailman/listinfo/odfwmarinereserves

ODFW Marine Reserves Program

Underwater Video Surveys – Ongoing in the Deep

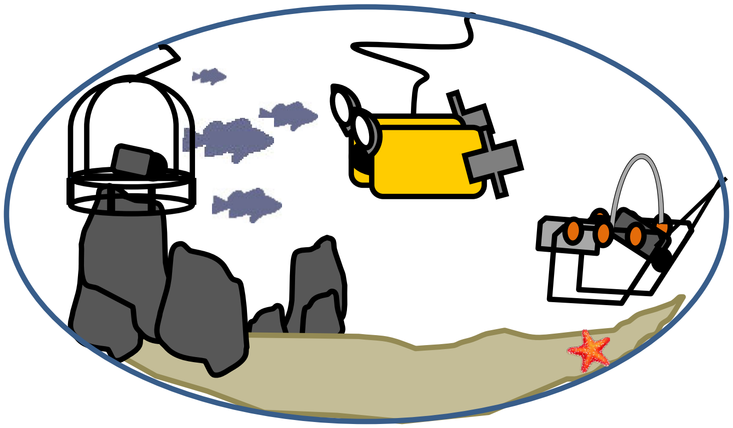
In 2012, Oregon completed designation of five marine reserve sites within its state waters to advance scientific research and conserve habitats and biodiversity. Oregon Department of Fish & Wildlife is responsible for overseeing the management and monitoring of Oregon's marine reserves.

Marine reserves contain a variety of habitats and depth ranges. To assess the animals and their habitats at these sites, we need a variety of tools . Scuba divers can only survey areas in depths up to about 75 feet. We use underwater video as our eyes for getting into the vast remainder of places where divers can't go. Video survey tools can collect information on animal behaviors and life history stages unable to be captured by extractive methods, and allow us to watch animals in their native habitats. Video surveys are also non-lethal, an important consideration for monitoring marine reserves.

Video Sled

Our **video sled** lets us "skim the bottom" in broad areas of sand and mud habitat. This camera system uses a time-clock synced to the vessels GPS to record where it is each second, allowing us to accurately determine the location of habitat changes, fish observations, and any other "events" seen on the video. From the video recorded by the sled, we count fish and invertebrates. We also compare our observations with habitat maps, created using high-resolution multibeam sonar, for accuracy.

Lander, Sled, and ROV: 3 types of tools – 3 places



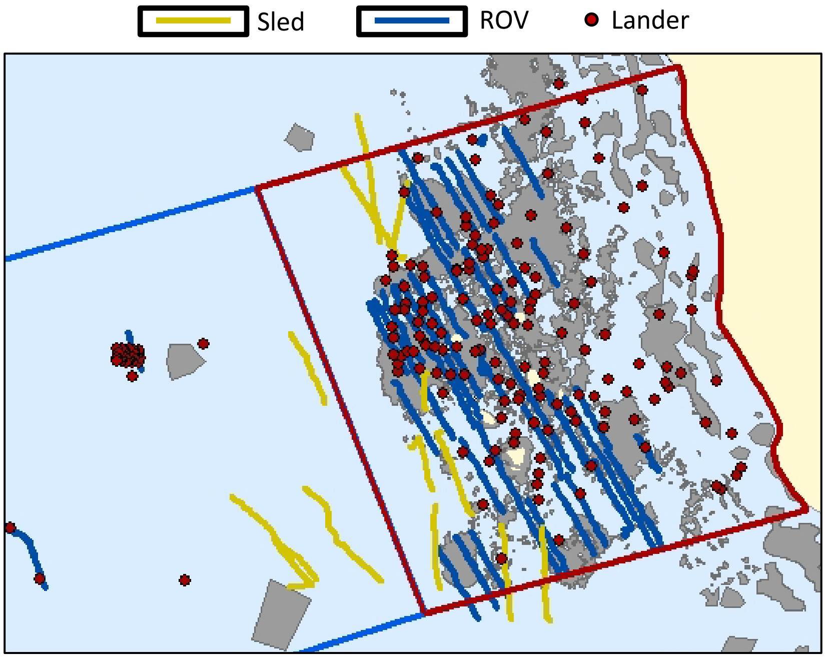
Video Lander

The **video lander** is a camera that can be dropped anywhere. Typically used in rocky habitats, this high-definition camera and frame is built to withstand the abuse of being dropped into the unknown and survive the trip. Left on the bottom for up to 5 minutes, the lander gives us a "snapshot" of fish, algae, invertebrates, and the habitat in places too deep for divers and too shallow for the Remotely Operated Vehicle (ROV).

Remotely Operated Vehicle (ROV)

The **ROV** is our most complex video tool. It is "flown" by a person on the surface, controlled via an umbilical cable. The ROV can swim up, down, and around obstacles and follow along a transect line, like a SCUBA diver. The high-definition video is later analyzed for fish, invertebrates, and habitat. The ROV is perfect for surveying rocky habitats all the way out to the deepest parts of the reserves (and well beyond!).

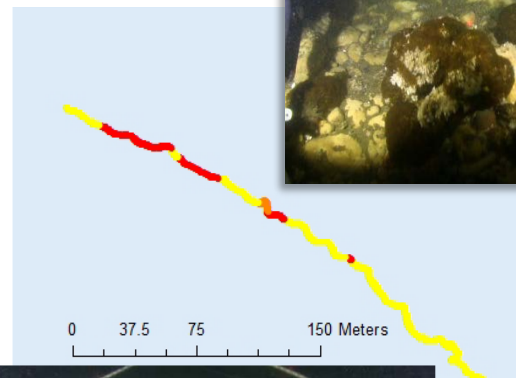
Where do we use video survey tools?



Map of surveys conducted in 2010-11 at Redfish Rocks Marine Reserve. The shoreline is on the right. Red denotes the reserve boundary; blue, the MPA boundary. Rock habitat is in grey.

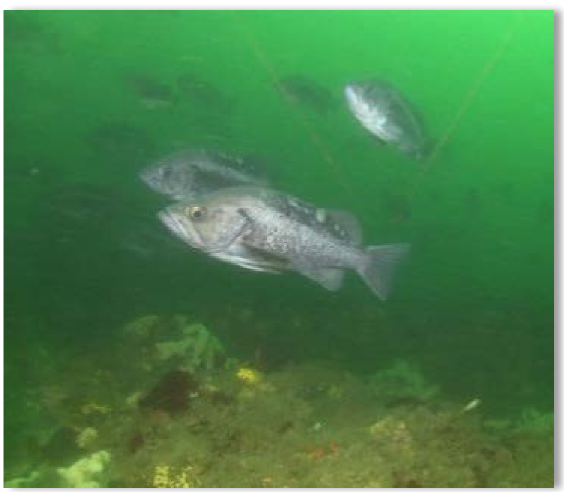
Encountering different habitat types

Below is a track that was surveyed by the video sled. The colors change as the substrate changes from sand (yellow) to rock (red and orange). The sled can detect detailed changes in habitat, finding rock where sonar seafloor surveys did not.



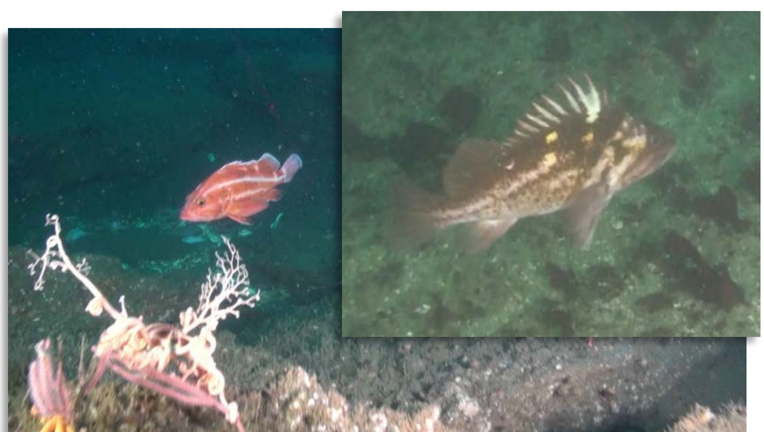
What does the lander see?

Top, we see a school of black rockfish above hard, rocky bottom covered with sponges and algae. Bottom, canary rockfish hover over a soft sandy bottom. Lander video gives us data on the community of species and the type of habitat they live in.



ROV Surveys

Unlike the sled or lander, the ROV has the ability to swim, stop, and look around. Investigations of a particular species or intensive surveys at a specific area too deep for divers becomes possible. Below is a yelloweye rockfish among slabs of bedrock, a species of particular management interest. On the right is a China rockfish, a species difficult to sample due to its cryptic nature.



OREGON Fish & Wildlife

For more information from ODFW

Website:
www.oregonocean.info/marinereserves

E-mail us:
odfw.marinereserves@state.or.us

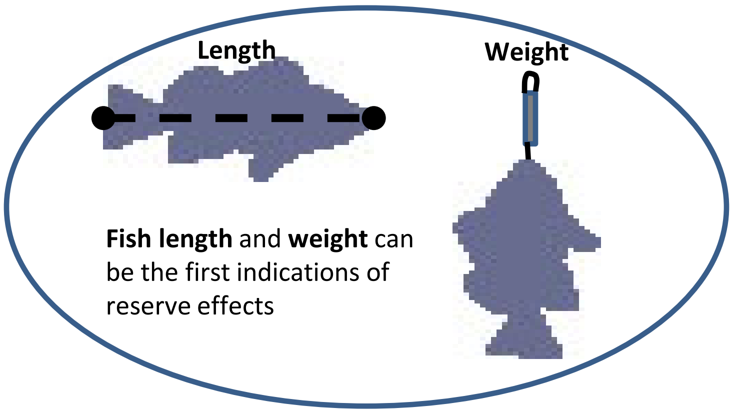
Join our email list and receive updates:
http://listsmart.osl.state.or.us/mailman/listinfo/odfwmarinereserves

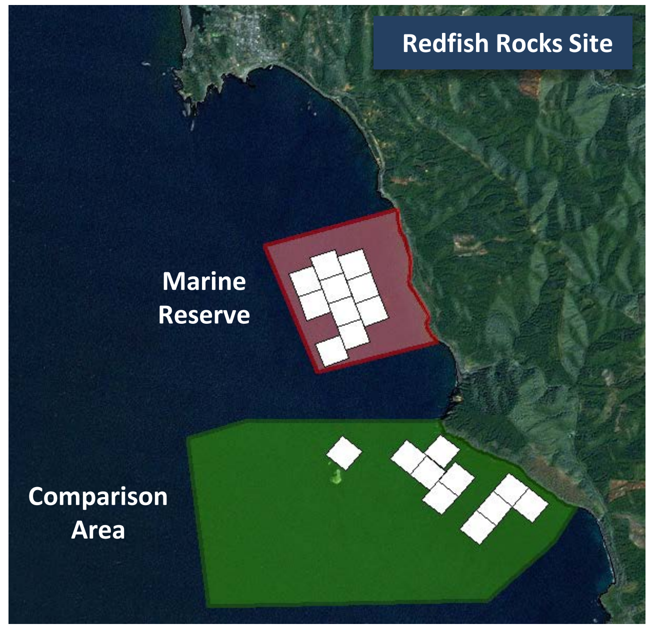
ODFW Marine Reserves Program

Hook-and-Line Survey – Fishing for Science

In 2012, Oregon completed designation of five marine reserve sites within its state waters to advance scientific research and conserve habitats and biodiversity. Oregon Department of Fish & Wildlife is responsible for overseeing the management and monitoring of Oregon's marine reserves.

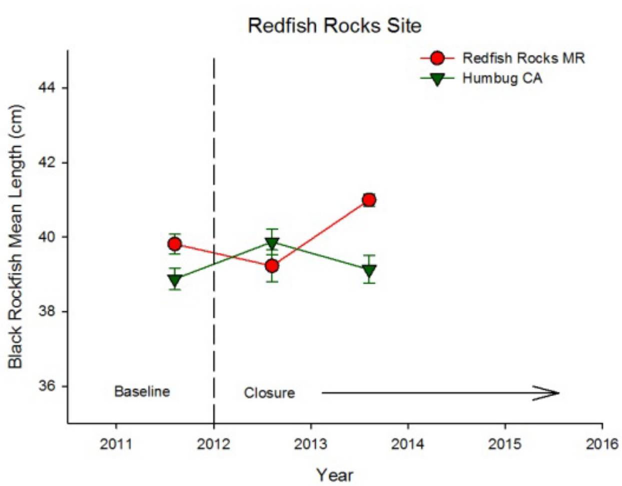
What is the hook-and-line survey?
Fishing for Science: We collect data on fish by bringing citizen scientists (volunteer anglers) out on chartered fishing boats to ***catch and release*** fish. Hook-and-line surveys are a good way to get fish in hand in order to take accurate length and weight measurements. Changes in fish length and weight are one of the first early signs of potential effects from marine reserve protections.





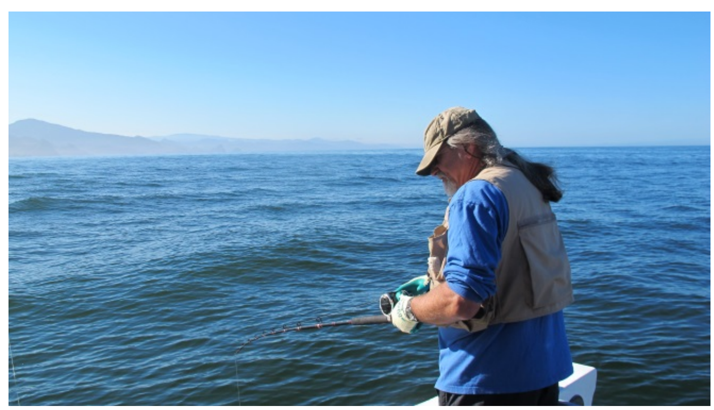
White squares indicate fishing grid cells.

Detecting changes in fish over time.
We look at differences in average fish length and weight **before** and **after** the reserve is closed to fishing. Also, we sample both **inside** the reserve and **outside** in the comparison areas (monitoring sites open to fishing). By sampling over time, we can determine whether fish sizes are changing due to cessation of fishing.



In this graph, we see the average (mean) length of black rockfish (± standard error) in the marine reserve (red) and comparison area (green) for our first three years of sampling. You can see the up and down caused by the natural variation of measurements from year to year. To tease out this natural variation from an actual effect of the reserve protections, we need long term monitoring. With time, we will determine if the **amount of change** in the average length of fishes inside the reserve is different than outside the reserve.

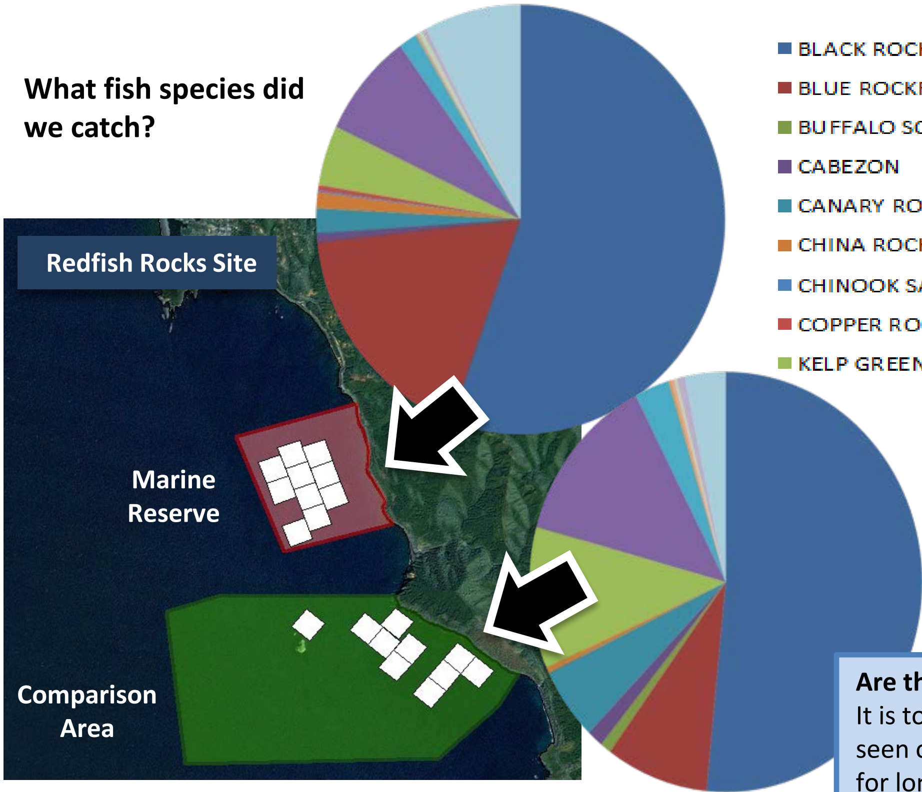
How do we sample?
We place fishing grid cells (500m x 500m areas) in rocky reef habitats. Local fishing knowledge helps ensure cells are placed in locations where fish are commonly caught. On a survey day, five cells are randomly selected. Each cell is fished for approximately 45 minutes by 5 volunteer anglers. All caught fish are measured and then released.

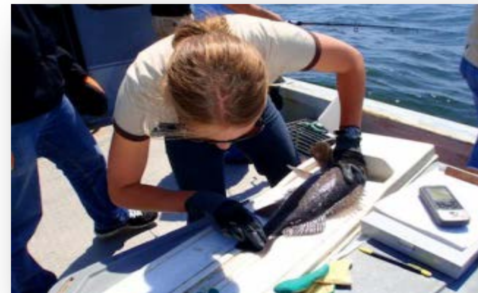


Sampling effort at Redfish Rocks site 2011-13.

- Surveys occurred once a month from July -October.
- One 8 hour day was spent fishing in the marine reserve followed by one day in the comparison area.
- We fished in five 500m x 500m cells per day, using 5 volunteer anglers to ***catch and release*** fish.
- Gear was standardized to a 6 ounce diamond jig for all anglers.

What fish species did we catch?





These pie charts show the fish species caught (color) and their proportions (size of pie wedge) in the marine reserve and in the comparison area during our 2013 survey. Our monitoring is tracking changes in abundance, length, and weight of fishes over time. To do this we need comparison areas with similar species to the reserve in order to compare.

Are the fish getting bigger in the marine reserve?
It is too early to tell. Reserve effects are projected to be seen on a **decadal timescale (10+ years)** creating a need for long term monitoring. To determine whether average fish sizes are getting bigger in the reserve, we need to continue hook-and-line surveys annually over the years to come.

Blue Rockfish

Black Rockfish

Lingcod

Kelp Greenling

Above are comparisons of fish length for the four most commonly caught species in Redfish Rocks. We see that for some species, we are starting with larger fish in the reserve. Knowing these initial baseline differences will help us determine the **amount of change** in fish sizes over time.

Fun facts from the 2013 survey at Redfish Rocks!

- We sampled a total of **1,197 fish** representing **17 different species** from the marine reserve and the comparison area.
- We had 24 volunteers join us for 8 days of fishing for science! Our average catch was 133 fish per day.
- The biggest fish caught was a 38 inch (20 lbs) lingcod and the smallest fish was a 1 inch sculpin (pictured above right).

For more information from ODFW

Website:
www.oregonocean.info/marinereserves
E-mail us:
odfw.marinereserves@state.or.us

Join our email list and receive updates:
http://listsmart.osl.state.or.us/mailman/listinfo/odfwmarinereserves

Table of Contents

Introduction

In 2008, the state of Oregon began a process to establish a limited system of marine reserve sites within state waters. In 2009, the state established its first two sites: Redfish Rocks Marine Reserve and Marine Protected Area located on the south coast of Oregon near Port Orford, and Otter Rock Marine Reserve located on the central coast near Depoe Bay.

The Oregon Department of Fish and Wildlife (ODFW) is the designated lead agency responsible for implementing Oregon's system of marine reserve sites. To that effect, in 2009, ODFW established a program comprised of staff responsible for marine reserves implementation, including the design and execution of an ecological monitoring program to provide information for marine reserves evaluation and to support nearshore resource management.

The ecological monitoring program has been developed by ODFW program staff, with assistance and collaboration from external scientists and marine reserve community members, and is designed for the long-term monitoring of Oregon's marine reserve system. The *Oregon Marine Reserves Ecological Monitoring Plan* (ODFW 2012) 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. Detailed methods, analyses, and results are to be presented in biennial monitoring reports.

This report serves as the first biennial monitoring report covering the first two years of baseline/T_0 data collected at the Redfish Rocks and Otter Rock marine reserve and their associated comparison areas (i.e. areas in which extractive use is allowed), prior to the cessation of harvest activities. Hereafter in the monitoring report, we use the term **site** to refer to a **marine reserve** and its associated **comparison areas**. The report characterizes the oceanographic conditions and marine habitats present at the sites as well as the algal, invertebrate, and fish community structure within the marine reserve sites.

Policies Guiding Monitoring

State policies that direct and guide the siting, development and implementation of Oregon's limited system of marine reserve sites include: Executive Order 08-07; House Bill 3013 (2009) and Senate Bill 1510 (2012) passed by the Oregon Legislature; and administrative rules adopted by state agencies (OAR 635-012, OAR 141-142, and OAR 736-029). In addition, the *Oregon Marine Reserve Policy Recommendations* developed and approved by the Ocean Policy Advisory Council (OPAC 2008) provides guidance for implementing Oregon's marine reserve sites. OPAC is a legislatively mandated body that advises the Governor, state agencies, and local governments on marine resource policy issues. The OPAC policy recommendations provide the foundation for the ecological monitoring program. In this chapter we lay out the key definitions, goals, and objectives provided by OPAC that guide the ecological monitoring program.

A. Marine Reserve Definition

The first policy recommendation that guides the monitoring program is the definition of a marine reserve. As established by OPAC, 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. Marine Reserve Goal

The goals of Oregon's marine reserves are 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).

C. Marine Reserve Objectives

Marine reserve objectives, established by OPAC, provide further guidance on planning and implementation of Oregon's system of marine reserve sites. Marine reserve objectives that direct the design of the 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.

D. 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, we focus 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. Examples of complementary protective measures include when an MPA:

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

E. Marine Reserves Evaluation

A comprehensive evaluation of Oregon's marine reserves is to be conducted after the system of sites 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 (OPAC 2008).

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

- Monitors 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, or biodiversity of the ecosystem.
- Determine if marine reserves serve as ecological reference areas which allow us to deduce natural changes from human-induced changes to certain species, habitats, or ecological function 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, and location of marine reserve sites, and the system as a whole, allow scientific evaluation of ecological effects.

Monitoring Design

Monitoring design and sampling methods were previously laid out in our *Oregon Marine Reserves Ecological Monitoring Plan* (ODFW 2012). Our research questions, metrics, field sampling activities, and data analyses have all been designed to provide the information needed to meet the goal and objectives of marine reserves evaluation. In this chapter we provide an overview of the monitoring design as implemented for the Redfish Rocks and Otter Rock sites in 2010 and 2011.

A. Research Questions

The following overarching questions provide general guidance for how we focus and structure our initial monitoring efforts. We attempted to address each question for the initial conditions (e.g. baseline) of both the marine reserves and the comparison areas. We then tested for any differences that may exists in baseline conditions between a given reserve and its associated comparison areas. We also asked whether these baseline conditions were consistent across the marine reserve system?

- What is the oceanographic condition of each site?
- What habitats exist within each site?
- What algal, invertebrate, and fish community structure exists at each site?
- What are the species-habitat correlations at each site?
- What are the species-specific size structures at each site?

As the marine reserve program continues, we will evaluate how these baseline conditions change through time and across areas the reserve boundaries.

B. Before, After, and Comparison

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 marine reserve protections. To this effect, each marine reserve was paired to other areas that we refer to as **comparison areas** (i.e. scientific controls). Having only one marine reserve site and one comparison area is simply a comparison between two areas and consequently decreases the degree of certainty when differentiating natural from human-caused changes. Therefore, we paired multiple comparison areas to each of the marine reserves. Given our limited monitoring resources, we assigned one area that most closely resembled a given marine reserve with respect to habitats present, oceanographic conditions, and depth as the **priority comparison area** in which the most detailed sampling would occur. Additional comparison areas were sampled to the extent possible.

We designed our monitoring studies to measure the same variables in the marine reserves as in 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 changes in the marine reserves might be caused by cessation of extractive use (i.e., fishing) and if the marine reserves are effective at conserving certain species and habitats.

C. Sampling Design

Our sampling design is constructed from a system approach, with the encompassing goal to compare 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; and
- Estimate the magnitude of the effects.

This monitoring design requires that sampling account for:

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

To meet these criteria, our sampling design for biological variables consists of comparing the marine reserve and comparison areas within specified habitat and 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: Conducted in the first two years, prior to harvest restrictions taking effect.

Systematic Rapid Assessment: Conducted in the first two years, prior to harvest restrictions taking effect, to establish a baseline dataset.

Detailed Assessment: Conducted both before and after harvest restrictions take effect, to establish a baseline data set and a long term dataset.

D. Selecting Comparison Areas

It is nearly impossible to identify truly independent comparison sites for monitoring the effects of marine reserves (Halpern et al. 2004). Reserves can affect neighboring areas both negatively, through displaced fishing effort, and positively, through spillover benefits. Furthermore, no true replica exists for a given marine reserve site with respect to abiotic environment, oceanography, and habitat. Despite these limitations careful measures were taken to choose comparison areas as similar as possible to their corresponding marine reserve. We chose comparison areas of comparable size to the marine reserve based on similarities of physical and biogenic habitat type, depth, species complexes, oceanographic condition, and fishing pressure. We also considered spacing between the marine reserve and potential comparison area and coastline characterization. The need for the comparison area to experience the same oceanographic conditions dictated that the comparison areas were reasonably close to the marine reserve. However, comparison areas required some degree of spatial separation from the reserve to favor statistical independence.

To identify comparison areas for Redfish Rocks and Otter Rock, we held workshops with members of the local fishing fleet and recreational users to acquire site specific information on habitat, species present, ocean condition, and fishing pressure. We also examined available seafloor maps and any existing datasets that would be helpful in site selection. We tabulated information on potential comparison areas and went through a scoring procedure to inform, define, and site comparison area placement.

D.1. Redfish Rocks Comparison Area Selection

Redfish Rocks is located between Tichenor Head and Humbug Mountain, south of Port Orford. The site includes a marine reserve adjacent to shore and an MPA west of the marine reserve that allows for commercial and recreational harvest of salmon and crab.

We sought to find comparison areas with similar characteristics to both the marine reserve and the MPA. The marine reserve component of Redfish Rocks is 2.6 square miles and lies between the extreme low water line and a water depth of 36 m. Within the shallow reaches of the marine reserve adjacent to shore, the area is predominately comprised of unconsolidated sediment in the form of gravel and sand. Seaward, there is a shallow inner rocky reef that is relatively flat. Beyond the inner reef lie six large emergent rocks surrounded by high relief rocky reef comprised of bedrock interspersed with cobble beds and boulder fields. The inside reaches of the reserve, between the emergent rocks and the shoreline, support extensive *Nereocystis* kelp beds. The MPA component of Redfish Rocks is 5.7 square miles and extends offshore from the marine reserve boundary to a water depth of approximately 80 m. The MPA is composed mainly of unconsolidated sediment with some patch reef complexes of varying size.

The emergent rocks posed some challenges when trying to find a suitable comparison area because they provide habitat features not present on all rocky reefs. This section of the coast does not have contiguous rocky reef habitat, but rather reefs separated by large deep areas of sand or other unconsolidated sediment. Based on available data and conversations with local commercial fishermen and divers, we considered the following areas: Blanco Reef, Breakers, Rogue Reef, Tichnor/Nellie's Cove, Humbug, McKenzie Reef, and Orford Reef. Blanco Reef has complex oceanography and is spaced 17 km away resulting in a low score. Breakers and Rogue Reef have similar habitats and depths but have significantly higher fishing pressure (albeit not as much as Orford Reef) and are spaced 22 and 28 km away, potentially placing them in a different water mass. Tichnor/Nellie's Cove scored relatively high but lacked reef at depth comparable to that of Redfish Rocks and is rarely fished. Humbug scored the highest with similar substrate types and habitat features in similar depth zones and comparable fishing pressure. Humbug is 3 km away and we postulated that this area experiences a similar oceanographic condition as Redfish Rocks. The Humbug area includes two large emergent rocks: Island Rock and an unnamed rock. Humbug was chosen as the priority comparison area (Figure 1). McKenzie also scored high in similar substrate types, habitat features, depth, species complexes, and fishing pressure. McKenzie is spaced 9 km away from Redfish Rocks and may experience different oceanography but was deemed appropriate as a second comparison area (Figure 1). Orford Reef has similar habitats and depth as Redfish Rocks as well as emergent rocks, though the fishing pressure is greater than Redfish Rocks. Hence, we selected Orford Reef as a third comparison area (Figure 1).

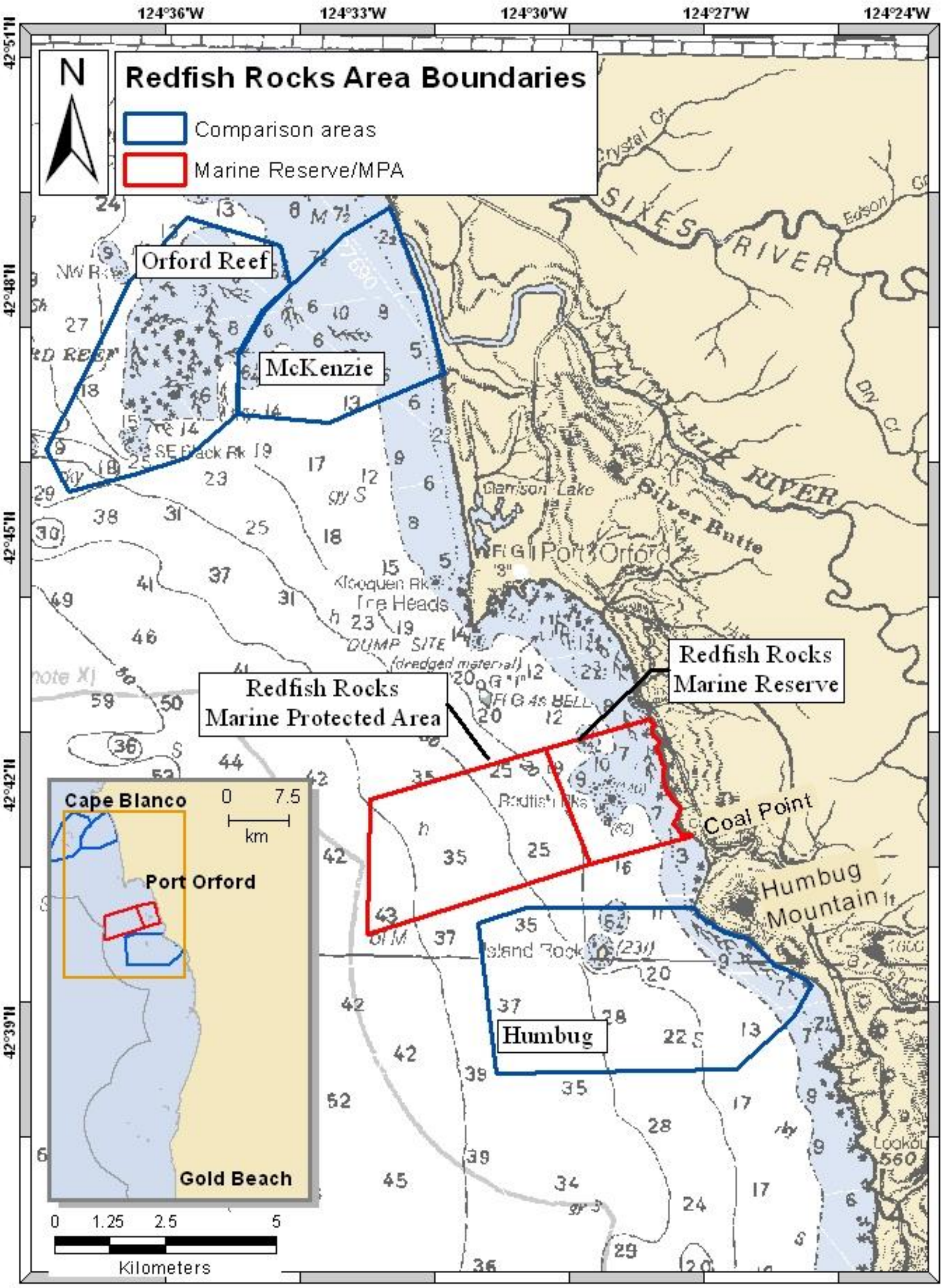


Figure 1. Redfish Rocks Marine Reserve, marine protected area (MPA), and associated comparison areas.

D.2. Otter Rock Comparison Area Selection

Otter Rock has three large emergent rocks and is in shallow water--approximately 3-12 m deep. Due to the shallow water, very little data had been collected on substrate in this area. Through conversations with local divers, charter fishermen and commercial fishermen we were able to glean that the Otter Rock marine reserve is composed largely of unconsolidated sediment, with patchy reef at specific spots, and large boulders and flat bedrock extending out from the emergent rocks. Through conversations with local fishermen and experienced ODFW researchers, we understood that the oceanography was somewhat different north of Government Point and south of the Yaquina Bay jetty.

The following areas were considered: Yaquina Head, Cape Foulweather and Moolack Beach. Yaquina Head has similar habitat: a sandy environment inside of rocky reef with kelp. However, this site experiences much more fishing pressure than Otter Rock and posed safety concerns for sampling and therefore received a low score. Cape Foulweather has rocky reef in similar depth zones to that of Otter Rock but lacks unconsolidated substrate in a comparable depth zone and has moderately more fishing pressure. Moolack is composed mainly of unconsolidated sediment at a similar depth as Otter Rock, but has very little to no rocky reef. Fishing pressure at Moolack is light. Given the constraints of depth and localized oceanography, we decided to have one comparison area for unconsolidated sediment at Moolack and one for rocky reef at Cape Foulweather. Cape Foulweather was deemed the priority comparison area.

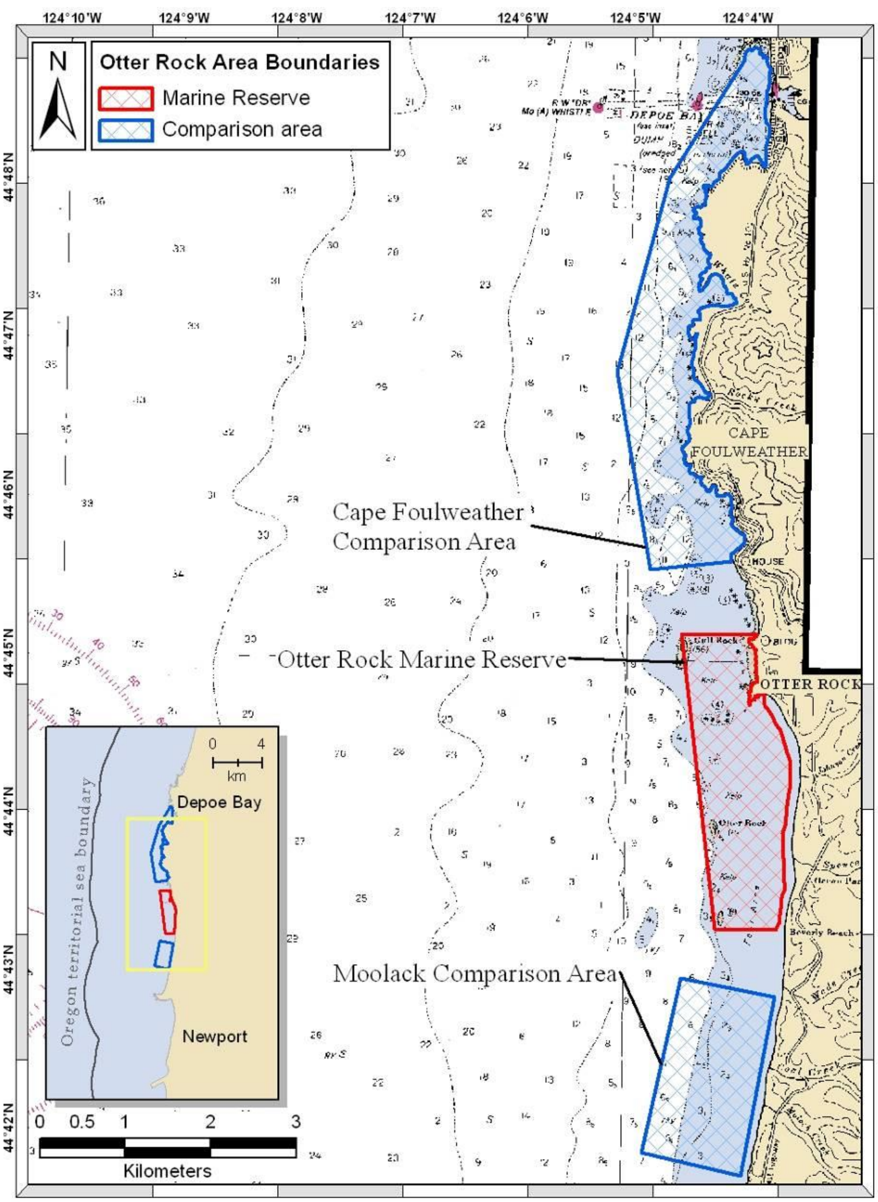


Figure 2. Otter Rock marine reserve and associated comparison areas.

E. Site Characterization

Site characterization was conducted in 2010 and 2011 for the Redfish Rocks and Otter Rock sites, before harvest restrictions took effect, to provide a general description of the habitats, oceanographic condition, and species present. Our site characterizations took the following steps: a literature review, synthesis of past studies and data, oceanographic sampling, and a systematic rapid assessment of habitats and species presence.

The metrics derived from our site characterization included:

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

F. Systematic Rapid Assessment

To begin our rapid assessment we used the best available data on substrate type and depth collected from previous seafloor mapping efforts, led by the Active Tectonics and Seafloor Mapping Laboratory at Oregon State University and the Oregon Department of Fish and Wildlife (see Chapter IV). In general and specifically for areas not covered by high-resolution mapping, we augmented the data with local knowledge from fishermen, scientific experts and local divers to delineate hard bottom areas and areas of unconsolidated sediment. We then designed a sampling program based on a systematic point grid in each marine reserve and comparison area. A 350 x 350 meter point grid was applied at the Redfish Rocks site and a 200 x 200 meter point grid was applied at the Otter Rock site. These grid sizes were chosen based on finding a balance between sampling resources available (i.e., boat time), the overall size of the site, and assurance of independence between units. We used a video lander (see Chapter IV) and standard vessel sounding equipment to sample on the grid to define (ground-truth) bottom type, as well as document fish and invertebrate species presence and abundance. We then analyzed the systematic grid to generate a map of bottom type and depth regime for the site. The systematic rapid assessment was conducted in the summer of 2010 at the Redfish Rocks and Otter Rock sites and produced information on:

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

The results of the rapid assessment were used to assign sampling methods and stratified random sampling designs for the more detailed assessment of biological response variables.

G. Detailed Assessments

We used stratified random sampling in our detailed assessments for biological response variables. At each site, sampling occurred within the marine reserve and the associated comparison areas. Random sampling efforts were stratified by substrate type (consolidated versus unconsolidated) and depth, often requiring different sampling tools. Data are not comparable across the two habitat types; rather they are additive and used together as part of our comprehensive assessment of habitat, species biometrics, and biodiversity for the site. Additional post-hoc stratifications were applied for physical and biogenic features such as topographic relief and kelp, as the analyses dictated.

The sampling tools and methods are described in detail in Chapter IV. All sampling methods were properly replicated and balanced, to the degree possible, within the marine reserve and comparison areas and across depth strata. Methodologies implemented were as similar as possible across the Redfish Rocks and Otter Rock sites, except when water depth dictated otherwise. Detailed assessments were conducted in 2010 and 2011 at both the Redfish Rocks and Otter Rock sites.

The metrics produced by the detailed assessments included:

- Oceanographic condition: temperature, salinity, chlorophyll, dissolved oxygen, and light
- Habitats: depth, relief, substrate type, and biogenic features
- Organisms: presence, distribution, abundance, size, age, and sexual maturity

H. References

Halpern BS, Gaines SD, Warner RR (2004) Confounding effects of the export of production and the displacement of fishing effort from marine reserves. Ecol Appl 14:1248-1256.

Ocean Policy Advisory Council (2008) Oregon marine reserve policy recommendations. Oregon Dept of Land Conservation and Development, Salem, Oregon :1-8.

Oregon Department of Fish and Wildlife (2012) Oregon marine reserves ecological monitoring plan. Marine Resources Program, Newport, Oregon 1-27.

Methods and Sampling

Monitoring design and sampling methods were previously laid out in our *Oregon Marine Reserves Ecological Monitoring Plan* (ODFW 2012). In this chapter, we provide further details on the methods employed and the sampling conducted as part of our baseline/time zero (T_0) data collection in 2010 and 2011 for the Redfish Rocks and Otter Rock sites.

Throughout this report, the term **site** refers to a **marine reserve** and its associated **comparison areas**. Below we present our monitoring activities in four general categories: oceanographic assessment, seafloor mapping, visual surveys, and extractive surveys.

A. Oceanographic Assessment

Metrics assessed: Temperature, salinity, fluorescence, and dissolved oxygen

Our two main objectives were to: 1) characterize the general oceanographic conditions of the sites, and 2) determine if a given reserve and its comparison areas experience different water masses. We used two primary tools to collect oceanographic data: moorings and benthic oceanographic platforms (BOPs). Each of these methods presented unique benefits and logistical challenges. High sea conditions combined with the shallow water depths of the reserves made maintaining moorings during the winter months challenging. Even during calmer summer months, moorings required frequent inspection and repairs. BOPs largely overcame this problem because they are bolted to rock on the seafloor, but do require SCUBA divers for servicing and instrument exchange. Through an adaptive process, we moved entirely to BOPs as our platform for oceanographic data collection.

In the sections that follow we have provided a description of the moorings and BOPs, along with sampling locations and duration.

A.1. Moorings

Our moorings were modeled after those developed and used by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) at Oregon State University. For the Redfish Rocks site, one mooring was placed within the reserve and one in the Humbug Comparison Area. Both moorings were anchored in 15m of water in 2010 and moved into 20m in 2011. For the Otter Rock site, one mooring was placed just outside the reserve in 15m of water (the reserve lies in water shallower than 15m) and another mooring was placed at the Cape Foulweather Comparison Area in 15m of water. All moorings were anchored in sand substrate.

The moorings within the marine reserves were equipped with a HOBO Water Temp Pro v2 temperature logger and a Seabird Electronics 16 plus Conductivity Temperature (CT) instrument mounted 1m above the substrate to measure conductivity, temperature, fluorescence (a proxy for chlorophyll), and dissolved oxygen every 15 minutes. A second HOBO temperature logger was placed 1m below the surface and recorded water temperature every two minutes. The comparison area moorings were equipped with similar temperature loggers 1m below the surface and 1m above the substrate. Although both temperature and salinity, which define density, are the true indicators of a water mass, we used temperature as a proxy to determine if the marine reserve and associated comparison area experienced different water masses. If water masses differed between the two we would likely see different temperature signatures.

A.1.a. Moorings: Sampling Conducted

Mooring locations for 2010 and 2011 at each site are shown in Figures 1 and 2 for Redfish Rocks and Otter Rock, respectively. The target mooring deployment period was May-October when the swell is smaller. Actual mooring deployment periods for each site and year are outlined in Table 1. Moorings were serviced and data were uploaded from instruments every 4-5 weeks. Servicing included cleaning the mooring hardware and CT of all fouling organisms and checking the shackles and lines for wear and integrity. In the field, the CT data were uploaded using Seabird SeatermV2 software and then processed with Seabird SBE data processing software. Plots were briefly examined to ascertain if sensors were drifting and for general interest. Batteries were changed and the CT's plumbing was cleaned with distilled water, bleach solution and Triton-X solution. Temperature logger data were uploaded, data and battery life checked, and reprogrammed with Onset HOBOware software.

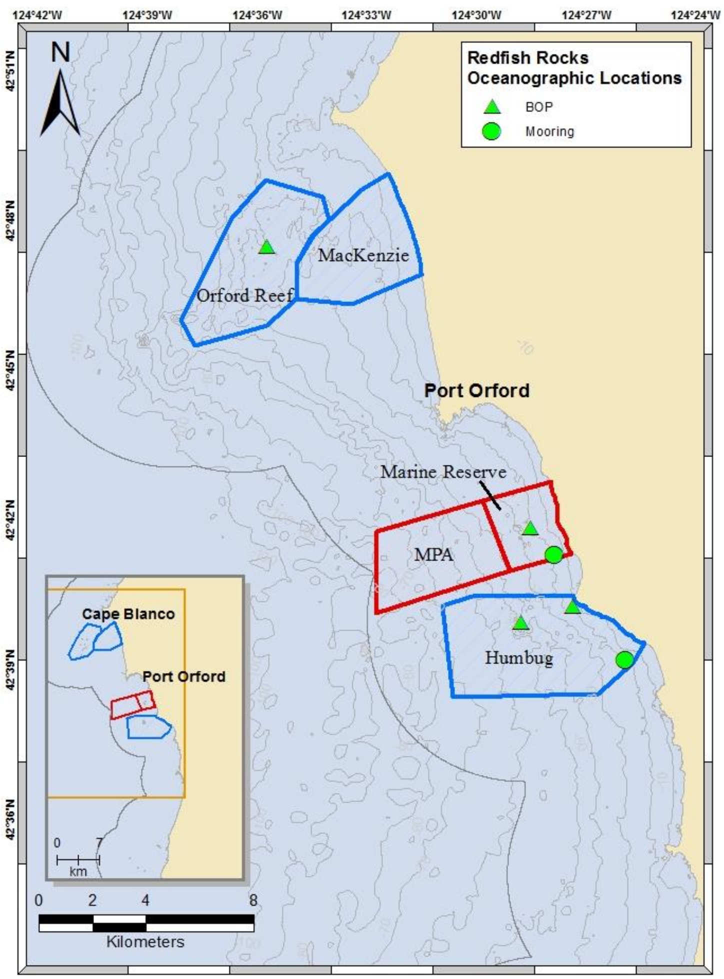


Figure 1. Location of oceanographic BOP plates and mooring locations in 2010 and 2011 for Redfish Rocks Marine Reserve and comparison areas. Comparison areas are delineated in blue; marine reserves and MPAs in red.

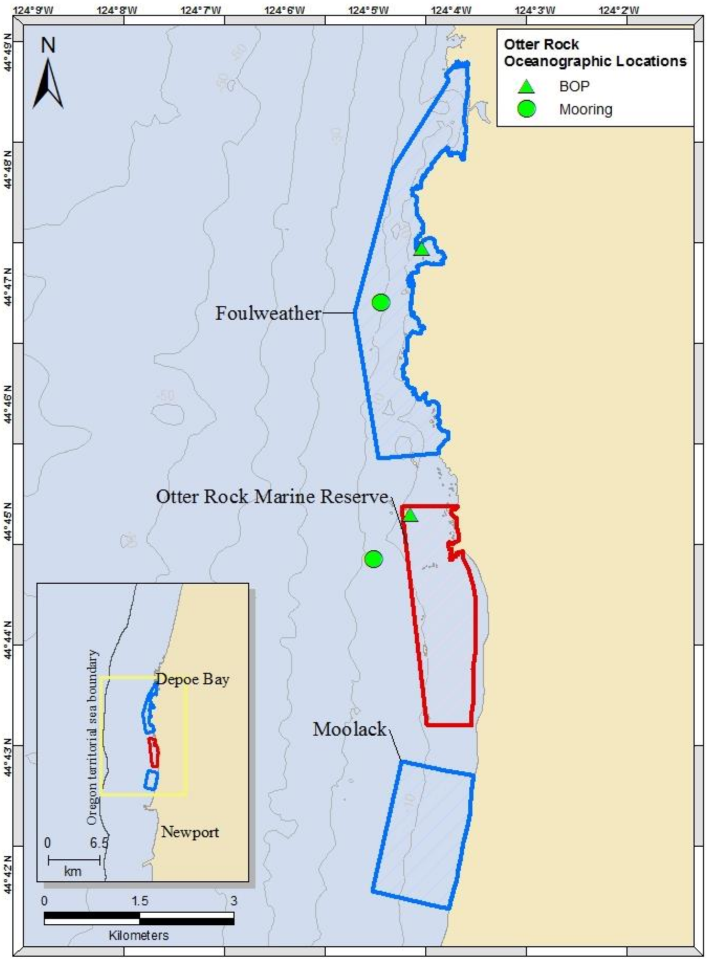


Figure 2. Location of oceanographic BOP plate and mooring locations in 2010 and 2011 for Otter Rock Marine Reserve and comparison areas. Comparison areas are delineated in blue; marine reserves and MPAs in red.

Table 1. Deployment periods moorings supporting temperature loggers and conductivity temperature instruments (CT) at four sampling locations.

