



Coastal Biodiversity

Developing a baseline monitoring status for marine reserves and comparison areas

Coastal biodiversity surveys help monitor the health of intertidal zones in Oregon's Marine Reserves. The Oregon Department of Fish and Wildlife (ODFW) Marine Reserves Ecological Monitoring Team partners with Multi-Agency Rocky Intertidal Network (MARINe) and the University of California, Santa Cruz (UCSC) to survey the marine reserves and comparison areas. Three sampling techniques are employed in order to monitor three different groups of intertidal organisms.

Otter Rock and Cascade Head Marine Reserves intertidal sites were monitored starting in 2015 to expand intertidal ecological monitoring efforts. These two sites include suitable rocky intertidal habitats to survey but previously were not monitored by ODFW or MARINe. In 2015 both Otter Rock and Cascade Head were surveyed for biodiversity using MARINe's protocols. A site within Cape Perpetua called Bob Creek has been monitored by MARINe from 2001 to 2013. A site near Cape Falcon Marine Reserve has been monitored by MARINe from 2001 to 2014. Additionally comparison sites to the marine reserves have been monitored by MARINe: Seal Rock is Cape Perpetua's comparison area and was sampled in 2013, Fogarty Creek is Cascade Head's comparison area and was sampled from 2001 to 2013, and Cape Meares is Cape Falcon's comparison area and was sampled in 2013.

This initial report is to assign a baseline of biodiversity to the marine reserves and their comparison areas. A baseline measurement is important so over long term management of the area we know how biodiversity can change with emerging issues and constant pressures such as sea star wasting disease and climate change respectively. From this knowledge we can better inform policy-makers about these issues and the effects marine reserves have on them. Additionally this report compares biodiversity across the marine reserves and comparison areas to demonstrate in what ways each site is unique and how biodiversity changes along the Oregon coast.

Protection Began:

2016

2014

2012

2014

2012



Methods

All surveys are conducted on a bedrock intertidal bench that is at least 30 meters wide, gently slopes from the high to low zone, and contains representative samples of the intertidal community of the entire sample site. Permanent parallel transect lines are then established from the high to low zone and spaced every three meters. The survey grid size varies across sites: Otter Rock Marine Reserve was 20 meters along the shore and 60 meters seaward, Cascade Head Marine Reserve was 20 meters along the shore and 33 meters seaward, Fogarty Creek was split into two sections with one being 12 meters along the shore and 50 meters seaward and the other being 15 meters along the shore and 50 meters seaward, Bob Creek (Cape Perpetua) was also split into two sections with one 12 meters along the shore and 33 meters seaward and the other being 15 meters along the shore and 33 meters seaward, Seal Rock was split into two sections with one being 15 meters along the shore and 10 meters seaward and the other being 12 meters along the shore and 10 meters seaward, Ecola was 18.9 meters along the shore and 33 meters seaward, and Cape Meares was 20 meters along the shore and 20 meters seaward. These protocols were designed by MARINe at UCSC (<https://www.eeb.ucsc.edu/pacificrockyintertidal/biodiversityprotocol.pdf>).

Descriptions of sites

At each site the primary bench type, general degree of sloping, general degree of relief, orientation, surrounding coast type, the number of cracks and folds, and if human visitation is limited are recorded. For further information about how the description of sites are defined and categorized contact MARINe.

Point-Contact Survey

Point-Contact surveys target spatially abundant sessile organisms. Along each transect 100 evenly spaced points are sampled. The organisms directly under each point are recorded to lowest possible taxa. If species are layered under the point, all species are recorded. This data gets transformed into percent cover to measure relative abundance. These surveys also are used to determine spatial distribution of species by indicating which species are together under a point. If there are less than three taxa below a point than species very close (less than half the distance between points) to the point are recorded.

Point-Contact surveys were conducted once at Otter Rock on 7/15/2015 (N=1); once at Cascade Head on 7/17/2015 (N=1); four times at Fogarty Creek on 6/21/2001-6/22/2001, 7/12/2003-7/13/2003, 6/4/2004, and 7/22/2013 (N=4); three times at Bob Creek on 6/23/2001, 5/15/2007, and 8/21/2013 (N=3); once at Seal Rock on 7/19/2013-7/20/2013 (N=1); three times at Ecola on 6/24/2