	Deployment Period	
Location	Temperature	CT
Redfish Rocks MR		Aug-Sept 2010 May-Sept 2011
Humbug CA	Aug-Sept 2010 May-Sept 2011	
Otter Rock MR		Jul-Sept 2010 May-Sept 2011
Foulweather CA	Jul-Sept 2010 May-Sept 2011	

A.2. Benthic Oceanographic Platforms (BOPs)

Given the need to collect year-round oceanographic data, and the limitations of using moorings in Oregon’s high energy environment, we sought additional tools. We designed, constructed and implemented pilot Benthic Oceanographic Platforms (BOPs) in the winter and early spring of 2010 and 2011. A BOP plate, consisting of a stainless steel plate with mounting brackets for oceanographic instruments, was designed to be anchored to rock substrate on the seafloor (Figure 3). Sand inundation and swell exposure were considered when determining platform placement on the seafloor. Anchor bolts for the BOP plate were drilled into rock substrate by divers using a pneumatic rotary hammer-drill and the plate was fitted with oceanographic sensors.

Figure 3. BOP plate with oceanographic instrument mounts (right) and anchor bolts.

A.2.a. BOPs: Sampling Conducted

A pilot plate was installed in the Redfish Rocks Marine Reserve on December 2010 in 20 meters of water. The plate was fitted with a HOBO temperature sensor programmed to collect data every 15 minutes. This plate was assessed in June of 2011 for data integrity and physical damage. The platform was cleaned of all fouling organisms, data were uploaded, and sensors were re-programmed. Data and platform were completely intact after six months of deployment. A pilot plate with the same instruments was installed in the Otter Rock Marine Reserve in April 2011 in 5 meters of water. This plate was assessed in August 2011. The platform was cleaned of all fouling organisms, data were uploaded, and sensors were re-programmed.

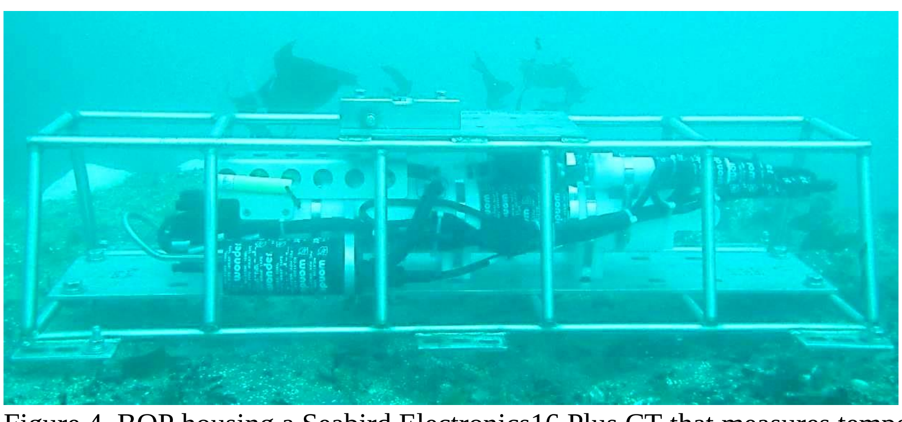


Figure 4. BOP housing a Seabird Electronics16 Plus CT that measures temperature, conductivity, dissolved oxygen, and fluorescence.

Following positive results from the pilot study BOP plates, we fabricated a larger BOP that could safely house a CT (Figure 4). This larger BOP, which houses a Seabird Electronics16 Plus CT (measuring temperature, conductivity, dissolved oxygen, fluorescence), was deployed in Sept 2011 in the Redfish

Rocks Marine Reserve in 20 meters water depth (Table 2). The smaller, pilot BOP plate was taken out of Redfish Rocks Marine Reserve and placed in the Humbug Comparison Area with a temperature logger in September 2011. The Humbug BOP plate with temperature logger was replaced with a CT cage BOP plate in May 2012. We also installed a BOP plate with a temperature sensor at Island Rock in Humbug Comparison Area (Nov 2011). Finally, we installed a plate with a temperature sensor at Orford Reef Comparison Area in Nov 2011.

A CT-cage was not installed at the Otter Rock site given the shallow water of the reserve and assumed high levels of sand in the water as well as sand movement, making burial a risk. BOP plates replaced the mooring configuration for 2012. BOP locations at each site are shown in Figures 1 and 2. Installation dates are shown in Table 2. BOP plates are serviced every six months or less and CT-cages are serviced every 6-12 weeks.

Table 2. Installation dates for Benthic Oceanographic Platform (BOP) supporting temperature loggers, conductivity temperature (CT) instruments, and temperature/salinity loggers at six sampling locations.

	Installation Date		
Location	Temperature	CT	Temp/conductivity
Redfish Rocks MR	Dec 2010	Sep 2011	
Humbug CA	Sep 2011	May 2012	
Humbug - Island Rock CA	Nov 2011		
Orford Reef CA	Nov 2011		
Otter Rock MR	Apr 2011		May 2012
Cape Foulweather CA			May 2012

B. Seafloor Mapping

Metrics assessed: Depth, relief, substrate type, and habitat classification.

Our two main objectives were to: 1) determine what benthic habitat types exist within the sites, and 2) determine if a given reserve and its comparison areas contain different habitats. We used several seafloor mapping tools and data sources that provided us with information on depth and substrate type. These data were used to classify habitats within the Redfish Rocks and Otter Rock sites for stratified random sampling.

B.1. High-Resolution Multibeam Sonar

Since 1995, various efforts have been underway to map the seafloor of Oregon's Territorial Sea using high-resolution multibeam sonar. Data from these efforts have in turn been used to construct habitat maps (Fox et al. 1998; 1999; 2000; Romsos et al. 2007; Amolo 2010; Goldfinger 2010). To date, most of the multibeam survey work has been conducted in water deeper than 10 meters due to logistical constraints.

B.2. Surficial Geological Habitat Maps

For areas not mapped with high-resolution multibeam sonar (e.g. areas shallower than 10m or areas not surveyed to date with high-resolution multibeam sonar), we used Surficial Geologic Habitat (SGH) maps produced for the Oregon and Washington continental margins (Romsos et al. 2007) and further refined for Oregon's Territorial Sea (Agapito 2008).

B.3. Visual Survey Data

During Systematic Rapid Assessments, we collected video imagery data using the video sled and video lander survey tools within the Redfish Rocks and Otter Rock sites. These data were used to ground-truth substrate type for locations previously surveyed using multibeam sonar, and identify substrate type in un-surveyed areas. More information on the visual survey methods are found below in section C.

All available data sources coupled with local knowledge were compiled within ArcGIS to stratify sampling by substrate type (consolidated or unconsolidated) and depth.

C. Visual Surveys

Metrics assessed: Algal, invertebrate and fish community structure and distribution
Substrate type and relief

Our main objectives were to: 1) determine what benthic habitat types exist within the sites, 2) determine the algal, invertebrate, and fish community composition within the sites, 3) determine the biodiversity of the sites, and 4) determine if a given reserve and its comparison areas differ in these metrics. We used a suite of visual survey tools to collect data for biological communities and habitat type. Substrate type and depth identified from seafloor mapping dictated which type of visual survey and equipment were used to collect these data. Video lander, remotely operated vehicle (ROV), and SCUBA divers were used to conduct visual surveys in areas of consolidated hard bottom. Video sled, video lander, and ROV were used to conduct visual surveys in unconsolidated sediment areas.

We acknowledge there are limitations and inherent sampling biases associated with different visual survey tools in detecting organisms. Water clarity, currents, and sea state 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 been shown to be adequate for surveying cryptic and smaller organisms well. In light of these different sampling techniques and their associated biases, data were not readily integrated across sampling methods. Rather, analysis results for each method were compared among the various sampling techniques to determine consistency or inconsistency of significant patterns.

In the sections that follow we have provided a description of each of the visual surveys conducted at the Redfish Rocks and Otter Rock sites in 2010 and 2011 along with sampling locations and dates, and how the data were analyzed.

C.1. 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; Kaimmer 1999; Cappo et al. 2003). 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.

We selected using a video lander for several reasons. First, it can be dropped onto nearly any substrate type and relief and be successfully retrieved. It can be used in nearly any depth, up against emergent rock, and in high-energy areas such as the outer surf zone. Also, it is relatively inexpensive and quite dependable, allowing us to move rapidly over an area obtaining point-source information on anything in view.

Our video lander consisted of an aluminum frame, with breakaway mild steel sections in case of snagging (Figure 5). The video system consisted of a Deep Sea Power and Light (DSPL) 2060 low-light color camera, paired with an LED light in a DSPL Rite-light housing. A DSPL parallel laser with 10 cm spacing was used to estimate scale in the image. A cable harness custom-made by Teledyne Impulse, Inc. connected the camera, light, and lasers to an aluminum pressure tube containing a micro-controller card, a set of batteries powering the system and a Sony camcorder utilizing mini-DV tape. A pressure switch, externally located on the pressure tube, provided the means to manually activate the system and start recording. An appropriate length of floating buoy-line and three crab floats were also attached to the lander.

Figure 5. Video lander suspended by buoy line. At top is the breakaway link; at bottom is the breakaway base. Camera, lasers, light and pressure tube are mounted within the aluminum frame.

Once the boat was maneuvered over the sampling station, the camera was turned on via the pressure switch and “drop point” data were taken: date, target grid point, actual latitude and longitude, tape number, drop number, as well as any other information pertinent to later analysis of the video. The lander was then launched overboard so that it hit the water flat on its base, and the buoy line was rapidly fed by hand so that the line remained slack and the lander would free-fall. A stopwatch recorded the time from when the lander hit the water until the lander came out of the water, to estimate on-bottom time and keep track of video tape used. The buoy line and buoys were released, leaving the lander to sit on the bottom undisturbed by any influence from the boat. Once the appropriate on-bottom time had elapsed, the lander was retrieved and hauled aboard using a crab block. All video “drops” occurred during daylight hours, being confined to one hour after sunrise until one hour before sunset. This avoided confounding our data with imagery collected during crepuscular periods and the possible change of animal behavior and visibility.

Vessel and drop site position data were collected using a Garmin 546 GPS chart-plotter connected to a Panasonic Tough Book laptop running Fugawi Marine ENC navigational software. An external GPS antenna was mounted high on the vessel as close over the lander launch point as possible. The Fugawi ENC software allowed us to import GIS shapefiles showing study area boundaries or grids of points to target for sampling. It also allowed accurate collection of the locations/times of actual lander drops with a keystroke. The positional accuracy of the GPS was generally five meters or less. It should be noted that no attempt was made to account for lander horizontal drift as it descended.

We targeted an on bottom-time of four minutes, giving us sufficient time to examine and classify the benthic substrate type, and observe any organisms present. Organism relative abundance was assessed as maximum N observed within a single frame of the video to minimize the risk of repeat sampling the same mobile individuals. Four minutes bottom time (as recommended by Hannah and Blume 2012) allowed enough time for stirred up sediment to clear and to encounter the maximum number of fish (maximum N) on a given drop.

C.1.a. Video Lander: Sampling Conducted

The lander was used over the course of two field seasons: from August to October in 2010, and May to October in 2011. For Systematic Rapid Assessments, the video lander was deployed on a regular grid system at each site. For the Otter Rock site, a 200 x 200 meter spaced grid was used; for the Redfish Rock site a 350 x 350 meter spaced grid was used (Figure 6 and 7). These experimental units were chosen to balance sampling effort based on differences between reserve sizes and to assure independence between units. For Detailed Assessments, the video lander was deployed targeting rocky substrate types using a stratified random design. Random drop points were assigned in areas with rocky substrate within depth bins of 0-7 m, 7-14 m, 14-21 m, and 21+ m. Drop points were separated by a minimum distance of 100 meters to assure independence. The lander was not used in unconsolidated substrate for Detailed Assessments.

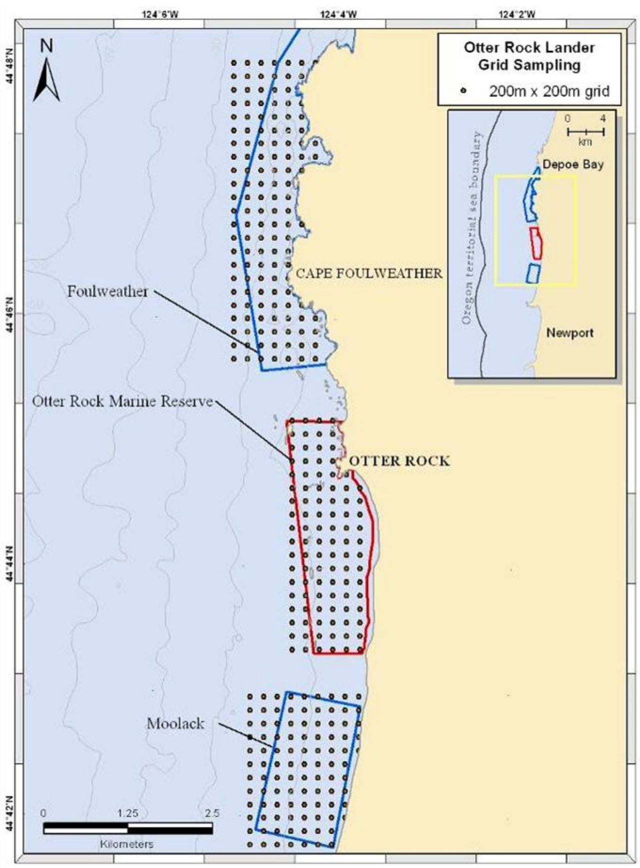


Figure 6. Otter Rock site 200 x 200 meter sampling grids for initial lander surveys.

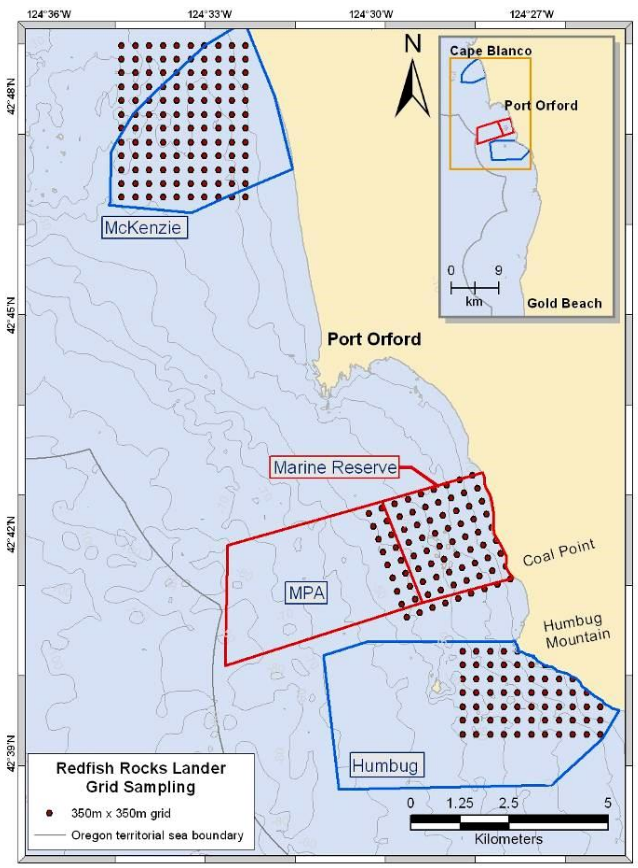


Figure 7. Redfish Rocks site 350 x 350 meter sampling grids for initial lander surveys.

C.1.b. Video Lander: Data Extraction

We developed a standard method to examine the video from each lander drop. Video was captured using Adobe Premiere software and examined for viewing properties (e.g. visibility, view obstruction), substrate type, topographic relief, and biotic community. Primary substrate was defined as the substrate type that comprised 50% or more of the field of view. Secondary substrate was defined as the substrate that comprised 20-50% of the remaining field of view. The list of substrate classifications and interpretations can be found in the video lander survey results section. Fish were identified to species level and the maximum number seen in a single video frame. Maximum fish counts overcame the problem of fish entering and leaving the video (Hannah and Blume 2012). Select sessile macroinvertebrates were identified to species when possible and enumerated in an identical manner. Biogenic habitat (including macroalgae, sponges, and gorgonians) were classified into functional forms based on habitat provided and indexed according to percentage of habitat occupied.

A Microsoft Access database allowed the data from the lander video to be analyzed by GPS location. The waypoints collected at sea were linked between the GIS files and the database, allowing accurate mapping of the data taken from the video on each drop.

For quality assurance of video observations, we randomly selected 20% of the drops for review by a second observer. Prior to QC review, an 85% agreement rate between QC and primary reviewers was set as the desired level of consistency. The results of QC review were to meet our 85% agreement rate. All database entries were error-checked against the original paper copies for entry error.

C.2. 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). Both the Otter Rock and Redfish Rocks sites contain large areas of unconsolidated sediment. For these areas we chose to conduct video sled surveys.

In its initial 2010 configuration, the sled frame was towed in contact with the bottom, with the lower frame rails acting as runners. A single video system was used with an inexpensive battery-powered Aqua-Vu unit which sent a black-and-white image via a 91-meter umbilical to the boat, where we recorded it on mini-DV videotape. Time, location, and depth data were collected every two minutes or as frequently as possible. The video was later analyzed and data on time, depth, location, habitat type, and organisms observed were entered into an Excel spreadsheet.

In 2011, a new sled frame was constructed, with the goal of having the sled frame float at a controllable distance off-bottom to adapt to changing relief. “Dropper chains” were used to pull the sled down until approximately half the chain was supported on-bottom, allowing the sled frame to settle into a neutrally buoyant state a short, controllable distance off-bottom. The height of the frame above bottom could be adjusted by varying the length of line connecting the frame to the top link of dropper chains. In the event of a firm hang-up, the line could break, sacrificing the chain but freeing the sled. The towline incorporated a depressor weight 18.3 m (10 fathoms) in front of the sled, weighing approximately 34 kg (75 lbs). The weight was lowered until it was approximately four to five meters off the bottom, which pulled the towline down at a steep angle from the boat, and then extended back from the weight to the sled at a shallow angle (Figure 8). This allowed for a straight-ahead pull on the sled. It also isolated the sled from the up-down surge of swell lifting the boat, as well as dampened changes in speed if the boat changed in and out of gear to reduce speed. If the sled frame got hung up on a rock, the weighted line had a great deal of “spring” in it, allowing the sled time to lift over the obstacle as the boat proceeded forward.

In practice, we were able to successfully tow the new sled system over long tracts of hard bottom, including instances of high-relief benthic structure.

The video systems were revised at the start of the 2011 season. We incorporated the autonomous underwater video system or "tube" system previously used on the lander. This system used an aluminum pressure tube to house a Sony mini-DV camcorder and batteries, and cables ran out to a Deep Sea Power & Light (DSPL) 2060 low-light color camera, DSPL Rite-lite light with 5-watt LED flood, and DSPL parallel red lasers with 10-cm spacing to estimate scale. The autonomous system allowed for high quality standard-definition color video to be collected for later analysis, and used a Horita PG-2100 time-code generator synced to an onboard GPS unit collecting location data, so that the video could be accurately geo-referenced (Tissot 2008). The system also included a wired underwater Sea-Viewer camera with 183 m (600 ft) umbilical cable connected to a 12-volt battery and Sony GV-HD700 video recording deck on the boat. This camera delivered a live video image to the boat that showed the sled frame attitude and status as well as potential obstacles in the tow path of the sled.

As with the lander, we used the Garmin 546 chartplotter, ToughBook computer, and Fugawi software to collect track data for the sled. We defined a "track" as a record, taken once per second, of Greenwich mean time and the latitude/longitude and UTM location along the length of a transect. The "tube" video system was powered on and "start-point" data taken: date, transect number, latitude and longitude, tape number, tow number, as well as any other information pertinent to later analysis of the video. A track log was started on the laptop using Fugawi software. The sled was lowered over the side and towline paid out as the boat maneuvered back across the transect starting point, and the tow begun. Depth and the amount of towline extended were recorded to calculate layback, or the distance between boat and sled.

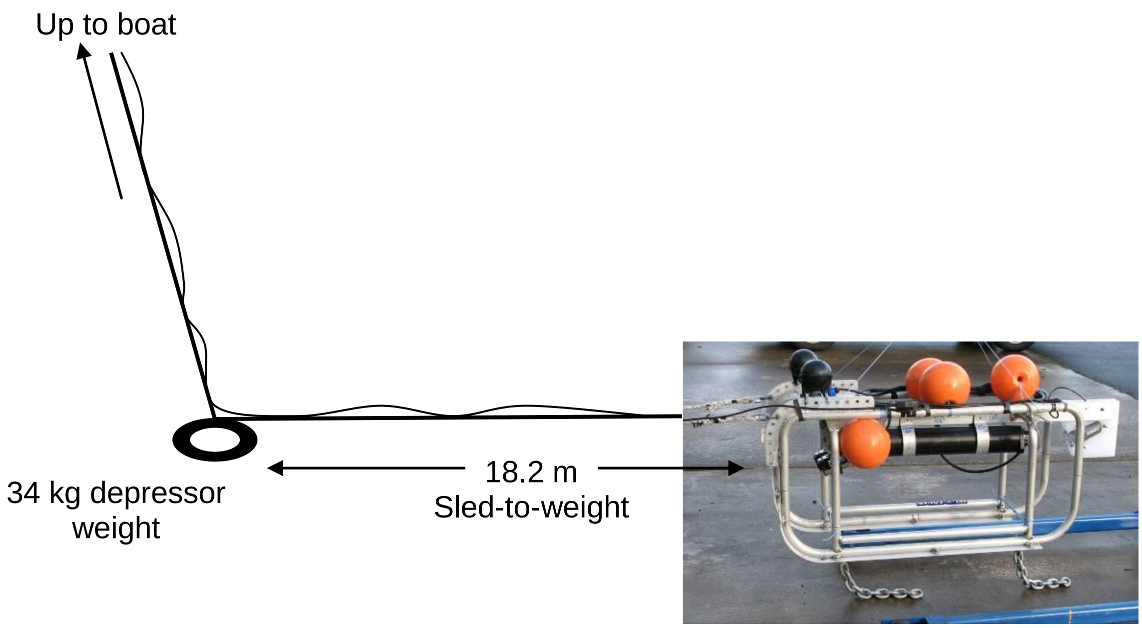


Figure 8. Image of the 2011 revised sled design including a diagram of the towline setup.

C.2.a. Video Sled: Sampling Conducted

For Detailed Assessments, the video sled was deployed in a stratified random design within the Otter Rock and Redfish Rocks sites. Random points were assigned within unconsolidated substrates binned by depth (0-7, 7-14, 14-21, 21+ meters). The random points within each depth stratum were used as starting points for sled tows. Once the boat was on-station, we would generally drift down-current while making final preparations and then turn into the current to begin the tow. Optimal towing speed was 0.5 – 0.8 meters per second (1-1.5 knots). We aimed for a 20-30 minute tow time, yielding a tow length of 700-1,000 meters. The topside video monitor was continually observed for sled safety. Once the appropriate on-bottom time had elapsed, or if inappropriate habitat was encountered, the sled was retrieved and hauled aboard using a crab block.

Survey months and number of transects conducted in 2010 and 2011 at the Otter Rock site and the Redfish Rocks site are provided in Table 3. In 2010, our video sled survey transects totaled 3,551 meters at the Otter Rock site and 8,049 meters at the Redfish Rocks site (Figure 9, left). In 2011 our video sled survey transects totaled 5,057 meters at the Otter Rock site and 5,553 meters at the Redfish Rocks site (Figure 9, right).

Table 3. Video sled surveys conducted at the Otter Rock and Redfish Rocks sites.

Site	2010 Survey Dates	No. of Transects	2011 Survey Dates	No. of Transects
Otter Rock Marine Reserve	Aug	3	Aug, Oct.	4
Moolack Comparison Area	Sept., Oct.	5	Aug, Oct.	3
Total		**8**		**7**
Redfish Rocks Marine Reserve	Aug., Sept	4	Oct.	4
Humbug Comparison Area	Aug., Sept	6	May, Oct.	4
McKenzie Comparison Area	Aug.	2		0
Redfish Rocks MPA	Aug., Sept. , Oct.	4	May	1
Total		**16**		**9**

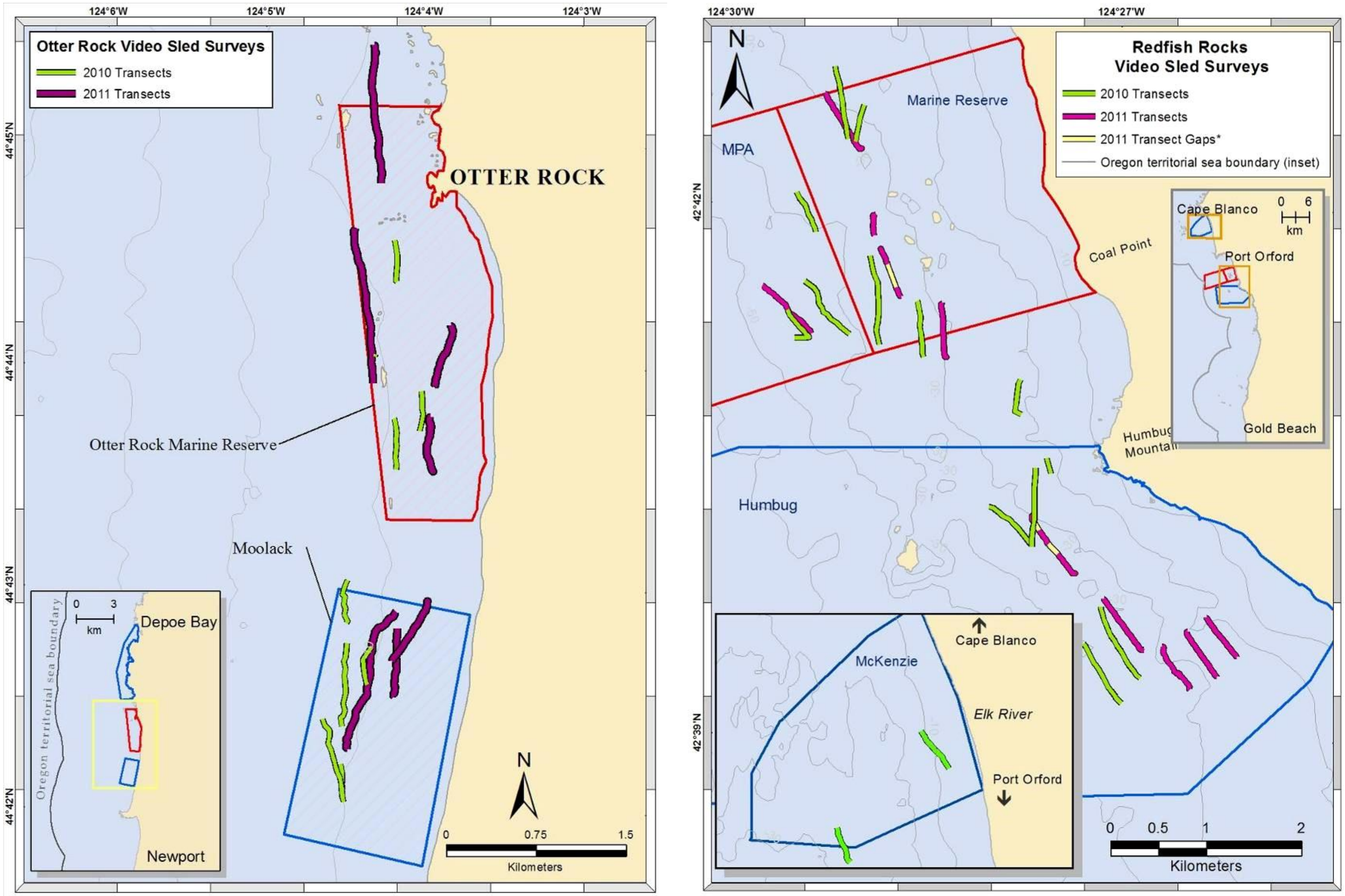


Figure 9. Video sled transects conducted in 2010-2011 for the Otter Rock site (left) and Redfish Rocks site (right).

C.2.b. Video Sled: Data Extraction

We developed a standard method to examine the video from each sled transect. Video was captured using Adobe Premiere software and examined for sled status, substrate type, and biotic community. We overlaid a mask on the video screen, superimposing two horizontal lines: one corresponding to 80% of the vertical distance from the bottom of the screen and another at 50%, roughly the level where the lasers struck the substrate. Primary substrate was defined as comprising >50% of the video screen from the 50% line to the bottom of the screen; secondary substrate was defined as comprising 20-50% of the same area. Fish in the water column were counted when any part of the fish passed below the 80% line, constraining the survey to a fixed width and accounting for the practical limits of underwater visibility (Amend et al. 2001; Donnellan et al. 2008). Invertebrates, macroalgae, and other bottom-dwellers were counted as they passed below the 50% line. Substrate was classified as it passed through the bottom of the screen. During analysis of the video, the timecode (Greenwich Mean Time) produced by the timecode generator was displayed on-screen. Each entry in the database included the timecode for the frame containing the event or object of note.

A Microsoft Access database allowed the data from the sled video to be analyzed by GPS location. The track files from the GPS and Fugawi software with time and position information were linked to the time coded organismal data, allowing for spatial positioning of the organismal and habitat data collected during the sled transects.

The QC procedure for sled video review was similar to that conducted for the video lander. Twenty percent of the 2011 video sled transects were randomly selected and reanalyzed by a second observer. Fish and invertebrates were summed per transect and across all transects within a site and compared between reviewers to verify consistency in species identifications. All database entries were error-checked against the original paper copies for entry error and corrected.

As the sled physical configuration, database entry process, and organism scoring protocol changed between 2010 and 2011, pre-treatment differed between these two sampling years.

In 2010, the sled was towed touching the benthos, therefore the transect area (m^2) was calculated as a fixed width based on the distance between the rails of the sled, visible within the field of view, when sled was on bottom (0.88 m) x transect length (provided by the 2010 Access database based on handheld GPS points taken approximately every two minutes). It should be noted that these lengths may not represent the true length of the transect as distances were calculated as if the boat traveled in a straight line between points taken every two minutes. Additionally, touchdown time on the bottom was usually well noted, but liftoff from the bottom at the end of the transect was not. Occasionally the tow was “ended” prior to the sled leaving the bottom, in which case we may have underestimated total transect length. Organisms were scored in 10 second segments over the course of the transect. These segments were summed to generate a total abundance per organism per transect. Organisms were assumed to be observed “on bottom” as no mention of ascent/descent was made in the database. Abundances were then divided by the transect area to generate relative organism density (indiv./m^2) per transect. Each transect serves as a single replicate, irrespective of total area surveyed. Mean depth (m) of each transect was calculated from the depth data collected periodically along the track line of the transect. If no depth data was recorded from field collection, depth data was extracted from a bathymetric raster layer in ArcGIS based on the spatial position of the transect.

In 2011, the sled was towed slightly above the benthos. Transect length was calculated using the Fugawi (navigational software) tracks which recorded a coordinate every 2-3 seconds. These tracks represent the maximum transect length (including time to descend and ascend the sled from the ship). In order to restrict the transect length to "on bottom" time only, the tracks were segmented to the first occurrence of habitat scoring when we assume bottom contact was made. Likewise, "gaps" exist where the sled loses view of the benthos rendering that section 'un-scorable' for habitat and organisms. Both the gaps and pre-transect and post-transect track lines (during ascent and descent) were excluded from calculating the adjusted transect length (m). As the camera was not consistently mounted at a fixed angle, the transect area (m^2) varied from transect to transect (this camera system was used on other platforms, and even a difference of 1-2 degrees on reassembly made a measurable difference in camera view). Transect width (m) was estimated from repeated measures of the width of field of view using the two fixed parallel 10-cm width lasers as a reference point which appear near the middle of the reviewing screen. The width of the laser reflection points were measured with calipers on the monitor with the image at a fixed size and resolution. As the sled moves closer to the benthos, the laser width appears to widen. The width of view can be calculated as a proportion of the apparent laser width to the overall screen width. The number of width measurements varied among transects; additional replicate measurements were taken until the standard error of the mean width was less than .1m or the standard error stopped appreciably changing. Factors increasing the variability of the laser width measurements are large irregular sand waves and occasional rock encountered, with resultant higher rugosity. The estimated transect area (m^2) was then calculated from the adjusted transect length x the estimated width.

In 2011, organisms were scored continuously over the course of the transect and summed to generate a total abundance per organism per transect. Organisms were queried to exclude those observed on descent or ascent. Observations of "Unknown Species" were observed but excluded from the analysis (resulting in 144 individual organisms excluded from the analysis). Likewise, one transect completed in the Redfish Rocks site did not fall within the boundaries of the marine reserve, MPA, or comparison areas and hence was excluded from analysis. Organism abundances were divided by the transect area to generate relative organism density (indiv./m^2) per transect. Each transect serves as a single replicate, irrespective of total area surveyed. Mean depth (m) per transect was calculated from the depth data collected from the vessel's sounder approximately every two minutes and recorded in Access.

C.3. SCUBA

Baseline surveys of shallow (< 20m depth) rocky reef and kelp forest habitats and their associated biological communities were conducted in the Redfish Rocks and Otter Rock pilot marine reserves and associated comparison sites during the months of August in 2010 and 2011. The purpose of these baseline surveys were three-fold: (1) to characterize the habitats and associated biological communities within the reserves and comparison sites at the time of reserve establishment, (2) to inform the design of longer-term monitoring efforts to study reserve effects, and (3) to allow comparison of baseline and subsequent surveys to detect long-term trends in response variables and evaluate the effects of reserve establishment. Surveys were conducted by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) subtidal monitoring group under a contract with the Oregon Department of Fish and Wildlife.

Benthic surveys were conducted using protocols established for the PISCO kelp forest monitoring program, a large-scale, long-term monitoring study designed to describe the geographic patterns and dynamics of kelp forest ecosystems. These monitoring protocols have been adapted for the purpose of monitoring the effects of newly created networks of marine protected areas (MPAs) and have been successfully applied not only in documenting baseline conditions at the time of

MPA implementation, but also in detecting the first signs of change occurring within the initial five years of establishment. These surveys provide data on habitat features, the abundance and size structure of populations of key fish species, macroalgae, and invertebrates, and provide insight into the structure and function of the targeted populations and communities.

PISCO fish sampling protocols are designed to quantify the size structure and density of the fish populations and the species composition and structure (i.e. relative abundance) of the fish assemblages. Sampling is conducted using replicate belt transects to identify, count, and size all conspicuous fishes within three portions of the water column (bottom, midwater, and canopy). Sampling protocols for algae and invertebrates are designed to quantify the size structure and density of macroalgae and invertebrate populations and the species composition and structure of their assemblages. Belt-transects and uniform point count are used to complete this sampling. Detailed sampling methods can be found at the PISCO website (PISCO 2009).

C.3.a. SCUBA: Sampling Conducted

The overall baseline survey design consists of multiple survey sites on shallow (< 20m depth) rocky reef habitat within each pilot reserve area and corresponding comparison sites outside of the reserve. The distribution of survey sites within each reserve reflects efforts to identify and characterize the variety of habitats included within each reserve. In both Otter Rock and Redfish Rocks reserves, two key habitat types were identified and included among the survey sites: emergent rocks and forests of the bull kelp, *Nereocystis luetkeana*. Because the abundance of species vary with depth, surveys included a range of depths (5m – 20m) within each habitat to ensure sampling of the diversity of species associated with each habitat type. Thus, each study site is typically divided into four "zones" (by depth - 20m, 15m, 10m, 5m - or from offshore to inshore at sites with little depth variation) to assure that samples are distributed across any spatial gradient of species composition. For all surveys, sampling occurred at fixed locations identified with GPS coordinates.

Comparison sites outside of each reserve were chosen based on habitat features similar to those sampled within each reserve. The purpose of this design is to increase the ability to track and compare the population and community trajectories of similar species inside and outside of the reserves over time. Because of the uniqueness of habitat features in each reserve, comparison sites were not always direct matches with sites sampled within reserves. For example, Redfish Rocks Marine Reserve contains a multitude of offshore emergent rocks, which are rare outside of the reserve. The one survey site of similar habitat, Island Rock, was sampled only in the second year of the baseline surveys. Similarly, rocky reef habitat within Otter Rock Marine Reserve is characterized by very shallow emergent rock, which is essentially nonexistent outside that reserve. However, habitats at both reserves, including the emergent rocks of Otter Rock reserve, are characterized by high relief rocky reef with forests of bull kelp protected in the lee of reef structure. Therefore, comparison sites outside Otter Rock and Redfish Rocks reserves were chosen to include high relief rocky reef with stands of bull kelp in the lee of reef structure, or inshore stands of bull kelp on low relief rocky reef.

In 2010, survey sites were established within the Redfish Rocks Marine Reserve and comparison areas at Humbug to the south and McKenzie Reef to the north. The survey sites within and around Redfish Rocks Marine Reserve were resampled in 2011. At the two comparison areas for Redfish Rocks Marine Reserve, Humbug Comparison Area to the south and McKenzie Reef Comparison Area to the north, sampling sites were added in the second year (2011) to enhance similarities between sites inside the reserve. At Humbug, the emergent rock, Island Rock, was added and at McKenzie Reef, we pinpointed a high relief structure, both of which increased the representation of habitat more similar to the emergent rocks within Redfish Rocks Marine Reserve. Interannual differences in habitat features and algae at these comparison sites reflect these changes in sampling location.

In 2010, initial surveys were conducted within Otter Rock Marine Reserve, but poor weather conditions allowed sampling at only a single site, Otter Rock. In 2011, the Otter Rock site was resampled and additional sites were added within the reserve area (Gull Rock) and at outside comparison areas (Figure 12).

At Redfish Rocks Marine Reserve and at McKenzie Reef and Humbug Comparison Areas (Figure 11), a total of 67 fish and 24 benthic survey transects were completed in August 2010, and 63 fish and 24 benthic transects were completed in August 2011 (Table 4). At Otter Rock Marine Reserve, a total of 11 fish and 4 benthic survey transects were completed in August 2010 (Figure 12). No comparison sites for Otter Rock Marine Reserve were sampled in 2010 due to poor weather conditions. In August of 2011, a total of 61 fish and 34 benthic survey transects were completed (Table 4) at Otter Rock Marine Reserve and its comparison areas at Whale Cove, Spouting Horn, and Otter Crest (Figure 12). These transects were essentially distributed evenly between depth zones except for at McKenzie Reef where there were no shallow areas to survey, and at Otter Rock Marine Reserve where all transects were done in the shallow zone as there were no deep areas.

Table 4. Total number of transects sampled by survey type and depth zone at all locations in 2010 and 2011.

FISH			20 m	15 m	10 m	5 m	Total
	2010	**Redfish Rocks Marine Reserve**	8	8	20	8	44
		Humbug Comparison Area	4	4	4	2	14
		McKenzie Reef Comparison Area	1	10			11
		Otter Rock Reserve			1	11	12
	2011	**Redfish Rocks Marine Reserve**		14	22		36
		Humbug Comparison Area		5	11	2	18
		McKenzie Reef Comparison Area	2	9	1		12
		Otter Rock Marine Reserve		2	7	19	28
		Otter Rock Comparison Areas			4	30	34
BENTHIC							
	2010	**Redfish Rocks Marine Reserve**	4	5	3	3	15
		Humbug Comparison Area	1	2		2	5
		McKenzie Reef Comparison Area	2	2			4
		Otter Rock Marine Reserve				4	4
	2011	**Redfish Rocks Marine Reserve**		6	10		16
		Humbug Comparison Area		2	6	2	10
		McKenzie Reef Comparison Area		4			4
		Otter Rock Marine Reserve			4	10	14
		Otter Rock Comparison Areas			1	19	20

C.3.b. SCUBA: Data analysis

Data analysis for the SCUBA surveys was completed by Dr. Kristen Milligan, Dr. Mark Carr, Dan Malone, and Emily Saarman of PISCO. A complete report is included in Appendix A summarizing the survey methods, providing detailed results, and discussing conclusions for both Otter Rock and Redfish Rocks Marine Reserve.

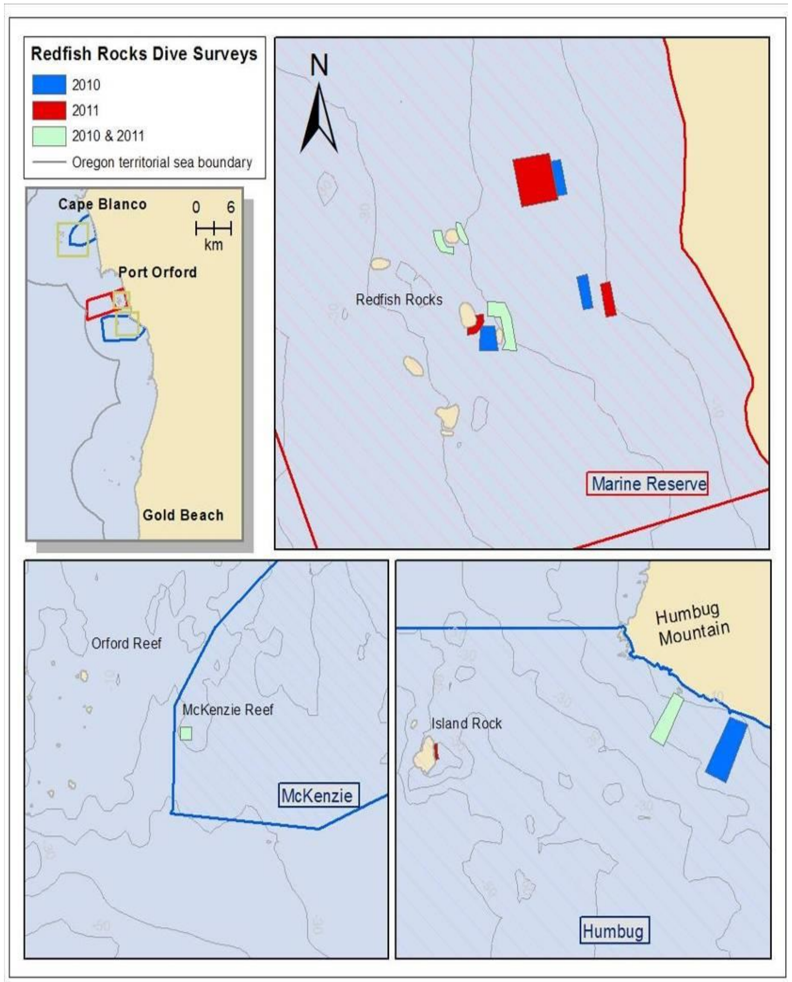


Figure 11. Dive survey locations within the Redfish Rocks Marine Reserve and comparison areas at McKenzie Reef and Humbug for 2010, 2011, and both years. These sites represent the area within which a given number of transects were distributed, and are not necessarily indicative of the total area sampled.

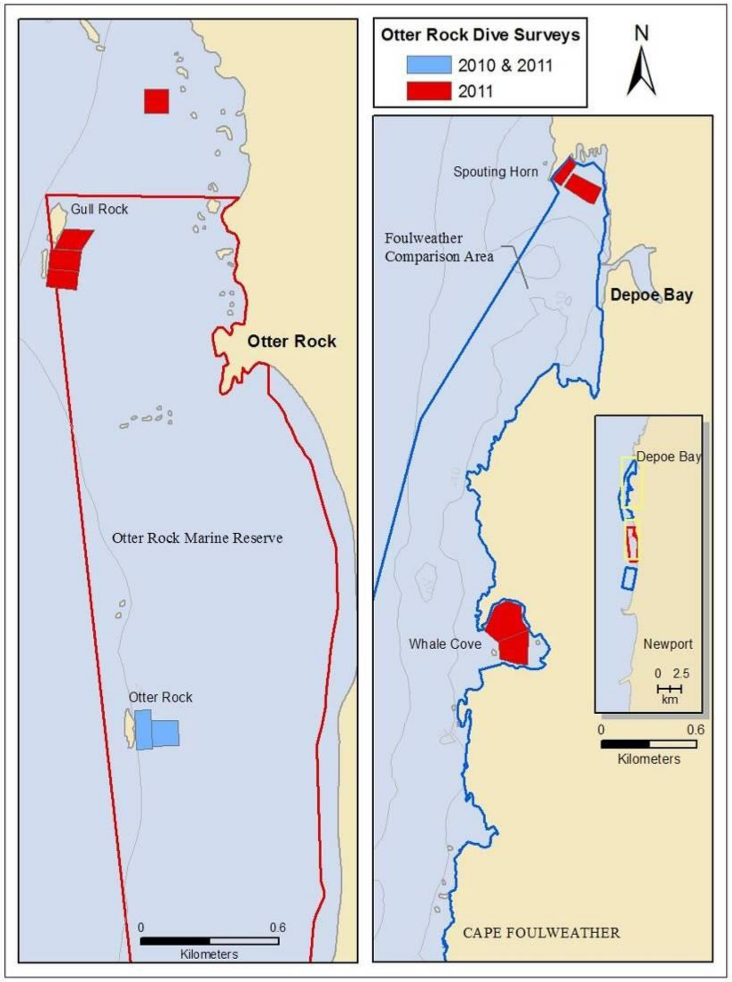


Figure 12. Dive survey locations within the Otter Rock Marine Reserve and comparison area at Cape Foulweather for 2010, 2011, and both years. These sites represent the area within which a given number of transects were distributed, and are not necessarily indicative of the total area sampled.

C.4. Remotely Operated Vehicle (ROV)

ODFW's Phantom HD2+2 ROV (Deep Ocean Engineering) was used to conduct habitat and biota visual surveys targeting rocky reefs in depths greater than 20 meters using a simple random sampling design. The ROV was equipped with 4 horizontal thrusters, 2 lateral thrusters, and one vertical thruster. A high definition camera (Canon Vixia HFS-100) in a pressure tube (The Sexton Company, LLC) was mounted on the front of the ROV at an angle of 30° below horizontal, and a pair of parallel red lasers (Deep Ocean Engineering) spaced 10 cm apart were mounted on the housing to provide a scale reference. Altitude above the seafloor was tracked visually and with the aid of two ranging altimeters, one mounted on the forward-looking camera housing and one mounted vertically at the rear of the ROV. Two Nuytco 200-watt HMI lights provided illumination for the forward-looking camera. ROV heading and positioning was controlled using a Trackpoint III navigation system (ORE Offshore) and high-precision heading sensor GPS (Hemisphere VS101), tracking and recording software (TracMan and Hypack), and a motion reference unit (ORE Offshore), all of which cumulatively contributed to relatively precise geographic positioning (± ~ 4 m). The ROV was generally "flown" at a speed of 0.5–1 knot, depending upon the speed of the survey vessel's drift. Continuous video footage was recorded for 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 was recorded with an associated time and geographic position, along with accessory telemetry data (e.g., height of ROV above the bottom, camera tilt, pitch, and roll).

C.4.a. ROV: Sampling Conducted

For Detailed Assessments, we conducted strip transects that were 500 meters in length with variable transect widths 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. ROV sampling only occurred at the Redfish Rocks site as the Otter Rock site is too shallow to survey using the ROV.

Potential sampling transects were delineated using ArcGIS. A series of adjacent, parallel 500 meter-wide rectangular polygons planning swaths were digitized and overlaid on each site. Within each swath, potential transects were randomly placed (Figure 13). The potential transects were randomly selected based on total number of transects that we wanted to retain within each area. Potential transects were eliminated from further consideration if they:

1) Did not intersect any known rocky substrate
2) Were mostly outside the depth zone of interest
3) Were completely inside the perimeter of kelp forests (based on historical kelp canopy photos)
4) Were completely inside the perimeter of ESA-designated Critical Habitat for Steller Sea Lions

Furthermore, in order to maximize survey efficiency, transects were also eliminated from consideration if they did not intersect at least 200-250 linear (but not necessarily contiguous) meters of rocky substrate. The results of the process of transect elimination described above yielded the following number of potential transects: Orford/McKenzie: 118, Humbug: 60, Redfish Rocks: 73. To the extent possible, ROV surveys were conducted at all 3 areas within a given sampling visit, but usually only 1 area was surveyed per day for logistical reasons. All surveys were conducted during September (11 days) and October (3 days), when seas and weather were calmest. A total of 42 transects were surveyed in Redfish Rocks Marine Reserve, 31 in Humbug Comparison Area, and 40 in Orford/McKenzie Comparison Areas (Figure 14).

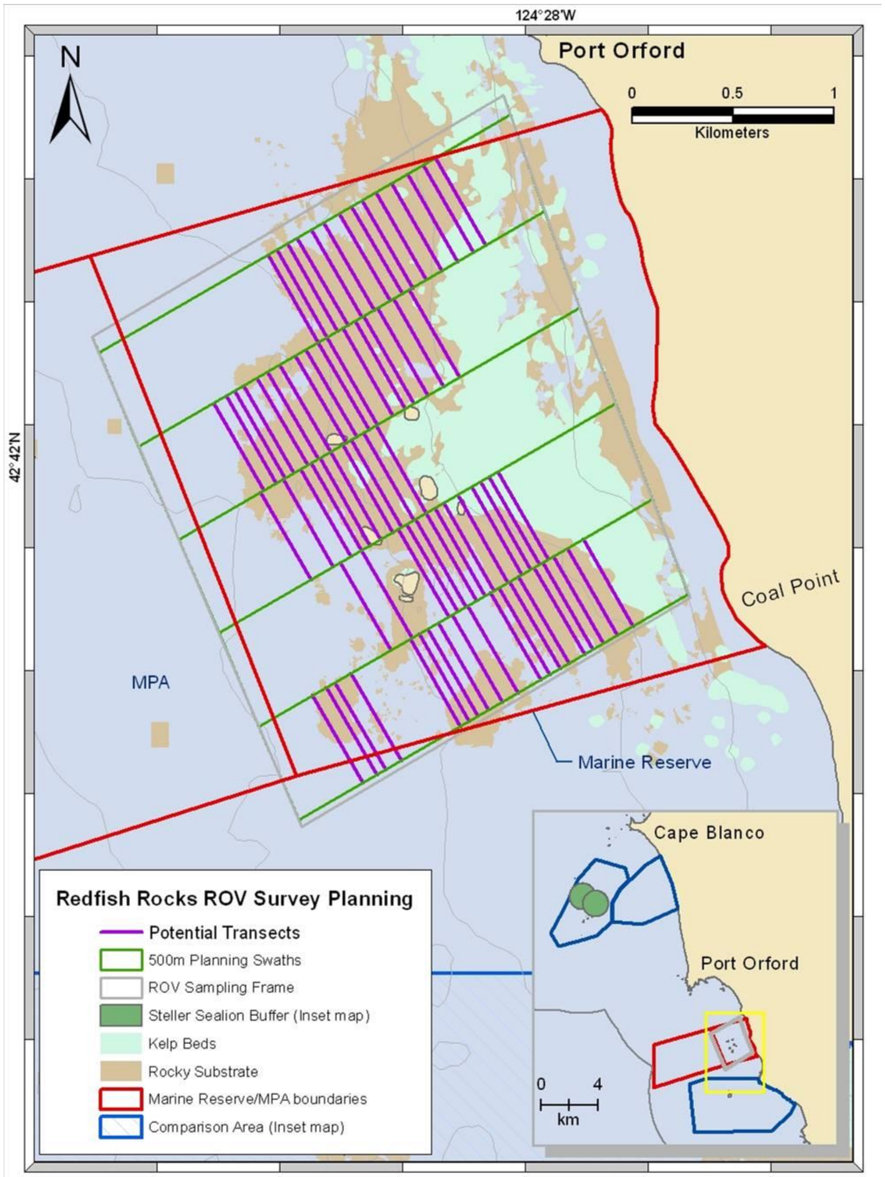


Figure 13. An example of the randomized selection process for potential ROV transects in Redfish Rocks Marine Reserve.

C.4.b. ROV: Data Analysis

Video was reviewed by trained technicians in the lab for habitat and fish metrics. The time associated with each observation was related to the geographic position recorded by the tracking software at that same time. Habitat (i.e., substrate) type was continuously sampled along the length of the transect. Fish were counted and identified to the highest taxonomic resolution possible (species, usually), and length class was estimated for a subset of species that included most rockfish species as well as Hexagrammids (greenlings and Lingcod). Due to problems with identifying small organisms in video footage, all young-of-the-year rockfish were grouped into a single category. Fish counts were converted to fish density (# individuals/100 m^2) for portions of the transect that could be seen clearly and therefore generally met the primary assumption of a strip transect (i.e. that no target individuals within the strip are missed).

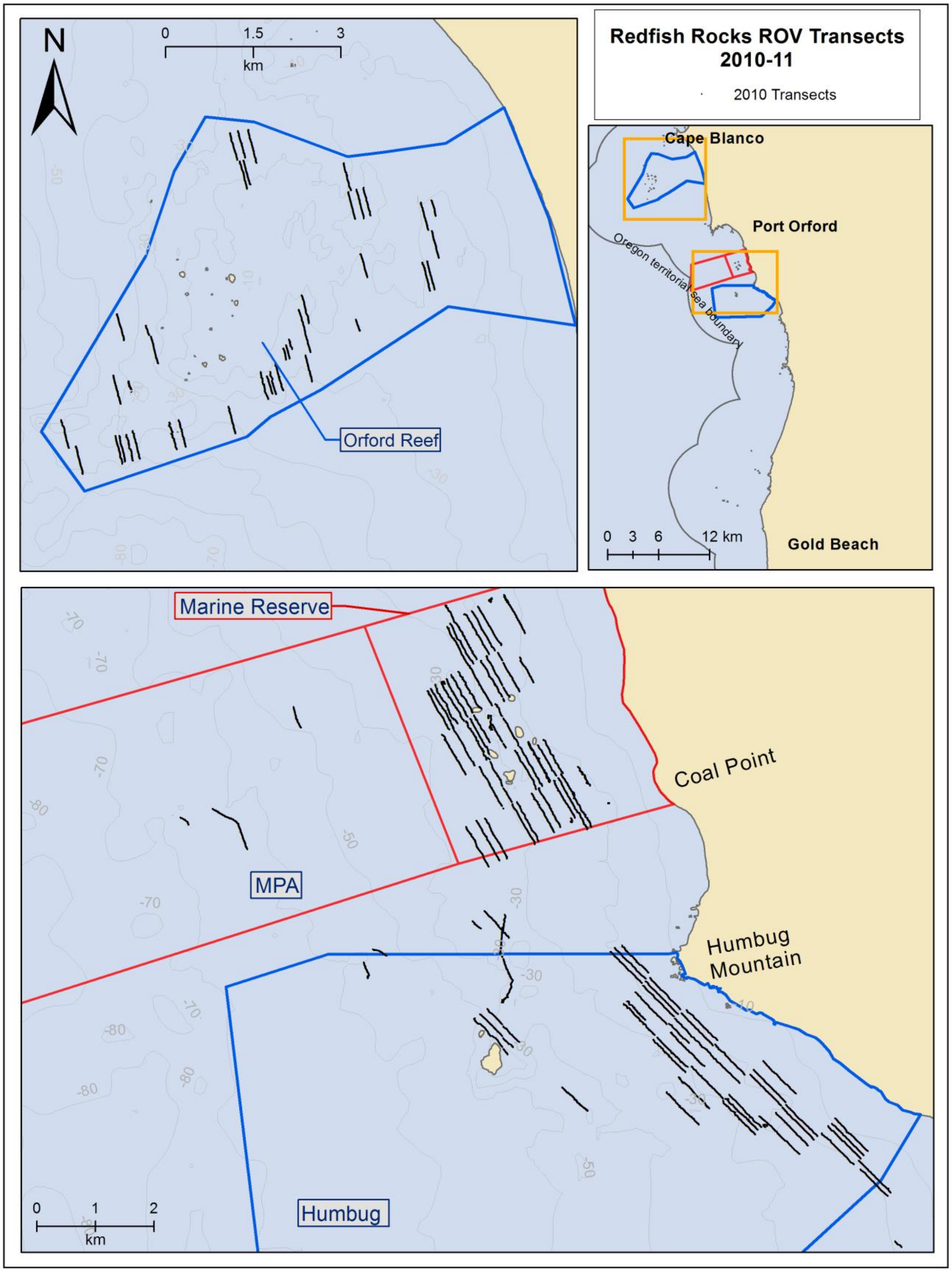


Figure 14. Transects sampled using ROV in Redfish Rocks in 2010-2011.

D. Extractive Surveys

Metrics derived: Urchin population structure and abundance
Focal fish population, sex, and age structure
Community composition of invertebrate and macroalgal communities on rock habitat

Our main objectives were to: 1) determine the macroalgal and invertebrate community composition within the sites, 2) determine fish size frequency distributions within the sites, 3) determine age and maturity relationships for select fish species, and 4) determine if a given reserve and its comparison areas differ in these metrics. We conducted several types of extractive surveys as a means of collecting specific biological data that our visual surveys were deficient in collecting.

D.1. Red Sea Urchin (Strongylocentrotus franciscanus)

The Redfish Rocks Marine Reserve and the Humbug and Orford Reef Comparison Areas have been subject to commercial urchin harvest. Our survey was designed to gather population structure data (i.e., length frequencies) and an absolute abundance estimate for specified areas within each of these three locations. We used a simple random sampling design. We began by drawing polygons in ArcGIS within the marine reserve and the Humbug and Orford Reef Comparison Areas using the following parameters: 1) an area of approximately 100 hectares, 2) a perimeter that roughly encompassed the “commercial urchin beds” of the area, and 3) depths of 20 meters or less. It was necessary to work within areas of “commercial urchin beds” in order to compare treatments of fished vs. unfished in the future. Random transect starting points were then assigned within each area. Transects began at these random starting points and continued in azimuths selected using a random number generator.

We employed a standard urchin transect sampling method with a two person dive team. This method included laying out a 40 meter belt transect, with a one meter width on either side of the transect. Transect lines were divided into sixteen, 5 m x 1 m quadrats by two divers swimming five meters with a one meter length of PVC pipe, one on either side of the transect line. Divers swam simultaneously on either side of the transect line, enumerating and collecting all urchins within each quadrat. Mid-resolution video was recorded along the entire length of transect. All urchins were brought aboard and test diameter measured (mm) before releasing urchins overboard and moving to the next survey area. Emergent purple urchins and red, flat, and pinto abalones were also recorded when encountered; however, very few were seen.

D.1.a. Red Sea Urchin: Sampling Conducted

We contracted commercial urchin divers to conduct the surveys at the Redfish Rocks sites. ODFW staff was aboard the dive vessel while the surveys were being conducted. Two days of surveys were conducted in August 2010 and two days in June 2011. In 2010, seven urchin transects were completed in Redfish Rocks Marine Reserve and four in the Humbug Comparison Area. In 2011, five urchin transects were completed in Redfish Rocks Marine Reserve, eight in Humbug Comparison Area, and 34 in Orford Reef Comparison Area.

D.1.b. Red Sea Urchin: Data Analysis

Urchin density, mean test diameter, and test size structure were determined from pooled 2010-11 data and compared among the reserve and two comparison areas for significant differences.

D.2. Benthic Extraction: Rocky Reefs

We conducted benthic extractive surveys in rocky subtidal habitats in order to: 1) focus attention on macroinvertebrates and algae that our visual surveys do not capture, and 2) obtain a greater understanding of the biodiversity of these groups for each marine reserve site. These quadrat-extraction surveys were carried out using SCUBA divers, at depths between 7-20 meters, and were conducted separately from the SCUBA surveys described earlier.

We used a stratified random sampling design, striving to collect an equal number of quadrats between two depth strata (between 0-9 m and > 9 m for Otter Rock site, 0-12 m and >12 m for Redfish Rocks site) at each reserve and each priority comparison area. We randomly located transect starting points *a priori* using ArcGIS in the laboratory. In the field, SCUBA divers placed 30 m transects on randomly assigned azimuths at each dive site. Divers placed the 0.25 m^2 quadrat at the 10 m, 20 m and 30 m marks along the transect regardless of the substrate encountered. We chose the 0.25 m^2 quadrat size because it is more efficient than larger quadrats for most macroinvertebrates and macroalgae (Dayton 1971; Pringle 1984). One diver used a paint scraper to remove macroalgae and invertebrates from the quadrant. The second diver used an airlift supplied with compressed air from the surface to collect all detached materials into a fine mesh bag (6.3 mm mesh).

The contents of each bag were grossly sorted into macroalgal and invertebrate containers and fixed in 5 or 10% formalin, respectively. We contracted with Dr. Gayle Hansen from Oregon State University to conduct the macroalgal analysis. Dr. Hansen identified all macroalgae to the species (when possible) and measured biomass (wet weight, g) of each species per quadrat. Invertebrate samples were sorted as abundance and biomass (g) of taxonomic phyla by EcoAnalysts, Inc. All sponge material (Phyla Porifera) was removed from the samples and sent to the Oregon Porifera Project for species identification, when possible.

D.2.a. Benthic Extraction: Sampling Conducted

We contracted commercial urchin divers to conduct the surveys. ODFW staff was topside aboard the dive vessel while surveys were being conducted. Surveys were conducted in June 2011 at the Redfish Rocks site and in September 2011 at the Otter Rock site. At the Otter Rock site we conducted a total of 10 transects (30 quadrats), sampling 12 quadrats from Otter Rock marine reserve and 18 quadrats from the Cape Foulweather Comparison Area (and surrounding waters) in depths ranging from 5-14m. At the Redfish Rocks site we conducted a total of 12 transects (36 quadrats), sampling 18 quadrats from both Redfish Rocks Marine Reserve and Humbug Comparison Area in depths ranging from 9-15m. The starting points of each dive transect are depicted in Figure 15.

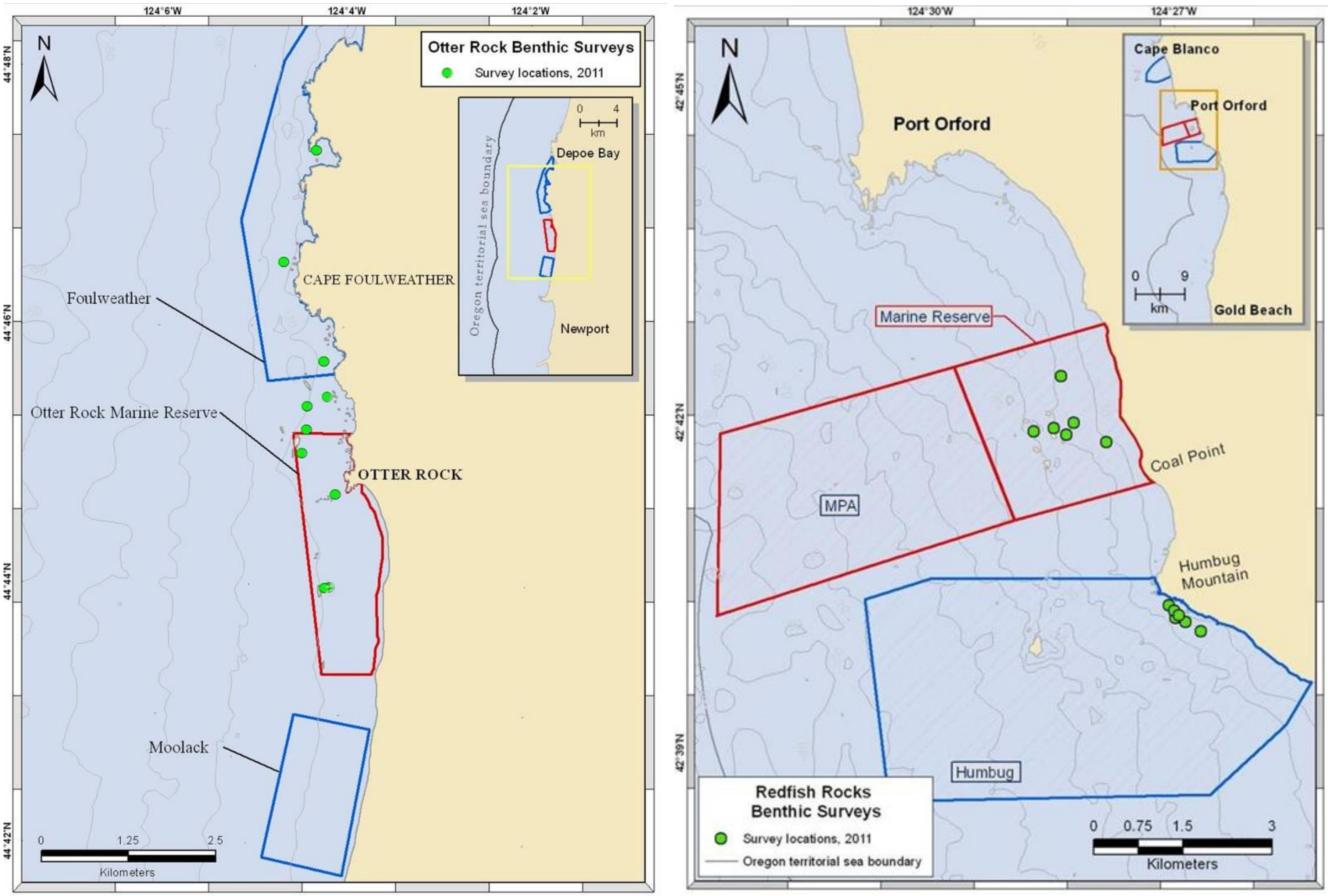


Figure 15. Transect start points of consolidated benthic extraction surveys conducted in 2011 at the Otter Rock and Redfish Rocks sites. Transects initiated outside marine reserve boundary were grouped with comparison area transects for analysis.

D.2.b. Benthic Extraction: Data Analysis

Macroalgal species richness, biomass (g) and community composition were calculated per transect from replicate quadrat samples and then compared among the reserve and comparison areas for significant differences. Similarly, invertebrate biomass (g) and community composition (based on taxonomic phyla) were calculated per transect from replicate quadrat samples and then compared among the reserve and comparison areas for significant differences.

D.3. Hook-and-Line Surveys

Video lander and sled surveys have a limited capacity to accurately estimate fish lengths, while visual ROV and SCUBA surveys are incapable of determining sex, age, and breeding condition. In response to these limitations, fishery-independent hook-and-line surveys were used to generate size structure data to determine (1) whether fish sizes are changing over time, and (2) whether these changes are due to alterations to juvenile recruitment, adult retention, or mortality (Buxton 1993; Bohnsack 1999; Ault et al. 2005). Fishery-independent sampling methods are preferable to fishery-dependent methods because regulations often forbid harvest of small size classes. Hook-and-line surveys were conducted at Redfish Rocks and Humbug Comparison Area to establish a baseline size-frequency distribution for the most commonly caught fish species. Subsequent re-sampling will be used to detect changes in size and age structure post-closure.

Hook-and-line sampling was conducted during summer, over several months to improve data accuracy (Fox and Starr 1996; Karnauskas and Babcock 2012). Common, harvested fish species that exhibit small home ranges (Jorgensen et al. 2006; Parker et al. 2007; Tolimieri et al. 2009) were targeted for the surveys, as these species are the most likely to experience change in size in response to no-take protection (Kramer and Chapman 1999) while offering large enough sample sizes. This study focuses on rock structure and therefore, rockfish species, with some greenling species being caught in larger abundances. All caught species were measured for length and weight before being released regardless of whether they were targeted or not.

Lethal hook and line sampling

Lethal hook-and-line sampling was used to gather age data on individual fishes, as larger, older rockfish are exponentially more fecund and can produce higher fitness offspring (Berkeley et al. 2004). Age data, determined from otoliths, is a more precise than age estimates from non-lethal length measurements. To avoid extensive lethal sampling in marine reserve sites, lethal surveys were conducted prior to closure to establish baseline age-frequency distributions and will be re-sampled at 10 year intervals post-closure. Constructing representative age-frequency distributions requires lethal extraction of approximately 150-200 individuals (Gómez-Buckley et al. 1999). We collected otoliths from the most common species including Black Rockfish, Blue Rockfish, China Rockfish and Kelp Greenling; though due to limited sample sizes, only Black Rockfish were abundant enough to warrant analysis. Otoliths were not yet analyzed for age data by the time of this report writing; hence, age-frequency data is not presented in the results section at this time.

Non-lethal hook and line sampling

For all other species, we measured length and weight as a proxy for age and then released the fish. As fecundity in rockfish is very strongly correlated with length and weight (Eldridge et al. 1991), we will use these metrics to calculate reproductive output. We ran power analyses using the statistical program G*power to determine the sample size per group (N) needed to detect a ten percent or fifteen percent increase in fork length using both one and two-tailed t-tests for each species (Table 5). We used commercial landings data collected from Redfish Rocks from 2004-2009 to determine the current mean size (fork length) and standard deviations. We used the highest and lowest of these values as our target sample size range. The variances found in the commercial data are likely to be smaller than the actual natural fork length variance within the reserve. This is because commercial fishermen do not retain small size classes, and often release large gravid females. Thus, the following target sample sizes are underestimated. To negate this underestimation in the case of Black Rockfish, we continued to collect samples after the upper end of our target range had been attained.

Table 5. Sample size needed to detect increase in fork length, based on power analysis.

Species	N: 10% mean size difference (2-tailed)	N: 10% mean size increase (1-tailed)	N: 15% mean size difference (2- tailed)	N: 15% mean size increase (1-tailed)
Black Rockfish	16	13	8	7
Blue Rockfish	19	16	9	8
Lingcod	56	46	24	20
Kelp Greenling	15	12	8	6
China Rockfish	16	13	8	7
Quillback rockfish	28	24	13	11
Cabezon	63	52	8	7

D.3.a. Hook-and-Line Surveys: Sampling Conducted

Growth rates of rockfish can differ between neighboring reefs, 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 over time, we identified index areas in both the reserve and comparison area. We identified rocky reef substrate using seafloor habitat data in ArcGIS. Index areas were delineated around patches of rocky reef substrate within four depth strata (11.9-18.3 m, 18.6-24.4 m, 24.7-30.5 m, and 30.8-36.6 m) at both the Redfish Rocks Marine Reserve and the Humbug Comparison Area.

We deployed both hook-and-line and cable gear from chartered vessels. During a single fishing day, effort was usually allocated at both the reserve and the comparison area. At the beginning of the study we allocated an equal amount of effort at each area, across index areas. However, as the study progressed we needed to focus additional effort on specific index areas to obtain fish from certain depths. The charter captain selected fishing drift locations within index areas. Drift time over these locations ranged in duration from 2-45 minutes, depending on fishing success in a given area.

Five anglers each used a six-ounce chrome plated diamond jig with a treble hook. This gear type was selected after we conducted a pilot study that compared the size distributions of fish caught on shrimp flies, plastic worms, and diamond jigs. Diamond jigs caught a large diversity rockfish and Hexagrammid species and the widest size range of fish. Anglers were responsible for keeping track of their efforts with a stopwatch. The watch was paused when the angler had a fish on, hung up, reeled up for any reason or when the boat was moving. The time at which each fish was caught was recorded, and later matched with a GPS tracklog, so that each fish had an associated GPS location. Each fish was identified, measured (fork length; mm), weighed (kg) and released. Great care was taken with fish on deck and release cages were utilized when fishing in deep water (depths greater than 20 meters) or with fish susceptible to barotrauma. During the hook-and-line fishing, up to 200 individuals of Black Rockfish and Kelp Greenling from each area were retained for aging and reproductive studies. These fish were weighed and measured, marked with a unique number, and retained. Once on the dock, otoliths were removed and stored for later aging analysis and fish were sexed and assessed for sexual maturity.

For fishing with cable gear, we deployed 10-20 sets (depending on habitat availability) of gear within each index area, each with five baited circle hooks on a weighted two meter braided steel wire. Hooks were baited with squid. Gear was soaked for 30-60 minutes before retrieval. The location of each deployment was recorded with a handheld GPS. Each fish was identified, measured (fork length; mm) and weighed (kg). Great care was taken with fish on deck and release cages were utilized when fishing in water deeper than 10 meters or with fish susceptible to barotrauma.

Hook-and-line (jig) fishing was conducted from June-October 2011. We fished for 13 half days at the Redfish Rocks Marine Reserve and nine half days at the Humbug Comparison Area. We also fished two half days at the McKenzie Reef Comparison Area, but determined that the catchable fish abundance was too low to justify more sampling effort (CPUE = 3.0 fish/angler hour). We fished using cable gear at the Redfish Rocks Marine Reserve for 1.5 days, and spent two half days at each comparison area. The diversity of fish caught on cable gear was higher compared to hook-and-line. However, extremely low catch rates per unit effort (mean = 13.67 fish/day +/- 7.94, 95% CI) prompted us to remove this method of fishing from our monitoring design.

D.3.b. Hook-and-Line Survey: Data Analysis

Data were entered into a Microsoft Access database, checked for quality assurance and quality control and outliers were assessed. For each species, mean lengths were initially pooled by area and then averaged to compare lengths at the marine reserve and at the comparison area. A t-test was used to test for differences in mean lengths among the two areas. The assumptions of normality were evaluated using Shapiro-Wilk's test and the assumption of homogeneity of variance using Levene's test. When necessary, data were transformed to meet assumptions. In some cases, data could not meet parametric statistical assumptions after transformation and the Mann-Whitney U test was used. For each species, differences in mean lengths among index areas were assessed using a one-way ANOVA (when assumptions were met) or a Kruskal-Wallis test (when normality assumptions were not met). Additionally, differences in mean lengths among depth strata were assessed using either a one-way ANOVA or a Kruskal-Wallis test. Length frequency distributions were assessed for skewness and a K-S test was used to compare distributions of target species in the marine reserve and the comparison area.

For each species, hook and line catch rates (CPUE; catch per unit effort) were calculated by dividing the total number of fish caught by total angler hours in a day. These values were then averaged by area. Biomass per unit effort (BPUE) was calculated by dividing the total weight of fish caught by total angler hours in a day. These values were also averaged by area. Only ANOVA results from species that met all assumptions are reported with p-values.

E. References

Agapito MT (2008) Mapping and lithologic interpretation of the territorial sea, Oregon. 1-92

Amend M, Fox D, Romsos C (2001) Nearshore rocky reef assessment, ROV survey. Oregon Department of Fish and Wildlife, 1-30

Amolo RC (2010) Habitat mapping and identifying suitable habitat of Redfish Rocks pilot marine reserve, Port Orford, Oregon. 1-106

Ault JS, Smith SG, Bohnsack JA (2005) Evaluation of average length as an estimator of exploitation status for the Florida coral-reef fish community. ICES Journal of Marine Science: Journal Du Conseil 62(3): 417-423

Berkeley SA, Hixon MA, Larson RJ, Love MS (2004) Fisheries sustainability via protection of age structure and spatial distribution of fish populations. Fisheries 29(8): 23-32

Bohnsack JA (1999) Incorporating no-take marine reserves into precautionary management and stock assessment. Providing Scientific Advice to Implement Precautionary Approach Under the Magnuson-Stevens Fishery Conservation and Management Act.NOAA Tech.Memorandum NMFS-F/SPO-40 : 8-16

Buxton CD (1993) Life-history changes in exploited reef fishes on the east coast of South Africa. Environ Biol Fishes 36(1): 47-63

Cappo M, Harvey E, Malcolm H, Speare P. 2003. Potential of video techniques to monitor diversity, abundance and size of fish in studies of marine protected areas. In: Beumer JP, Grant A,Smith DC (eds) Aquatic protected areas--what works best and how do we know? Proc World Congr on Aquat Protected Areas, Australian Society for Fish Biology, North Beach, Australia, pp 455

Dayton PK (1971) Competition, disturbance, and community organization: The provision and subsequent utilization of space in a rocky intertidal community. Ecol Monogr 41(4): 351-389

Donnellan M, Merems A, Miller W (2008) Developing fish monitoring methods on southern Oregon reefs. Final Report to the Department of Land Conservation and Development in Fulfillment of 2006-07 Coastal Zone Management Section 309 Grant, Cooperative Agreement PS06005: 1-43

Eldridge MB, Whipple JA, Bowers MJ, Jarvis BM, Gold J (1991) Reproductive performance of yellowtail rockfish, *Sebastes flavidus*. Environ Biol Fishes 11: 91-102

Fox DS, Amend M, Merems A (1999) Nearshore rocky reef assessment. Oregon Department of Fish and Wildlife Final Report Contract No. 99-072: 1-40

Fox DS, Amend M, Merems A, Appy M (2000) Nearshore rocky reef assessment. Oregon Department of Fish and Wildlife Final Report Contract No. 01-01: 1-32

Fox DS, Amend M, Miller B, Golden J (1998) Nearshore rocky reef assessment. Oregon Department of Fish and Wildlife Final Report Contract No. 99-020: 1-53

Fox DS and Starr RM (1996) Comparison of commercial fishery and research catch data. Can J Fish Aquat Sci 53(12): 2681-2694

Goldfinger C (2010) Oregon state waters multibeam mapping project: A progress report. Active Tectonics and Seafloor Mapping Laboratory pub. 2010-1: 1-26

Gómez-Buckley MC, Conquest L, Zitzer S, Miller B (1999) Use of statistical bootstrapping for sample size determination to estimate length-frequency distributions for pacific albacore tuna *(Thunnus alalunga*). National Marine Fisheries Service FRI-UW-9902: 1-10

Hannah RW and Blume MT (2012) Tests of an experimental unbaited video lander as a marine fish survey tool for high-relief deepwater rocky reefs. J Exp Mar Biol Ecol 430: 1-9

Jorgensen SJ, Kaplan DM, Klimley A, Morgan SG, O'Farrell MR, Botsford LW (2006) Limited movement in Blue Rockfish S*ebastes mystinus*: Internal structure of home range. Mar Ecol Prog Ser 327: 157-170

Kaimmer S (1999) Direct observations on the hooking behavior of Pacific halibut, *Hippoglossus stenolepis*. Fisher Bulletin-NOAA 97(4): 873-883

Karnauskas M and Babcock EA (2012) Comparisons between abundance estimates from underwater visual census and catch-per-unit-effort in a patch reef system. Mar Ecol Prog Ser 468: 217-230

Kramer DL and Chapman MR (1999) Implications of fish home range size and relocation for marine reserve function. Environ Biol Fishes 55(1-2): 65-79

Oregon Department of Fish and Wildlife (2012) Oregon marine reserves ecological monitoring plan. Marine Resources Program, Newport, Oregon : 1-27

Parker SJ, Rankin PS, Olson JM, Hannah RW (2007) Movement patterns of Black Rockfish (*Sebastes melanops*) in Oregon coastal waters. Biology, Assessment, and Management of North Pacific Rockfishes.Edited by J.Heifetz, J.Dicosimo, AJ Gharrett, MS Love, VM O'Connell, and RD Stanley.Alaska Sea Grant College Program, University of Alaska Fairbanks, Fairbanks, Alaska : 39-57

Partnership for Interdisciplinary Studies of Coastal Oceans (2009) Subtidal sampling protocols.

Priede I, Bagley P, Smith A, Creasey S, Merrett N (1994) Scavenging deep demersal fishes of the porcupine seabight, north-east Atlantic: Observations by baited camera, trap and trawl. J Mar Biol Assoc U K 74(03): 481-498

Pringle J (1984) Efficiency estimates for various quadrat sizes used in benthic sampling. Can J Fish Aquat Sci 41(10): 1485-1489

Romsos CG, Goldfinger C, Robison R, Milstein RL, Chaytor JD, Wakefield WW. 2007. Development of a regional seafloor surficial geologic habitat map for the continental margins of Oregon and Washington, USA. In: Todd BJ and Greene HG (eds) Mapping the seafloor for habitat characterization. Geological Association of Canada, St. John's, Canada, pp 219

Spencer ML, Stoner AW, Ryer CH, Munk JE (2005) A towed camera sled for estimating abundance of juvenile flatfishes and habitat characteristics: Comparison with beam trawls and divers. Estuar Coast Shelf Sci 64(2): 497-503

Tissot BN. 2008. Video analysis, experimental design, and database management of submersible-based habitat studies. In: Reynolds JR and Greene HG (eds) Marine habitat mapping technology for Alaska. Alaska Sea Grant College Program, University of Alaska Fairbanks, pp 157

Tolimieri N, Andrews K, Williams G, Katz S, Levin P (2009) Home range size and patterns of space use by Lingcod, copper rockfish and quillback rockfish in relation to diel and tidal cycles. Mar Ecol Prog Ser 380: 229-243

Redfish Rocks Results & Discussion

To robustly characterize the baseline ecological conditions within Redfish Rocks Marine Reserve, our analyses focused on comparing the oceanographic, habitat, and biological composition in the marine reserve to the associated comparison areas. All data presented below were collected in 2010-11, prior to closure of the Redfish Rocks Marine Reserve to extractive activities (with the exception of some oceanographic data collected in 2012). Oceanographic analyses consisted of comparing physical parameters between the reserve and comparison areas over time to determine if differences exist. Habitat comparisons were made to determine how comparable the substrates found within the marine reserve were represented by the selected comparison areas. Lastly, biological comparisons were structured to address the following questions for the various communities surveyed:

Does community composition differ between the reserve and comparison areas?

What species or species groups, and in what proportions, define the communities in the reserve and comparison areas?

Do organism abundance and/or size differ between the reserve and comparison areas?

Does diversity differ between the reserve and comparison areas?

A. Oceanography

Baseline oceanographic monitoring activities generated large datasets with the objective of comparing temporal patterns in oceanographic conditions between reserve sites and their comparison areas. Should the reserve and comparison areas experience similar temporal variation in oceanographic parameters, it suggests that ocean water masses are acting on all areas equally.

In this section, we present both data collected via oceanographic moorings as well as via Benthic Oceanographic Platforms (BOPs), as the methods for deploying oceanographic instruments evolved over the course of the baseline period. Due to both oceanographic instrument and funding constraints, paired data collection between the reserve and comparison area was extremely limited in the 2010-11 baseline period. Hence, we report additional data from 2012 and early 2013 to aid in addressing our research goals.

Temperature, salinity, and oxygen data were collected at Redfish Rocks Marine Reserve and Humbug Comparison Area between June 2011 and February 2013 (Figure 1). Temperature at Redfish Rocks was closely correlated by temperature at Humbug. Salinity was also closely correlated between the two sites, though in January 2013 Humbug was lower than the salinity at Redfish Rocks. This could be due to the advection of low salinity water from a fresh water input near the Humbug study site. Analysis of rainfall and wind data would greatly assist with further investigation. Oxygen levels at the marine reserve were consistently lower than oxygen levels at Humbug. While the magnitude of the salinity and oxygen data did differ between the reserve and Humbug Comparison Area, both sites show similar temporal fluctuations in the data suggesting that both areas are tracking environmental change in a similar manner.

Both Redfish Rocks and Humbug sites were very similar in temperature, and varied less than 2ºC between September 2012 and January 2013(Figure 2).

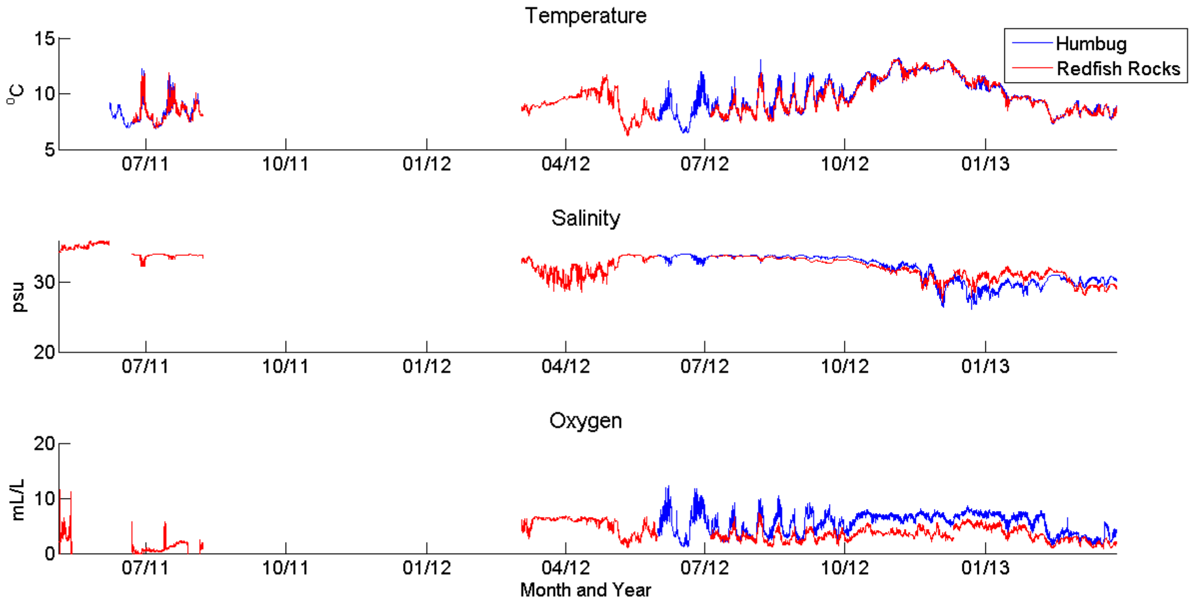


Figure 1. Available temperature, salinity, and oxygen data in Redfish Rocks Marine Reserve (red) and Humbug Comparison Area (blue) from June 2011-February 2013. Raw data are shown reflecting an hourly sampling interval.

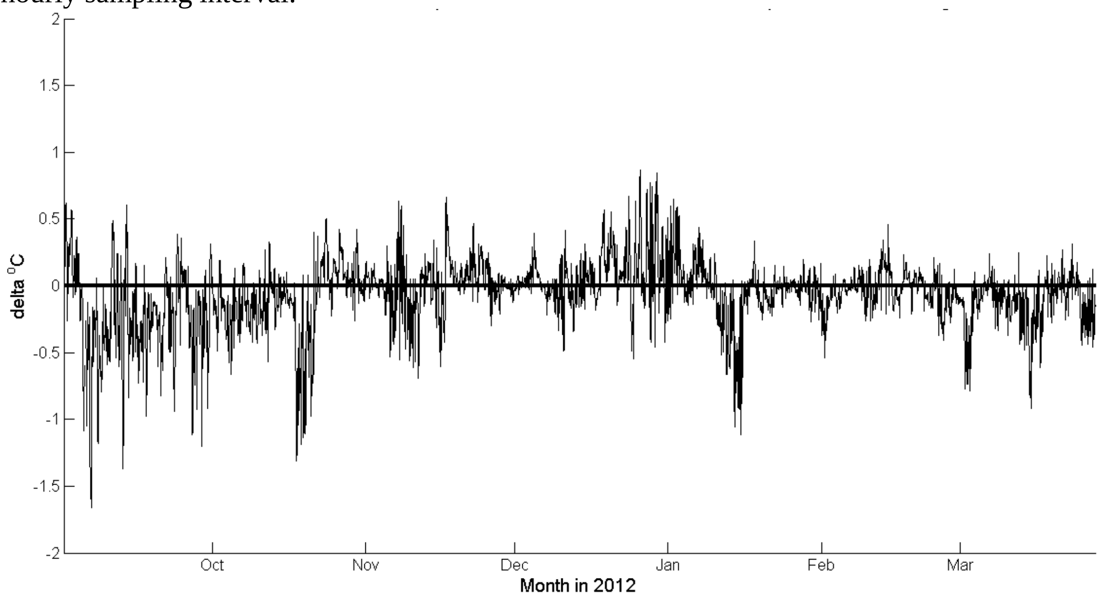


Figure 2. Temperature differences (ΔºC) between Redfish Rocks Marine Reserve and the Humbug Comparison Area from September 2012-March 2013. Values above the zero line indicate warmer temperatures in Redfish Rocks; values below indicate warmer temperatures in Humbug.

When Redfish Rocks and Humbug temperatures were plotted with salinity in a T-S diagram, distinct water masses were evident (Figure 3). Period 1 was characterized by a high salinity, increasing temperature water mass. Period 2 was characterized by a high temperature, low salinity mass. Period 3 was characterized by a low salinity, low temperature mass. Both Redfish Rocks and Humbug areas experienced similar water masses during each time period, supporting our goals of establishing a comparison area that experiences similar oceanographic conditions over time to the marine reserve.

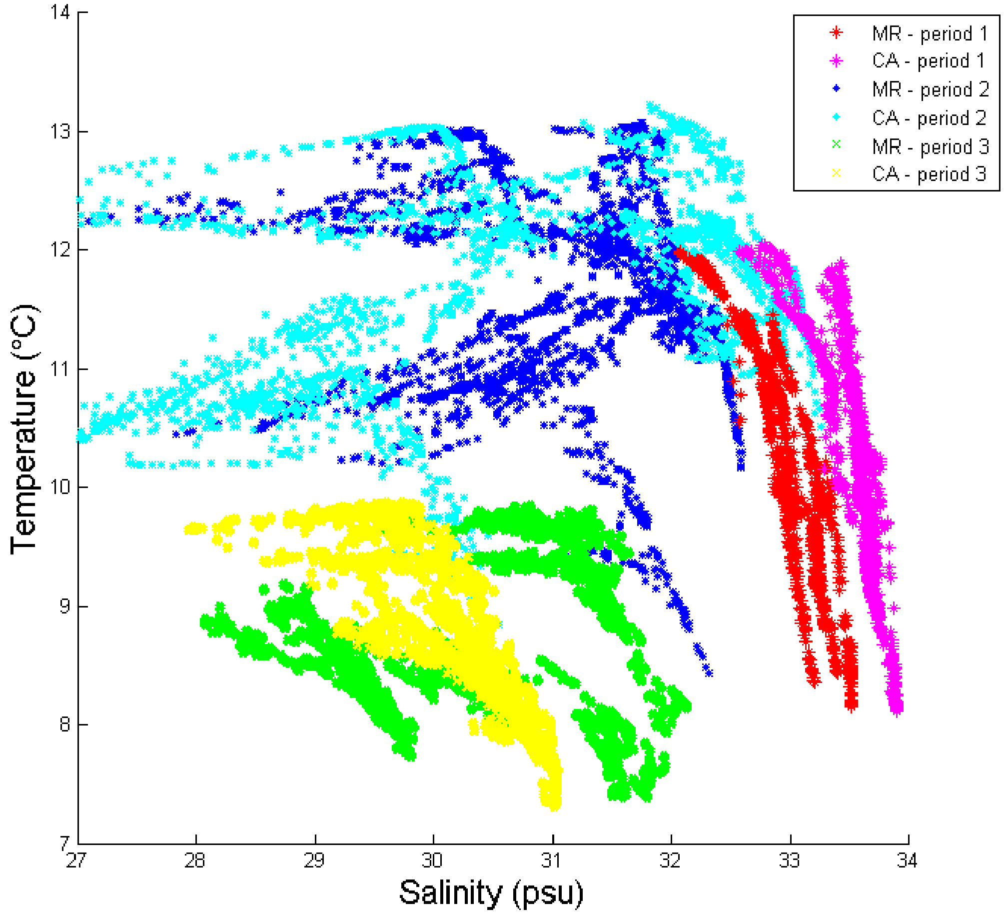


Figure 3. Temperature-salinity plot comparing Redfish Rocks Marine Reserve (MR) and the Humbug Comparison Area (CA). Temporal changes are shown across three time periods (Period 1: Sept 1st-Oct18th, 2012; Period 2: Oct. 18th, 2012-Jan. 18th, 2013; and Period 3: Jan. 18th – Mar. 28th, 2013. Symbols correspond to the three different periods. Darker colors (blue, red, green) are the MR data while lighter colors (aqua, pink, yellow) are the CA data.

While our oceanographic data are spatially limited, our results indicate high agreement between the oceanographic variables measured in the Redfish Rocks Marine Reserve and Humbug Comparison Area over time. Differences in temperature between the reserve and the comparison area are small (predominantly < 1ºC), with Humbug exhibiting slightly warmer temperatures in the fall months and spring months, and Redfish Rocks exhibiting slightly warmer temperatures in the winter. Temperature-salinity plots reveal that these physical metrics vary over time, but both the marine reserve and the Humbug Comparison Area site experience similar temperature and salinity ranges for the three time periods we examined. Hence, we conclude the Humbug Comparison Area is an appropriate comparison site to the Redfish Rocks Marine Reserve with respect to oceanographic characteristics. On-going oceanographic monitoring will continue to expand our dataset and lend further support to these preliminary findings.

B. Seafloor Mapping

B.1 Video Lander

For the Systematic Rapid Assessment in Redfish Rocks, the video lander was deployed on a 350m x 350m spaced grid among the marine reserve, and the Humbug, and McKenzie Reef Comparison Areas. No lander drops were completed in the Orford Reef Comparison Area. A total of 108 grid drops were completed in 2010 and used to determine the prevalence of various benthic substrate types present among the reserve and comparison areas (Table 1). Sand was the most abundance substrate type encountered in the marine reserve and Humbug Comparison Area; flat bedrock was most abundant substrate in the McKenzie Reef Comparison Area.

Table 1. Prevalence (%) of benthic substrate types encountered using the video lander during the Systematic Rapid Assessment during 2010. The number of drops follows in parentheses. MR = marine reserve; CA = comparison area.

Substrate Type	Redfish Rocks MR (n = 42)	Humbug CA (n=33)	McKenzie Reef CA (n=33)
Bedrock Outcrop	2% (1)	3% (1)	3% (1)
Flat Bedrock	0% (0)	0% (0)	42% (14)
Large Boulder	14% (6)	9% (3)	3% (1)
Small Boulder	12% (5)	21% (7)	15% (5)
Cobble	12% (5)	0% (0)	15% (5)
Gravel Pebble	0% (0)	3% (1)	0% (0)
Sand	60% (25)	64% (21)	21% (7)

B.2. High-Resolution Multibeam Sonar

Substrate data from the lander were used to supplement surficial geologic habitat maps, as well as compare to the high-resolution multibeam benthic habitat maps released in 2011 (Goldfinger 2010). While discrepancies exist between the lander data and multi-beam data as to the proportions of each substrate type present in a given area (Table 2), this is largely due to the sample planning for the lander in the Humbug and McKenzie Reef Comparison Areas where rocky habitats were intentional targetted. Hence the lander data shows higher proportion of rock habitats compared to the multibeam. Redfish Rocks Marine Reserve was sampled using the lander in a systematic grid design. For this areas, there is near perfect aggreement between the lander and multibeam data when comparing proportions of consolidated to unconsolidated habitat. The lander data in conjunction with the multibeam habitat maps helped establish a spatial explicit map of benthic substrate types that was instrumental in structuring the sampling design for our Detailed Assessment (Figure 4). Using these maps, we were able to target areas of consolidated and unconsolidated substrates by depth within the marine reserve and comparison areas for biological sampling.

Table 2. Comparison of benthic substrate types encountered using the video lander versus substrate maps created from high-resolution multibeam for the Redfish Rocks Marine Reserve and comparison areas. Given that different substrate categories were assessed between the lander and multibeam datasets, substrates are grouped into four types only to facilitate comparison (i.e. bedrock and boulder classes were

pooled to comprise Rock). All values are percentages (%) of each substrate type encountered for video lander followed by the multibeam habitat maps (lander/ multibeam).

	Lander / Multibeam (% of total)			
Benthic Substrate type	Redfish Rocks MR	Humbug CA	McKenzie Reef CA	Orford Reef CA
Rock	29 / 30	33 / 14	64 / 35	NA / 94
Cobble	12 / 0	0 / 0	15 / 0	NA / 0
Gravel Pebble	0 / 21	3 / 4	0 / 1	NA / 1
Sand	60 / 45	64 / 81	21 / 63	NA / 5

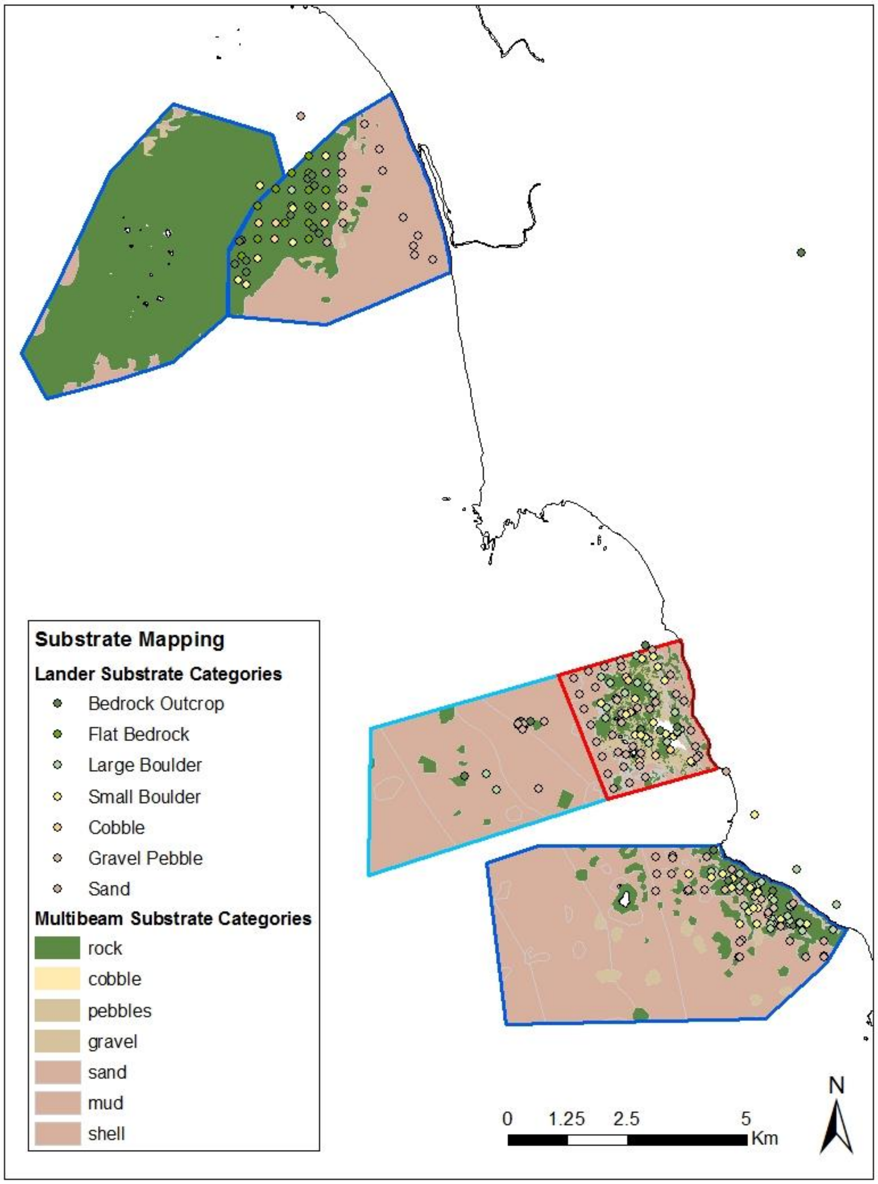


Figure 4. Mapping of substrate types detected by the video lander (circles) and high resolution multibeam survey (polygons). Different substrate classes were defined for each method; each type of substrate is represented by like colors regardless of sampling method. Marine reserve boundary (red), MPA (light blue) and comparison areas (dark blue) are shown.

C. Visual Surveys

C.1 Video Lander

Species differences

Lander data from 2010 and 2011 were pooled for the analyses presented below. For fishes identified to species, mean relative abundance (quantified as maximum N) was compared using a nonparametric Kruskal-Wallis test followed by a Steel-Dwass All Pairs multiple comparison test (the nonparametric equivalent of a Tukey HSD post hoc analysis) due to lack of normality in the data. Data were pooled regardless of depth or substrate type for these analyses. Black Rockfish were significantly more abundant in the Redfish Rocks MPA compared to the reserve and comparison areas (Table 1; $P < 0.001$). Canary Rockfish were significantly more abundant in the MPA compared to all other areas, and Canary Rockfish were also less abundant in the McKenzie comparison area compared to either the Humbug Comparison Area or the reserve ($P < 0.001$). Copper rockfish were significantly more abundant in the MPA than either of the comparison areas ($P = 0.03$). Quillback rockfish were significantly more abundant in the MPA than either the reserve or the comparison areas ($P < 0.001$). Yelloweye rockfish were significantly more abundant in the MPA compared to the reserve ($P = 0.002$). Lastly, yellowtail rockfish were significantly more abundant in the MPA compared to the reserve and comparison areas ($P = 0.008$).

Table 3. Mean relative abundance (# of fish/ lander drop), followed by standard error within parentheses, of fish observed in Redfish Rocks Marine Reserve (n=122), Marine Protected Area (n=41), Humbug Comparison Area (n=71), and McKenzie Comparison Area (n=103). * denotes a significant difference based on Kruskal-Wallis nonparametric analysis.

Species/group	Redfish Rocks MR	Redfish Rocks MPA	Humbug CA	McKenzie Reef CA
Black Rockfish*	0.53 (0.14)	4.32 (1.02)	0.52 (0.12)	0.44 (0.13)
Blue Rockfish	0.35 (0.13)	0.41 (0.24)	0.27 (0.09)	0.14 (0.06)
Canary Rockfish*	0.25 (0.07)	1.95 (0.59)	0.14 (0.06)	0.01 (0.01)
China Rockfish	0.02 (0.01)	0.12 (0.08)	0 (0)	0.01 (0.01)
Copper Rockfish*	0.22 (0.04)	0.12 (0.05)	0.3 (0.06)	0.27 (0.06)
Kelp Greenling	0.07 (0.02)	0.07 (0.04)	0.1 (0.04)	0.07 (0.02)
Lingcod	0.01 (0.01)	0.27 (0.1)	0 (0)	0 (0)
Quillback Rockfish*	0.04 (0.02)	0.08 (0.08)	0.14 (0.07)	0.04 (0.03)
Sculpin	0.01 (0.01)	0 (0)	0 (0)	0 (0)
Spotted Ratfish	0.1 (0.04)	1.39 (0.71)	0.14 (0.06)	0.04 (0.02)
UNID Juvenile Rockfish	0 (0)	0 (0)	0.09 (0.05)	0.02 (0.02)
Vermilion Rockfish	0.02 (0.02)	0 (0)	0 (0)	0 (0)
Yelloweye Rockfish*	0.02 (0.02)	0 (0)	0 (0)	0.02 (0.02)
Yellowtail Rockfish*	0 (0)	0.21 (0.13)	0 (0)	0 (0)

Community composition

We compared fish community composition between the marine reserve, MPA, and comparison areas using a one-way ANOSIM (PRIMER v6) for the lander data. With the exception of unidentified juvenile rockfish, all unidentified fish observations were excluded from the analysis (Hannah and Blume 2012). Prior to the analysis, drops with no fish observed were excluded (156 drops remained). The relative abundance data were first standardized to control for differences in total abundance due to variable fields of view among lander drops, and then square root transformed to deemphasize dominate species in the matrix (Clarke and Gorley 2006). Standardization converts the raw max N values for each species into a percentage of the total max N (summed) observed during that lander drop. Standardization was used for the community composition analysis to de-emphasize differences in total number of fishes observed among drops, allowing the analysis to focus on the relative proportion of each fish species present. This objective for community composition is distinct from the prior objective to compare, for a single species, differences in observed max N between the study sites. For this prior objective, standardization was not applied. Fish community composition differed minimally between the marine reserve, MPA, and comparison areas (Global R = 0.06; P = 0.001). Pairwise comparisons revealed the greater (albeit marginal) difference existed between the MPA and McKenzie Reef Comparison Area (R = 0.253). Similarly, fish community composition was not found to differ between lander drops encountering different substrates (Global R = 0.062; P = 0.007).

Organism abundance

Mean fish density (irrespective of species) was compared between the marine reserve, MPA, and comparison areas using a Kruskal-Wallis test followed by a Steel-Dwass All Pairs multiple comparison test. Fishes were found to be significantly more abundant in the MPA compared to all other areas (P <0.001; Figure 5)

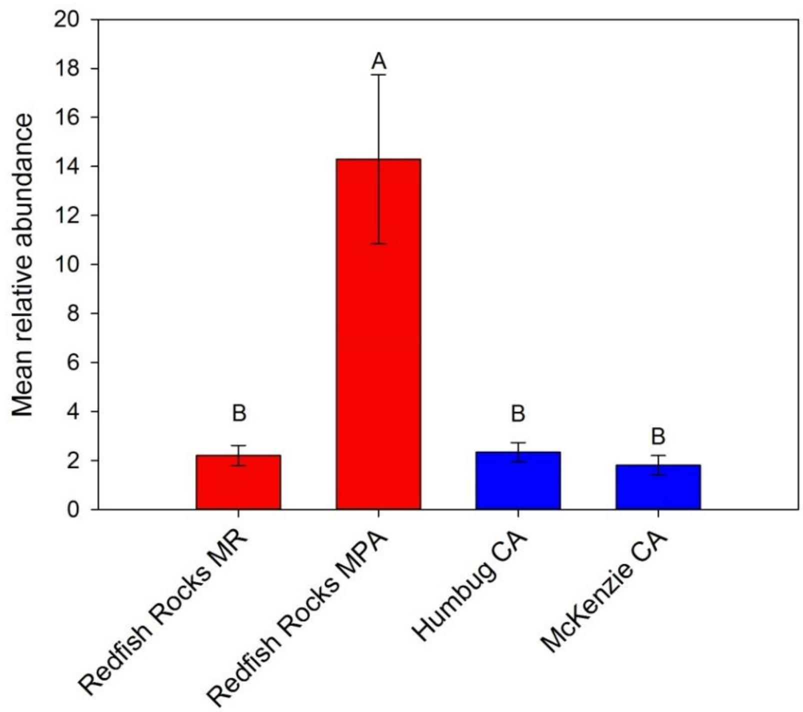


Figure 5. Mean relative abundance (±SE) of all fishes observed with the lander in Redfish Rocks. Marine reserve and MPA are shown in red; comparison areas in blue. Letter groups above the bars signify results from nonparametric post-hoc analyses; bars that differ in letter group are statistically different.

Benthic substrate type significantly influenced how many fish (irrespective of species) were observed in a given lander drop (P<0.001, Kruskal-Wallis test followed by nonparametric comparisons for each pair using Wilcoxon methods, Table 4). Fishes were more abundant in lander drops encountering small boulder, large boulder, and bedrock outcrop substrates than drops encountering sand or cobble.

Table 4. Mean relative abundance (# of fish/ drop) of fish observed during replicate video lander drop samples based on substrate type encountered.

Substrate	N	Mean relative abundance
Bedrock Outcrop	105	5.59
Large Boulder	52	4.63
Small Boulder	42	3.86
Gravel Pebble	19	2.21
Sand	92	1.60
Flat Bedrock	15	1.53
Cobble	12	0.42

C.2. Video Sled

A total of 24 sled transects were completed in the Redfish Rocks site (Table 5). Mean transect depths ranged from 13-48m.

Table 5. Sled transects completed from 2010-11 for the Redfish Rocks site. Total area (m^2) surveyed and the mean depth of the sled transect is provided per sampling area.

Area	N	Total Transect Area (m^2)	Mean transect depth (m) ± SE
Redfish Rocks MR	9	4901	31 ± 1.7
Redfish Rocks MPA	4	2038	45 ± 1.5
McKenzie Reef CA	2	1506	22 ± 9.1
Humbug CA	9	4804	30 ± 2.7

Fish density

ANCOVA analysis (continuous covariate = mean transect depth, factor = sampling area) was used to compare total fish density (indiv./m^2) among the reserve, MPA, and comparison area while exploring the influence of depth (m). Fish density was $\log_{10}$ transformed prior to analysis to achieve normality. Total fish density did not vary with mean transect depth (ANCOVA; P = 0.93), nor was there a significant interaction between depth and sampling area (P = 0.47). There was no difference in mean fish density between Redfish Rocks Marine Reserve (mean = 0.083 ± 0.041 SE), the MPA (mean = 0.015 ± 0.007 SE), Humbug Comparison Area (mean = 0.057 ± 0.009 SE), and McKenzie Reef Comparison Area (mean = 0.012 ± 0.011 SE; ANCOVA, P = 0.86).

Fish species-specific differences

Mean densities of individual species or species groups were compared using non-parametric Kruskal-Wallis test due to the lack of normality and homoscedasticity in the density data. No significant differences in fish densities were detected between the reserve and comparison area (Table 6). The fish observations in both the MPA and McKenzie Comparison Area consisted only of flatfish likely due to the lack of hard substrates encountered by the sled in these two areas.

Table 6. Mean fish density (indiv./m^2), followed by SE within parentheses, from sled transects completed in 2010-11 for Redfish Rocks Marine Reserve (MR), Marine Protected Area (MPA), and two comparison areas (CA). UNID = unidentified.

Fish species/group	Redfish Rocks MR	Redfish Rocks MPA	Humbug CA	McKenzie Reef CA
Kelp Greenling	0.0035 (0.0017)	0 (0)	0.0012 (0.0007)	0 (0)
Sculpin	0.0034 (0.0029)	0 (0)	0.0011 (0.0011)	0 (0)
Black Rockfish	0.0038 (0.0038)	0 (0)	0.0058 (0.0058)	0 (0)
Blue Rockfish	0.0099 (0.0067)	0 (0)	0.0011 (0.0011)	0 (0)
Cabezon	0.0007 (0.0005)	0 (0)	0.0002 (0.0002)	0 (0)
Canary Rockfish	0.0014 (0.0014)	0 (0)	0.0007 (0.0007)	0 (0)
Lingcod	0.0017 (0.0011)	0 (0)	0.0004 (0.0003)	0 (0)
Prickleback	0.0003 (0.0003)	0 (0)	0 (0)	0 (0)
UNID Fish	0.0023 (0.0021)	0 (0)	0.0013 (0.0006)	0 (0)
UNID Flatfish	0.0282 (0.012)	0.0147 (0.0072)	0.0336 (0.0098)	0.0117 (0.0105)
UNID Juvenile Rockfish	0.007 (0.0058)	0 (0)	0.0026 (0.0017)	0 (0)
UNID Rockfish	0.0161 (0.0122)	0 (0)	0.0039 (0.0031)	0 (0)
UNID Roundfish	0.0047 (0.0035)	0 (0)	0.0091 (0.0059)	0 (0)
Yellowtail Rockfish	0.0003 (0.0003)	0 (0)	0 (0)	0 (0)

Fish community composition
Species specific identification was low during the 2010-11 sled tows; the majority of the fish observations were categorized as unidentified fish, flatfish, or rockfish (Table 6). Once unidentified fishes were excluded from the analysis, only eight of the 24 sled transects contained species-specific fish observations. Without species-specific resolution in the density data, exploring community composition among the marine reserve and comparison sites is not informative. Hence, ANOSIM analyses were not conducted on the fish data from sled tows in Redfish Rocks for 2010-11.

Mobile invertebrate density
ANCOVA analysis (continuous covariate = mean transect depth, factor = sampling area) was used to compare mean mobile invertebrate density (indiv./m^2), $\log_{10}$ transformed to achieve normality, among the reserve, MPA, and comparison areas while exploring the influence of depth (m). Total mobile invertebrate density did not vary with mean transect depth (ANCOVA; P = 0.92), nor was there a significant interaction between depth and sampling area (P = 0.76). There was no significant difference in mean mobile invertebrate density between Redfish Rocks Marine Reserve (mean = 0.430 ± 0.15 SE), MPA (mean = 0.037 ± 0.017 SE), the Humbug Comparison Area (mean = 0.098 ± 0.038 SE), and the McKenzie Reef Comparison Area (mean = 0.091 ± 0.057 SE; ANCOVA, P = 0.27).

Mobile invertebrate species-specific differences
Mean densities of individual species or species groups were compared using a non-parametric Kruskal-Wallis test due to the lack of normality and homoscedasticity in the density data. No significant differences in mobile invertebrate densities were detected between the Redfish Rocks Marine Reserve, MPA, and comparison areas (Table 7).

Table 7. Mean mobile invertebrate density (indiv./m^2), followed by SE within parentheses, from sled transects completed in 2010-11 for Redfish Rocks Marine Reserve (MR) , Marine Protected Area (MPA), and Humbug and McKenzie Reef Comparison Areas (CA).

Mobile Invertebrate	Redfish Rocks MR	Redfish Rocks MPA	Humbug CA	McKenzie Reef CA
Unidentified Crab	0.2184 (0.1548)	0.0083 (0.0032)	0.0064 (0.0022)	0.0628 (0.0424)
Haliotis walallensis	0.0002 (0.0002)	0 (0)	0 (0)	0 (0)
Hermit Crab	0.1407 (0.0784)	0.0076 (0.0024)	0.0785 (0.0488)	0.0048 (0.0012)
Mysid	0.002 (0.0016)	0 (0)	0.0035 (0.0028)	0 (0)
Sand Dollar	0 (0)	0 (0)	0.0003 (0.0003)	0.0042 (0.0042)
Sea Star and Brittle Star	0.0325 (0.0069)	0.0028 (0.0018)	0.0153 (0.0052)	0.0191 (0.0179)
Sea Urchin	0.0018 (0.0018)	0 (0)	0 (0)	0 (0)
Basket Star	0 (0)	0 (0)	0.0003 (0.0003)	0 (0)
Chiton	0 (0)	0 (0)	0.0002 (0.0002)	0 (0)
Clam	0.0001 (0.0001)	0 (0)	0 (0)	0 (0)
Metacarcinus magister	0 (0)	0.0007 (0.0007)	0.0013 (0.0007)	0 (0)
Nudibranch	0.0006 (0.0006)	0 (0)	0 (0)	0 (0)
Sea Cucumber	0.0016 (0.0012)	0 (0)	0.0006 (0.0003)	0 (0)
Shrimp	0.0004 (0.0004)	0 (0)	0.0004 (0.0003)	0 (0)
Snail	0.0043 (0.0029)	0 (0)	0.0027 (0.0018)	0 (0)
Pycnopodia helianthoides	0.0015 (0.0007)	0 (0)	0.0017 (0.0009)	0 (0)
Worm	0.0245 (0.0133)	0.0141 (0.0141)	0.0007 (0.0007)	0 (0)

Mobile invertebrate community composition

ANOSIM (factor = sampling area) was used to explore differences in community composition of mobile invertebrates. Density data was first square root transformed, then Bray-Curtis similarity calculated for each transect. ANOSIM did not reveal any significant grouping of the observed mobile invertebrate communities among the four sampling areas ($P = 0.21$; Global R: 0.065).

Sessile invertebrate density

Mean sessile invertebrate density (indiv./m^2) was $\log_{10}$ transformed to achieve normality and ANOVA (factor = sampling area) used to determine if mean densities differed among sampling areas. There was no significant difference in mean sessile invertebrate density between Redfish Rocks Marine Reserve (mean = 0.114 ± 0.04 SE), the MPA (mean = 0.004 ± 0.001 SE), the Humbug Comparison Area (mean = 0.050 ± 0.028 SE), and the McKenzie Reef Comparison Area (mean = 0.023) P = 0.21).

Sessile invertebrate species-specific differences

Mean densities of individual species or species groups were compared using non-parametric Kruskal-Wallis test due to the lack of normality and homoscedasticity in the density data. Sea pens differed significantly in abundance between the Redfish Rocks MPA and Humbug Comparison Area ($P = 0.024$). No other significant differences in sessile invertebrate densities were detected between the reserve and comparison area (Table 8).

Table 8. Mean mobile invertebrate density (indiv./m^2), followed by SE within parentheses, from sled transects completed in 2010-11 for Redfish Rocks Marine Reserve (MR) , Marine Protected Area (MPA),

and Humbug and McKenzie Reef Comparison Areas (CA). * denotes a significant difference in mean density between the MR and CA. Only a single sea anemone was observed in McKenzie Reef CA so no SE presented.

Sessile Invertebrate	Redfish Rocks MR	Redfish Rocks MPA	Humbug CA	McKenzie Reef CA
Balanus glandula	0.0004 (0.0004)	0 (0)	0.0002 (0.0002)	0
Urticina spp.	0.002 (0.0015)	0 (0)	0.0005 (0.0005)	0
Hydroid	0.002 (0.002)	0 (0)	0.0002 (0.0002)	0
Metridium spp.	0.0456 (0.0396)	0 (0)	0.022 (0.0174)	0
Gorgonian	0.0119 (0.0082)	0 (0)	0.007 (0.0043)	0
Sea Pen*	0.0004 (0.0004)	0.0035 (0.0015)	0.0001 (0.0001)	0
Balanophyllia elegans	0.0148 (0.0148)	0 (0)	0.0122 (0.0092)	0
Crassedoma giganteum	0.0012 (0.0008)	0 (0)	0 (0)	0
Sea Anemone	0.035 (0.0192)	0 (0)	0.0077 (0.005)	0.024
Sponge	0.0004 (0.0004)	0 (0)	0 (0)	0

Sessile invertebrate community composition

Species specific identification was low during the 2010-11 sled tows. Without species-specific resolution in the density data, exploring community composition among the marine reserve and comparison sites is not informative. Additionally, low densities (i.e. often a single organism type was observed during the entire transect), make a community composition analysis unreasonable. Hence, ANOSIM analyses were not conducted on the sessile invertebrate data from sled tows in Redfish Rocks for 2010-11.

C.3. SCUBA

All results from SCUBA visual surveys in Redfish Rocks are found in Appendix A.

C.4. Remotely Operated Vehicle (ROV)

To date, ROV data processing and analysis is ongoing. Results will be added to this report as an addendum at a later date.

D. Extractive Surveys

D.1. Red Sea Urchins

Study design included replicate quadrats sampled along a single transect, with multiple transects occurring within each study area.

Urchin Density

To compare urchin density among the three study areas, urchin density was first calculated as a mean from the replicate quadrats within a single transect, and then ANOVA analysis used to test whether urchin density varied among the areas. Red urchin (*Strongylocentrotus franciscanus*) density (indiv./m2) was log10+1 transformed to achieve normality and compared among the Redfish Rocks Marine Reserve (n=16) and the Humbug (n=15) and Orford Reef Comparison Areas (n=39). Mean urchin density differed significantly among the three areas (Figure 6; ANOVA; F2, 67 = 3.23, P <0.046). Urchins were significantly more abundant within the reserve compared to the Humbug Comparison Area (Tukey's post-hoc analysis).

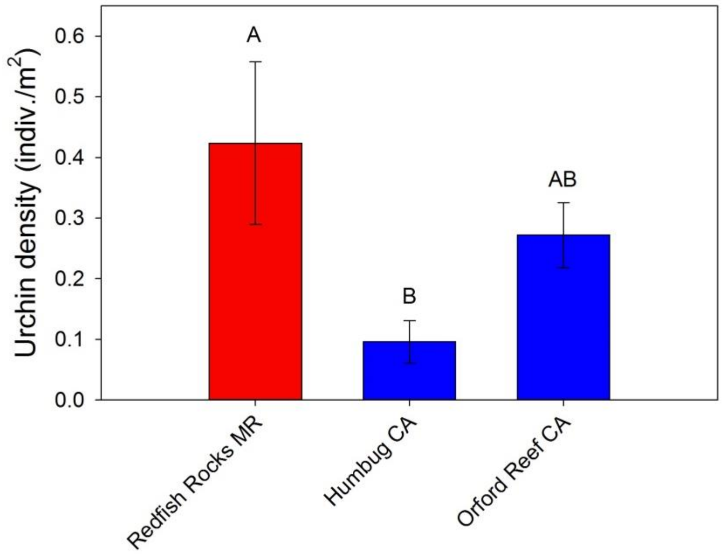


Figure 6. Mean urchin density (indiv./m2) ± SE of red urchins between Redfish Rocks Marine Reserve (MR) and the Humbug and Orford Reef Comparison Areas (CA). Shared letter groups above the bars indicate statistically similar means (single-factor ANOVA, followed by Tukey's post-hoc analysis).

Urchin size

Urchin test diameter (mm) was compared among Redfish Rocks Marine Reserve (n=12) and the Humbug (n=12) and Orford Reef Comparison Areas (n=34). Mean urchin diameter differed significantly among all three area's samples (Figure 7; ANOVA; F2, 55 = 6.67, P =0.003). Urchins were smaller within the reserve and larger in the two comparison areas (Tukey's post-hoc analysis).

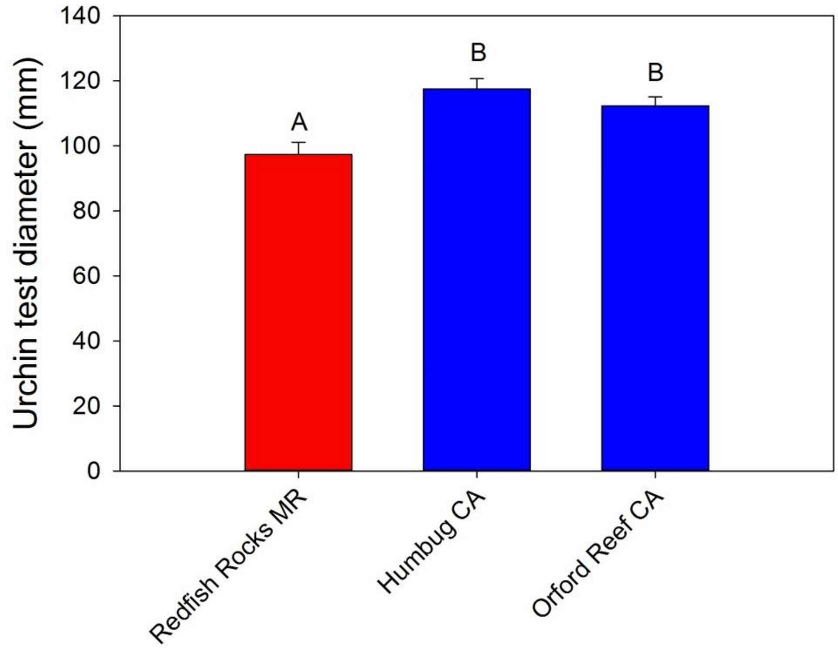


Figure 7. Mean urchin test diameter (mm) ± SE of red urchins between Redfish Rocks Marine Reserve and two adjacent comparison areas. Shared letter groups above the bars indicate statistically similar means (single-factor ANOVA, followed by Tukey's post-hoc analysis).

Population structure

Size frequency distributions of test diameter showed significantly different population structure of the urchins within the reserve compared to the comparison areas (Kolmogorov-Smirnov test, KS = 0.146, Dmax = 0.307, $P < 0.001$). The urchin community is negatively-skewed in the comparison areas and supports a larger maximum size class than the reserve community, which exhibit a smaller and normally-distributed size distribution (Figure 8).

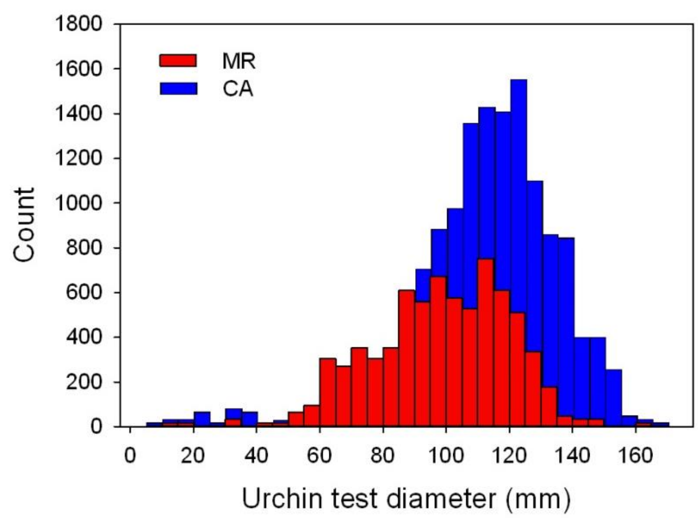


Figure 8. Size frequency distributions of red urchins from the marine reserve and the two comparison areas (urchin sizes pooled between Humbug and Orford Reef Comparison Areas).

Red urchin populations differed significantly between the Redfish Rocks Marine Reserve and the two comparison areas. Urchins in the reserve were smaller yet more abundant than their counterparts in the two comparison areas. These different baseline conditions among the red urchin population will be crucial to accurately assessing change over time due to no-take protection.

D.2. Benthic Extraction: Rocky Reef Macroalgae

Community composition

Slight differences exist in the community composition of macroalgae between the reserve and the Humbug Comparison Area (ANOSIM, Global $R = 0.23$, $P = 0.001$, based on Bray-Curtis similarity on 4th root transformed macroalgal biomass). At the transect-scale, 38% similarity is shared among both the reserve and comparison area sites (Figure 9).

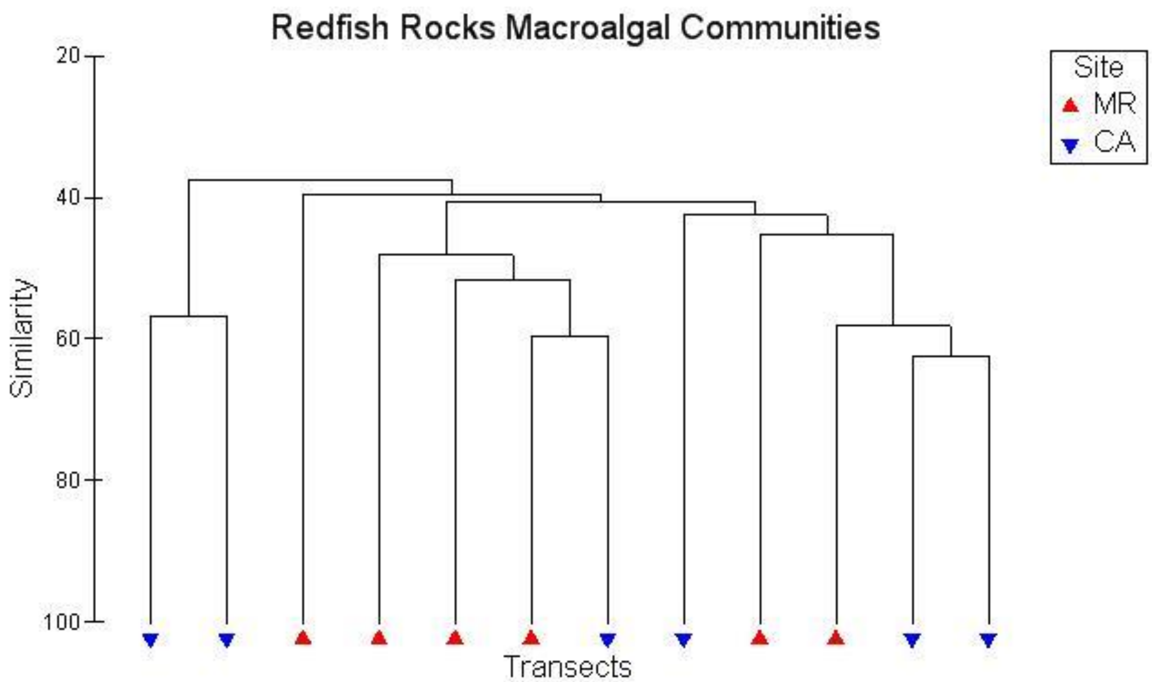


Figure 9. Cluster diagram of Bray-Curtis similarity of macroalgal community composition (biomass) among transects sampled inside the Redfish Rocks Marine Reserve (red) and the Humbug Comparison Area (blue). Biomass of macroalgal species were averaged across three replicated quadrats per transect to generate mean community composition at the transect-scale.

Species differences

Species-specific differences exist in relative abundance of macroalgae between the Redfish Rocks Marine Reserve and Humbug Comparison Area. The eight algal species listed are the most dominant species sampled (each comprising >1% of the total macroalgal biomass collected) and constitute 97% of the marine reserve biomass and 92% of the comparison area biomass. Reserve response ratios were used to compare differences in biomass between the reserve and comparison area for these dominant species (Figure 10).

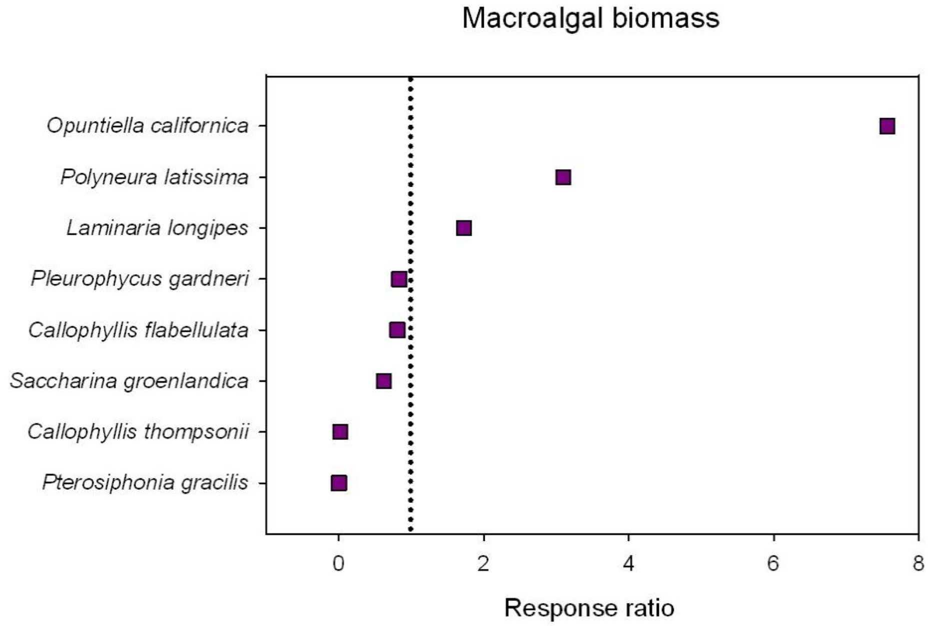


Figure 10. Baseline response ratios (inside reserve/outside reserve) for the most common macroalgal species (> 1% of the total sampled community biomass) at Redfish Rocks. Biomass means (based on transect averages) were ($\log_{10}$ +1) transformed prior to calculating the response ratios to reduce the biomass differences between the reserve and comparison area for graphing purposes. Species to the right of the dashed line are more prevalent within the reserve; those to the left are more prevalent in the Humbug Comparison Area.

Macroalgal Biomass

The Redfish Rocks Marine Reserve supports nearly 4x the total biomass of macroalgae (mean = 469 g/m^2 ± 200 SE) present in the Humbug Comparison Area, though the high variability among sample transects in the reserve makes this difference not statistically significant (mean = 129 g/m^2 ± 36 SE; T-test, t ratio= 1.62, df = 10.0, P = 0.14; Figure 11). Data analysis is based on mean biomass per transect.

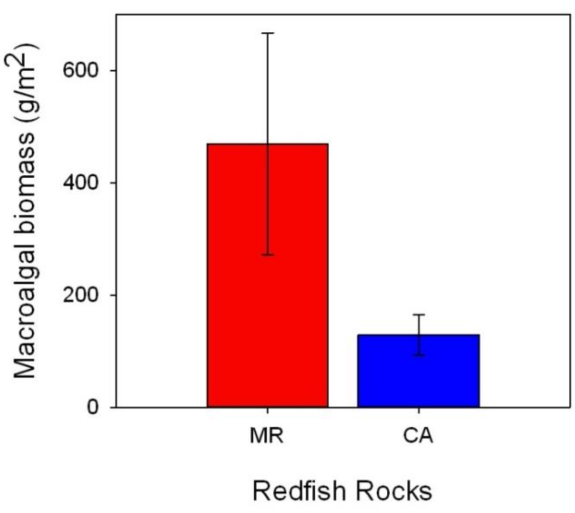


Figure 11. Mean macroalgal biomass (g) per m^2 in the Redfish Rocks Marine Reserve (MR) and the Humbug Comparison Area (CA).

Species diversity

The species richness of the macroalgal community did not differ between the Redfish Rocks Marine Reserve (mean = 39.1 species/m^2 ± 5.5 SE) and the Humbug Comparison Area (mean = 34.4 species/m^2 ± 6.9 SE; T-test, t ratio= 0.53, df = 10.0, P = 0.61; Figure 12). Data analysis based on mean species richness per transect.

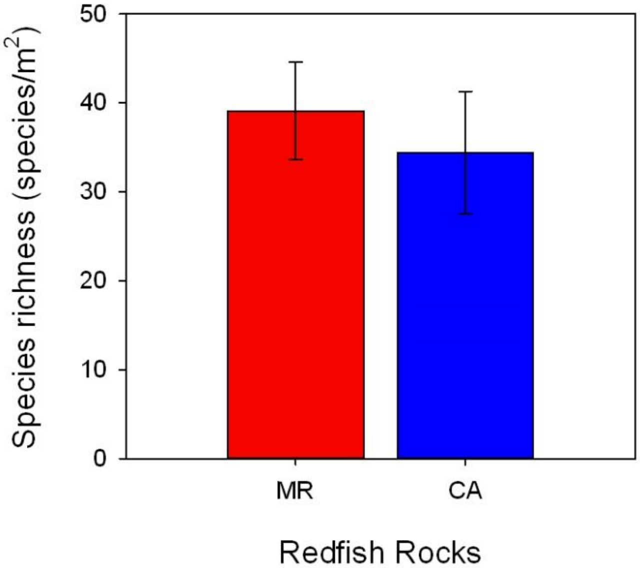


Figure 12. Mean species richness in the Redfish Rocks Marine Reserve (MR) and the Humbug Comparison Area (CA).

While macroalgal species richness and biomass did not differ significantly between Redfish Rocks Marine Reserve and the Humbug Comparison Area, macroalgae was nearly four times more abundant in the reserve. These differences in biomass were largely driven by three macroalgal species: the red alga, Polyneura latissima; the brown northern rhizome kelp, Laminaria longipes; and brown broad-ribbed kelp, Pleurophycus gardneri. Species-accumulation curves predicting species richness through Chao2 and Jacknife extrapolation permutations indicate that we are likely under-sampling the total macroalgal diversity of these regions (Colwell and Coddington 1994); however, budgetary constraints limit increased sampling at this time.

D.2. Benthic Extraction: Rocky Reef Invertebrates

Community Composition

Community composition did not vary between quadrats sampled in the reserve versus comparison areas (ANOSIM, Global R = 0.06, P = 0.057, based on Bray-Curtis similarity on square root transformed invertebrate biomass, g/m^2). At the transect-scale, 66% similarity is shared among both reserve and comparison area transects (Figure 13).

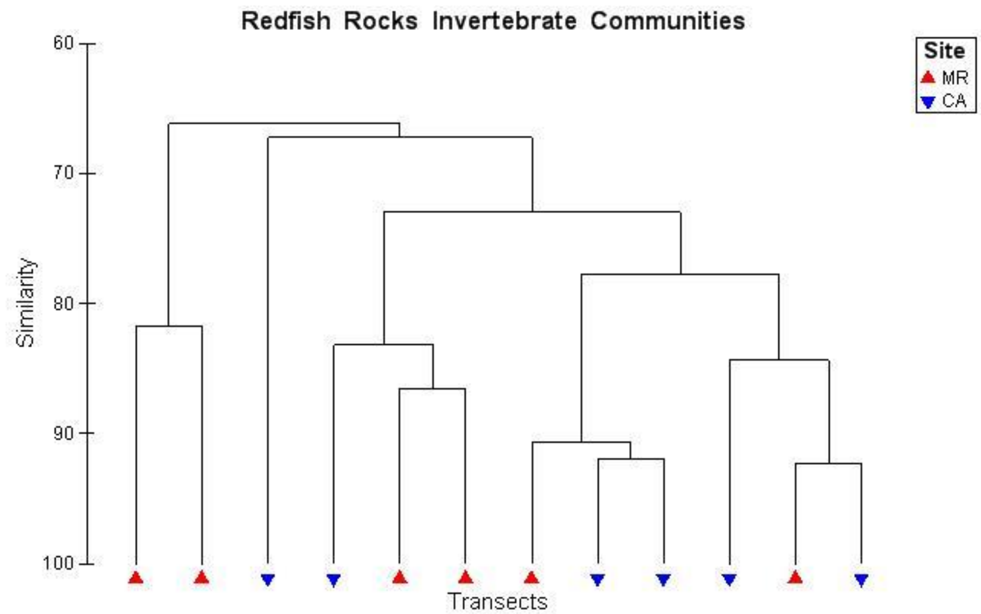


Figure 13. Cluster diagram of Bray-Curtis similarity of invertebrate community composition (biomass) among transects sampled inside the Redfish Rocks Marine Reserve (red) and the Humbug Comparison Area (blue). Biomass of invertebrate phyla were averaged across three replicate quadrats per transect to generate mean community composition at the transect-scale.

Phyla differences

Differences in biomass per phylum were explored between the Redfish Rocks Marine Reserve and the Humbug Comparison Area. High variability among transects led to no significant differences between the reserve and comparison area despite large differences in means for both Porifera and Mollusca (t-test using $\log_{10}(x+1)$ transformed biomass; Figure 14).

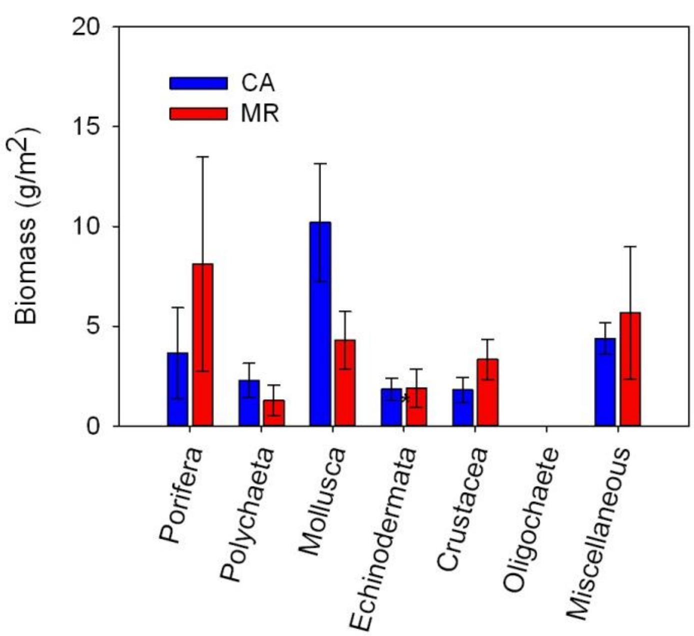


Figure 14. Mean biomass (g/m^2) ± SE of varying phyla between Redfish Rocks Marine Reserve (MR) and Humbug Comparison Area (CA). Data based on replicate transect means.

Porifera community composition

Eight sponge families were found to be the most dominant families sampled (comprising >1% of the total sponge volume collected) and constituted 98% of the marine reserve sponge volume and 97% of the Humbug Comparison Area volume. Reserve response ratios were used to compare differences in sponge family volume between the reserve and comparison area for these dominant groups (Figure 15). There were no significant differences in volume between the reserve and comparison area for these eight most abundant families (ANOVA, $P > 0.05$).

rese

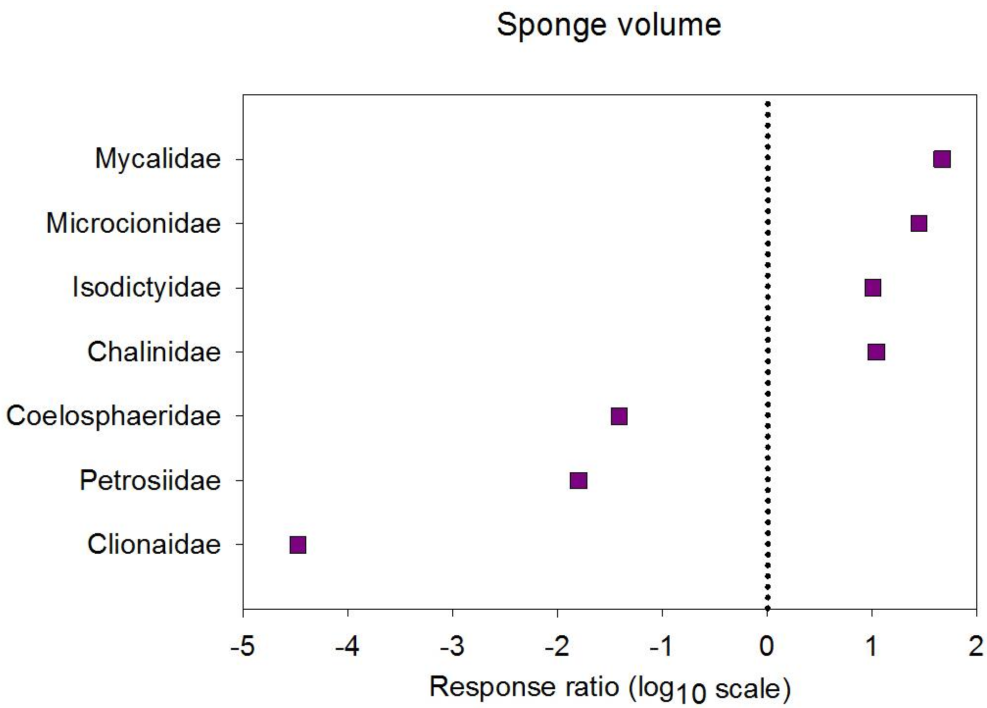


Figure 15. Baseline response ratios (volume inside reserve/volume outside reserve) for the dominant sponge families (comprising >1% of total biomass) at Redfish Rocks. Ratios are presented on a $\log_{10}$ scale due to the wide range of the ratios generated among the seven sponge families. Families to the right of the dashed line are more prevalent within the reserve; those to the left are more prevalent in the Humbug Comparison Area. Although Family Tetillidae was greater than 1% of the total sampled community biomass it was not encountered in the reserve, hence no response ratio is possible.

Similarly, the total volume of sponges did not differ between the reserve (mean = 15.71 $cm^3/m^2 \pm 10.24$ cm^3/m^2 SE) and comparison area (mean = 9.07 $cm^3/m^2 \pm 4.65$ cm^3/m^2 SE; T-test, t ratio= -0.44, df = 9.41, $P = 0.67$). Nor did the diversity of the sponge community (based on taxonomic family) differ between the reserve (mean = 1.67 families ± 0.31 SE) and the comparison area (mean = 1.89 families ± 0.40 SE; T-test, t ratio= -0.44, df = 9.41, $P = 0.67$). Data analysis was based on replicate transect means.

Abundance and biomass

Invertebrate biomass at Redfish Rocks Marine Reserve (mean = 98.4 $g/m^2 \pm 31$ SE) is not significantly different from the Humbug Comparison Area (mean = 96.7 $g/m^2 \pm 20$ SE; Wilcoxon test, $P = 0.87$). Similarly, invertebrate abundance at the reserve (mean = 412.7 indiv./$m^2 \pm 121$ SE) is not significantly different from the comparison area (mean = 399.1 indiv./$m^2 \pm 54$ SE; Wilcoxon test, $P = 0.69$). Data analysis was based on replicate transect means.

The mean biomass of various invertebrate phyla was not found to vary between the Redfish Rocks Marine Reserve and the Humbug Comparison Area, though the taxonomic resolution achieved in the macroalgal data was not available for the invertebrate dataset (with the exception of Porifera). With the assistance of Dave Alvin of the Oregon Porifera Project, sponge volumes were generated for taxonomic families, though again, no significant changes in community composition at the family-level was detected between the reserve and the comparison area.

D.3. Hook-and-Line Survey

Community composition

For each fish species caught during the 2011 hook and line surveys, catch rates (CPUE; catch per unit effort) were calculated by dividing the total number of fish caught in a drift by the combined fishing effort for that drift. For BPUE (biomass per unit effort) the sum of all fish weights caught in a drift was divided by the total angler hours of that drift. Analyses were conducted on BPUE and CPUE data averaged by sampling day and sampling area (i.e. MR versus CA).

No differences existed in the community composition of fish caught (CPUE) between Redfish Rocks Marine Reserve and the Humbug Comparison Area (ANOSIM, Global R = 0.001, P = 0.425 based on Bray-Curtis similarity on 4th root transformed CPUE data). Likewise, depth was not a significant factor distinguishing community composition (ANOSIM, Global R = 0.1, P= 0.001). However, fish community composition as BPUE differed significantly among months in which the hook and line surveys were conducted (June-September 2011), underscoring the need to sample equally in and out of the reserve across survey months (ANOSIM, Global R = 0.55, P = 0.001; Figure 16 & 17).

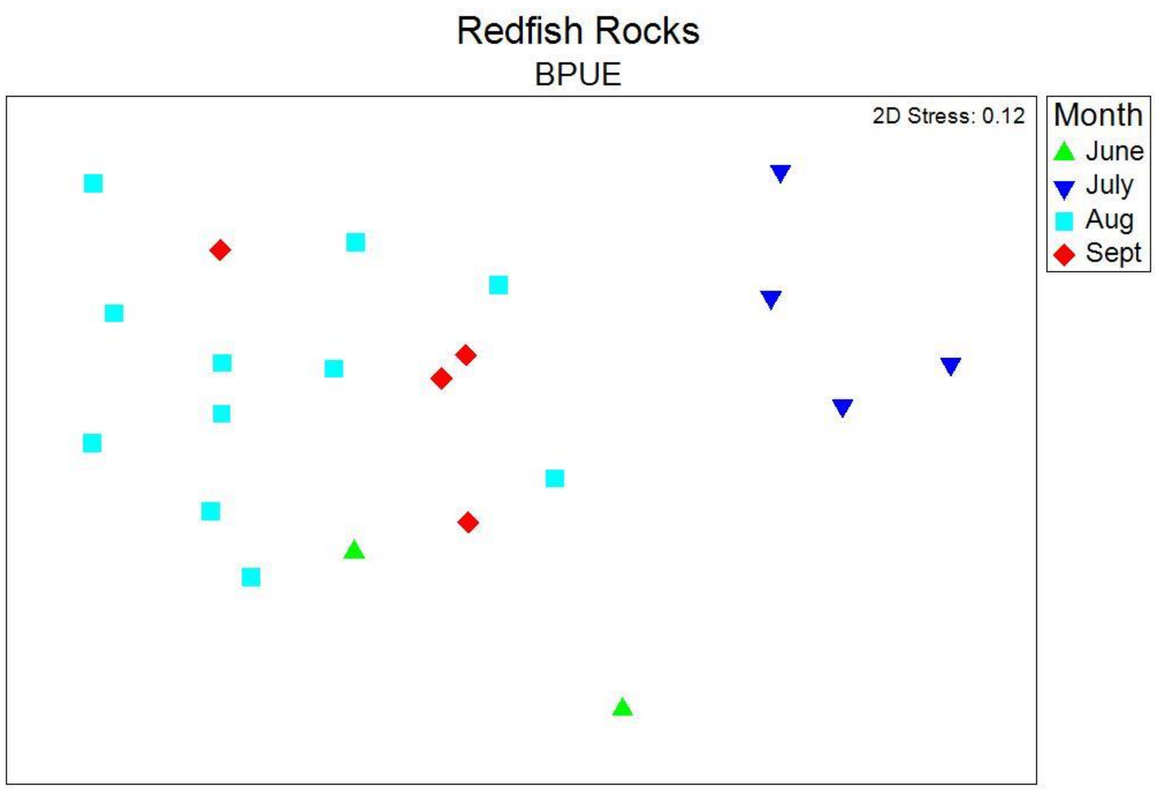


Figure 16. nMDS plot of biomass per unit effort (BPUE) data for all fish species caught in Redfish Rocks Marine Reserve and the Humbug Comparison Area. Colors indicate the month in which hook and line surveys were conducted.

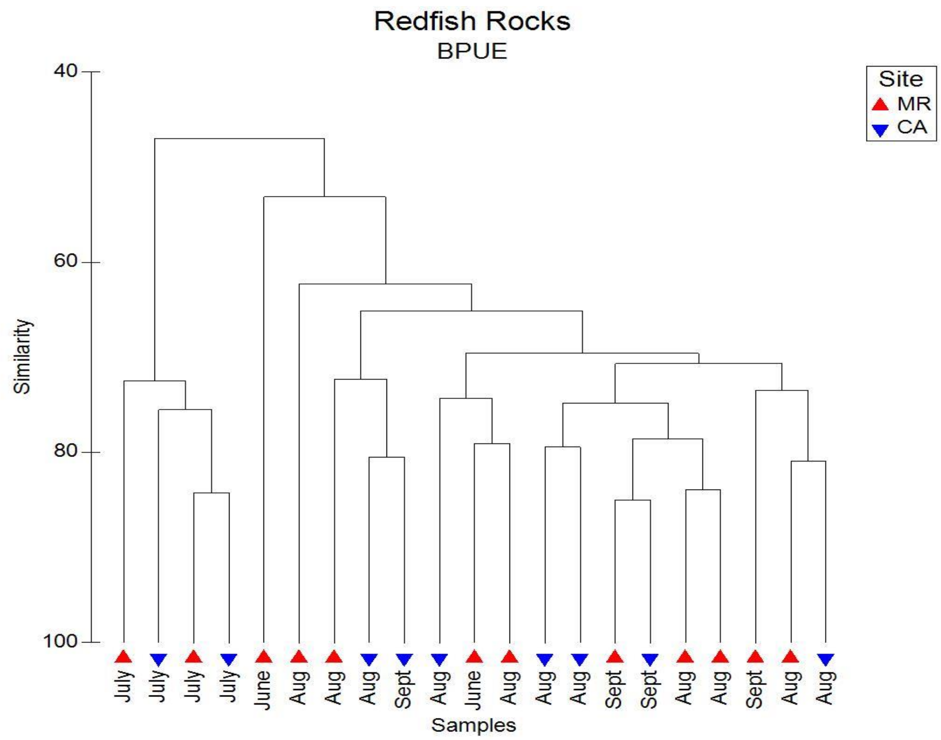


Figure 17. Cluster diagram of Bray-Curtis similarity of fish community composition (BPUE) among hook and line surveys conducted inside the marine reserve (red) and the Humbug Comparison Area (blue). Surveys along the x-axis are labeled by the sampling month in which the survey occurred.

Species differences

CPUE for individual species inside and outside the reserve were compared using the non-parametric Wilcoxon rank sums test. Species compositions were very similar between Redfish Rocks Marine Reserve and the Humbug Comparison Area (Figure 19). For several of the rarely caught species, more were caught per unit effort inside the reserve than outside, but this difference was only significant for China Rockfish (Wilcoxon rank-sums test, z= -2.96, p = 0.003).

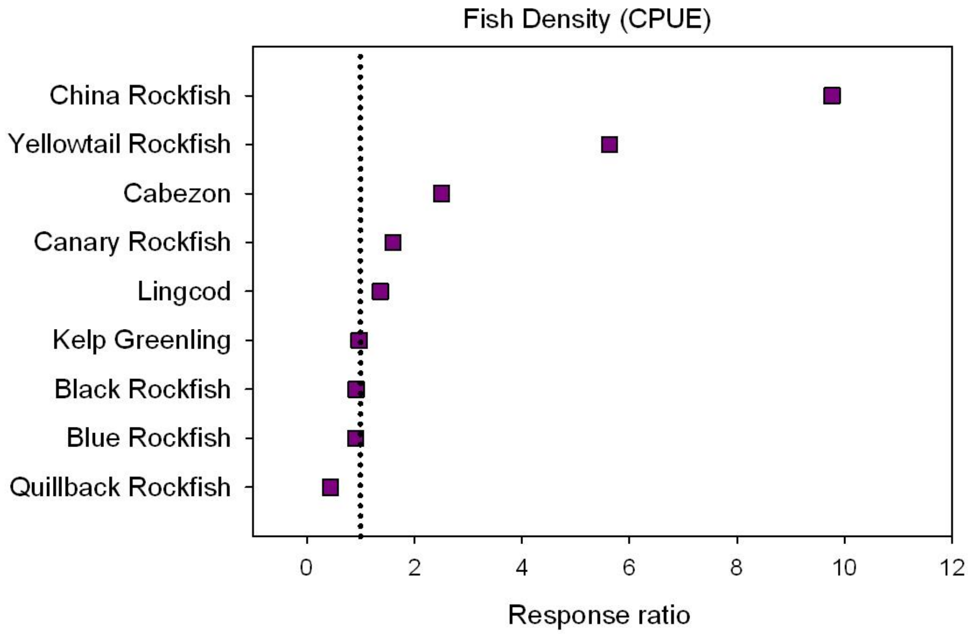


Figure 19. Baseline response ratios (inside reserve/outside reserve) of CPUE data for fish species comprising >1% of the total CPUE, irrespective of reserve boundary. Fishes to the right of the dashed line are more prevalent within the reserve; those to the left are more prevalent in the Humbug Comparison Area. Data presented is untransformed.

Biomass

A two-tailed t-test was used to determine differences of log transformed BPUE (all species combined) inside and outside the reserve. Redfish Rocks Marine Reserve had similar fish biomass per unit effort (mean = 10.18 kg/hr ± 1.80 SE) as the Humbug Comparison Area (mean = 9.08 kg/hr ± 1.74 SE; T-test, log transform, t ratio= -0.67, df = 98, P = 0.50; Figure 20).

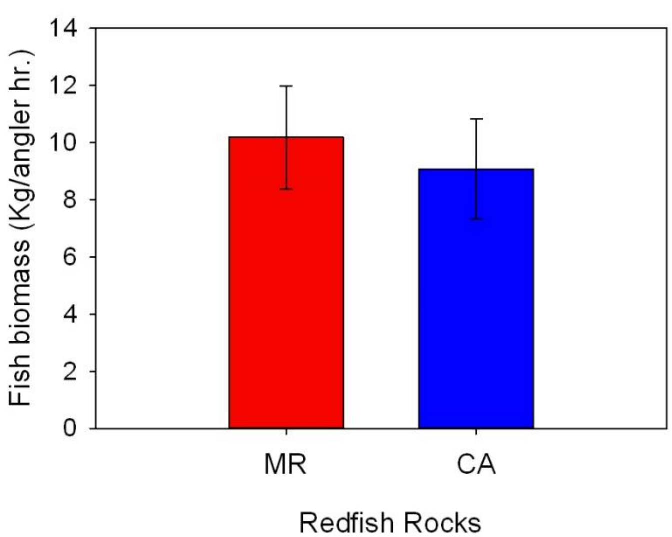


Figure 20. Mean biomass per angler hour in the Redfish Rocks Marine Reserve and Humbug Comparison Area. Error bars represent standard error.

Fish size and weight

Average fork length (FL), when compiled across all sampling depths, differed significantly between the reserve and comparison area for Black Rockfish and Kelp Greenling (Table 9). The grand average of Black Rockfish was larger in the reserve, but when fish caught within 20ft depth bins were compared inside and outside the reserve, no significant differences were found in any depth bin. When average fork length in 20ft depth bins were compared for Kelp Greenling, only fish caught within the 40-59ft bin were significantly different, with longer fish at the reserve.

Table 9. Mean fish fork lengths for Redfish Rocks Marine Reserve and Humbug Comparison Area. Lengths presented are binned by depth (ft) as well as averaged across all depths for the four most commonly caught fish species. Significant values are indicated in bold text (α = 0.05).

		Mean fork length (mm)				
Species	Depth Range (ft)	Redfish Rocks MR	Humbug CA	DF	t-ratio	p
Black Rockfish	40-59.9	380.8	367.7	113	1.53	0.13
	60-79.9	391.5	379.9	106	1.64	0.10
	80-99.9	400.1	389.7	172	1.68	0.09
	100-119.9	416.4	427.0	102	-1.28	0.20
	all depths	398.1	388.8	523	**2.37**	**0.02**
Blue Rockfish	40-59.9	304.0	282.6	8	0.77	0.46
	60-79.9	300.5	274.3	19	1.50	0.15
	80-99.9	300.0	303.2	54	-0.30	0.76
	100-119.9	314.5	338.8	15	-1.15	0.26
	all depths	302.8	300.3	114	0.31	0.76
Kelp Greenling	40-59.9	359.8	310.7	17	**3.85**	**0.00**
	60-79.9	328.4	331.5	24	-0.30	0.75
	80-99.9	330.2	325.4	18	0.34	0.74
	100-119.9	290.0	343.8	n/a	n/a	n/a
	all depths	342.5	325.3	94	**2.49**	**0.01**
Lingcod	40-59.9	512.4	570.0	n/a	n/a	n/a
	60-79.9	507.2	552.9	10	-1.06	0.31
	80-99.9	646.7	527.7	9	**2.29**	**0.05**
	100-119.9	606.0	514.1	8	1.79	0.11
	all depths	540.0	530.2	95	0.51	0.61

Mean fish weights, when averaged across all sampling depths, did not differ significantly between the reserve and comparison area, except for Black Rockfish (Table 10). When depth bins were analyzed separately, fish weighed significantly more in 40-59.9ft depths and 80-99.9 ft depths. Kelp Greenlings were significantly heavier at the reserve, but only in the shallowest depth bin.

Table 10. Mean fish weights (kg) for Redfish Rocks Marine Reserve and Humbug Comparison Area. Weights presented are binned by depth (ft) as well as averaged across all depths for the four most commonly caught fish species. Significant values are indicated in bold text (α = 0.05).

Species	Depth Range (ft)	Mean fish weight (kg) Redfish Rocks MR	Humbug CA	DF	t-ratio	p
Black Rockfish	40-59.9	1.1	0.9	115	**2.46**	**0.02**
	60-79.9	1.1	1.0	99	1.53	0.13
	80-99.9	1.2	1.1	175	**1.92**	**0.05**
	100-119.9	1.3	1.4	88	-1.00	0.32
	all depths	1.2	1.1	520	**3.41**	**0.00**
Blue Rockfish	40-59.9	0.6	0.5	6	0.76	0.47
	60-79.9	0.6	0.5	19	1.15	0.26
	80-99.9	0.6	0.6	52	-0.06	0.95
	100-119.9	0.6	0.8	15	-1.17	0.26
	all depths	0.6	0.6	107	0.39	0.07
Kelp Greenling	40-59.9	0.7	0.4	18	**3.87**	**0.00**
	60-79.9	0.5	0.5	22	-1.07	0.30
	80-99.9	0.5	0.5	18	-0.04	0.97
	100-119.9	0.3	0.7	n/a	n/a	n/a
	all depths	0.6	0.5	91	1.36	0.17
Lingcod	40-59.9	1.2	1.8	n/a	n/a	n/a
	60-79.9	1.2	1.7	8	-1.20	0.26
	80-99.9	2.9	1.5	7	1.68	0.13
	100-119.9	2.3	1.3	6	1.69	0.14
	all depths	1.6	1.5	95	0.54	0.53

Fish length frequency distributions of the four most commonly caught species did not differ between the reserve and comparison area, except for Black Rockfish (Figure 18; K-S 2-sample test, P = 0.013). Similarly, of the four most commonly caught species, only Black Rockfish weights differed between the reserve and comparison area (K-S 2-sample test, p = 0.0057). Black Rockfish in the reserve exhibited a skewed distribution towards larger, heavier individuals compared to the comparison area.

Published fork lengths at 50% maturity (Echeverria 1987; Silberberg et al. 2001) are shown for Black Rockfish, Blue Rockfish, and Lingcod suggesting that many of the fishes caught in our study were sexually mature (Figure 21).

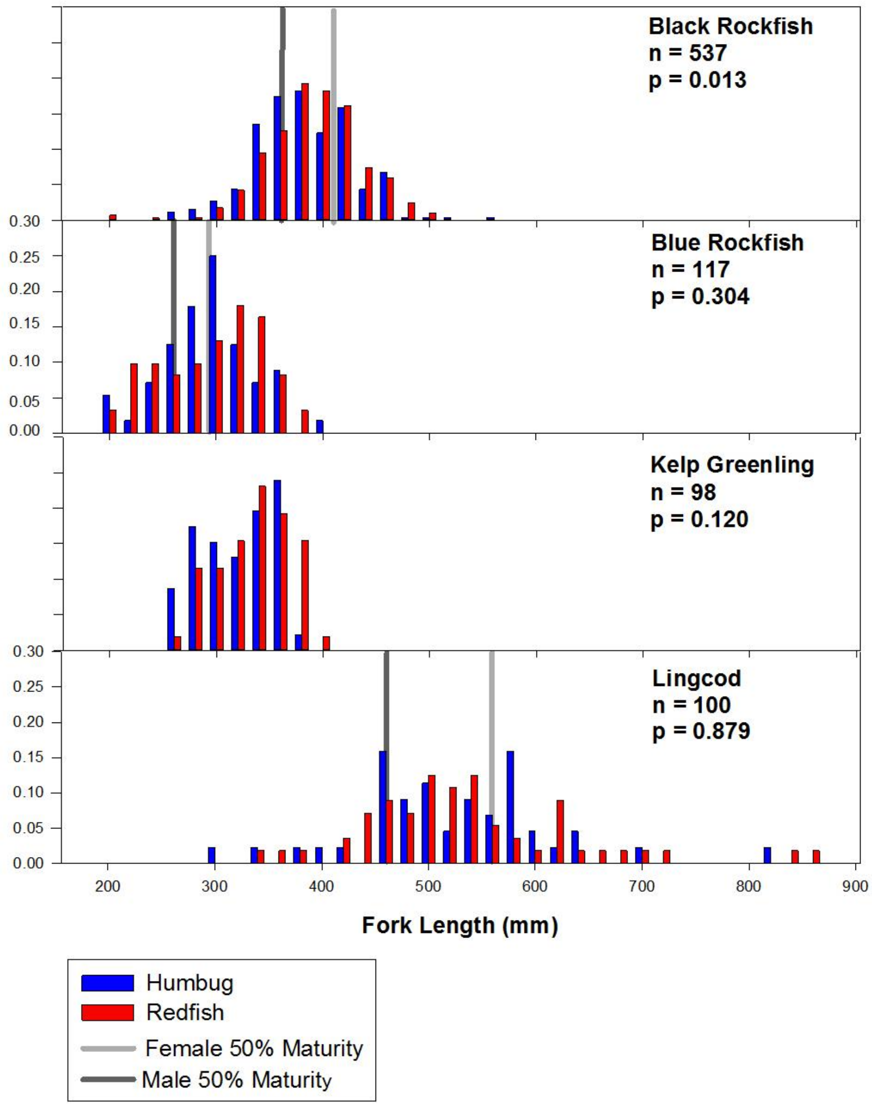


Figure 21. Fork length distributions for the four most commonly caught species. Vertical lines represent age at 50% maturity for females (light grey) and males (dark grey) from published data (Echeverria 1987; Silberberg et al. 2001). P-values are the result of Kolmogorov-Smirnov 2-sample tests comparing data from Humbug and Redfish.

The fish community composition captured through hook and line surveys were similar among the Redfish Rocks Marine Reserve and Humbug Comparison Area. Furthermore, response ratios for the four most commonly caught fish species (Black Rockfish, Blue Rockfish, Lingcod, and Kelp Greenling) were extremely close to one, indicating that catch per unit effort for these species were very similar inside the reserve compared to the Humbug Comparison Area. The lack of significant difference in total fish biomass between the reserve and comparison area again indicate the fish community composition and size structure is similar among the reserve and the comparison area overall. However, some caution should be used when interpreting CPUE data as it has long been recognized that CPUE may not accurately reflect true abundance (Beverton and Holt 1957).

Fish length data by species reveal that Black Rockfish, Kelp Greenling, and Lingcod (at specific depths) are significantly larger in the reserve, though these differences disappear for Kelp Greenling and Lingcod when viewed across all depths fished. These baseline size frequency distributions for these common species will be used to assess further changes in fish size structure through time.

Individual age data (determined from otoliths) and sexual maturity (determined from gonad samples) have yet to be processed from the 2011 hook and line samples. Once those samples are processed, they will be used to establish ecological baselines from which to assess change in average fish age for Black Rockfish.

E. Discussion

Oceanography

Baseline monitoring, consisting of oceanographic, habitat and biological data, was completed over two years prior to the closure of Redfish Rocks Marine Reserve to extractive activities on January 1, 2012. Oceanographic data indicate that water temperature, dissolved oxygen, and salinity were comparable over time between the marine reserve and the Humbug Comparison Area (data collected in 2012-13). Temperature in particular varied within half a degree Celsius (0.5°C) between the reserve and Humbug Comparison Area. Although our oceanographic baseline comparisons are spatially limited, the high agreement between the oceanographic variables measured in the Redfish Rocks Marine Reserve and Humbug suggests that Humbug is an appropriate oceanographic comparison to the reserve. On-going monitoring of oceanographic data will continue over time, enabling more robust long-term comparisons. In addition, oceanographic monitoring will expand to track temperature data at the Orford Reef and McKenzie Reef Comparison Areas, facilitating the comparison of oceanographic conditions at these additional comparison areas to the marine reserve.

Habitats

Systematic Rapid Assessments of the habitats in the reserve and the Humbug and McKenzie Reef Comparison Areas reveal that proportion of substrate types are very similar between the reserve and Humbug. Both areas are approximately two-thirds sand substrate; with the remaining dominate substrate (~1/3) comprised of consolidated rocky reefs (i.e. bedrock and boulder). In contrast, McKenzie Reef is approximately two-thirds consolidated habitat with the remainder sand. Orford Reef is almost entirely consolidated bedrock habitat. The MPA is primarily sand and mud habitat. Hence, the Humbug Comparison Area is the most directly comparable substrate composition to the marine reserve.

Fishes

Underwater visual surveys revealed low abundance of nearshore fishes for both the lander and sled sampling tools. The low abundances combined with limited species-specific identification hindered the assessment of fish community comparisons between the marine reserve and comparison areas. As with the Otter Rock site, fishes were more commonly observed on rugose, consolidated substrates (i.e. bedrock outcrops and boulders) compared to gravel, cobble, and sand substrates. For many species of rockfish observed to species, the relative abundances were significantly higher in the MPA than either the reserve or comparison areas. However, the relative abundances rockfishes were comparable between the reserve and comparison areas in data from both the lander and sled surveys. Similarly, community composition of fishes observed with the lander did not differ between the reserve and comparison areas. In rocky habitats, total fish realtive abundance (all species pooled) was nearly seven times greater in the MPA than in the reserve or comparison areas. SCUBA surveys yielded low fish species richness estimated at the scale of individual transects (~3 taxa per transect), and only slight differences in species richness were seen between Redfish Rocks Marine Reserve and its comparison areas or between any of these sites in successive years. With respect to biodiversity, the McKenzie Comparison Area showed the highest species richness in both 2010 and 2011. The fish assemblage at Redfish Rocks Marine Reserve is characterized by high numbers of Blue and Black Rockfish followed by lower abundance of Kelp Greenling.

Similarity in the fish assemblage between the reserve and comparison areas was supported by hook and line sampling. The community composition of fishes (as either counts or biomass) did not vary among the reserve and Humbug Comparison Area or according to depth. Only China Rockfish were found to be more abundant (CPUE) inside the reserve than in Humbug. Fish community composition as BPUE differed significantly among months in which the hook and line surveys were conducted (June-September 2011), underscoring the need to sample equally in and out of the reserve across survey months. Fish length frequency distributions from SCUBA surveys for the three most common species (Blue and Black Rockfish and Kelp Greenling) show similar patterns between Redfish Rocks Marine Reserve and the comparison areas at McKenzie and Humbug, however median lengths were higher in the reserve area for Kelp Greenling, Black Rockfish in 2011, and for Blue Rockfish in 2010 (see Appendix A for full results of SCUBA surveys). These findings were mirrored in the hook and line length data in which mean lengths of Black Rockfish, Kelp Greenling, and Lingcod (only at specific depths) were higher in the reserve than the Humbug Comparison Area.

Invertebrates
Abundance and community composition of mobile invertebrates were not found to differ between the reserve and comparison areas using the video sled. Similarly, few differences were found in the abundance of sessile invertebrates. Sea pens were more in abundant in the Redfish Rocks MPA compared to the Humbug Comparison Area. Comparison of community composition for sessile invertebrates was not informative with the limited data. In contrast to these patterns from the sled data on sandy substrates, urchin surveys and SCUBA surveys revealed significant differences in the invertebrate community. Red urchin populations differed significantly between the reserve and Humbug and Orford Reef Comparison Areas. Urchins in the reserve were smaller yet more abundant than their counterparts in the two comparison areas. These different baseline conditions among the red urchin population will be crucial to accurately assessing change over time due to no-take protection. SCUBA surveys in the rocky subtidal detected greater species richness of mobile and conspicuous sessile invertebrates at McKenzie Reef Comparison Area than at either Redfish Rocks Marine Reserve or Humbug Comparison Area. Diversity indices, however, were higher at McKenzie in 2010, but higher at Redfish Rocks in 2011. Interestingly, the white plumed anemone, *Metridium* spp., was conspicuously abundant in SCUBA surveys at Redfish Rocks Marine Reserve but absent or rare in either comparison area, perhaps reflecting the abundant vertical substrates within the reserve. While many of the invertebrate species are not of great ecological or economic importance, the differences in their absolute and relative abundance, reflect similarities or dissimilarities in the habitats sampled between the reserve and comparison areas.

Macroalgae
From SCUBA surveys, macroalgal species richness (i.e., number of species per transect) and diversity indices were similar to or slightly higher at the McKenzie and Humbug Comparison Areas than at the Redfish Rocks Marine Reserve in both 2010 and 2011. Extractive surveys found similar results with no significant differences in macroalgal species richness and biomass between the reserve and Humbug. However, macroalgae was nearly four times more abundant in the reserve (albeit not statistically significant). These differences in biomass were largely driven by three macroalgal species: the red alga, *Polyneura latissima*; the brown northern rhizome kelp, *Laminaria longipes;* and brown broad-ribbed kelp, *Pleurophycus gardneri*. Similarly, the SCUBA surveys identified the three most dominant sub-canopy forming algae as *Pterygophora, Laminaria, and Pleurophycus.*

Conclusion

Overall, both reserve and its comparison areas shared many species and in similar abundances, especially with respect to fishes. In comparison to the reserve and comparison areas, the MPA supported a more abundant fish community. The Humbug Comparison Area presents the most analogous habitat to the reserve and received the majority of the detailed biological monitoring. Humbug, supplemented by McKenzie Reef and Orford Reef Comparison Areas, will allow for comparisons of population trajectories inside and outside of the reserve and facilitate assessment of the response of several common fishes, invertebrates and algae to marine reserve designation. Future monitoring efforts within these study areas will continue to be improved and refined to generate the most robust datasets possible for monitoring ecological change through time.

F. References

Beverton RJH and Holt SJ (1957) On the dynamics of exploited fish populations. Fish Invest Ser II Mar Fish G B Minist Agric Fish Food 19: 533

Clarke K and Gorley R (2006) Primer. Primer-E, Plymouth v6

Colwell RK and Coddington JA (1994) Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society of London.Series B: Biological Sciences 345(1311): 101-118

Echeverria TW (1987) Thirty-four species of California rockfishes: Maturity and seasonality of reproduction. Fish Bull 85(2): 229-250

Goldfinger C (2010) Oregon state waters multibeam mapping project: A progress report. Active Tectonics and Seafloor Mapping Laboratory Pub. 2010-1: 1-26

Hannah RW and Blume MT (2012) Tests of an experimental unbaited video lander as a marine fish survey tool for high-relief deepwater rocky reefs. J Exp Mar Biol Ecol 430: 1-9

Silberberg KR, Laidig TE, Adams PB, Albin D (2001) Analysis of maturity in Lingcod, *Ophiodon elongatus*. California Fish Game 87(4): 139-152

Otter Rock Results & Discussion

To robustly characterize the baseline ecological conditions within Otter Rock Marine Reserve, our analyses focused on comparing the oceanographic, habitat, and biological composition in the marine reserve to the associated comparison areas. All data presented below was collected in 2010-11, prior to closure of the Otter Rock Marine Reserve to extractive activities. Oceanographic analyses consisted of comparing physical parameters between the reserve and comparison areas over time to determine if differences exist. Habitat comparisons were made to determine how comparable the substrates found within the marine reserve were represented by the selected comparison areas. Lastly, biological comparisons were structured to address the following questions for the various communities surveyed:

Does community composition differ between reserve and comparison area?

What species or species groups, and in what proportions, define the communities in the reserve and comparison area?

Do organism abundance and/or size differ between reserve and comparison area?

Does diversity differ between the reserve and comparison area?

A. Oceanography

Baseline oceanographic monitoring activities generated large datasets with the objective of comparing temporal in oceanographic conditions between reserve sites and their comparison areas. Should the reserve and comparison area(s) experience similar temporal variation in oceanographic parameters, it suggests that ocean water masses are acting on all areas equally.

In this section, we present both data collected via oceanographic moorings as well as via Benthic Oceanographic Platforms (BOPs), as the methods for deploying oceanographic instruments were modified over the course of baseline period.

In 2010 and 2011, temperature loggers were deployed for ~3 months at 1m and 14m depths in the marine reserve and comparison area using moorings. Good quality data were collected by all instruments. The addition of a CTD deployed west of the Otter Rock Marine Reserve during this time allowed for observations of additional oceanographic parameters (i.e. salinity, oxygen, and fluorescence). Temperature data from 2010-11 revealed that temperatures in the marine reserve were closely correlated through time to those in the comparison area (Figure 1 & 2). As expected, near-surface instruments (1m below the surface) recorded a larger variance in temperature than near-bottom instruments (14m below the surface) during both 2010 and 2011.

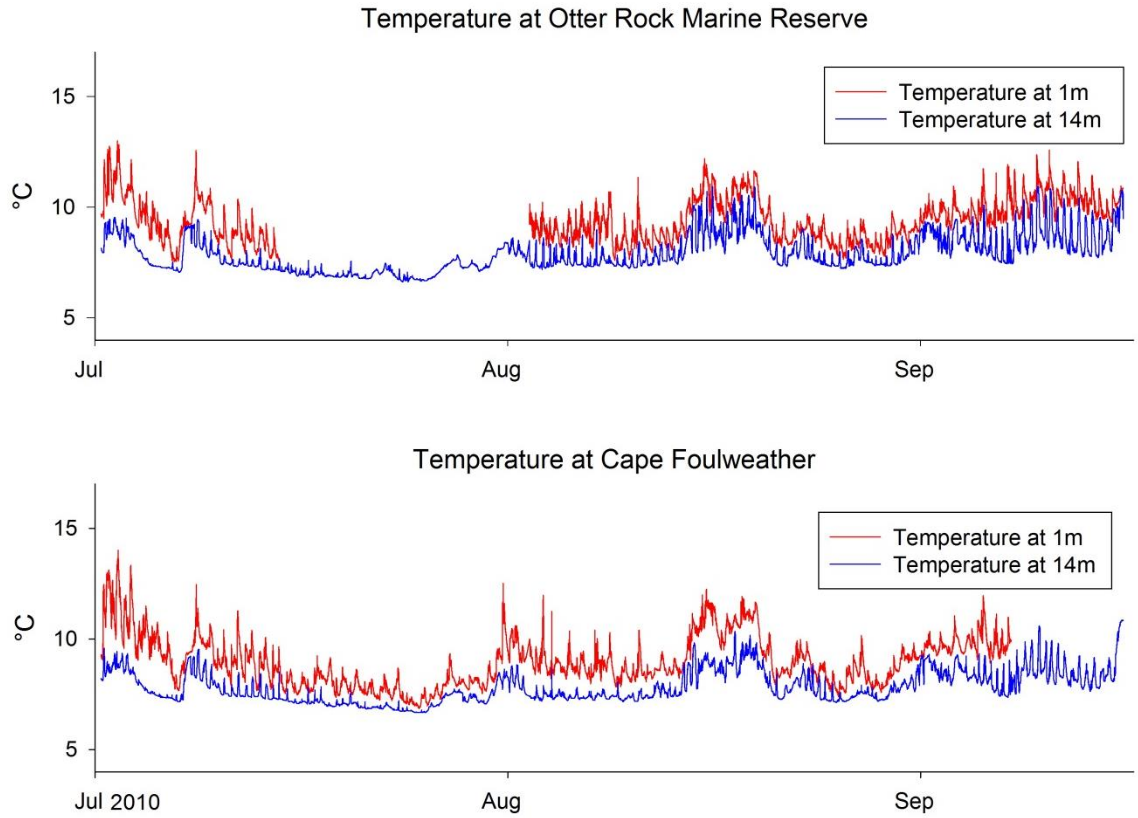


Figure 1. Comparison of temperature in Otter Rock Marine Reserve (top panel) and Cape Foulweather Comparison Area (bottom panel) from HOBO-temp sensors moored at 1m below the surface (red) and 14m below the surface (blue) from July-September 2010.

In 2010, daily variability in temperature 1m below the surface differed minimally between the reserve (mean = 9.45 °C ± 0.98 SE) and comparison area (mean = 8.99 °C ± 1.12 SE). These differences in mean temperature were less pronounced at the 14m depth where the marine reserve was slightly warmer (mean = 7.91 °C ± 0.83 SE) than the comparison area (mean = 7.84 °C ± 0.73 SE). No obvious downwelling signatures were recorded in 2010.

In June and July 2011, at both the reserve and the comparison area, there was a persistent cycle of colder temperature suggesting upwelling, followed by a long period of relaxation and downwelling in July (Figure 2). Temperature was highest in July during these downwelling conditions. In August and September, daily temperature at both sites cooled and remained between 8 – 11 °C.

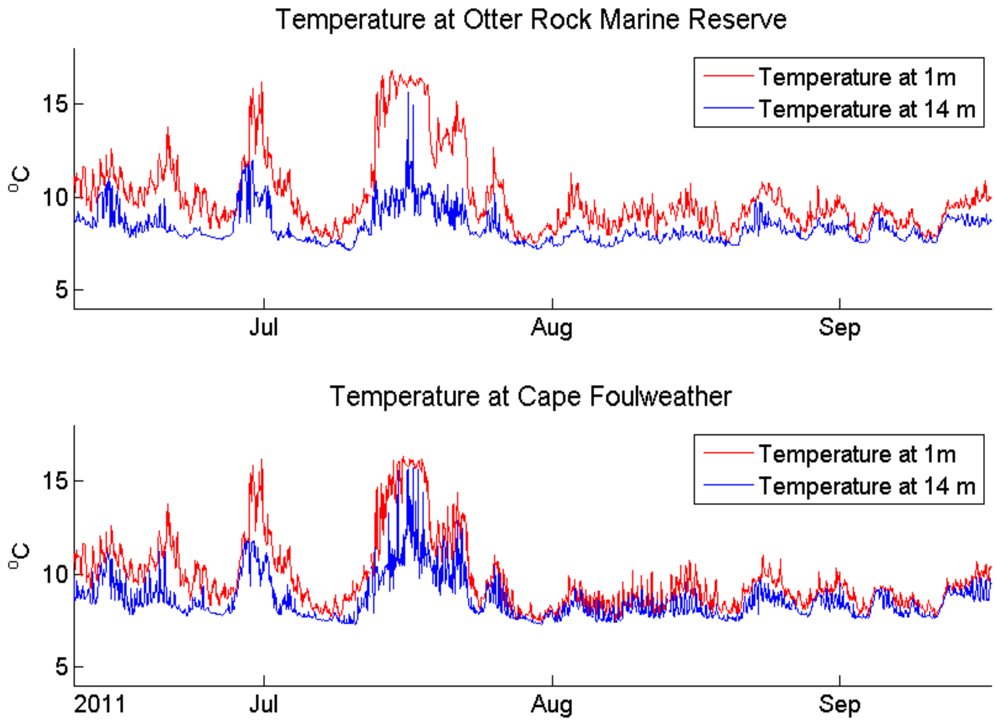


Figure 2. Comparison of temperature at Otter Rock Marine Reserve (top panel) and Cape Foulweather Comparison Area (bottom panel) from HOBO-temp sensors moored at 1m below the surface (red) and 14m below the surface (blue) from June-October 2011.

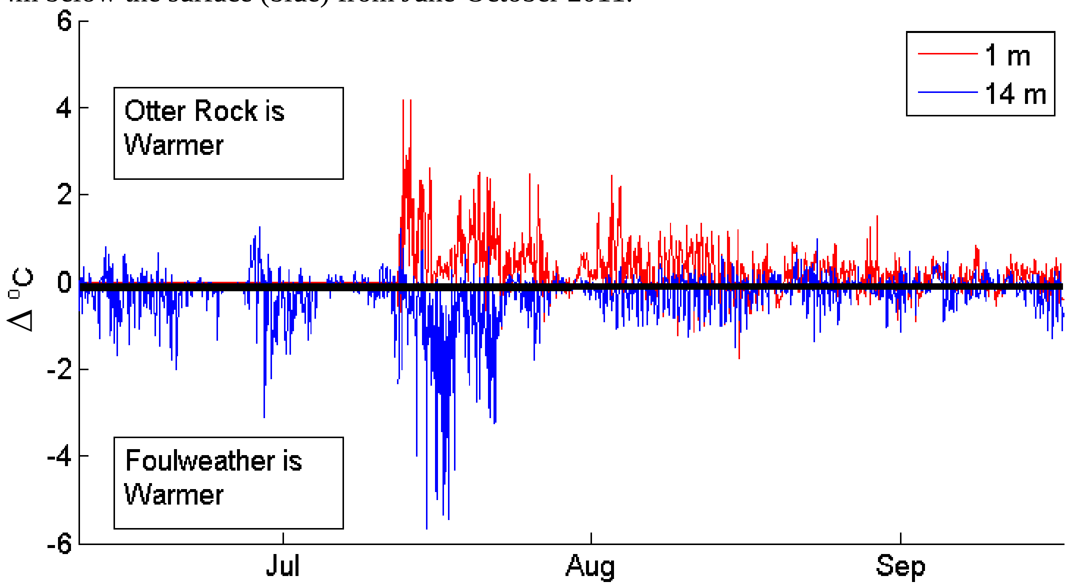


Figure 3. Temperature difference (ΔT) between Otter Rock Marine Reserve and Cape Foulweather Comparison Area for both 1m depth (red) and 14m depth (blue) from June 2011-October 2011. Values above the zero line indicate warmer temperatures in the reserve; values below indicate warmer temperatures in the comparison area.

In 2011, surface temperatures in the marine reserve were generally warmer than in Cape Foulweather. Conversely, at 14m depth, temperatures at Cape Foulweather were warmer than the same depth at Otter Rock (Figure 3). During mid-July, Cape Foulweather was 6°C warmer at 14m than Otter Rock. During June and the first part of July, the difference between the two sites was less than 2°C, which is lower than the natural 7-day variability at the site.

While the temperature data are spatially limited to single sampling sites within the reserve and comparison area, our results indicate high agreement between the Otter Rock Marine Reserve and Cape Foulweather Comparison Area over time. Temperature differences between the reserve and comparison area were small (predominantly < 2ºC) and highly correlated over time between the reserve and comparison area at both the surface and 14m depth. Although our oceanographic baseline comparisons are restricted to this single physical parameter, the results from the temperature data suggest that Cape Foulweather is an appropriate oceanographic comparison site to the Otter Rock Marine Reserve. On-going monitoring, including the addition of conductivity and light sensors, will expand this dataset to include more oceanographic parameters quantified over longer time scales.

B. Seafloor Mapping

B.1 Video Lander

For the Systematic Rapid Assessment in Otter Rock, the video lander was deployed on a 200m x 200m spaced grid among the marine reserve, Cape Foulweather and Moolack comparison areas. A total of 78 grid drops were completed in 2010 and used to determine the prevalence of various benthic substrates among the reserve and comparison areas. An additional 121 lander drops were randomly deployed within the reserve and Cape Foulweather Comparison Area in an effort to map the benthic habitats in areas where hard bottom was suspected to occur based on the Rapid Assessment. Habitat data from both the grid drops and random drops were pooled to determine the proportion of each of 7 substrate types within the site (Table 1). Sand was the most abundance substrate type encountered in the marine reserve and the only substrate encountered in the Moolack comparison area; bedrock outcrop was most abundant substrate in the Cape Foulweather Comparison Area. Hence, the Moolack site serves as a comparison area to the sand habitats present in the marine reserve; the Cape Foulweather site serves as a comparison for the mixed and consolidated substrate types found within the reserve.

Table 1. Prevalence (%) of benthic substrates encountered using the video lander during the Systematic Rapid Assessment in Otter Rock during 2010-11. The number of drops completed in an area follows in parentheses. MR = marine reserve; CA = comparison area.

Benthic Substrate Type	Otter Rock MR (n = 104)	Cape Foulweather CA (n=84)	Moolack CA (n=20)
Bedrock Outcrop	10% (10)	50% (50)	0% (0)
Flat Bedrock	0% (0)	4% (4)	0% (0)
Large Boulder	3% (3)	10% (10)	0% (0)
Small Boulder	2% (2)	10% (10)	0% (0)
Cobble	0% (0)	4% (4)	0% (0)
Gravel Pebble	0% (0)	1% (1)	5% (5)
Sand	86% (86)	23% (23)	95% (95)

B.2. High-Resolution Multibeam Sonar

Lander data were used to supplement surficial geologic habitat maps and for comparison to the multibeam benthic habitat maps released in 2011 (Goldfinger 2010). While discrepancies exist between the lander data and multi-beam data as to the proportions of each substrate type present in a given area (Table 2), the lander data in conjunction with the multibeam habitat maps helped establish a spatial explicit map of benthic substrate types that was instrumental in structuring the sampling design for the Detailed Assessment (Figure 4). Using these maps, we were able to target areas of consolidated and unconsolidated substrates by depth within the marine reserve and comparison areas for biological sampling.

Table 2. Comparison of benthic substrate types detected using the video lander versus substrate maps created from high-resolution multibeam for Otter Rock Marine Reserve, Foulweather comparison area, and Moolack comparison area. Given that different substrate categories were assessed between the lander and multibeam dataset, substrates were grouped as either consolidated rock (e.g. bedrocks, boulders, etc.) or unconsolidated (e.g. cobble, gravel, pebble, sand, etc.). All values given are the percentage (%) of each substrate type encountered for video lander followed by the multibeam habitat maps (lander/ multibeam).

	Lander / Multibeam (% of total)		
Benthic substrate type	Otter Rock MR	Cape Foulweather CA	Moolack CA
Consolidated rock	14 / 25	73 / 59	0 / 7
Unconsolidated	86 / 75	27 / 41	100 / 93

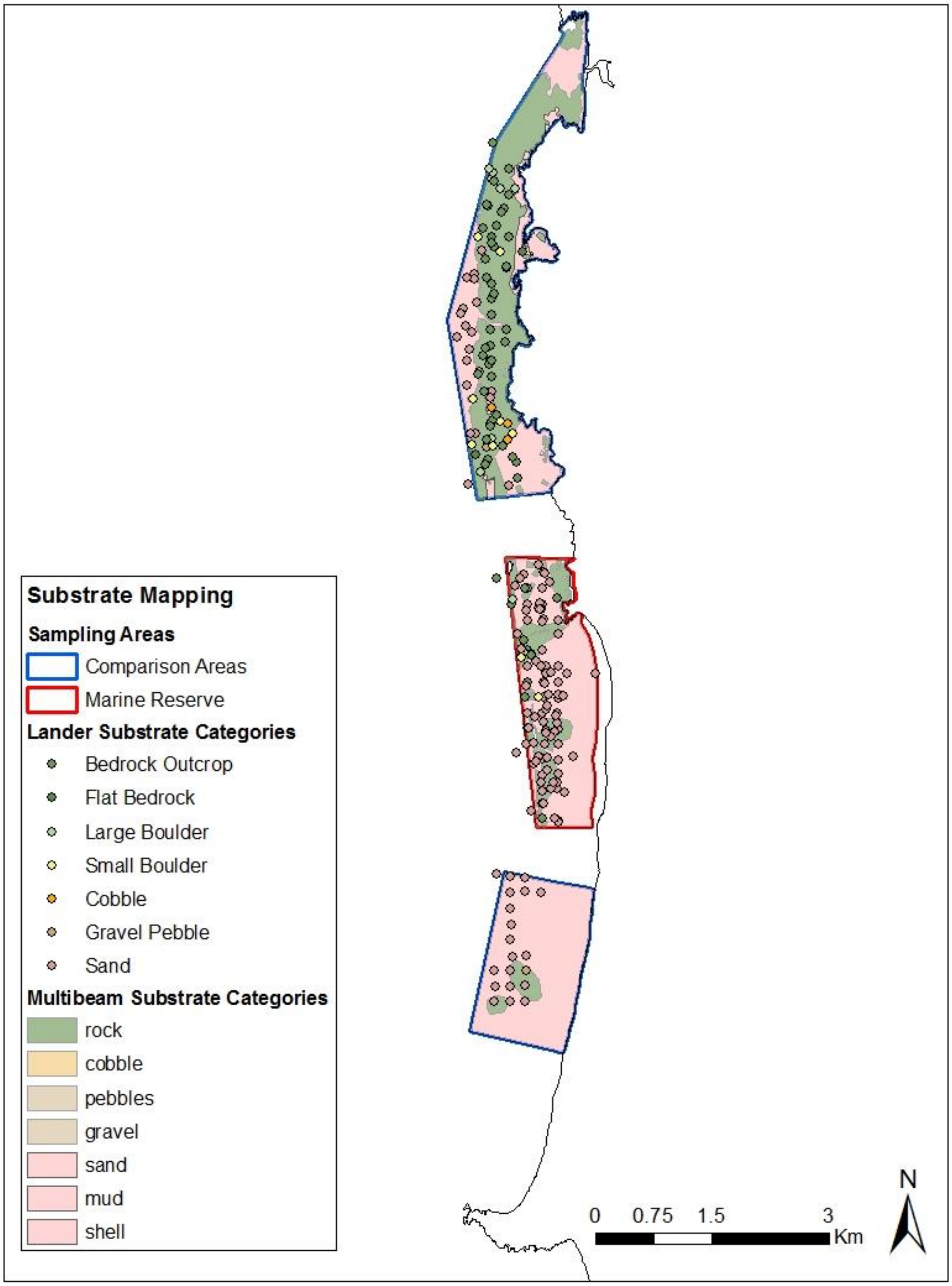


Figure 4. Mapping of substrate types detected by the video lander (circles) and high resolution multibeam survey (polygons). Difference substrate classes were defined for each method; each type of substrate is represented by like colors regardless of sampling method.

C. Visual Surveys

C.1 Video Lander

Species differences
Lander data collected in 2010 and 2011 were pooled for all the analyses presented below. For fishes identified to species, mean relative abundance (quantified as maximum N) was compared using a nonparametric Mann-Whitney test due to lack of normality in the data. Data were pooled regardless of depth or substrate type for these analyses. No fishes were observed from lander drops conducted in the Moolack comparison area. Black Rockfish were significantly more abundant in the Foulweather comparison area compared the to the marine reserve (Table 1; Z=2.73; P = 0.006), as were Kelp Greenling (Z=2.48; P = 0.013), and Lingcod (Z=3.03; P = 0.002).

Table 3. Mean relative abundance (# of fish/ lander drop), followed by standard error within parentheses, of fish observed in Otter Rock Marine Reserve (n=94) and Cape Foulweather Comparison Area (n=74). * indicate a significant difference between the areas based on Mann-Whitney nonparametric analysis.

Species/group	Otter Rock MR	Cape Foulweather CA
Black Rockfish*	0.245 (0.11)	0.459 (0.154)
Blue Rockfish	0.011 (0.011)	0.054 (0.038)
China Rockfish	0 (0)	0.014 (0.014)
Kelp Greenling*	0.032 (0.018)	0.149 (0.046)
Lingcod*	0 (0)	0.095 (0.034)
Starry Flounder	0.011 (0.011)	0 (0)
UNID Juvenile Rockfish	0 (0)	0.068 (0.068)

Community composition
Only 15 lander drops yielded fish observations, and the vast majority of these were dominated by a single fish observation. Hence, community composition analyses were not conducted.

Organism abundance
Mean fish density (pooled across all species) was compared between the marine reserve and comparison area using a Mann-Whitney nonparametric analysis due to lack of normality and unequal variance. Fishes were found to be significantly more abundant in the comparison area compared to the marine reserve (Z=2.90, P = 0.004; MR mean = 0.05 ±0.04 SE, CA mean = 0.20 ± 0.06 SE). However, fish densities were very low in both sampling areas.

Benthic substrate type significantly influenced how many fishes (regardless of species) were observed in a single lander drop (P<0.001, Kruskal-Wallis test followed by nonparametric comparisons for each pair using Wilcoxon methods, Table 4). Fish were less likely to be observed on sand compared to all other substrate classes except for flat bedrock. Fish observations on bedrock outcrops were also significantly lower than large boulder. However, limited sample sizes in some of the substrate categories (e.g. gravel pebble) limit a complete pairwise comparison among all substrate types.

Table 4. Mean relative abundance (# of fish/ drop) of fish observed during replicate video lander drop samples based on substrate type encountered.

Substrate	n	Mean relative abundance
Bedrock Outcrop	48	0.52
Cobble	3	0.33
Flat Bedrock	3	0.00
Gravel Pebble	1	0.00
Large Boulder	9	1.22
Sand	100	0.02
Small Boulder	7	0.14

C.2. Video Sled

As the sled physical configuration, database entry process, and organism scoring protocol changed between 2010 and 2011, pre-treatment differed between these two sampling years.

In 2010, the sled was towed touching the benthos, therefore the transect area (m^2) was calculated as a fixed width based on the distance between the rails of the sled, visible within the field of view, when sled was on bottom (0.88 m) x transect length (provided by handheld GPS points taken approximately every two minutes). It should be noted that these lengths may underestimate the true length of the transect as distances were calculated as if the boat traveled in a straight line between points. Additionally, touchdown time on the bottom was usually well noted, but liftoff from the bottom at the end of the transect was not. Occasionally the tow was "ended" prior to the sled leaving the bottom, in which case we may have underestimated total transect length. Organisms were scored in 10 second segments over the course of the transect. These segments were summed to generate a total abundance per organism per transect. Organisms were assumed to be observed "on bottom" as no mention of ascent/descent was made in the database. Abundances were then divided by the transect area to generate relative organism density (indiv./m^2) per transect. Each transect serves as a single replicate, irrespective of total area surveyed. Mean depth (m) of each transect was calculated from the depth data collected periodically along the track line of the transect. If no depth data was recorded from field collection, depth data was extracted from a bathymetric raster layer in ArcGIS based on the spatial position of the transect.

In 2011, the sled was towed slightly above the benthos. Transect length was calculated using the Fugawi (navigational software) tracks which recorded a coordinate every 2-3 seconds. These tracks represent the maximum transect length (including time to descend and ascend the sled from the ship). In order to restrict the transect length to "on bottom" time, the tracks were segmented to the first occurrence of habitat scoring when we assume bottom contact was made. Likewise, "gaps" exist where the sled loses view of the benthos rendering that section 'un-scorable' for habitat and organisms. Both the gaps and pre-transect and post-transect track lines (during ascent and descent) were excluded from calculating the adjusted transect length (m). As the camera was not consistently mounted at a fixed angle, the transect area (m^2) varied from transect to transect (this camera system was used on other platforms, and even a difference of 1-2 degrees on reassembly made a measurable difference in camera view). Transect width (m) was estimated from repeated measures of the width of field of view using the two fixed parallel 10-cm width lasers as a reference point. The width of the laser reflection points were measured with calipers on the monitor with the image at a fixed size and resolution. As the sled moves closer to the benthos, the laser width appears to widen. The width of view can be calculated as a proportion of the apparent laser width to the overall screen width. The number of width measurements varied among transects; additional replicate measurements were taken until the standard error of the mean width was less than 0.1m or the standard error stopped appreciably changing with increasing replicates. Factors increasing the variability of the laser width measurements are large irregular sand waves and occasional rocks encountered, with resultant higher rugosity. The estimated transect area (m^2) was then calculated from the adjusted transect length x the estimated width.

In 2011, organisms were scored continuously over the course of the transect and summed to generate a total abundance per transect. Analyses presented here excluded those organisms observed on descent or ascent. “Unknown Species” were observed but excluded from the analysis (resulting in 144 occurrences excluded from the analysis). Abundances were then divided by the transect area to generate relative organism density (indiv./m^2) per transect. Each transect serves as a single replicate, irrespective of total area surveyed. Mean depth (m) per transect was calculated from the depth data collected from the vessel’s sounder approximately every two minutes.

In 2010-11, a total of 12 sled transects were completed in the Otter Rock site (Table 5). Transect depths ranged from 5-13m.

Table 5. Sled transects completed from 2010-11 in Otter Rock. Total area (m^2) surveyed and the mean depth of the sled transect is provided per sampling area.

Site	Area	N	Total Transect Area (m^2)	Mean transect depth (m) ± SE
Otter Rock	Marine Reserve	7	6025	9 ± 1.1
Otter Rock	Moolack CA	5	4137	10 ± 1.1

Fish density

Analysis of covariance (ANCOVA; continuous covariate = mean transect depth, factor = sampling area) was used to compare total fish density (indiv./m^2) among the reserve and comparison area while exploring the influence of depth (m). Total fish density did not vary with mean transect depth ($P = 0.28$), nor was there a significant interaction between depth and sampling area ($P = 0.80$). There was no difference in total fish density between Otter Rock Marine Reserve (mean = 0.007 ± 0.002 SE) and the Moolack comparison area (mean = 0.014 ± 0.010 SE; ANCOVA, $P = 0.67$).

Fish species-specific differences

Mean densities of individual fish species or species groups were compared using non-parametric Wilcoxon test due to the lack of normality and homoscedasticity in the density data. No significant differences in fish densities were detected between the reserve and comparison area (Table 6).

Table 6. Mean fish density (SE), followed by SE within parentheses, from sled transects completed in 2010-11 for Otter Rock Marine Reserve (MR) and Moolack Comparison Area (CA). UNID = unidentified.

	Mean density (indiv./m^2)	
Fish species /group	Otter Rock MR	Moolack CA
Kelp Greenling	0 (0)	0.0003 (0)
Black Rockfish	0 (0)	0.0018 (0.002)
Lingcod	0 (0)	0.0002 (0)
Skate	0.0001 (0)	0 (0)
UNID Fish	0.0006 (0)	0.0006 (0.001)

UNID Flatfish	0.0133 (0.01)	0.0036 (0.001)
UNID Rockfish	0 (0)	0.0001 (0)

Fish community composition
Species specific identification was limited during the 2010-11 sled tows; the majority of the fish observations were categorized as unidentified fish, flatfish, or rockfish (Table 6). In addition, fish abundances were very low resulting in several tows observing a single fish over the duration of the transect. Without species-specific resolution in the density data, coupled with low fish densities, analyzing community composition among the marine reserve and comparison sites is not informative. Hence, multivariate ANOSIM analyses were not conducted on the fish data from sled tows in Otter Rock for 2010-11.

Mobile invertebrate density
ANCOVA analysis (continuous covariate = mean transect depth, factor = sampling area) was used to compare mean mobile invertebrate density (log_{10} transformed to achieve normality) among the reserve and comparison area while simultaneously exploring the influence of depth (m). Total mobile invertebrate density did vary with mean transect depth (ANCOVA; P = 0.002), such that deeper depths correlated with higher relative densities of mobile invertebrates irrespective of sampling site (Figure 5). There was no difference in mean mobile invertebrate density between Otter Rock Marine Reserve (mean = 0.023 ± 0.014 SE) and the Moolack Comparison Area (mean = 0.145 ± 0.043 SE; ANCOVA, P = 0.12).

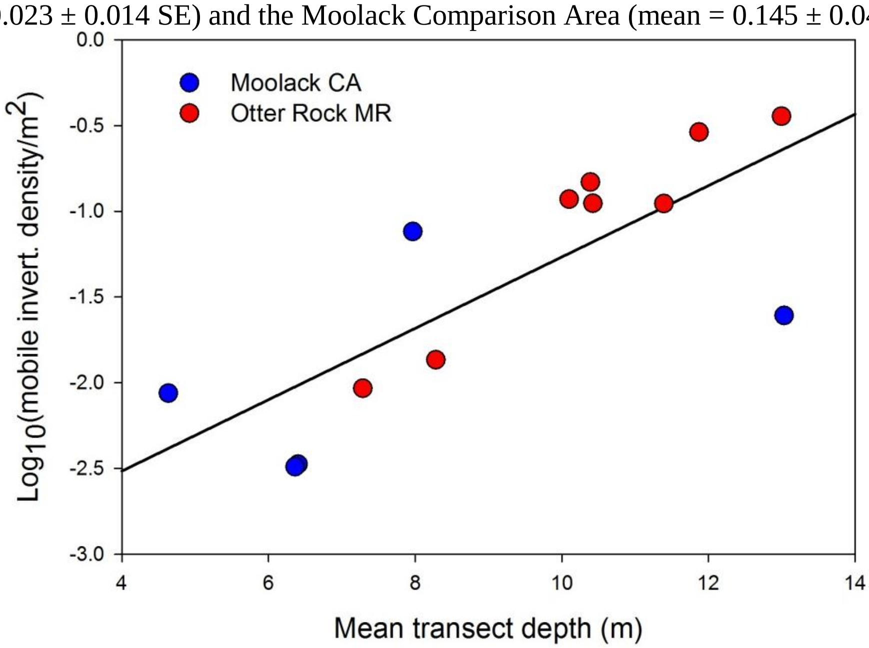


Figure 5. Regression relationship between transect depth and mobile invertebrate density (y-axis on log_{10} scale). Red circles are transects completed in the Otter Rock Marine Reserve (MR); blue circles are transects completed in the Moolack comparison area (CA). A single linear regression line is shown, as there was no difference between the two sampling areas (ANCOVA analysis).

Mobile invertebrate species-specific differences
Mean densities of mobile invertebrate species or species groups were compared using non-parametric Wilcoxon tests due to the lack of normality and homoscedasticity in the density data. Sand dollars (*Dendraster* spp.) were significantly more abundant within Moolack CA while sea stars and brittle stars were significantly more abundance in the reserve (Table 7). No other significant differences in mobile invertebrate densities were detected between the reserve and comparison area.

Table 7. Mean mobile invertebrate density (indiv./m^2), followed by SE within parentheses, from sled transects completed in 2010-11 for Otter Rock Marine Reserve (MR) and Moolack Comparison Area (CA). * denotes a significant difference in mean density between the MR and CA.

	Mean density (indiv./m^2)	
Mobile Invertebrate	Otter Rock MR	Moolack CA
Crab	0.0007 (0.0007)	0.0004 (0.0003)
Dendraster spp.*	0.0148 (0.0145)	0.1427 (0.044)
Sea Star and Brittle Star*	0.0049 (0.0037)	0 (0)
Jellyfish	0.0004 (0.0004)	0.0007 (0.0005)
Shrimp	0 (0)	0.0002 (0.0002)
Snail	0.0023 (0.0012)	0.0008 (0.0005)
Pycnopodia helianthoides	0.0001 (0.0001)	0 (0)

Mobile Invertebrate Community Composition
Species specific identification was also limited during the 2010-11 sled tows. Without species-specific resolution in the density data, exploring community composition among the marine reserve and comparison sites is not informative. Additionally, low densities (i.e. often a single organism type was observed during the entire transect), make a community composition analysis unreasonable. Hence, multivariate ANOSIM analyses were not conducted on the mobile invertebrate data from sled tows in Otter Rock for 2010-11.\

Sessile Invertebrates
Sea anemones were the only sessile invertebrate observed in Otter Rock sled transects. Mean densities of sea anemones were compared using a non-parametric Wilcoxon test due to the lack of normality and homoscedasticity in the density data. No significant differences were detected between the reserve (mean = 0.005 ± 0.004) and comparison area (mean = 0.001 ± 0.001).

C.3. SCUBA

All results from SCUBA visual surveys in Redfish Rocks are found in Appendix A.

D. Extractive Surveys

D.1. Red Sea Urchins

No red urchin surveys were completed at the Otter Rock Site during the baseline assessment period.

D.2.a Benthic Extraction: Rocky Reef Macroalgae

Community composition
Community composition of macroalgae differed somewhat between the Otter Rock Marine Reserve and the Cape Foulweather Comparison Area (ANOSIM, Global R = 0.30, P = 0.004, based on Bray-Curtis similarity on 4th root transformed macroalgal biomass). At the transect-scale, 50% similarity was shared among both the reserve and the comparison area (Figure 6).

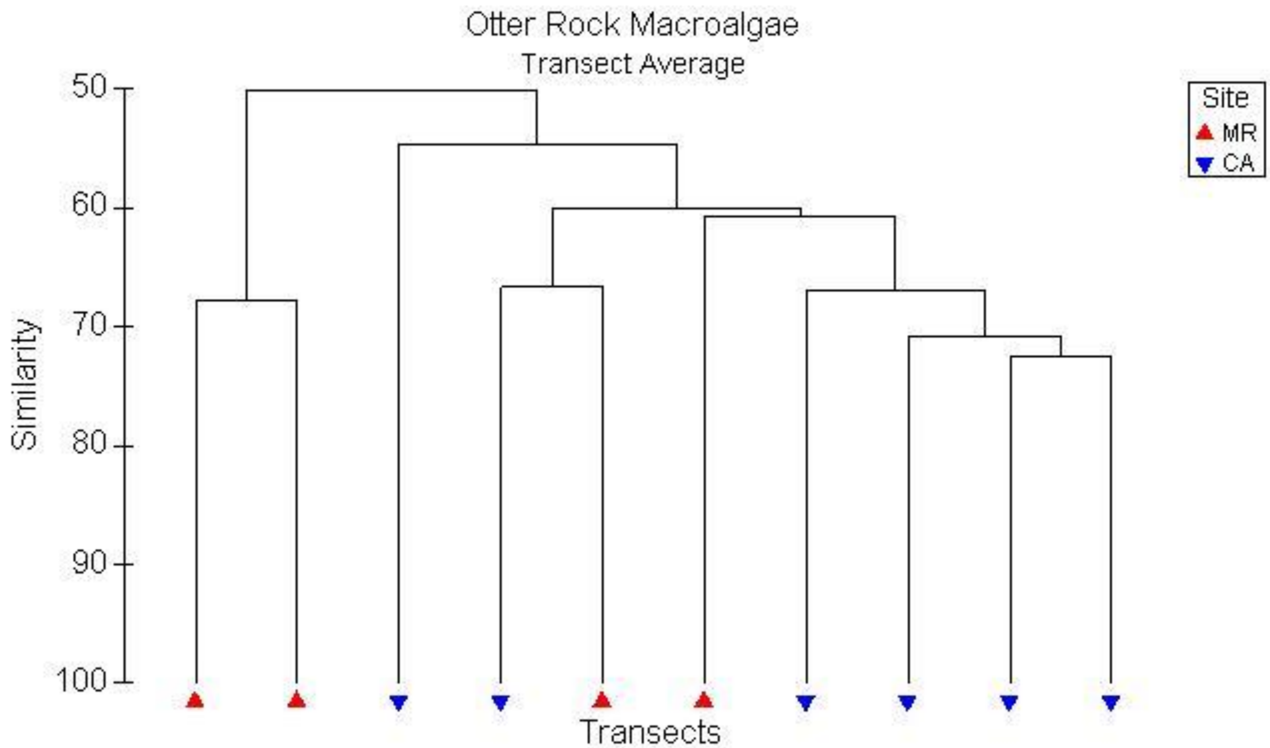


Figure 6. Cluster diagram of Bray-Curtis similarity of macroalgal community composition (biomass) among transects sampled inside the Otter Rock Marine Reserve (red) and the Cape Foulweather Comparison Area (blue). Biomass of macroalgal species were averaged across three replicated quadrats per transect to generate mean community composition at the transect-scale.

Species differences

Species-specific differences in relative abundance existed between the Otter Rock Marine Reserve and Cape Foulweather Comparison Area (Figure 7). The 12 macroalgal species listed were the most dominant species sampled (comprising >1% of the total macroalgal biomass collected, summed across sampling site) and constituted 71% of the marine reserve biomass and 90% of the comparison area biomass. Biomass of four macroalgal species differed significantly between the reserve and comparison area (ANOVA, $P < 0.05$, quadrats means were pooled among transects). Bossiella orbigniana was more abundant inside the reserve, while Pterosiphonia dendroidea, Caliarthron tuberculosum, and Crytopleura farlowiana were more abundant in the comparison area.

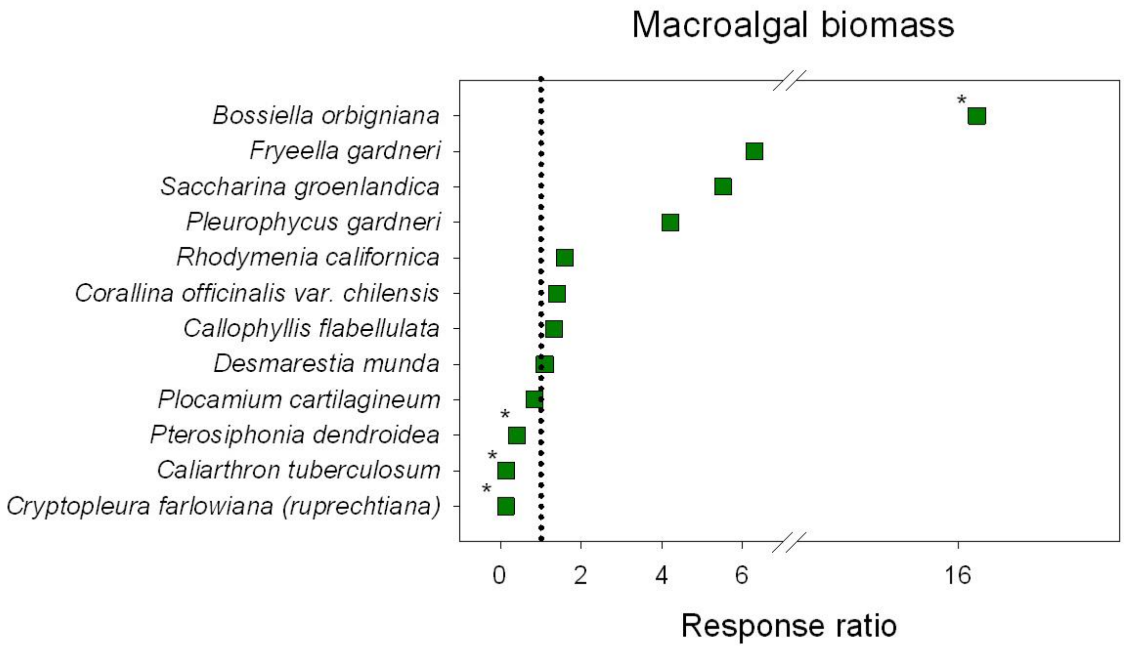


Figure 7. Baseline response ratios (inside/ outside) for dominant macroalgal species at the Otter Rock site. Values represent the $\log_{10}$ transformed response ratios for the most common algal species (> 1% of the total sampled community biomass) calculated as $\log_{10}$ (mean transect biomass +1). Species to the right of the dashed line were more prevalent within the reserve; those to the left were more prevalent in the comparison area. Species whose biomass differed significantly between reserve and comparison area were noted with an *.

Macroalgal Biomass

The Otter Rock Marine Reserve supported nearly 3x the macroalgal biomass (mean = 1542 g/m^2 ± 386 SE) sampled in the Cape Foulweather Comparison Area (mean = 554 g/m^2 ± 91 SE; T-test, t ratio= 2.92, df = 8.0, P = 0.02; Figure 8). Data based on replicate transect means.

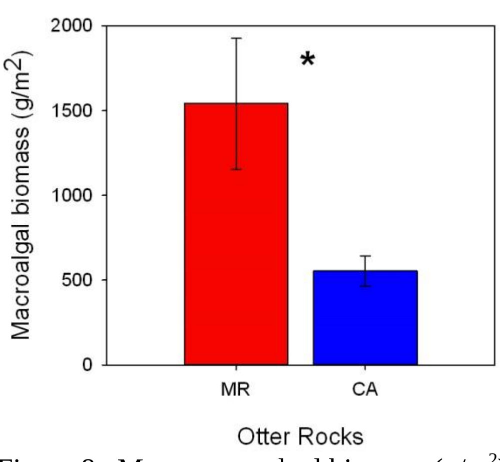


Figure 8. Mean macroalgal biomass (g/m^2) in the Otter Rock Marine Reserve (MR) and the Cape Foulweather Comparison Area (CA).

Species diversity

The diversity of the macroalgal community did not differ between the reserve (mean = 116 species ± 20.3 SE) and the comparison area (mean = 129 species ± 8.8 SE; T-test assuming unequal variance, t ratio= -0.57, df = 4.15, P = 0.60; Figure 9). Data based on replicate transect means.

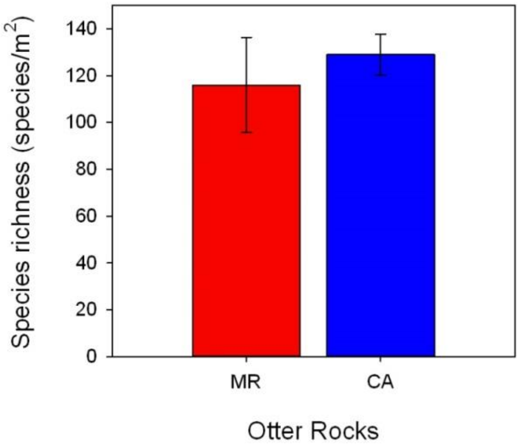


Figure 9. Mean species richness in the Otter Rock Marine Reserve (MR) and the Cape Foulweather Comparison Area (CA).

D.2.b Benthic Extraction: Rocky Reef Invertebrates

Community Composition

Community composition of invertebrates at the transect-scale was consistent across the reserve and comparison area (ANOSIM, Global R = 0.10, P = 0.086, based on Bray-Curtis similarity on 4^{th} root transformed invertebrate biomass, g/m^2). At the transect-scale, reserve and comparison area transects shared 72% similarity in biomass of invertebrate phyla (Figure 10).

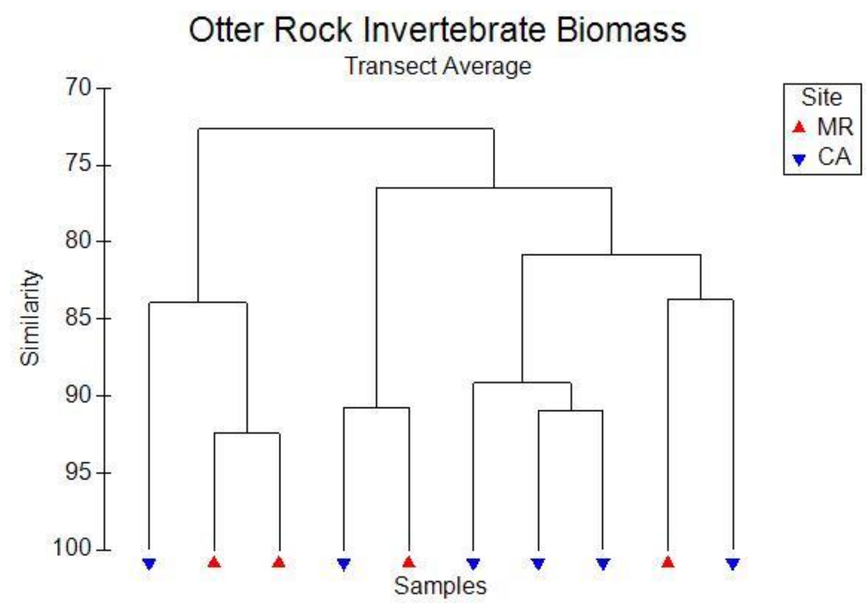


Figure 10. Cluster diagram of Bray-Curtis similarity of invertebrate community composition (biomass) among transects sampled inside the Otter Rock Marine Reserve (red) and the Cape Foulweather Comparison Area (blue).

Phyla differences

Differences in biomass per phyla were explored between the Otter Rock Marine Reserve and Cape Foulweather Comparison Area. High variability among transects led to limited significant differences (t-test using $\log_{10}$ transformed biomass) between the reserve and comparison area despite large differences in means for both Porifera and miscellaneous invertebrates (Figure 11).

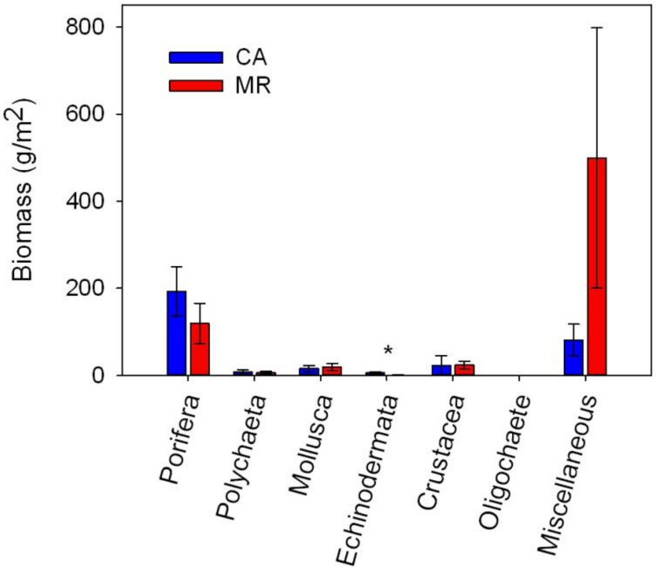


Figure 11. Mean biomass (g/m^2) ± SE of varying phyla between Otter Rock Marine Reserve (MR) and Cape Foulweather Comparison Area (CA). Data based on replicate transect means. * indicates significant differences (t-test on $\log_{10}$ transformed biomass).

Porifera community

At the transect scale, no significant difference exists between sponge family volume in the reserve versus the comparison area (ANOSIM, Global R = 0.06, P = 0.348, based on Bray-Curtis similarity on 4^{th} root transformed sponge family volume). At the transect scale there is 35% similarity between sponge families found in Otter Rock Marine Reserve and the Cape Foulweather Comparison Area. The four sponge families listed are the most dominant species sampled (comprising >1% of the total sponge biomass collected) and constitute 99% of the marine reserve biomass and 95% of the comparison area biomass (Figure 12).

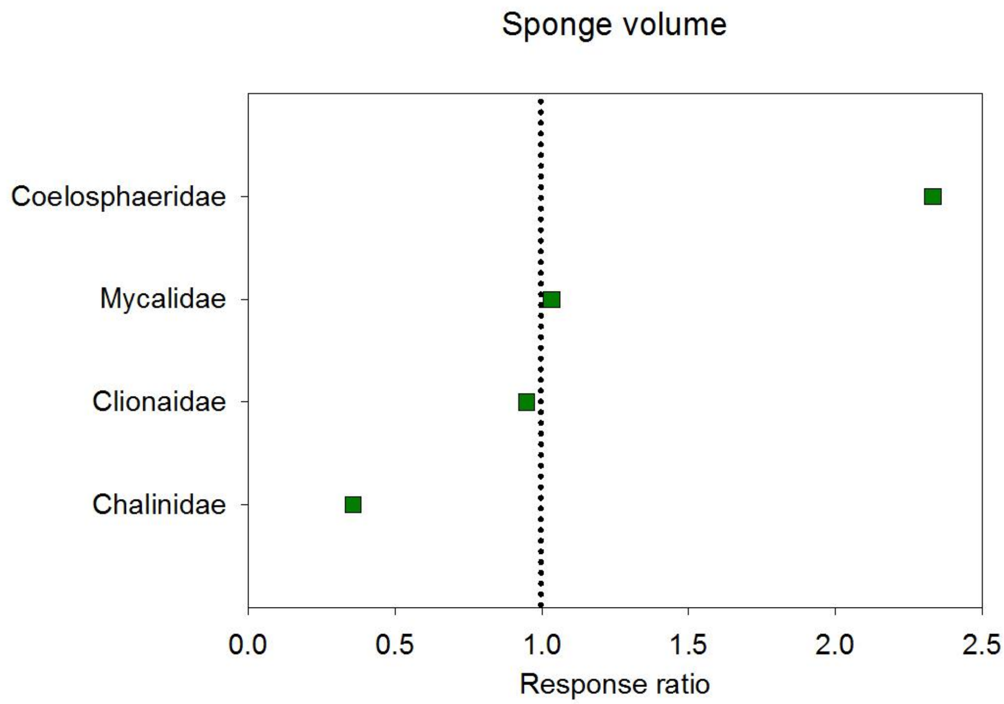


Figure 12. Baseline response ratios (volume inside/volume outside) for individual sponge families at the Otter Rocks site. Values represent the $\log_{10}$ transformed response ratios for the most common algal species (> 1% of the total sampled community biomass) calculated as $\log_{10}$(response ratio). Families to the right of the dashed line are more prevalent within the reserve; those to the left are more prevalent in the comparison area.

Sponge abundance (as cubic volume) at the reserve (mean = 111.14 cm^3 ±69.57 SE) did not differ significantly from the comparison area (mean = 108.30 cm^3 ± 41.09 SE; t-test, t ratio= 0.04, df = 5.09, P = 0.97). Similarly, the diversity of the sponge community did not differ between the reserve (mean = 1.67 species ±0.36 SE) and the comparison area (mean = 3.11 species ±0.52 SE; T-test assuming unequal variance, t ratio= -2.28, df = 7.91, P = 0.0524). Data based on replicate transect means.

Abundance and biomass

Invertebrate biomass at Otter Rocks Marine Reserve (mean = 668 g/m^2 ± 294 SE) was not significantly different from the Cape Foulweather Comparison Area (mean = 326 g/m^2 ± 94 SE; Wilcoxon test, P = 0.39). Similarly, invertebrate abundance at the reserve (mean = 578 indiv./m^2 ± 113 SE) was not significantly different from the comparison area (mean = 683 indiv./m^2 ± 249 SE; Wilcoxon test, P = 1.0). Data based on replicate transect means.

While the macroalgal community composition and species richness did not vary between Otter Rock Marine Reserve and the Cape Foulweather Comparison Area, macroalgae was three times more abundant in the marine reserve. This difference in biomass was largely driven by Bossiella orbigniana. Species-accumulation curves predicting species richness through Chao2 and Jacknife extrapolation permutations indicate that we are likely under-sampling the macroalgal diversity of these regions (Colwell and Coddington 1994); however, budgetary constraints limit increased sampling at this time.

The mean biomass of various invertebrate phyla was not found to vary among the Otter Rock Marine Reserve and the Cape Foulweather Comparison Area, though the taxonomic resolution achieved in the macroalgal data was not available for the invertebrate dataset (with the exception of Porifera). With the assistance of Dave Alvin of the Oregon Porifera Project, sponge volumes were generated for taxonomic families, though again, no significant changes in community composition at the family-level was detected between the reserve and the comparison area.

D.3.a Hook-and-Line Survey

No hook and line surveys were undertaken at the Otter Rock site.

E. Discussion

Baseline monitoring, consisting of oceanographic, habitat and biological data, was completed over two years prior to the closure of Otter Rock Marine Reserve to extractive activities on January 1, 2012. Time series oceanographic data indicate that water temperatures were comparable (predominantly < 2ºC) between the marine reserve and the Cape Foulweather Comparison Area at both the surface and the maximum depth of the marine reserve (~14m). Although our oceanographic baseline comparisons are spatially limited and restricted to the single physical parameter of temperature, the data presented here suggests that Cape Foulweather is an appropriate oceanographic comparison to the Otter Rock Marine Reserve. On-going monitoring of oceanographic data will continue and expand to include salinity and light parameters, enabling more robust long-term comparisons between the reserve and the comparison area.

Systematic Rapid Assessments of the habitats in the reserve and Moolack and Cape Foulweather Comparison Areas reveal large differences in substrate types. Otter Rock Marine Reserve consists of only 15% consolidated rocky reefs (i.e. bedrock and boulder), with the remaining ~85% comprised of sandy substrate. In contrast, Cape Foulweather Comparison Area is approximately two-thirds consolidated habitat with the remainder sand. In order to have a comparison area as sand dominated as Otter Rock, Moolack Comparison Area was included in the Systematic Rapid Assessments. While clearly sand dominated (95-100%), the biological community in this area was exceedingly rare and/or difficult to monitor using our underwater video surveys. Hence, while the Moolack Comparison Area may serve as an analogous habitat to the sand dominated substrates in the Otter Rock Marine Reserve, the utility of comparing the community composition in this area to the reserve to assess reserve performance is limited. Pending the development of refined underwater video sampling tools for unconsolidated sandy substrates or explicit hypothesis-driven experimental surveys targeting sand-dominated habitats, no further ecological monitoring will occur in Moolak comparison area.

Underwater visual surveys revealed very low densities of nearshore fishes for both the lander and sled sampling tools. The low densities combined with poor species-specific identification severely hindered the assessment of fish and invertebrate community comparisons between the marine reserve and comparison areas. However, those fishes observed were more common on rugose, consolidated substrates (i.e. bedrock outcrops and boulders). For Black Rockfish, Lingcod and Kelp Greenling, densities were significantly higher in the Foulweather comparison area. This difference is likely due to the more abundant rocky reef in Cape Foulweather, resulting in a higher proportion of the random lander drops encountering this substrate where fish densities were observed to be greatest. From the SCUBA surveys, species richness of the fish assemblage at Otter Rock Reserve was relatively low (2 species recorded per transect), in both the 2010 and 2011 and in the comparison areas in 2011. The density and relative abundance of fish species was generally similar in the reserve and comparison areas, however some species that occurred in low densities within the reserve (blue and Canary Rockfish, cabezon) were not observed across the comparison areas. SCUBA surveys found species richness and diversity of the macroalgae to be similar between years and between the reserve and comparison areas in 2011. Species richness of the most abundant mobile and conspicuous benthic invertebrates observed using SCUBA was relatively low in the Otter Rock region (an average of 6-9 species recorded per transect) but higher at Otter Rock Reserve than at the comparison areas in 2011. This same pattern of overall low densities of benthic invertebrates but higher in Otter Rock Reserve (excluding sand dollars) was observed in the lander data as well. Due to the high vessel costs needed to deploy the lander or sled and the limited biological data generated by these tools in the shallow habitats of Otter Rock Marine Reserve, ODFW is exploring smaller, more cost-effective video tools and considering limiting future visual surveys to underwater SCUBA efforts where divers can explicitly target rugose reef habitats.

Extractive sampling revealed that the Otter Rock Marine Reserve supported nearly three times the macroalgal biomass of Cape Foulweather, largely due to dominance of *Bossiella orbigniana* inside the reserve. In contrast, sponge diversity was largely comparable between the reserve and comparison area, as was invertebrate phyla abundance.

Overall, it is likely that the Cape Foulweather Comparison Area will allow for comparisons of population trajectories inside and outside of the reserve and facilitate assessment of the response of several common fishes, invertebrates and algae to marine reserve designation. Future monitoring efforts within these study areas will continue to be improved and refined to generate the most robust datasets possible for monitoring ecological change through time.

F. References

Colwell RK and Coddington JA (1994) Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society of London.Series B: Biological Sciences 345(1311): 101-118

Goldfinger C (2010) Oregon state waters multibeam mapping project: A progress report. Active Tectonics and Seafloor Mapping Laboratory pub. 2010-1: 1-26

Appendix A

Baseline Surveys of Kelp Forest Ecosystems at Redfish Rocks and Otter Rock Marine Reserve Pilot Sites 2010-2011

Submitted to: Oregon Department of Fish and Wildlife

By: Dr. Kristen Milligan (PI)*
Department of Zoology
Oregon State University
Corvallis, Oregon 97331-2914

Dr. Mark H. Carr (Co-PI)**
Mr. Dan Malone
Ms. Emily Saarman
Dept. of Ecology and Evolutionary Biology
University of California
Santa Cruz, California 95060

* office: (541) 737-8862
milligak@science.oregonstate.edu

** office: (831) 459-3958
carr@biology.ucsc.edu

In addition to this report of results, datasets generated by the sampling described below have been submitted to ODFW each year as Excel files along with geographic areas of sampling locations interpolated from field waypoints and compiled into ArcGIS shape files. Associated metadata including descriptions of sampling methods, taxonomic classifications used, and the locations and surveys conducted at individual sites were also incorporated in PISCO's data catalog. These datasets and metadata are also available via the data portal on the PISCO website.[1]

Methods

Baseline survey design

Protocols used in surveys of fishes, macroalgae, invertebrates and habitat characteristics are provided in detail online.[2] Fish are counted on approximately 12 transects per site (transects run end to end along a depth stratum in each of the four depth zones). Each "transect" includes a 2m x 2m x 30m "bottom" transect and a paired "mid-water" transect of the same dimensions. Sampling is conducted by a pair of divers surveying the bottom and mid-water transect simultaneously. Sampling consists of recording the number and size of all non-cryptic fishes. Ancillary data include underwater visibility on the bottom, water temperature, and sea state (surge). Benthic community surveys include swath transects to count stipitate kelps and mobile or conspicuous invertebrates and uniform point contact (UPC) surveys which record substrate type and relief, and percent cover of sessile invertebrates and understory algae. In benthic surveys, two transects are typically sampled end to end along an isobath in each of three zones (20m, 12.5m, 5m), for a total of approximately six transects per site. A pair of divers work together along each transect sampling swaths and UPC simultaneously. Swath sampling includes a 2m wide swath centered along a 30m long transect line. Density (i.e. number of plants per unit area) of kelps greater than 1m tall and macro-invertebrates greater than 2.5 cm in diameter are recorded in each of three 10m increments of the 30m long transect. If the count of any species reaches 30 within any of the three 10m increments, the distance is noted to derive a density estimate and that species is no longer recorded until the next 10m increment. Size estimates are also recorded for abalone and sea urchin species. UPC sampling is conducted by recording the substratum type, relief and organism attached to the substratum at each sampling point on the transect tape. Points are sampled at 1 m intervals (30 points per transect).

[1] http://data.piscoweb.org/DataCatalogAccess/DataCatalogAccess.html

[2] http://www.piscoweb.org/research/science-by-discipline/ecosystem-monitoring/kelp-forest-monitoring/sampling-protocols

Results

Redfish Rocks Reserve

Habitat Comparisons

The dominant substratum type within the Redfish Rocks Reserve is bedrock with an estimated cover ranging from 78% to 91% between the surveys in 2010 and 2011 (Figure 3), followed by lesser amounts of boulder (4-9%) and sand (5-11%). Here and elsewhere, differences in the cover of rock substratum between sampling years reflect differences in sampling areas (Figure 1, 2) and the placement of transects within sampling areas. Bedrock was also the predominant substrate type at the McKenzie comparison area (75-78%) with boulder (22% both years) contributing to the remainder. In contrast, the Humbug comparison area originally sampled in 2010 had only 10% bedrock cover and much higher cover of boulder (39%) and cobbles (35%). In 2011 an additional sampling site (Island Rock) was surveyed at the Humbug comparison area with much more extensive areas of bedrock. Because of the differences in substratum type between emergent rock and inshore kelp forest sites, the addition this emergent rock site brought the average substrate cover estimates for the area as a whole more in line with those at Redfish Rocks Reserve (89% bedrock, 10% boulder and 1% cobble).

The rocky substratum at Redfish Rocks Reserve was largely "high" (>2m) relief (42-43%; Figure 4) with the remainder of area composed mainly of either "slight" (0.1-1m) relief (26-50%) or "low" (<0.1m) relief (3-26%). High relief was characteristic of the emergent rock sites, whereas the lower relief was characteristic of the inshore kelp forests. In contrast, the McKenzie comparison area was predominantly "low" and "slight" (<1m) relief (63-97%). At the Humbug comparison area, the addition of a new sampling site of contiguous bedrock in 2011 reduced the percent cover of this "low" and "slight" relief area from 99% to 66%. Differences in the relative abundance of "low" and "slight" relief within each of these three areas between years (e.g., Figure 4) are largely inconsequential and mostly reflect subtle differences in the specific location of transects and the categorization of comparable, low relief habitat by different observers between years.

Macroalgal Assemblage

Other major sources of habitat and primary production are the kelps and other macroalgae (*Cystoseira).* Average species richness (i.e., number of species per transect) and diversity indices for these algal species were similar to or slightly higher at the McKenzie and Humbug comparison areas than at the Redfish Rocks Reserve area in both 2010 and 2011 (Figure 5).The four most abundant algal species at Redfish Rocks Reserve and the two comparison areas were the canopy forming bull kelp, *Nereocystis*, and sub-canopy forming *Pterygophora*, *Pleurophycus*, and *Laminaria* (Figure 6, Figure 7). *Cystoseira* and *Alaria* occurred at lower densities across the three areas. Sample sites at Redfish Rocks Reserve targeted both *Nereocystis* kelp forests and emergent rocks, whereas sample sites at McKenzie were located within and near the *Nereocystis* canopy. Differences in the relative abundance of *Nereocystis* and sub-canopy species (e.g., *Laminaria*, *Pleurophycus* and *Pterygophora*) between Redfish Rocks Reserve and McKenzie reflect these differences in the location of sample sites. *Nereocystis* densities were similar between Redfish Rocks and Humbug in 2010, but were much higher at Humbug in 2011 due to the addition of a new sampling site in a *Nereocystis* bed (Figure 6). *Alaria* was seen in low densities at Redfish Rocks Reserve and McKenzie comparison site in 2010 but not in 2011. Aside from these cases, densities of *Nereocystis* and other sub-canopy species were relatively similar between surveys in 2010 and 2011.

Invertebrate Assemblage

Species richness of mobile and conspicuous benthic invertebrates was greater at McKenzie comparison area than at either Redfish Rocks Reserve or Humbug in both 2010 and 2011 (Figure 5). Diversity indices, however, were higher at McKenzie in 2010, but higher at Redfish Rocks in 2011 (Figure 5). The white plumed anemone, *Metridium* spp., was conspicuously abundant at Redfish Rocks Reserve, but absent or rare in either comparison area. The greater abundance of *Metridium* in the reserve likely reflects the greater abundance of vertical substrates at the emergent rock sites (Figure 4, 8a). In contrast, the stalked tunicate, *Styela*, and the blood star, *Henricia*, which were present in lower, but comparable densities at Redfish Rocks Reserve, Humbug, and McKenzie, were the most abundant species at the two comparison sites. In 2011 there was a large increase in the density of orange sea cucumbers, *Cucumaria miniata*, particularly in the McKenzie and Humbug comparison areas. This is a short lived and weedy species, which may not be representative of long term community composition. For this reason, this species was removed from the depiction of relative abundance among benthic invertebrates so as not to obscure the patterns of similarity among other species (Figure 9). Although these invertebrate species are not of great ecological or economic importance, the differences in their absolute and relative abundances, like the cover of sessile species described below, reflect similarities or dissimilarities in the habitats sampled between the reserve and comparison areas.

The cover of sessile invertebrates and turf algal species (foliose and crustose red algae) at Redfish Rocks Reserve is characterized by a high diversity of taxa that occur in low abundance (<15% cover; Figure 10). These values were generally similar between 2010 and 2011 except for the occurrence of higher cover of colonial tunicates in 2011.There was a low overall cover of foliose red algae at Redfish Rocks Reserve relative to McKenzie comparison area (13% vs. 50-55%). More comparable values for foliose red algae were seen at Humbug comparison area (19-20%) along with higher cover of erect and crustose coralline algae (22-45%). One reason for these differences may reflect the geomorphology of these sites. The higher relief rock in Redfish Rocks Reserve (Figure 4) may support a greater diversity and abundance of sessile invertebrates, thereby excluding foliose red algal species. The lower relief substratum at McKenzie comparison areas is more prone to scouring, enabling the more rapid colonization of foliose red algae. The absence of coralline algae at McKenzie supports this explanation as well. Thus, like the differences in invertebrate densities described above, the relative abundance of these species are indicators of the similarity or dissimilarity of habitats within and between the reserves and comparison sites.

Fish Assemblage

The species richness of fish assemblages estimated at the scale of individual transects was generally low (~3 taxa per transect; Figure 5), and only slight differences in species richness were seen between Redfish Rocks Reserve and its comparison areas or between any of these sites in successive years. With respect to diversity indices, the McKenzie comparison area showed the highest diversity in both 2010 and 2011. The fish assemblage at Redfish Rocks Reserve is characterized by high numbers of blue and black rockfish followed by lower densities of kelp greenling (Figure 11). These species were present in comparable densities and constituted similar percentages of the overall abundance (Figure 12) at the Humbug comparison area, however the highest densities of blue, black and china rockfish, and kelp greenling were recorded at the McKenzie comparison area. It is difficult to explain these discrepancies, though the inshore kelp forests sampled at Humbug in 2010 were possibly too shallow and low relief for China rockfish, which were recorded at this comparison area in 2011 when Island Rock was added. A major difference in the fish assemblage composition between 2010 and 2011 was due to the prevalence of young-of-year (YOY) rockfish of the Pteropodus group, which includes such benthic species as the gopher, quillback, and copper rockfish but are difficult to distinguish from one another at that size (Figure 12). This rockfish YOY group made up 14% and 50% of the fish assemblage at the McKenzie and Humbug comparison areas, respectively.

Fish lengths (total length to the nearest cm) were recorded for all individuals observed. Length frequency distributions for the three most common species (blue and black rockfish and kelp greenling; Figure 13) show similar patterns between Redfish Rocks Reserve and the comparison areas at McKenzie and Humbug, however median lengths were higher in the reserve area for kelp greenling (30 cm vs. 28 cm in 2010, 35 vs. 28 and 30 in 2011), black rockfish in 2011 (40 vs. 35 and 35) and for blue rockfish in 2010 (25 cm vs. 18cm).

Otter Rock Reserve

Habitat Comparisons

The dominant substratum type within the Otter Rock Reserve is bedrock with an estimated cover ranging from 54% to 75% between the surveys in 2010 and 2011 (Figure 3), followed by lesser amounts of boulder (21% and 15% in 2010 and 2011) and cobble/sand (25% and 10% in 2010 and 2011). The increase in bedrock in 2011 and corresponding decrease in cover of the other substrata reflect the addition of sampling sites at Gull Rock to the reserve area (Figure 2). In 2011, bedrock was very much the predominant substrate type in comparison areas (93%) with cobble (4%) and boulder (3%) contributing to the remainder. The rocky substratum at Otter Rock Reserve was largely “slight” (0.1-1m) relief (44% and 84% in 2010 and 2011, respectively; Figure 4) with the remainder of area composed mainly of either “high” (23%) or "moderate" (23%) relief in 2010 and "moderate" (10%) relief in 2011. The higher relative cover of slight relief in 2011 reflects the addition of low relief habitat in the lee of Gull Rock in 2011. Similarly, the predominant relief in the three comparison areas was "slight" (58%) with "low" and "high" relief constituting much of the remainder (21% and 14%, respectively). As such, substratum relief was generally similar between the Otter Rock Reserve and comparison areas, dominated by slight relief in the lee of the more vertical relief of the emergent rocks in these areas.

Macroalgal Assemblage

Within the reserve area, species richness and diversity of the macroalgae was similar between years and between the reserve and comparison areas in 2011. The most abundant algal species in the Otter Rock Reserve were *Nereocystis* and *Pterygophora*, followed by *Laminaria* and *Pleurophycus*, then *Alaria* (Figure 6, Figure 7). The apparent increase in relative abundance of *Nereocystis* in 2011 reflects the addition of the Gull Rock site. The relative abundance of these macroalgal species were generally similar for the comparison areas, however their densities were substantially lower than that at the reserve area (Figure 6). Also, although at low density in the Otter Rock reserve, *Alaria* was absent from the comparison areas. *Cystoseira* was not observed at any of the reserve or comparison sites.

Invertebrate Assemblage

Species richness of the most abundant mobile and conspicuous benthic invertebrates was relatively low in the Otter Rock region (an average of 6-9 species recorded per transect) but higher at Otter Rock Reserve than at the comparison areas in 2011 (Figure 5). The Otter Rock Reserve shows the slightly higher invertebrate diversity than the comparison areas in 2011, and higher measured diversity within the reserve in 2011 as compared to 2010 due to the addition of the sampling sites at Gull Rock within the reserve (Figure 5). The giant green anemone, *Anthopleura xanthogrammica*, was abundant at Otter Rock Reserve in both 2010 and 2011, but rare at the comparison sites in 2011. The ochre star, *Pisaster ochraceous,* orange sea cucumber, *Cucumaria miniata,* and stalked tunicate, *Styela* were also more abundant at the Otter Rock Reserve than the comparison areas in 2011, and the blood star, *Henricia,* was similarly abundant in both reserve and comparison areas, but made up a much greater proportion of mobile and conspicuous invertebrates in the comparison areas due to the lower abundance of other species (Figures 8 and 9). These differences may reflect differences in the depth distribution of rocky habitats and survey transects between the reserve and comparison areas; nearly all survey transects in the comparison areas were in the 5 meter depth zone, while the reserve area additionally included several transects in the 10 meter depth zone (Table 1). Although these invertebrate species are not of great ecological or economic importance, the differences in their absolute and relative abundances, like the cover of sessile species described below, reflect similarities or dissimilarities in the habitats sampled between the reserve and comparison areas.

The cover of sessile invertebrates and turf algal species (foliose and crustose red algae) at Otter Rock Reserve is characterized by a moderate diversity of taxa that occurred in relatively equal abundance in both 2010 and 2011. Within the reserve in 2011, five taxa constituted 69% of the overall cover with each taxa representing between 7% and 24% cover and the remaining cover made up of bare sand and rare (<5% of cover) taxa (Figure 10). In contrast, the diversity of sessile invertebrates and turf algae in the comparison areas was lower, with three taxa, foliose red algae and erect and crustose coralline algae, comprising 84% of the overall cover and the remaining taxa each representing less than 5% of the total cover. In contrast, foliose red and coralline algae comprised only 41% of the cover within the Otter Rock Reserve, with the remaining cover made up of bare sand, colonial tunicates, surfgrass, and rare taxa (Figure 10). The higher relative cover of these algal species at the shallow exposed sites of the comparison areas likely reflects the high wave turbulence that those sites are exposed to relative to the lee of Gull Rock in the reserve. Like the differences in invertebrate densities described above, the relative abundance of these species are indicators of the similarity or dissimilarity of habitats within and between the reserves and comparison sites.

Fish Assemblage

Species richness of the fish assemblage at Otter Rock Reserve was relatively low (2 species recorded per transect), in both the 2010 and 2011 surveys and in the comparison areas in 2011 (Figure 5). Measures of diversity in the Otter Rock Reserve area were higher in 2011 than 2010, and higher in the reserve than comparison areas in 2011 due, in both cases, to the dominance of black rockfish in the survey data. In 2010, the fish assemblage at Otter Rock Reserve was dominated by black rockfish (65%) followed by kelp greenling (15%) and striped surfperch (10%) with other species representing less than 10% of the total. This same pattern occurred in 2011, but was again obscured by the prevalence of rockfish YOY of the Pteropodus group (Figure 12). Young-of-year of the Sebastosomus group, comprised of black, yellowtail, olive and other rockfishes were also more abundant in 2011. Otherwise, the relative density of the fish species observed in the reserve was generally consistent between years, with the exception of canary rockfish, which were only observed in 2011 (Figure 11). The density and relative abundance of these species was generally similar in the reserve and comparison areas (Figure 11 and 12), however some species that occurred in low densities within the reserve (blue and canary rockfish, cabezon) were not observed across the comparison areas (Figure 11).

Size distributions of the three most abundant species vary in their similarity between reserve and comparisons areas (Figure 13). The size distribution of kelp greenling was very similar between the reserve and comparison areas in 2011. Size distributions of black rockfish were slightly larger in the reserve in 2011 (35cm vs. 30cm). Absence of blue rockfish in comparison areas precluded comparison of size distributions for this species.

General Conclusions

As expected, based upon the marked differences in coastal geomorphology and oceanographic environments between the two pilot reserves and surrounding areas, there are greater differences in the biological communities between these two regions than among areas within each region. These overall differences are most readily seen in non-metric multidimensional scaling (nMDS) plots. nMDS plots are multivariate descriptors of the relative abundance of species that constitute a community or assemblage in a sample (in this case, at an area in each year). The proximity of points on the plot reflects the similarity of the species composition to one another such that points closer together are more similar in assemblage or community structure. By plotting the areas separately for each year, the temporal constancy of differences between areas can be seen. The overall differences between the Otter Rock region and the Redfish Rocks region are illustrated by the persistent (i.e. both years) separation of these areas to the right and left of the nMDS plot, respectively (Figure 14). The same pattern is readily discerned for the invertebrate assemblages (Figure 15) and the fish assemblages (Figure 16), underpinning the clear separation (i.e. differences) in the structure of these communities (algae, invertebrates and fishes combined) between the two regions that are consistent between the two years of sampling (Figure 17).

Within the context of these regional differences, each of the pilot reserves appear to support a diversity of fishes, invertebrates and algae that are similar to what appears typical of shallow rocky reef habitats in the two regions, based on estimates generated at the comparison areas (Figure 5). The addition of sites in 2011 that seemed to differ in habitat type and relief (e.g., the Island Rock site at the Humbug comparison area and the Gull Rock sites within the Otter Rock Reserve) actually reduced the diversity of substratum types sampled in each area (Figure 3). The diversity of relief categories sampled also decreased in Redfish Rocks Reserve and Otter Rock Reserve. This result likely explains why the measured diversity of algae, invertebrates, and fishes did not increase at many areas in the second year of sampling (Figure 5).

On closer examination of the nMDS plots of the kelp assemblages (Figure 14), the closer proximity of samples taken in different years at each area indicate that differences among the areas were consistent between years, despite the addition of or change in sampling sites in 2011 (e.g., addition of Island Rock at the Humbug comparison area, focus on high relief at McKenzie Reef, addition of the Gull Rock sites in the Otter Rock Reserve). However, in spite of changes to sampling sites between 2010 and 2011, the observed kelp assemblages in the Redfish Rocks reserve and comparison areas do not appear more similar in 2011 than in 2010. Differences in the kelp assemblages among these areas is driven largely by changes in the relative abundance of understory kelps (e.g., *Alaria*, *Cystoseira*, *Pterygophora*) than by the bull kelp, *Nereocystis*.

The invertebrate assemblage in the Redfish Rocks Reserve appears to be characteristic of that region as depicted by the interspersion of both years of samples from that area among the comparison areas in the nMDS plots (Figure 15). This similarity likely reflects similarities in the geomorphology of reef structure among areas, especially after addition of sampling sites in 2011 (Figures 3 and 4). Of the mobile and conspicuous invertebrates, only one species, the red urchin, is of economic importance and also probably the most ecologically important invertebrate. Red urchins occurred at similar or higher densities in Redfish Rocks Reserve as compared to the Humbug and McKenzie comparison areas, respectively (Figure 8a). As such, this reserve is likely to be a source of larval supply to urchin populations elsewhere in the region. This is not as clearly the case for Otter Rock Reserve, where density of red sea urchins was lower than that observed at the comparison areas to the north. Perhaps the shallow depths, high exposure to swell, low rocky relief and surrounding expanses of sediment reduces the quality of habitat for this species in the Otter Rock Reserve. Additionally, there was greater harvest pressure in the reserve (before closure) than in the comparison areas. Also, Whale Cove (one of the sampling sites in the Foulweather comparison area) has been closed to urchin extraction for several decades. Given that only one of the observed invertebrates was of economic importance, patterns of invertebrate abundance are primarily informative in that they reflect similarity in habitat among reserve and comparison areas and suggest higher biodiversity within the Otter Rock Reserve relative to comparison areas.

The nMDS plots indicate that in some cases fish assemblages exhibit greater temporal variation (year-to-year) than spatial variation (among areas) within a region (Figure 16). The reserve and comparison areas at Redfish Rocks shift in a similar direction between years, suggesting that the assemblages changed similarly from 2010-2011. Examination of the pie charts suggest that this shift was the result of the high recruitment of young-of year rockfishes in 2011 across these three areas. Among these three areas, McKenzie differs the most within a given year, likely attributable to the preponderance of black rockfish at McKenzie Reef relative to Humbug comparison area and Redfish Rocks Reserve.

Appendices 1a, 1b, and 1c provide estimates of the mean and standard error of the density of macroalgae, invertebrates and fishes respectively. The magnitude of the standard error indicates the certainty of the estimates of the mean. The smaller the error, the more readily detectable change will be over time. The larger error for blue and black rockfish relative to other species, reflect the greater spatial variability of their abundance relative to the size of the sample unit (i.e. size of a transect). These abundant and aggregating species have greater error associated with their density estimates compared to the more residential and homogeneously distributed benthic fishes like kelp greenling. These comparisons are important for identifying the species for which temporal changes in abundance are most likely to be detectable given the sampling methodology.

The species accumulation curves generated for the fish assemblages at each reserve and comparison area indicate similar relationships between sample size (number of transects) and the number of fish species sampled (Appendix 2a). Although none of the curves asymptote entirely, the slope decreases markedly around 10 transects with diminishing returns in species number at around 20 transects. The one exception to this general pattern is Redfish Rocks Reserve, which continues to add rarer species across the range of sample sizes. Species accumulation curves generated for the assemblage of macroinvertebrates at each reserve and comparison site indicates a stronger tendency to asymptote by 10 transects across all reserve and comparison areas (Appendix 2b). In general, 10 transects appears sufficient to characterize the invertebrate assemblage at all of the study sites. Species accumulation curves generated for the assemblage of kelps at each reserve and comparison area indicates that even fewer transects (5-6) are sufficient to include the low diversity of kelps across these study areas (Appendix 2c). Overall, the species accumulation curves generated for the fish, macroinvertebrate and macroalgae (kelp) assemblages at the reserve and comparison areas suggest that a minimum of 20 fish and 10 benthic (invertebrate and macroalgae) transects are necessary to representatively sample the species composition at these areas (Appendix 2). The greater number or transects necessary to sample fishes relative to both macroinvertebrates and macroalgae reflects the lower densities and patchiness of fish species such that a greater number of transects is required to encounter less abundant fish species in an area. Fortunately, roughly twice as many fish transects than benthic transects can be sampled on a dive such that teams of fish and benthic samplers can simultaneously survey sites together and generate sufficient sample sizes for each of the three assemblages.

Overall, both pilot reserves shared many species with their comparison areas, especially with respect to the fishes and especially in the Redfish Rocks region. The similarities are not as strong between the fish assemblages in the Otter Rock reserve and its comparison areas, though this comparison is hampered by having only one year upon which to make the comparison. Another year of sampling may indicate greater similarity in the fish assemblage among these areas. Another notable pattern generated by these surveys is the difference in algae, invertebrate and fish assemblages associated with the emergent rock and inshore kelp bed habitats. These differences indicate how inclusion of these two habitats within the

Redfish Rocks Reserve increases habitat and overall biodiversity protected by that reserve. Overall, however, it is likely that these areas will allow for comparisons of population trajectories inside and outside of the reserve and facilitate assessment of the response of several common fishes, invertebrates and algae to the establishment of these two pilot reserves.

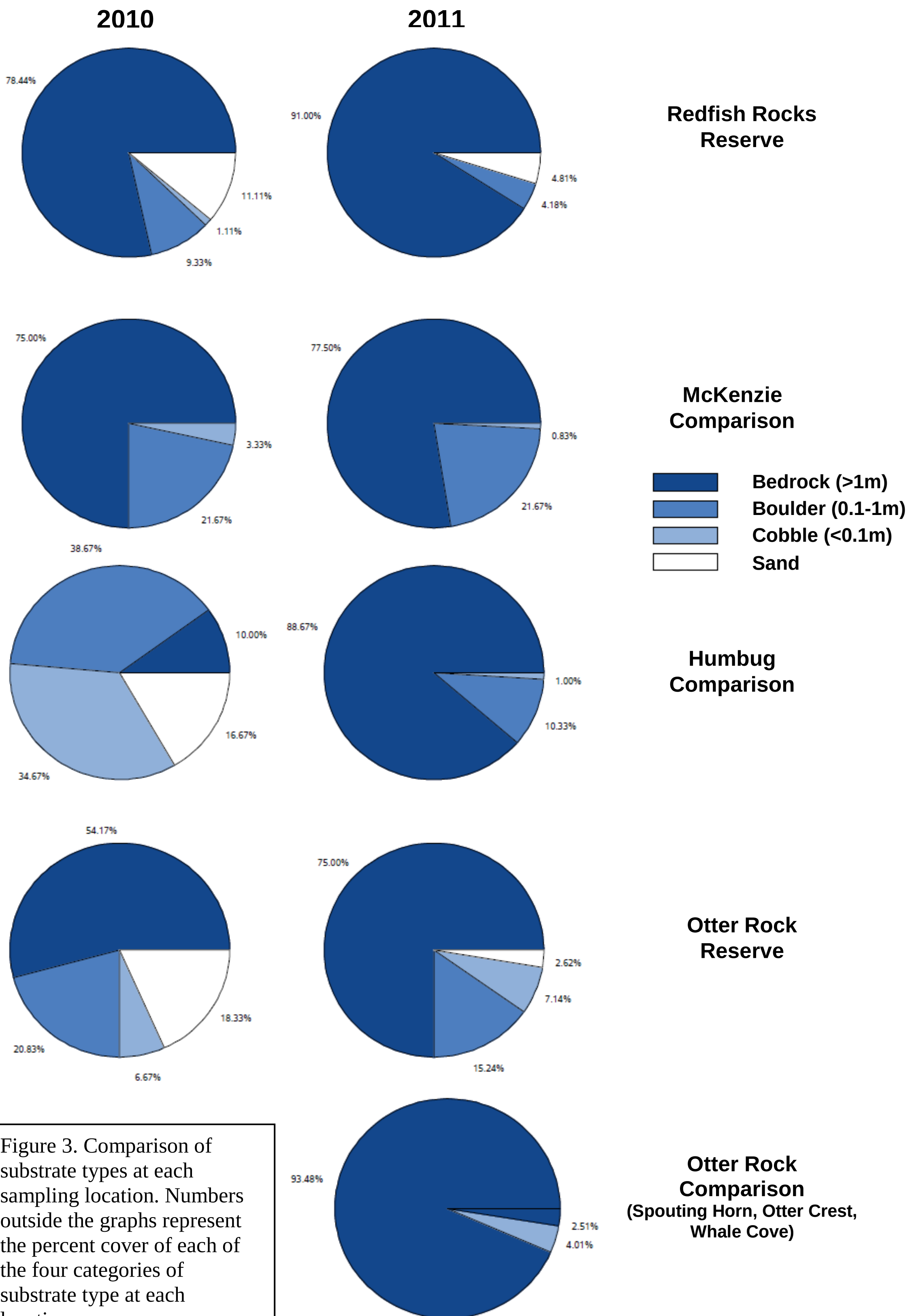


Figure 3. Comparison of substrate types at each sampling location. Numbers outside the graphs represent the percent cover of each of the four categories of substrate type at each location.

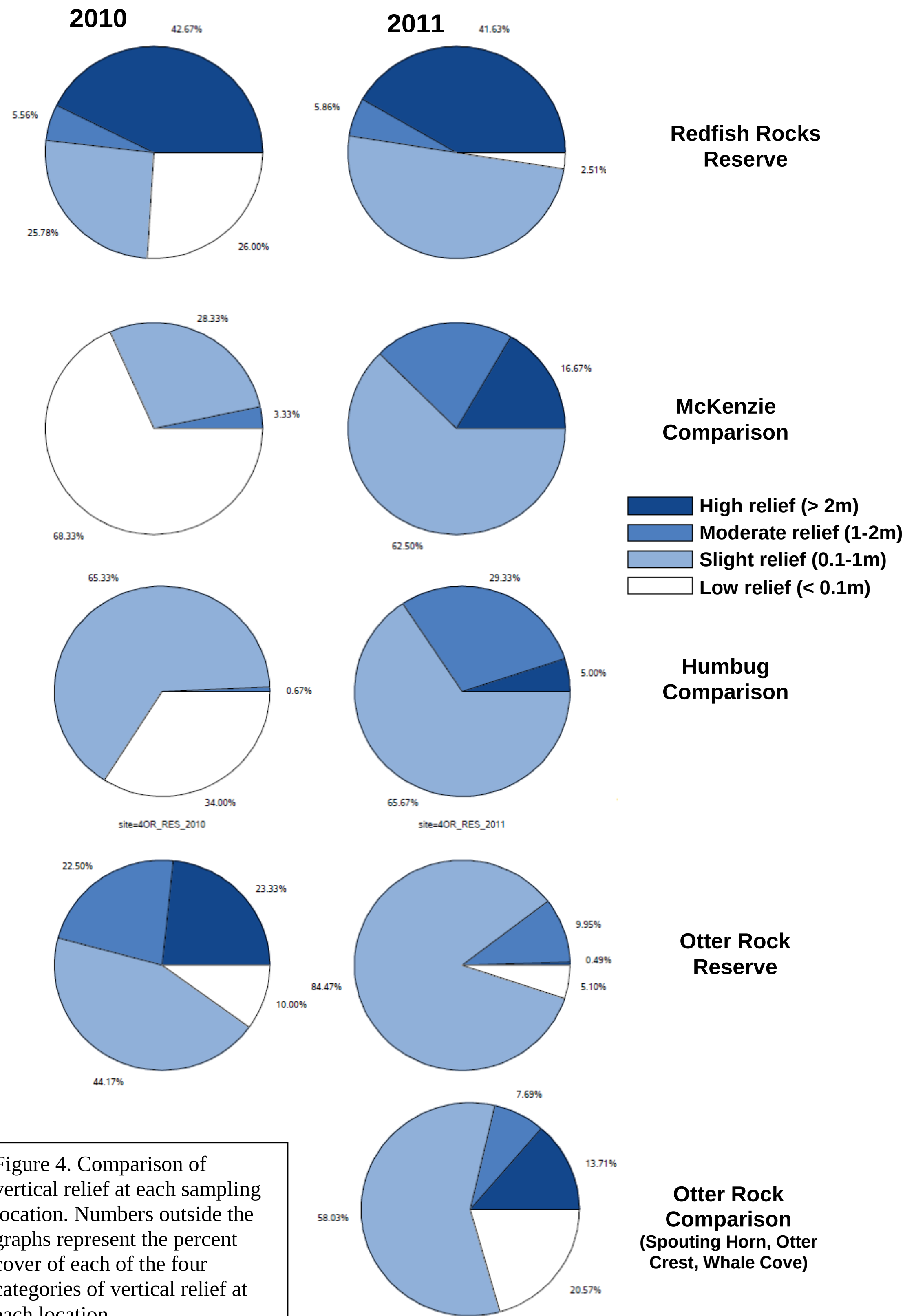


Figure 4. Comparison of vertical relief at each sampling location. Numbers outside the graphs represent the percent cover of each of the four categories of vertical relief at each location.

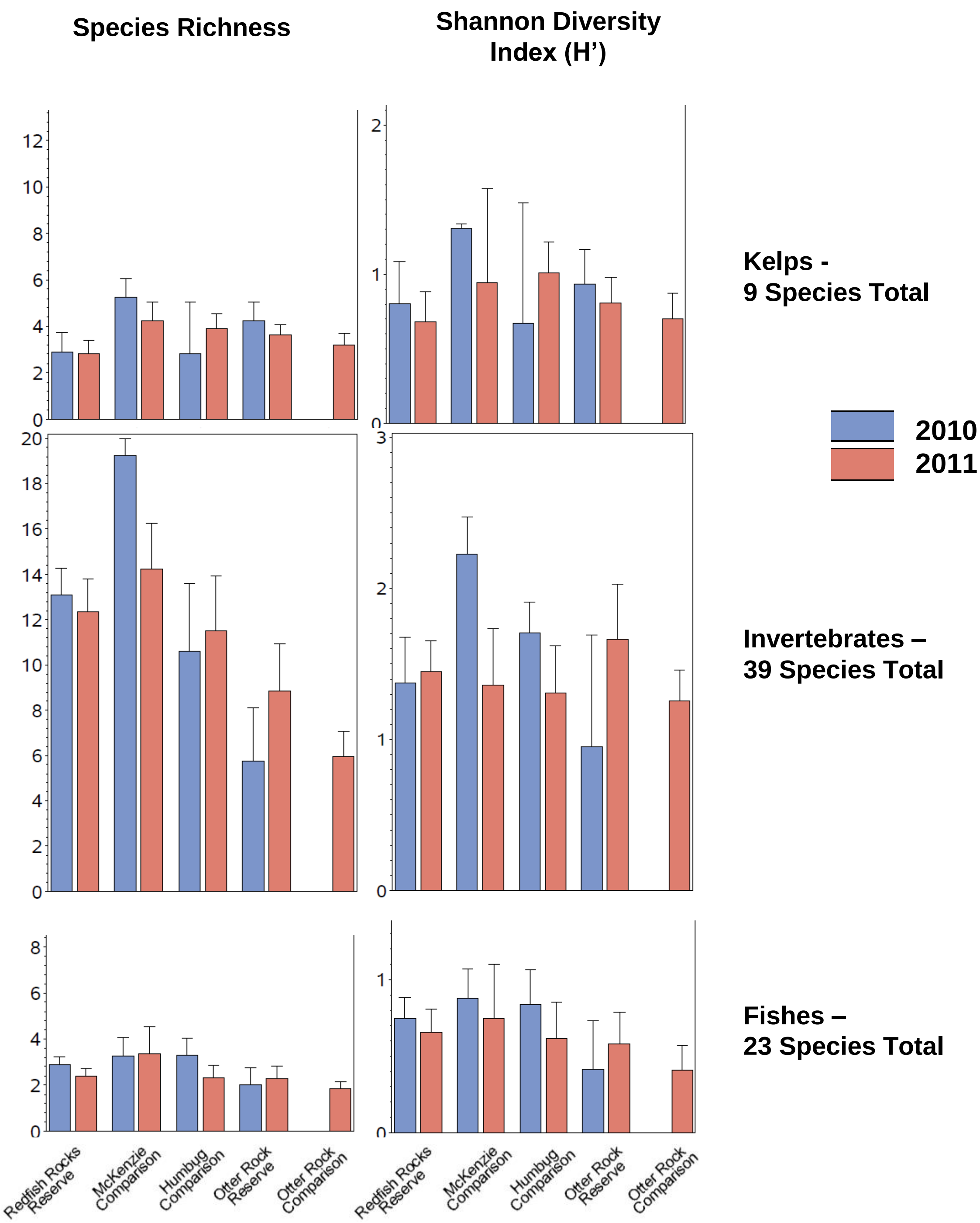


Figure 5. Species richness (number of species recorded per transect) and Shannon diversity index estimates calculated at the transect level across reserve and comparison sites for the kelp, invertebrate and fish communities. Error bars indicate 95 % confidence limits.

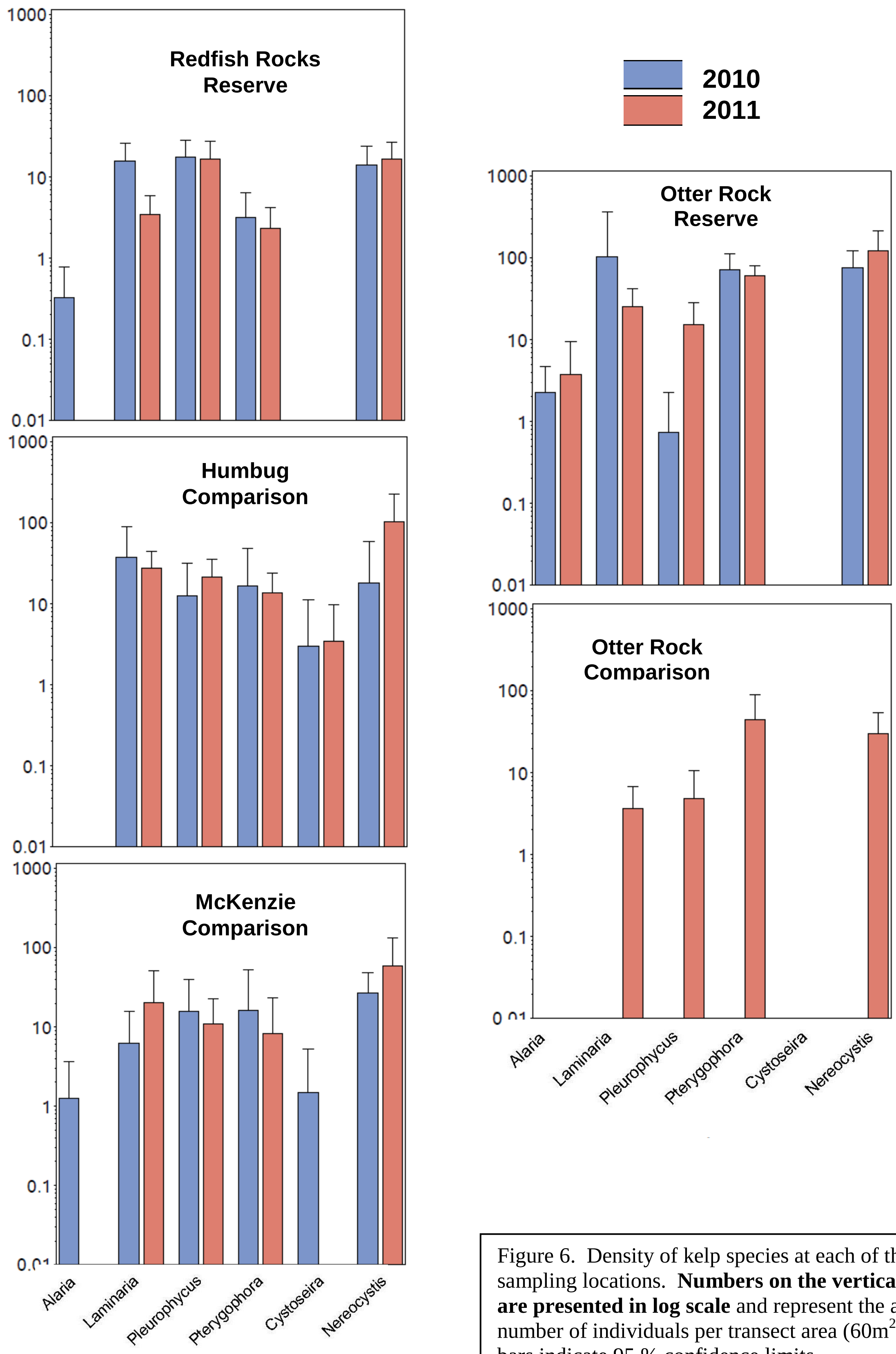


Figure 6. Density of kelp species at each of the sampling locations. **Numbers on the vertical axes are presented in log scale** and represent the average number of individuals per transect area (60m^2). Error bars indicate 95 % confidence limits.

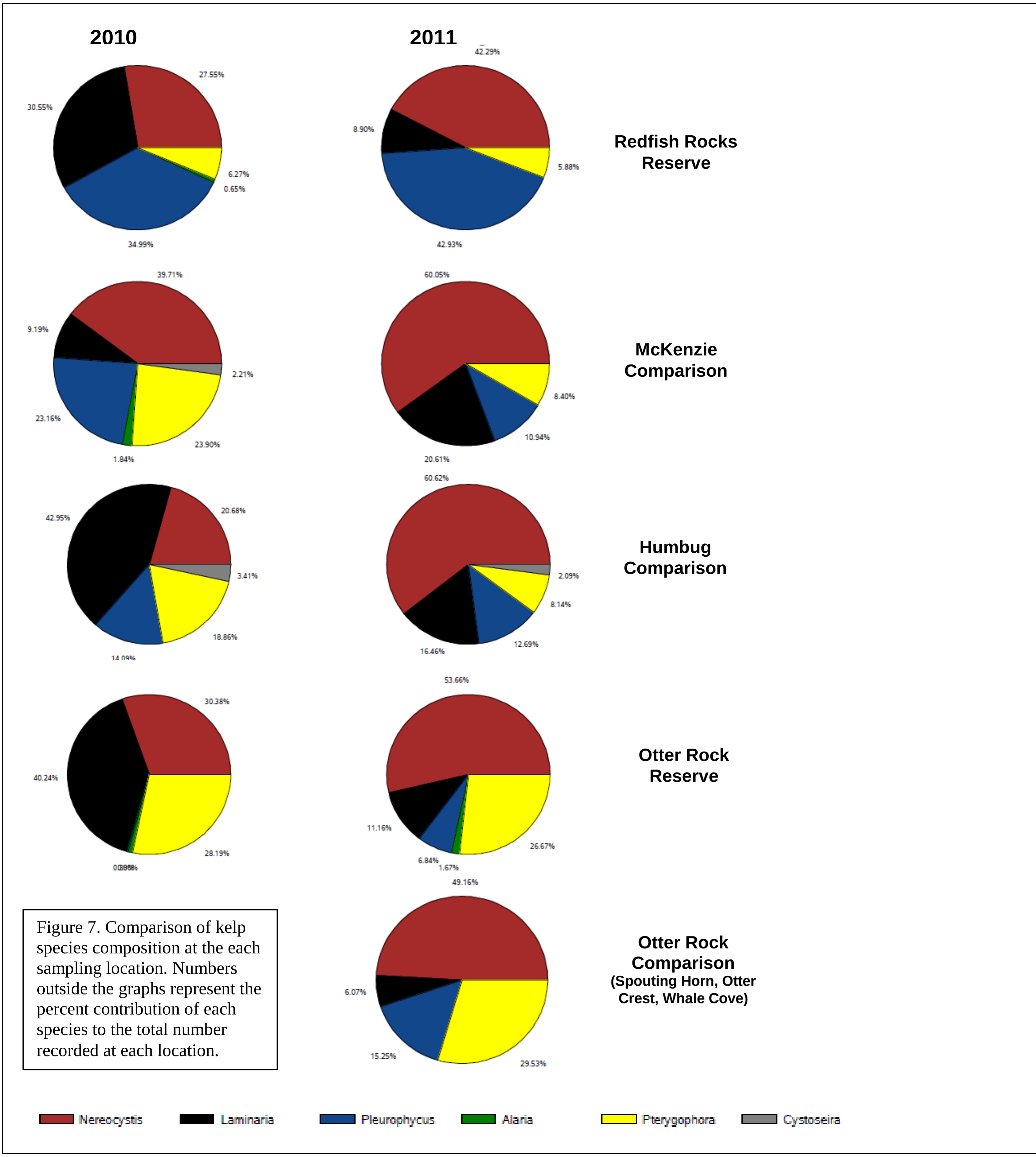


Figure 7. Comparison of kelp species composition at the each sampling location. Numbers outside the graphs represent the percent contribution of each species to the total number recorded at each location.

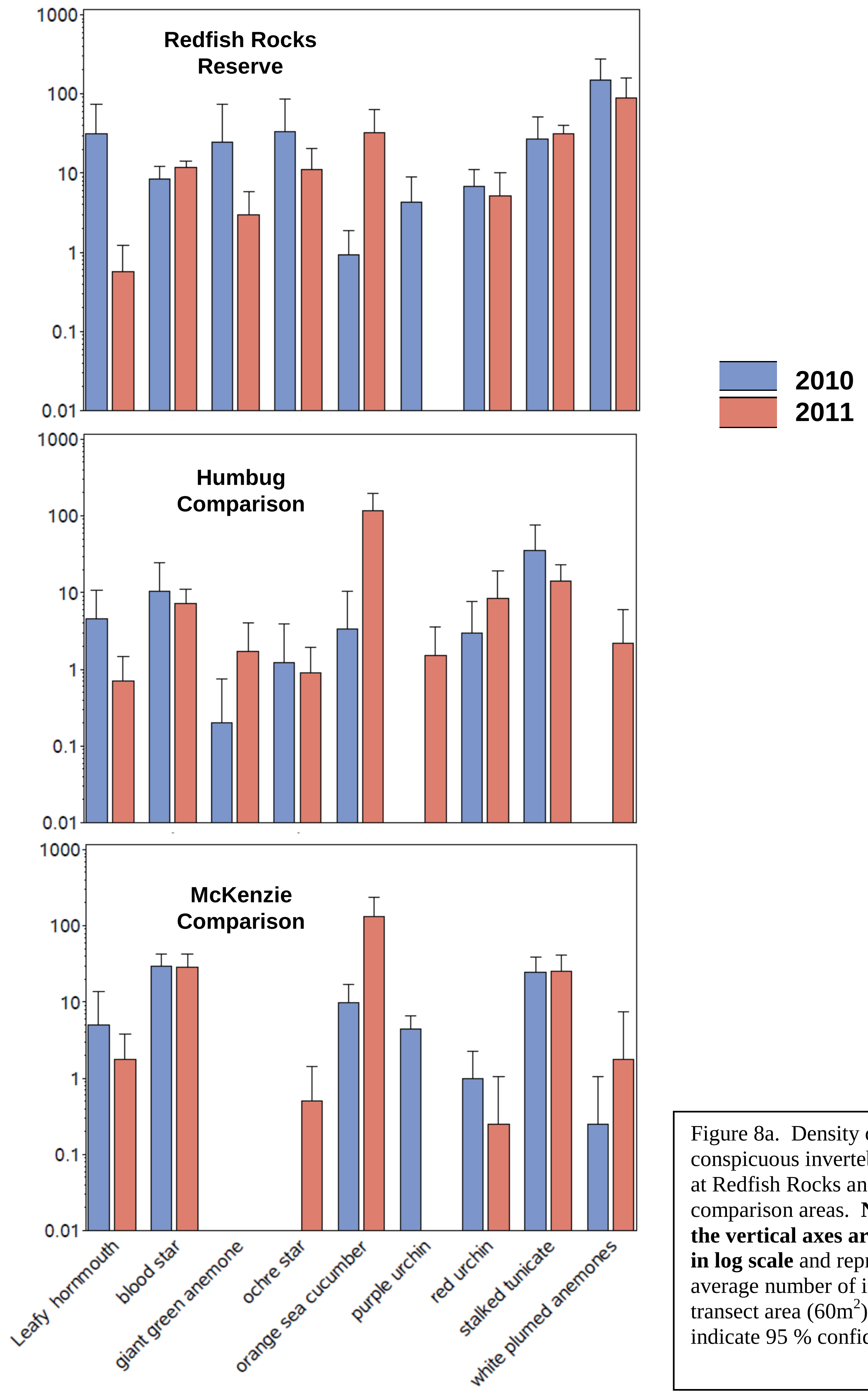


Figure 8a. Density of mobile and conspicuous invertebrate species at Redfish Rocks and its comparison areas. **Numbers on the vertical axes are presented in log scale** and represent the average number of individuals per transect area (60m^2). Error bars indicate 95 % confidence limits.

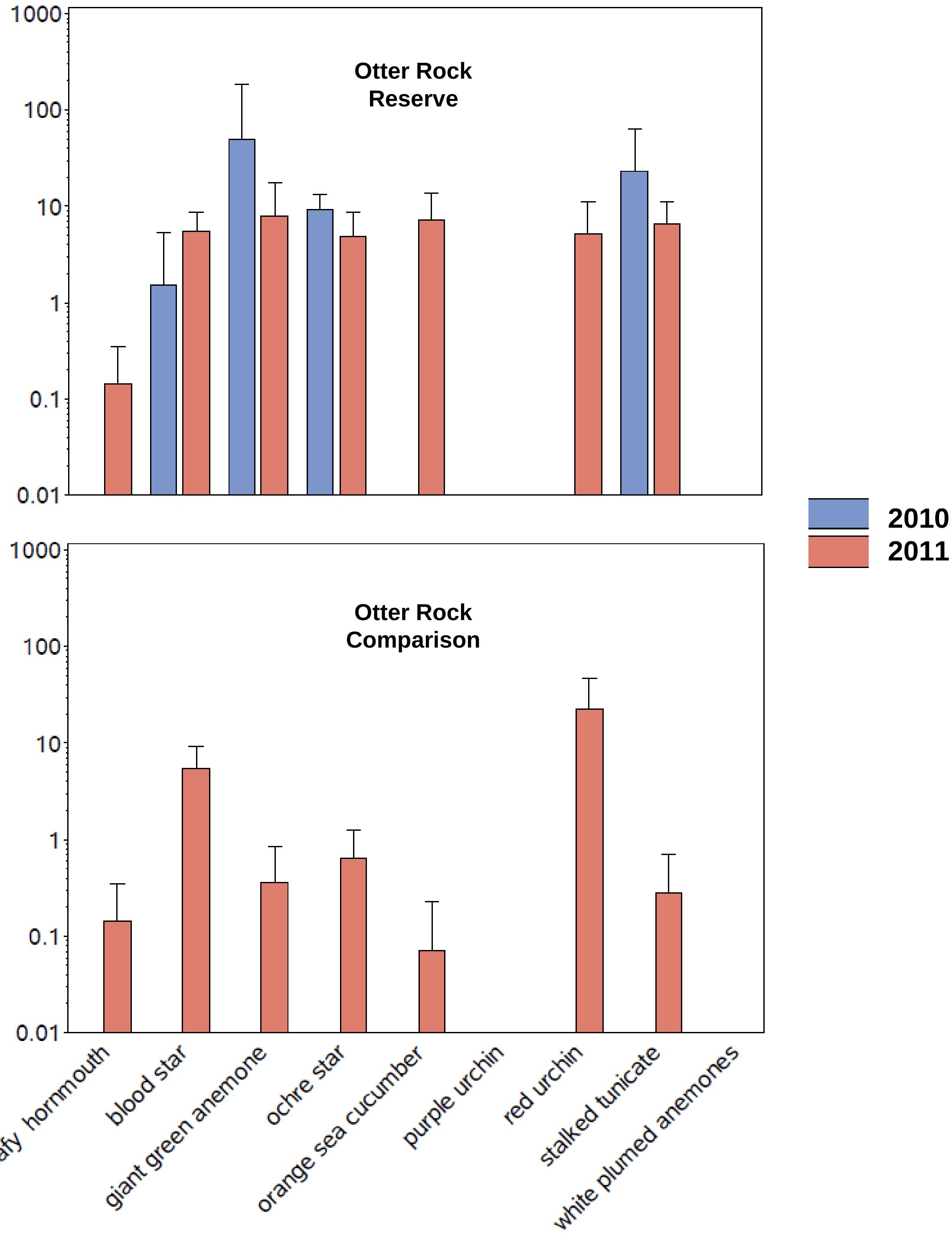


Figure 8b. Density of mobile and conspicuous invertebrate species at Otter Rock and its comparison areas. **Numbers on the vertical axes are presented in log scale** and represent the average number of individuals per transect area (60m^2). Error bars indicate 95 % confidence limits.

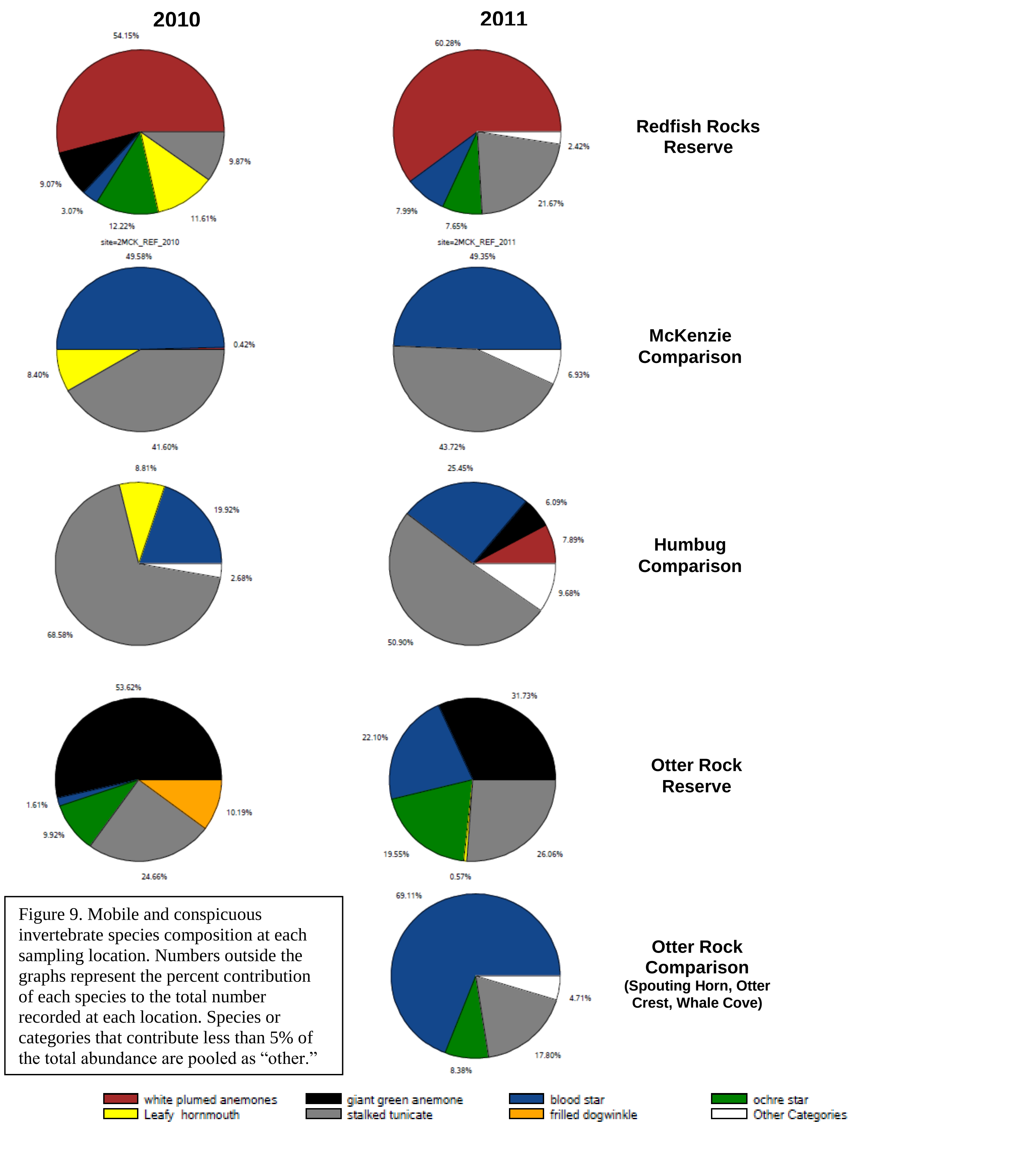
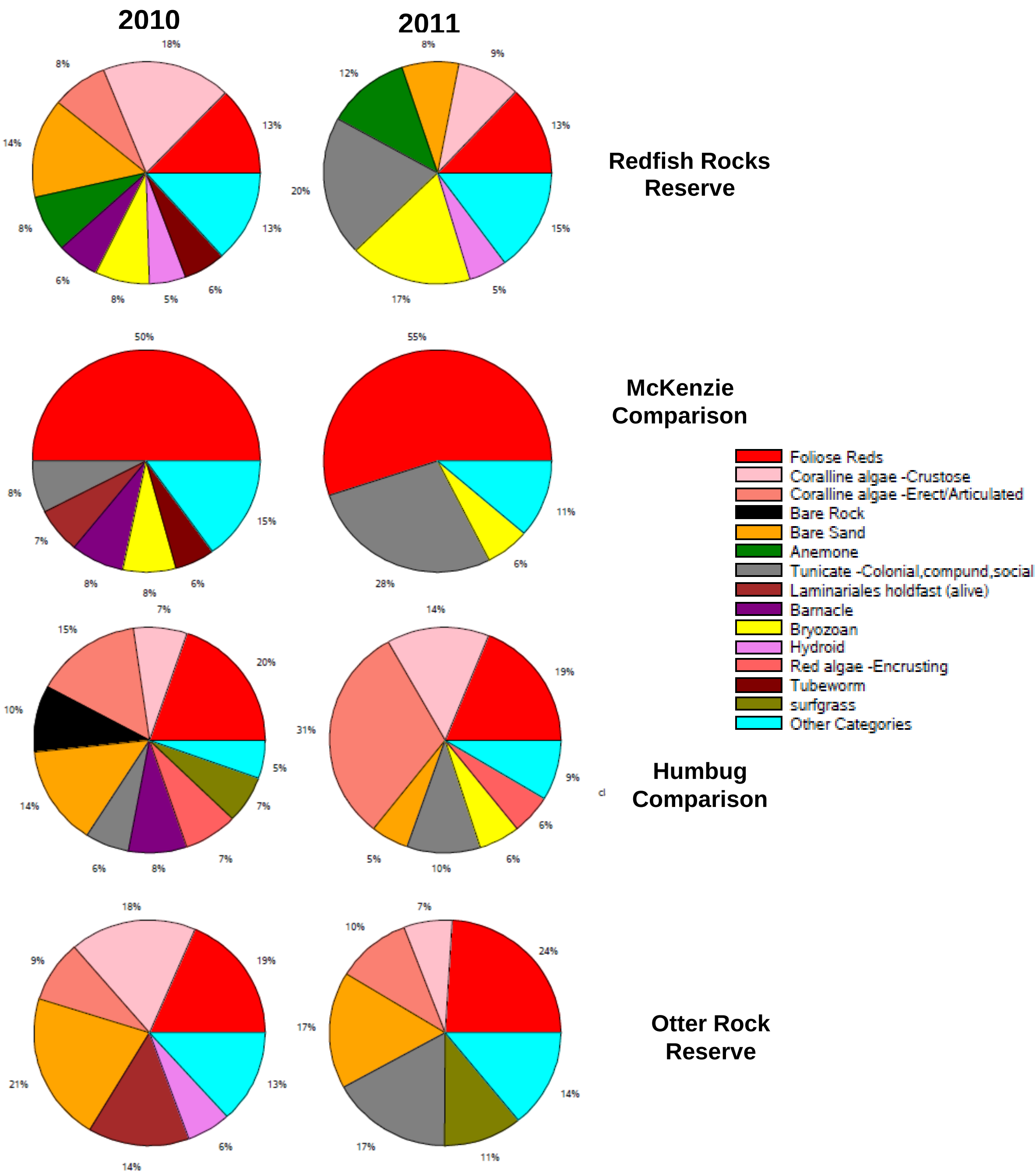


Figure 9. Mobile and conspicuous invertebrate species composition at each sampling location. Numbers outside the graphs represent the percent contribution of each species to the total number recorded at each location. Species or categories that contribute less than 5% of the total abundance are pooled as "other."



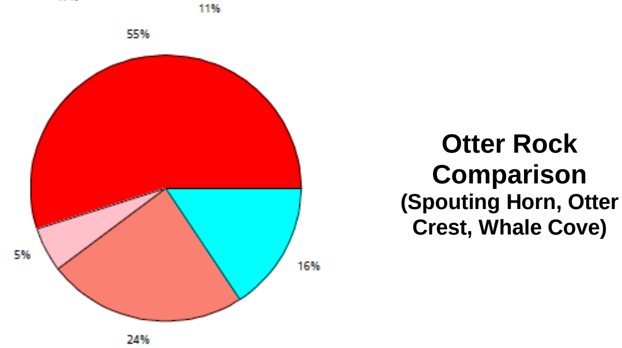


Figure 10. Percent cover of sessile invertebrates, algae and bare substrate (sand and rock) at each sampling location. Numbers outside the graphs represent the percent contribution of each category to the total cover recorded at each location. Species or categories that contribute less than 5% of the total cover are pooled as “other.”

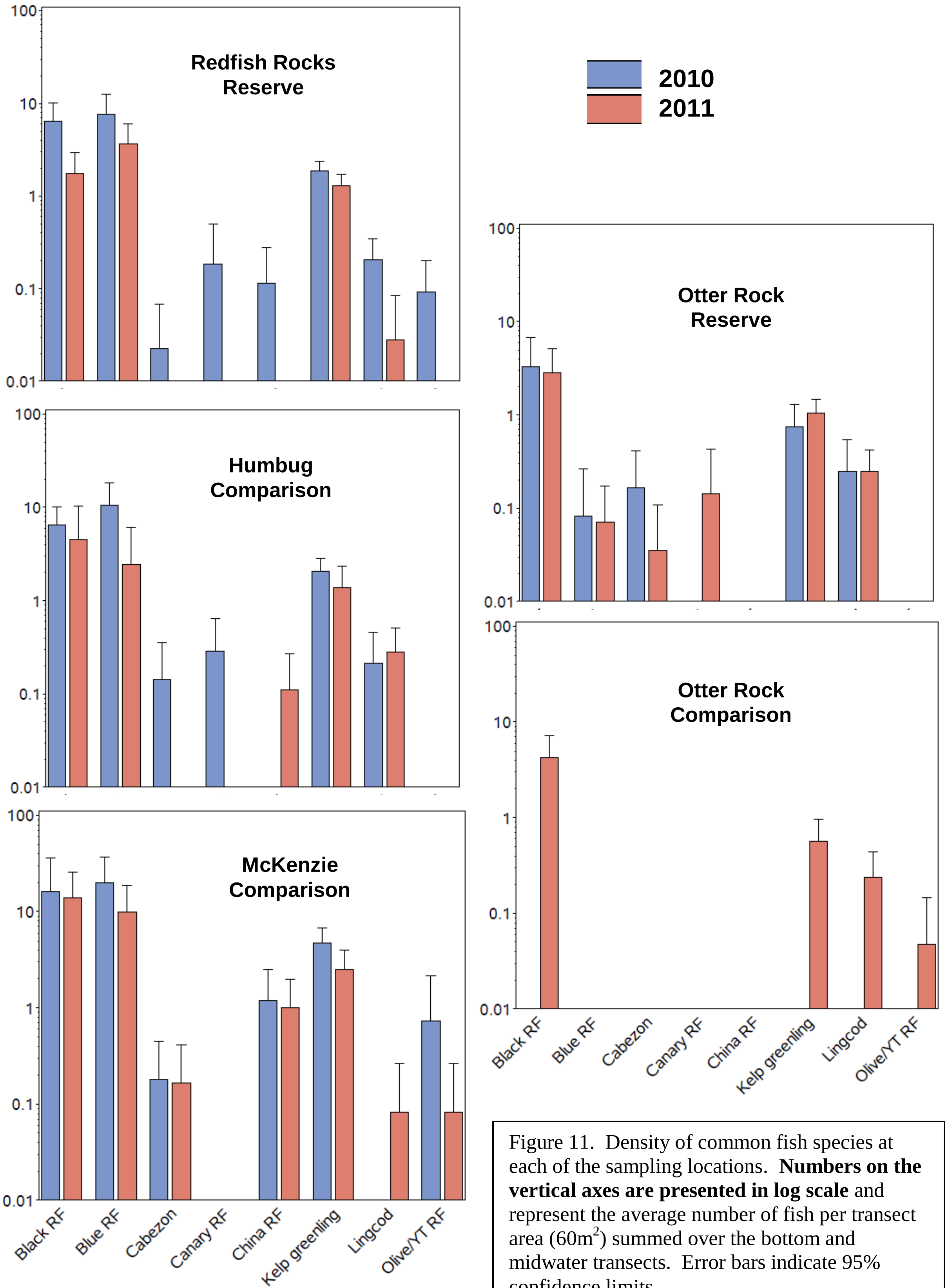


Figure 11. Density of common fish species at each of the sampling locations. **Numbers on the vertical axes are presented in log scale** and represent the average number of fish per transect area (60m^2) summed over the bottom and midwater transects. Error bars indicate 95% confidence limits.

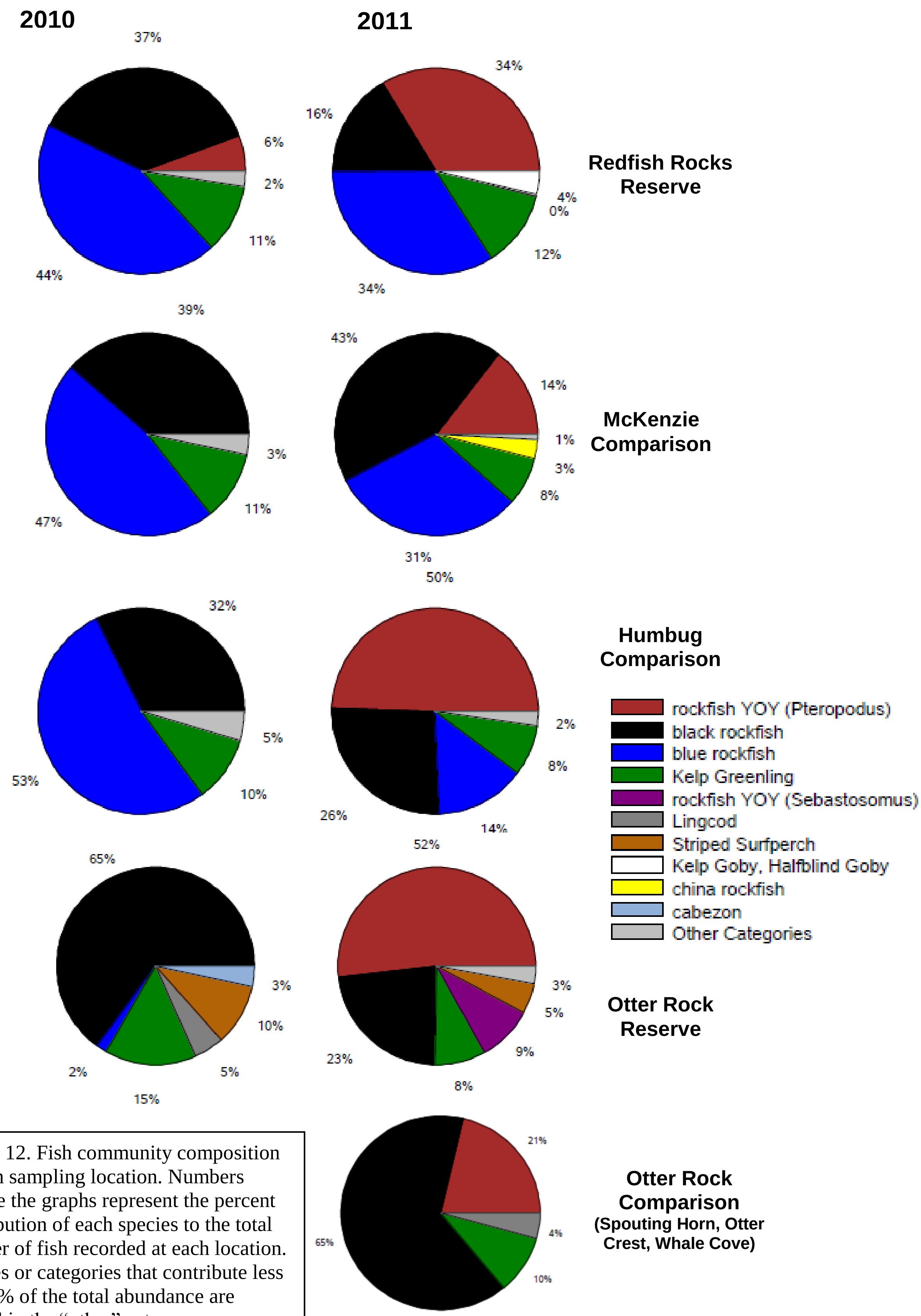


Figure 12. Fish community composition at each sampling location. Numbers outside the graphs represent the percent contribution of each species to the total number of fish recorded at each location. Species or categories that contribute less than 5% of the total abundance are pooled in the "other" category.

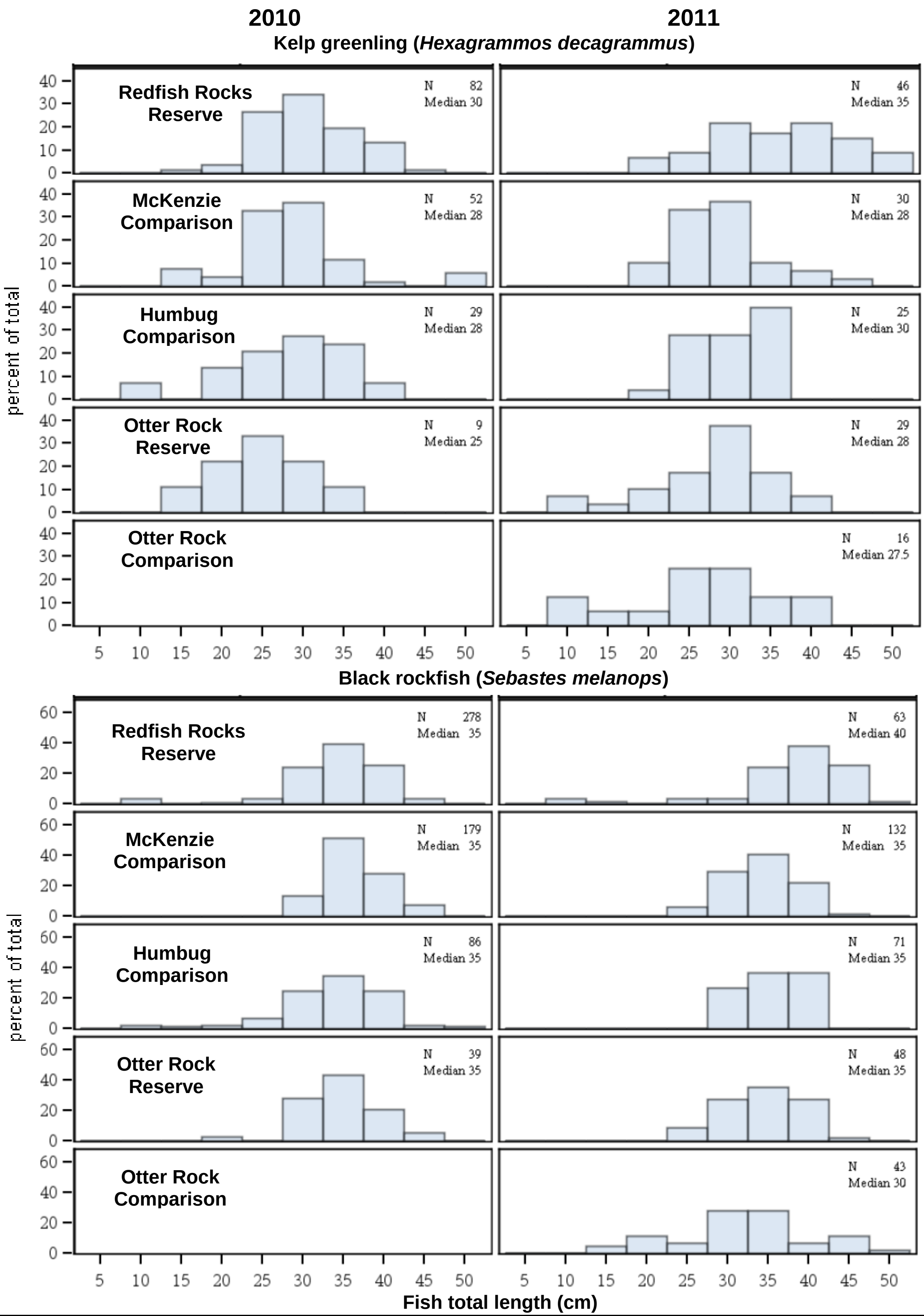


Figure 13. Comparison of size frequency distributions of the three most common fish species across all sampling locations. Numbers of fish recorded at each site and the median of their lengths are indicated in each box.

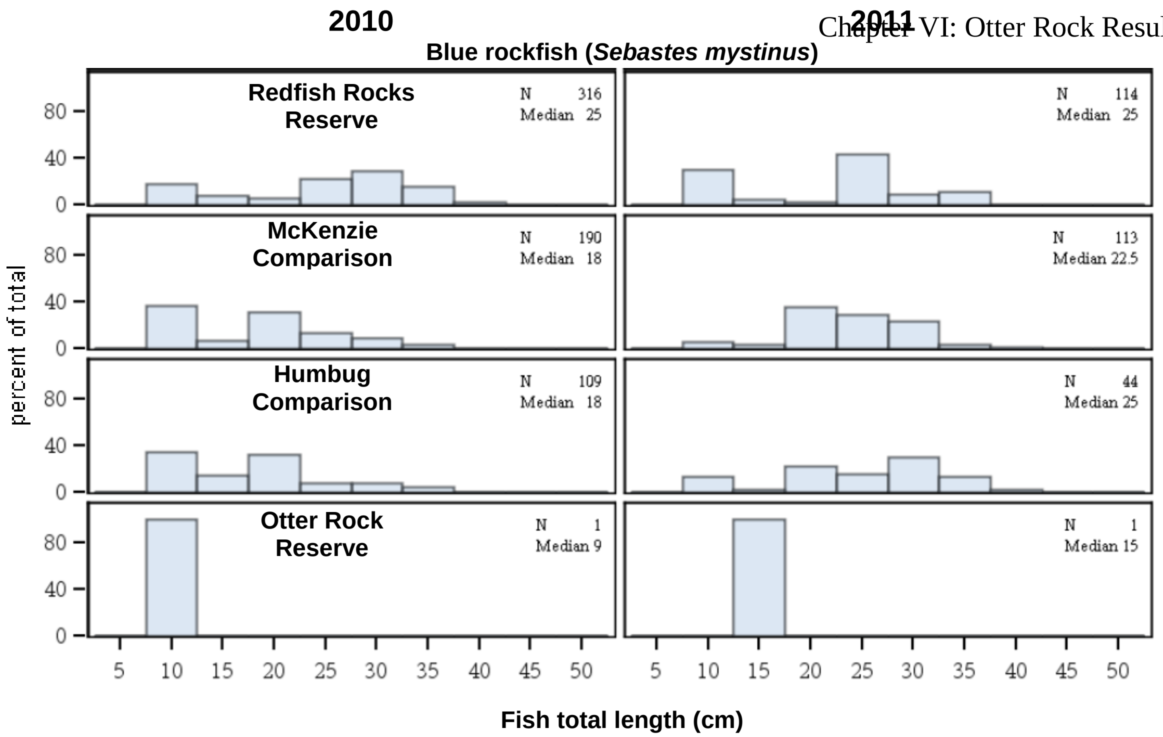


Figure 13 continued. Comparison of size frequency distributions of the three most common fish species across all sampling locations. Numbers of fish recorded at each site and the median of their lengths are indicated in each box.

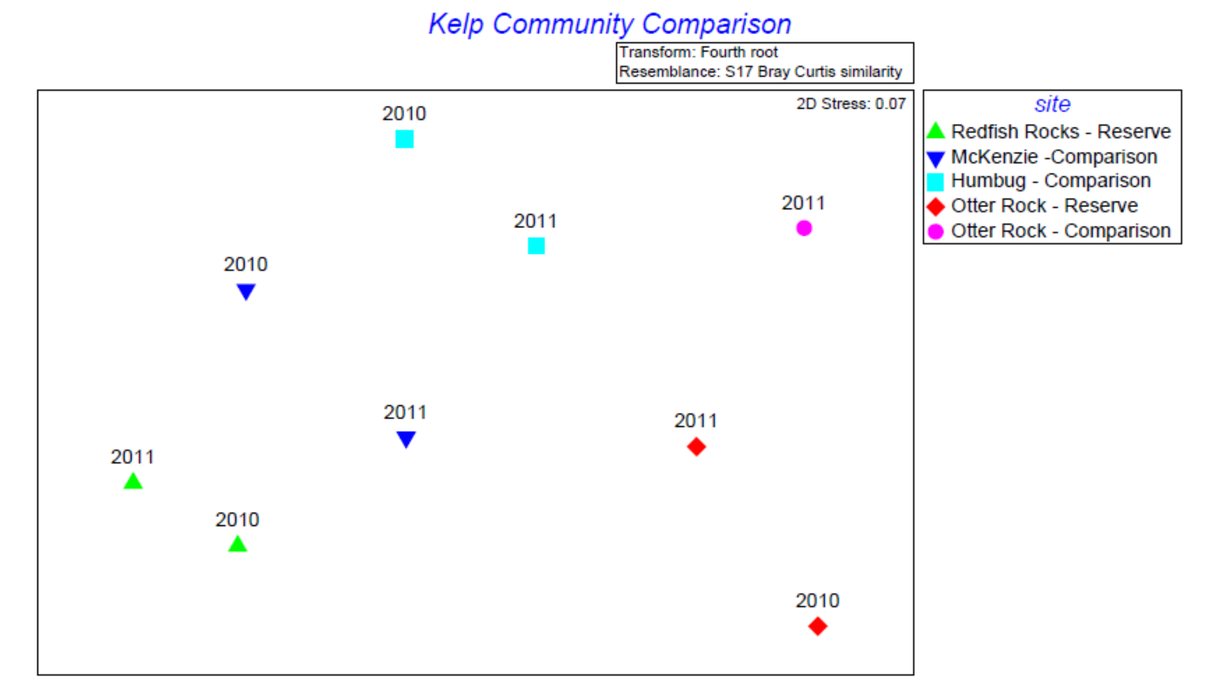


Figure 14. Non-metric multidimensional scaling (nMDS) plot depicting similarity of kelp community composition among the 5 survey areas and two survey years of monitoring.

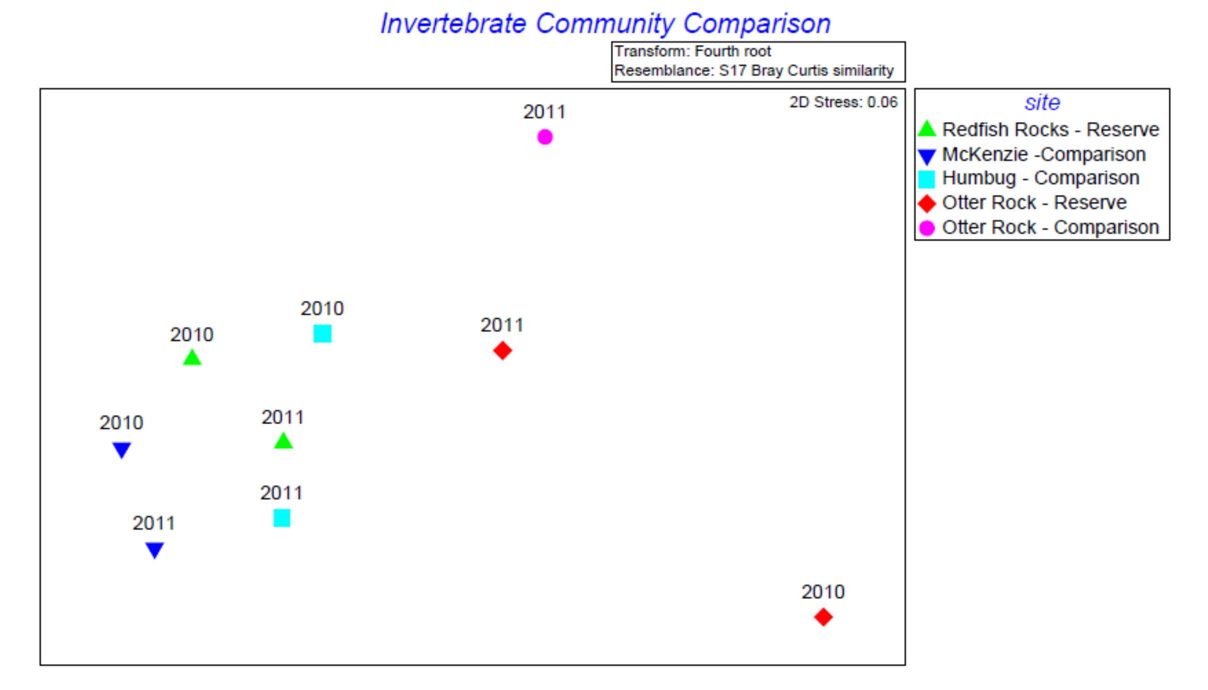


Figure 15. Non-metric multidimensional scaling (nMDS) plot depicting similarity of mobile/conspicuous invertebrate community composition among the 5 survey areas and two survey years of monitoring.

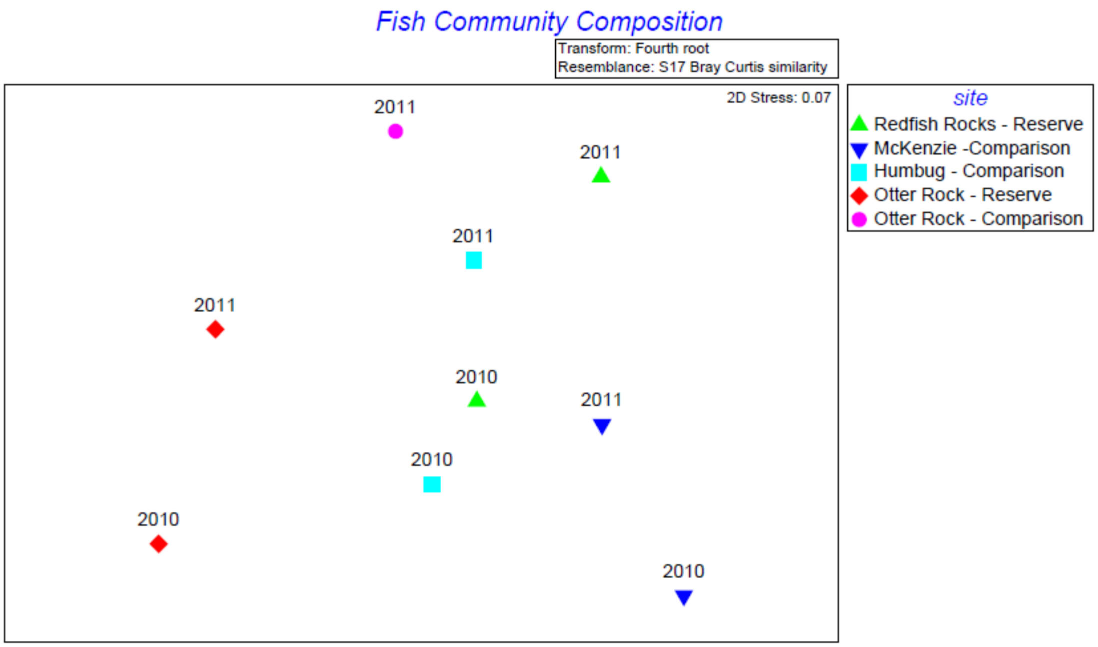


Figure 16. Non-metric multidimensional scaling (nMDS) plot depicting similarity of fish community composition among the 5 survey areas and two survey years of monitoring.

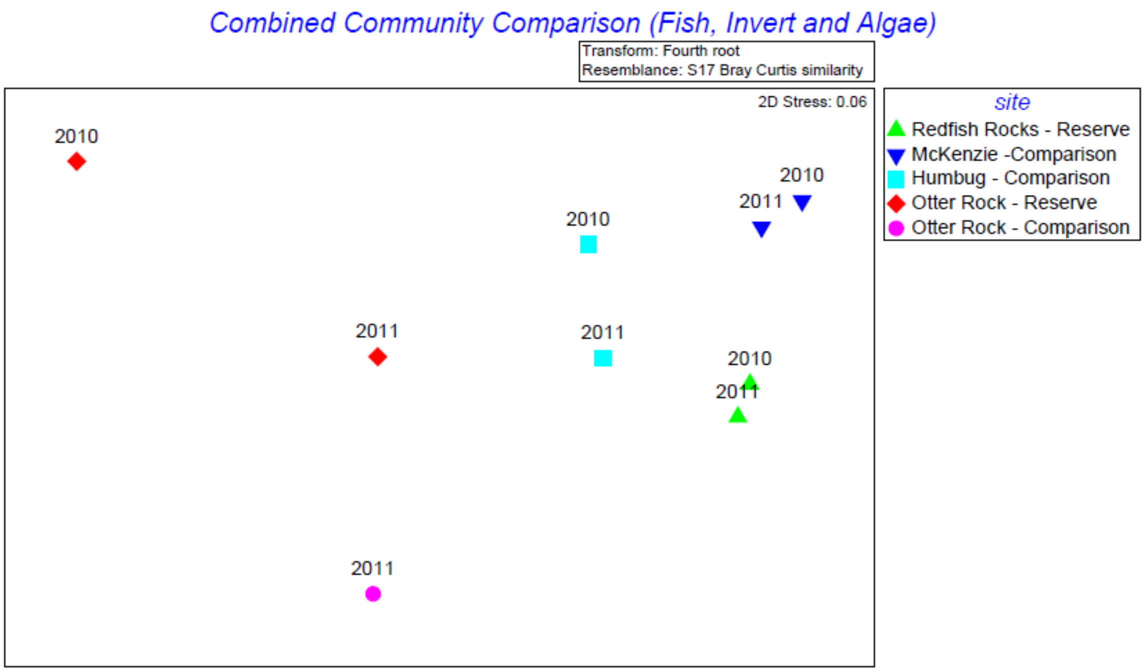
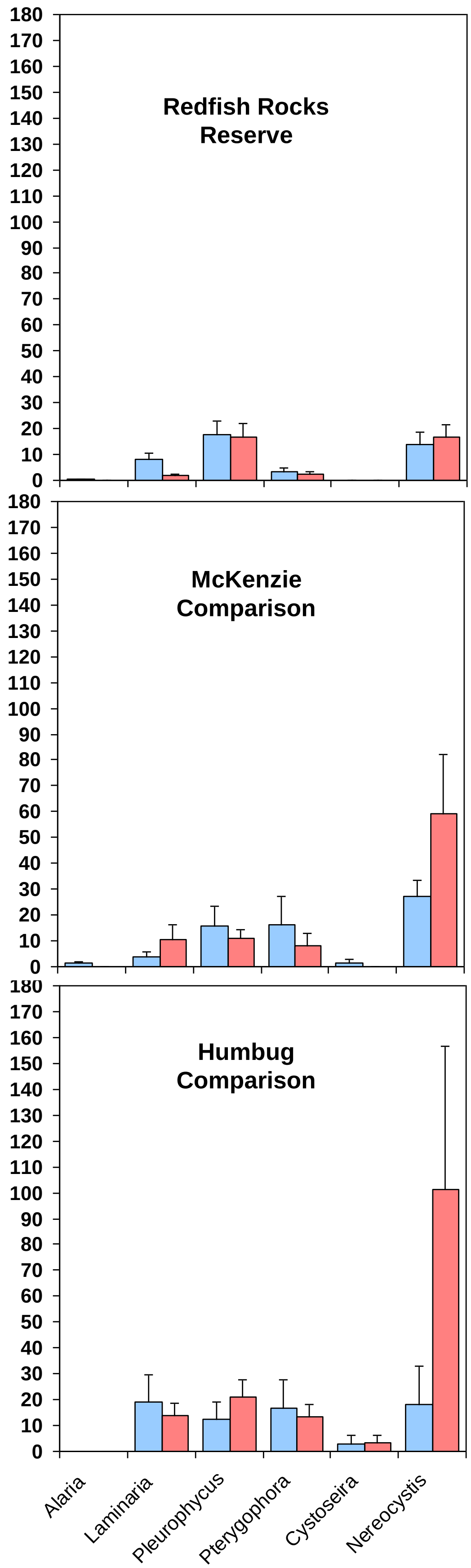
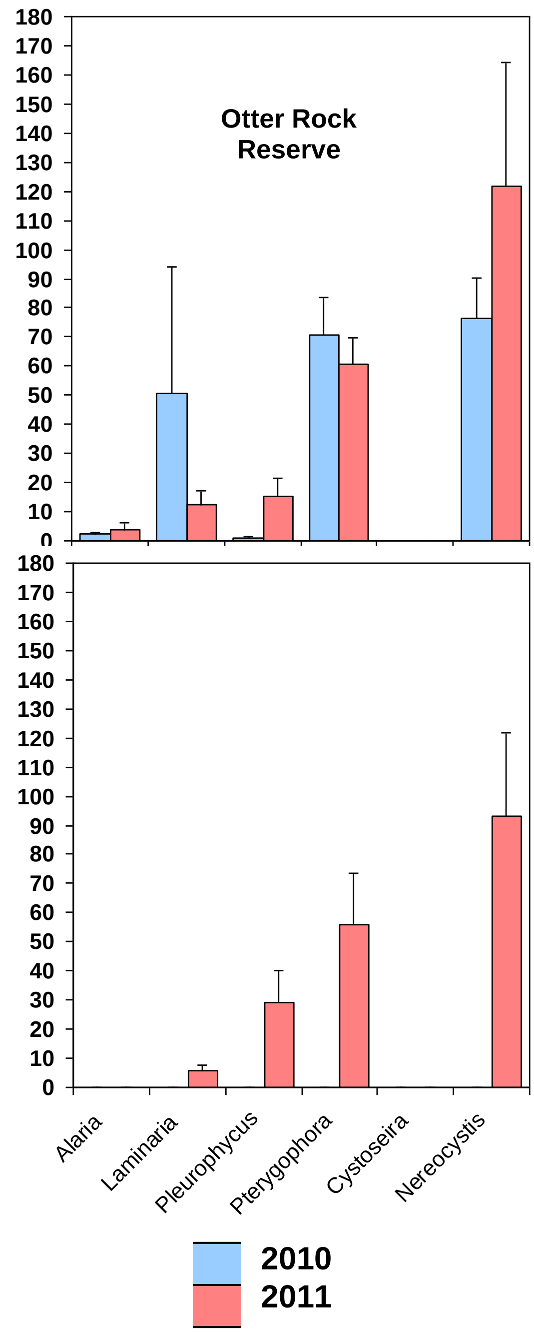
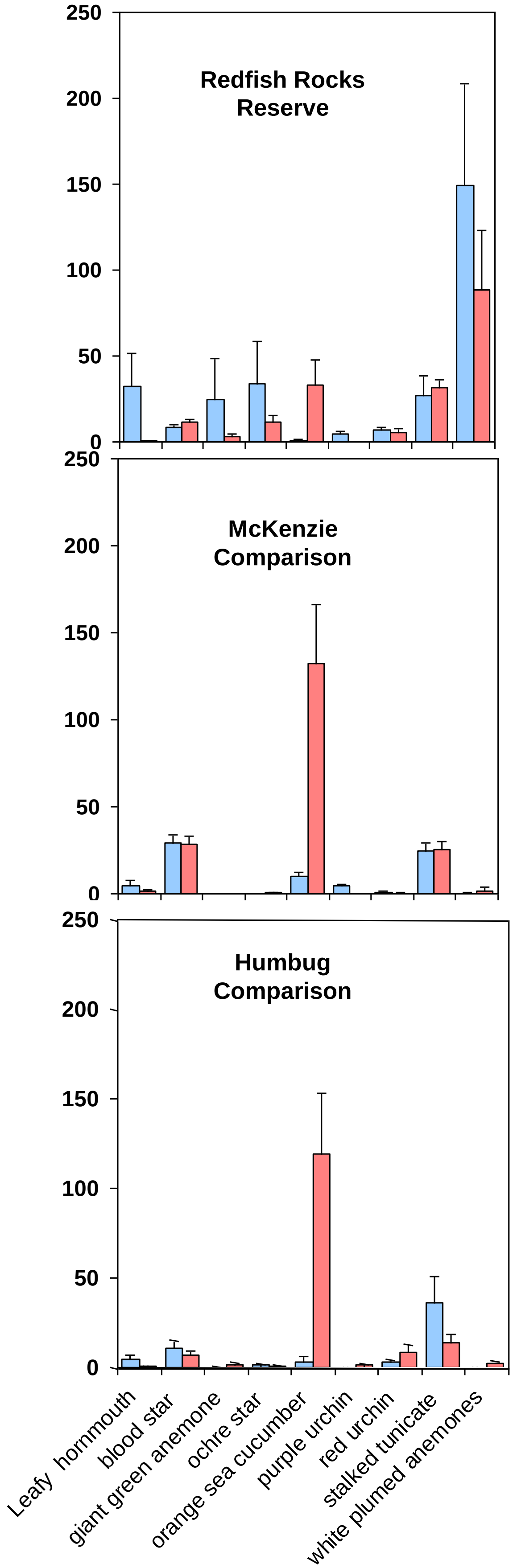


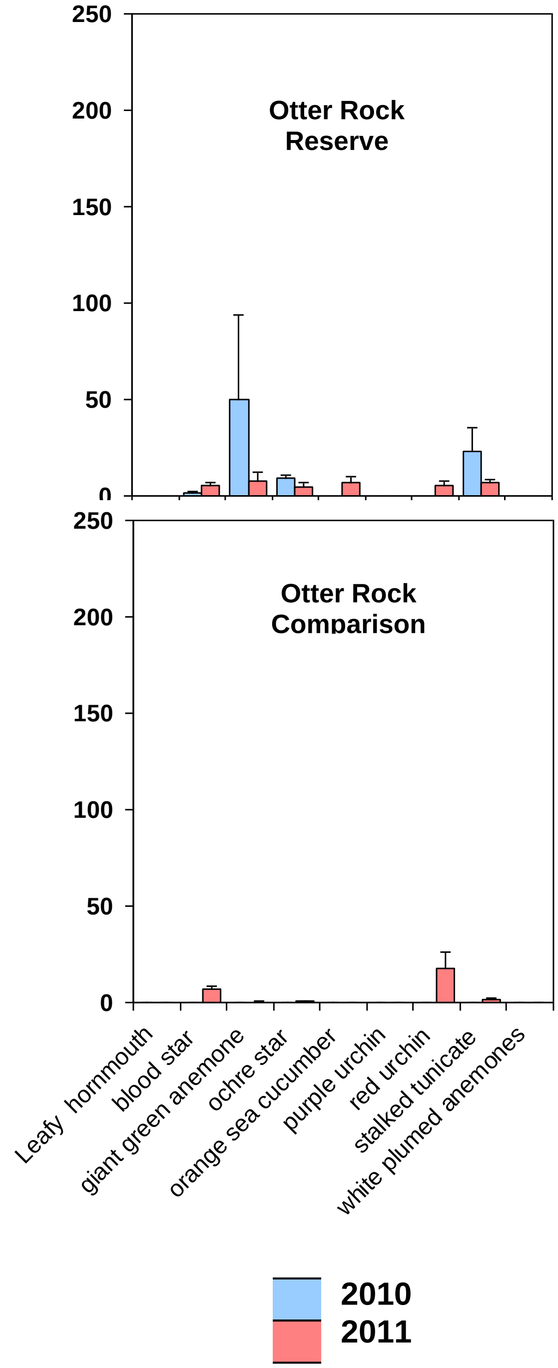
Figure 17. Non-metric multidimensional scaling (nMDS) plot depicting similarity of combined fish, invertebrate and kelp community composition among the 5 survey areas and two survey years of monitoring.



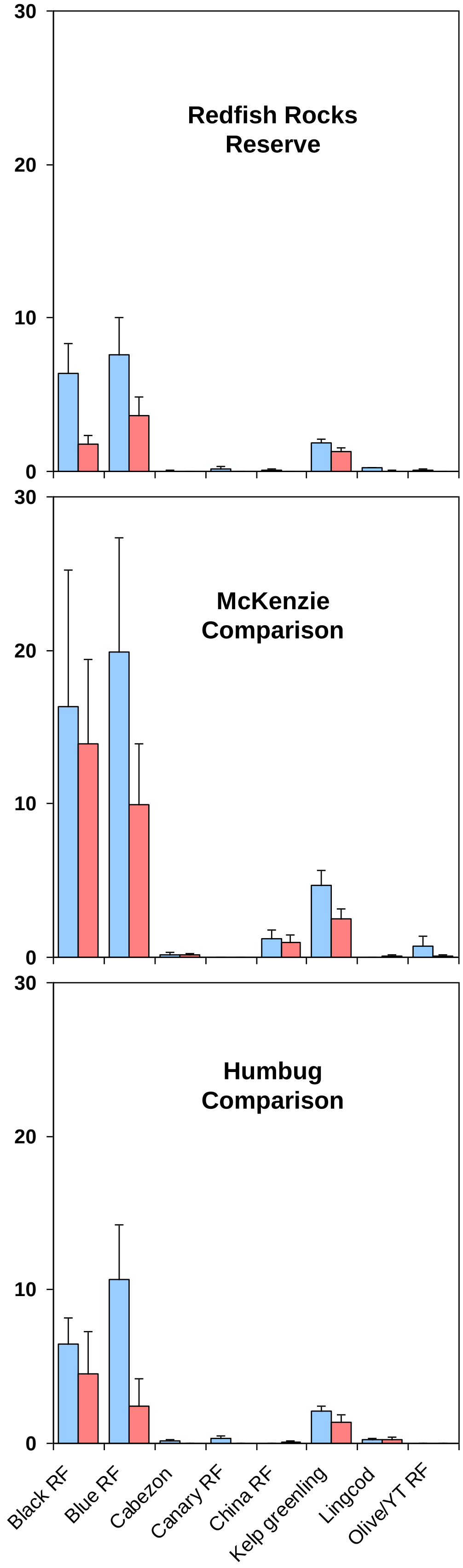


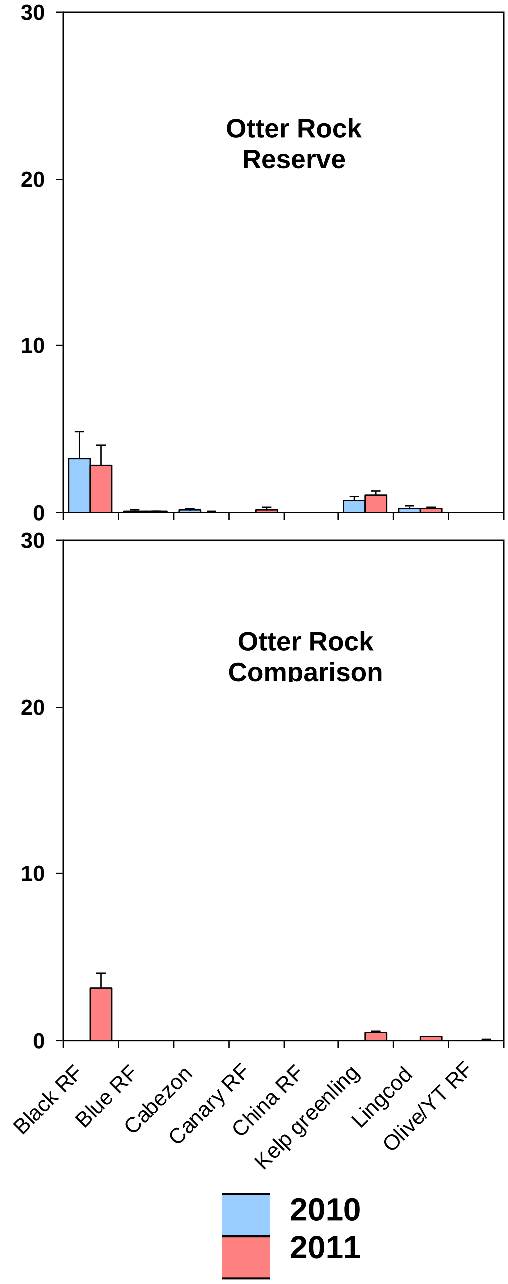
Appendix 1a. Density of kelp species at each reserve and comparison site. **Numbers on the vertical axes are presented in linear scale** and represent the average number of individuals per transect area (60m^2). Error bars indicate standard errors.



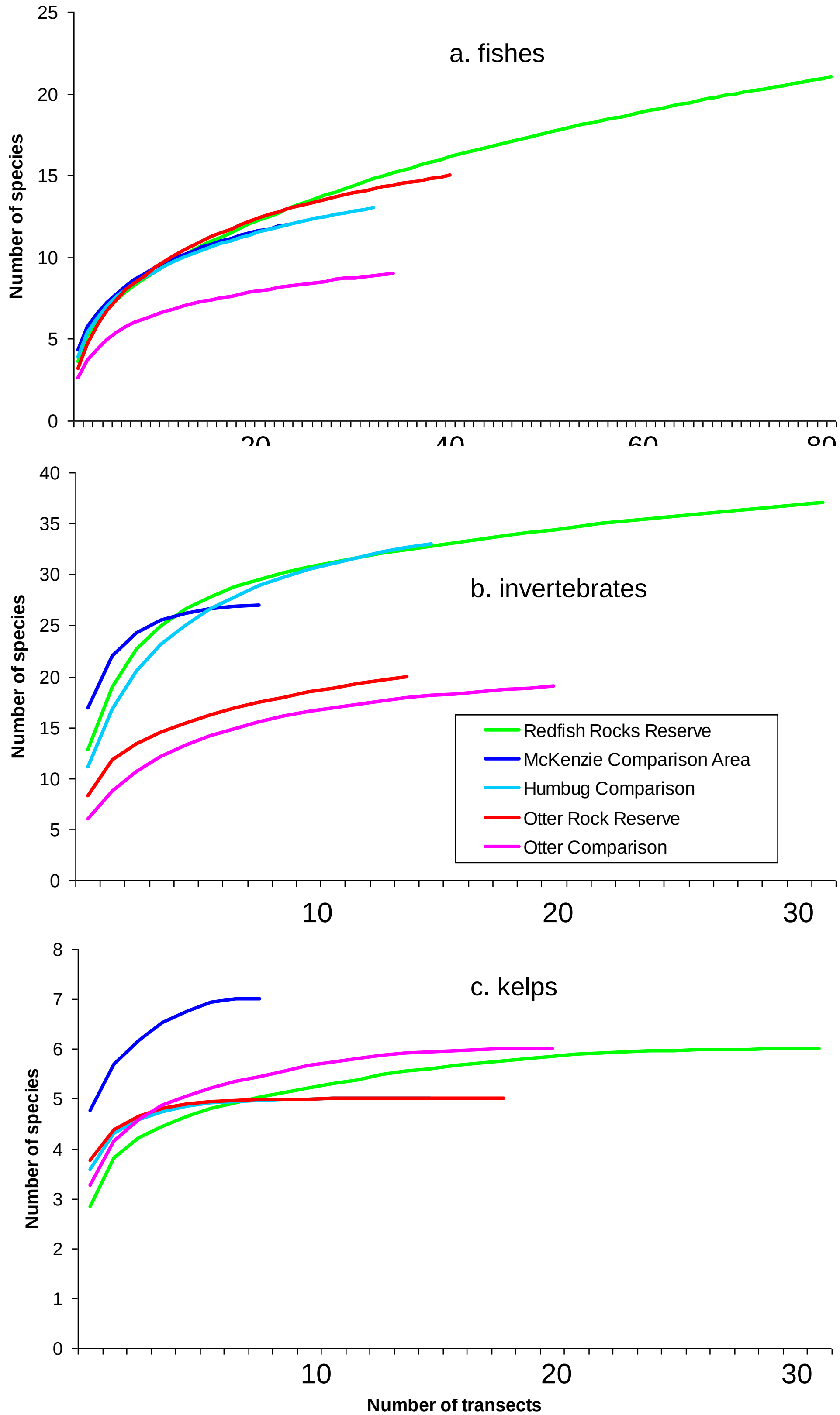


Appendix 1b. Density of mobile and conspicuous invertebrate species at each reserve and comparison site. **Numbers on the vertical axes are presented in linear scale** and represent the average number of individuals per transect area ($60m^2$). Error bars indicate standard errors.





Appendix 1c. Density of fish species at each reserve and comparison site. **Numbers on the vertical axes are presented in linear scale** and represent the average number of individuals per transect area (60m^2). Error bars indicate standard errors.



Appendix 2. Species accumulation curves for fish **(a)**, mobile and conspicuous invertebrate **(b)**, and kelp **(c)** species assemblages at each reserve and comparison site. Survey data from 2010 and 2011 were combined for this analysis.

Appendix B.

A. Benthic Extraction

A1. Macroalgal species: Preliminary List from Dr. Gayle Hansen (OSU)

Table 1. Macroalgal species occurrence at Otter Rocks and Redfish Rocks sites.

Macroalgal species	Otter Rock Marine Reserve	Cape Foulweather comparison area	Redfish Rocks Marine Reserve	Humbug comparison area
Acrochaete sp.			X	X
Acrochaetium microscopicum	X	X		
Acrochaetium pacificum	X	X	X	X
Ahnfeltia fastigiata				X
Ahnfeltiopsis gigartinoides	X			
Alaria marginata	X			
Amplisiphonia pacifica	X	X	X	X
Antithamnion defectum	X	X	X	X
Antithamnionella pacifica	X	X	X	X
Antithamnionella spirographidis	X	X	X	
Asterocolax gardneri				X
Bossiella orbigniana	X	X		
Bossiella orbigniana subsp. dichotoma	X	X		X
Bossiella sp.	X		X	X
Caliarthron tuberculosum	X	X		
Calliarthron tuberculosum			X	X
Callocolax fungiformis	X	X		X
Callophyllis crenulata	X	X		
Callophyllis flabellulata	X	X	X	X
Callophyllis heanophylla	X	X		
Callophyllis pinnata	X			
Callophyllis thompsonii			X	X
Callophyllis violacea	X	X		
Ceramium cimbricum	X	X		X
Ceramium pacificum	X			
Chondracanthus corymbiferus	X	X		
Colaconema desmarestiae	X	X		
Colaconema garbaryi	X			
Colaconema plumosum var. variabile			X	X
Colaconema subimmersum	X			
Compsonema serpens	X			

Conchocelis rosea				X
Constantinea simplex	X			
Corallina officinalis var. chilensis	X	X		
Corallina pinnatifolia	X	X		
Corallina sp.	X	X		
Corallina vancouveriensis	X	X		
Corallophila eatoniana		X		
Cryptopleura farlowiana	X	X	X	X
Cryptopleura peltata	X	X	X	X
Cryptopleura violacea	X	X		
Desmarestia foliacea			X	
Desmarestia latifrons			X	
Desmarestia munda	X	X	X	
Dictyota binghamiae		X		
Dilsea californica	X	X		
Ectocarpus parvus	X			
Egregia menziesii		X		
Endocladia muricata	X	X		
Erythrophyllum delesserioides	X	X		X
Faucheocolax attenuata	X	X		
Fryeella gardneri	X	X	X	X
Gloiocladia laciniata		X	X	
Gloiocladia sp.	X	X	X	X
Gonimophyllum skottsbergii	X			
Griffithsia pacifica	X	X		
Gymnogongrus cf. crustiforme		X		
Haematocelis zonalis	X			
Halosaccion glandiforme		X		
Halymenia gardneri	X	X		
Halymenia sp. 1	X	X		
Herposiphonia plumula	X	X	X	X
Heterosiphonia densiuscula	X	X		
Hymenena flabelligera	X	X	X	
Hymenena multiloba	X	X		X
Isabbottia ovalifolia		X		X
Kallymenia sp. 1		X		
Kallymeniopsis oblongifructa			X	X
Laminaria longipes	X	X	X	X
Laminaria setchellii	X			
Leachiella pacifica	X	X		X
Leptophytum foecundum var. sandrae			X	X

Lessoniopsis littoralis			X	
Mastocarpus papillatus	X			
Mazzaella sanguinea			X	
Meiodiscus concrescens	X	X	X	X
Melobesia mediocris	X			
Membranoptera edentata	X	X	X	X
Mesophyllum conchatum	X			
Microcladia borealis	X	X		
Microcladia coulteri		X		
Myriogramme caespitosa		X		
Myriogramme cf. caespitosa				X
Neoptilota hypnoides	X	X	X	
Nereocystis luetkeana	X	X	X	
Nienburgia andersoniana	X	X		
Nitophyllum cincinnatum	X	X		
Nitophyllum dotyi	X			
Nitophyllum hollenbergii	X	X		
Odonthalia floccosa	X	X		
Odonthalia kamtschatica	X	X		
Opuntiella californica	X	X	X	X
Osmundea spectabilis		X		
Ozophora latifolia	X	X		
Petroglossum parvum	X	X	X	
Peyssonnellia profunda	X	X	X	
Phycodrys setchellii	X	X		
Pikea californica	X			
Pikea pinnata	X	X	X	X
Pleonosporium vancouverianum		X	X	
Pleurophycus gardneri	X	X	X	X
Plocamium cartilagineum	X	X	X	X
Plocamium violaceum		X		
Pneophyllum sp. 1	X	X		
Polyneura latissima	X	X	X	X
Polysiphoina hendryi	X	X		
Polysiphonia scopulorum var. villum	X	X		X
Porphyra gardneri			X	
Porphyra nereocystis			X	X
Porphyra sp. 1	X			
Porphyropsis coccinea			X	X
Pterosiphoina dendroidea	X	X		
Pterosiphonia gracilis	X	X	X	X

Pterothamnion heteromorphum	X	X	X	X
Pterothamnion pectinatum	X	X	X	
Pterygophora californica	X	X	X	X
Ptilota filicina	X	X		
Ptilothamnionopsis lejolisea	X	X	X	X
Pugetia firma	X	X	X	X
Rhodymenia californica	X	X	X	X
Rhodymenia pacifica	X	X	X	
Saccharina groenlandica	X		X	X
Schizymenia pacifica	X	X		
Serraticardia macmillanii	X		X	X
Smithora naiadum	X			
Streblonema transfixum	X			
Stylonema alsidii	X		X	
Syringoderma phinneyi			X	

B2. Sponge families

Table 2. Sponge family occurrence at Otter Rocks and Redfish Rocks sites.

Family	Otter Rock Marine Reserve	Cape Foulweather comparison area	Redfish Rocks Marine Reserve	Humbug comparison area
Acarnidae		X		
Axinellidae	X	X	X	
Chalinidae	X	X	X	X
Clathrinidae			X	X
Clionaidae	X	X	X	X
Coelosphaeridae	X	X	X	X
Desmacellidae			X	
Desmoxyidae		X	X	
Halichondriidae		X	X	X
Hamacanthidae				X
Hymedesmiidae		X	X	X
Isodictyidae		X	X	X
Leucosoleniidae		X	X	X
Microcionidae	X	X	X	X
Mycalidae	X	X	X	X

Myxillidae			X	
Petrosiidae		X	X	X
Polymastiidae		X		
Suberitidae	X	X		
Sycettidae				X
Tetillidae		X	X	

B. Fishery-independent Surveys

B1. Fish species

Table 3. Total numbers of fish species caught in the Redfish Rocks Marine Reserve (MR) and the Humbug comparison area (CA) during hook and line sampling in 2011. Species are listed in order from mostly commonly caught.

Fish Common Name	**MR**	**CA**
BLACK ROCKFISH	285	253
BLUE ROCKFISH	61	56
LINGCOD	56	44
KELP GREENLING	52	46
YELLOWTAIL ROCKFISH	75	10
CANARY ROCKFISH	33	15
CHINA ROCKFISH	28	4
QUILLBACK ROCKFISH	5	11
CABEZON	9	3
RED IRISH LORD	2	3
YELLOWEYE ROCKFISH	2	0
BROWN IRISH LORD	1	1
COPPER ROCKFISH	1	1
BUFFALO SCULPIN	0	2
VERMILION ROCKFISH	0	2
Total	**610**	**451**

C. SCUBA Surveys

C1. Kelp species

Table 4. Scientific and common names and total numbers recorded for all kelp species seen on swath surveys in 2010 and 2011.

Genus	**Species**	**Common Name**	**Total 2010**	**Total 2011**
Nereocystis	*luetkeana*	bull kelp	715	5080
Pterygophora	*californica*	Pterygophora	479	2171

Laminaria	*setchellii*	Laminaria	852	996
Pleurophycus	*gardneri*	Pleurophycus	396	1320
Alaria	*marginata*	Alaria	19	53
Cystoseira	*osmundacea*	bladder chain kelp	21	35
Eisenia	*arborea*	southern sea palm	0	13
Laminaria	*saccharina*	Laminaria	10	6
Costaria	*costatum*	seersucker kelp	0	3
Macrocystis	*pyrifera*	giant kelp	0	0

C2. Fish species

Table 5. Scientific and common names and total numbers recorded for all fish species seen in 2010 and 2011.

Genus	Species	Common Name	Total 2010	Total 2011
Sebastes	atrovirens, carnatus, chrysomelas, caurinus	rockfish YOY (Pteropodus)	48	555
Sebastes	melanops	black rockfish	592	498
Sebastes	mystinus	blue rockfish	702	295
Hexagrammos	decagrammus	kelp Greenling	172	146
Sebastes	serranoides, flavidus, melanops	rockfish YOY (Sebastosomus)	0	32
Ophiodon	elongatus	lingcod	15	21
Embiotoca	lateralis	striped surfperch	11	17
Lethops	connectens	kelp goby, half blind goby	0	14
Sebastes	nebulosus	china rockfish	18	14
Synchirus/ Rimicola	spp.	manacled sculpin/ kelp clingfish	0	13
Hemilepidotus	hemilepidotus	red Irish lord	6	13
Sebastes	pinniger	canary rockfish	12	4
Enophrys	bison	buffalo sculpin	3	4
Scorpaenichthys	marmoratus	cabezon	7	3
Aulorhynchus	flavidus	tubesnout	1	2
Sebastes	serranoides, flavidus	olive or yellowtail rockfish	12	2
Hexagrammos	spp.	unidentified Hexagrammos	0	1
Chirolophis	nugator	mosshead warbonnet	0	1
Syngnathus	spp.	pipefish	0	1
Jordania	zonope	longfin sculpin	1	1
Hexagrammos	lagocephalus	rock greenling	0	1
Sebastes	chrysomelas	black and yellow rockfish	0	1
Sebastes	caurinus	copper rockfish	0	1
Anarrhichthys	ocellatus	wolf eel	1	0
Hexagrammos	stelleri	whitespotted greenling	1	0

C1. Invertebrate species

Table 6. Scientific and common names and total numbers recorded for all mobile or solitary/ conspicuous invertebrate species seen on swath surveys in 2010 and 2011.

Genus	Species	Common Name	Total 2010	Total 2011
Cucumaria	miniata	orange sea cucumber	70	2350
Metridium	spp.	white plumed anemone	2239	1448
Styela	montereyensis	stalked tunicate	778	879
Strongylocentrotus	franciscanus	red urchin	122	599
Henricia	leviuscula	blood star	303	583
Balanus	nubilis	barnacle	69	379
Pisaster	ochraceous	ochre star	548	276
Anthopleura	xanthogrammica	giant green anemone	576	182
Cryptochiton	stelleri	gumboot chiton	21	173
Dermasterias	imbricata	leather star	43	164
Epiactis	prolifera	brooding anemone	2	112
Pycnopodia	helianthoides	sunflower star	67	93
Tealia	lofotensis	strawberry anemone	20	62
Craniella	arb	grey tennis ball sponge	39	60
Crassedoma	giganteum	rock scallop	64	55
Scyra/Oregonia	acutifrons/gracilis	decorator crab, moss crab	67	48
Urticina	coriacea	stubby rose anemone	7	44
Evasterias	troschelli	mottled star	5	39
Pisaster	brevispinus	short spined star	32	38
Ceratostoma	foliatum	leafy hornmouth	523	29
Cancer	spp.	cancer crab	15	27
Orthasterias	koehleri	rainbow star	24	21
Solaster	stimpsoni	Stimpson's sun star	3	21
Solaster	dawsoni	Dawson's sun star	21	18
Stylaster	californicus	california hydrocoral	5	17
Strongylocentrotus	purpuratus	purple urchin	83	15
Diodora	aspera	rough keyhole limpet	19	13
Nucella	Lamellosa	frilled dogwinkle	38	11
Urticina	piscivora	fish-eating anemone	12	4
Tethya	aurantia	orange puff-ball sponge	7	3
Pisaster	giganteus	giant spined star	0	3
Parastichopus	californicus	california sea cucumber	13	2
Urticina	spp.	Urticina spp.	9	2
Haliotis	rufescens	red abalone	0	2
Patiria	miniata	bat star	0	1
Megastrea	gibberosum	red turban snail	14	1
Urticina	crassicornis	christmas anemone	0	1
Cryptolithoides	sitchensis	umbrella crab	3	1
Anthopleura	sola	green anemone	1	0
Haliotis	wallalensis	flat abalone	1	0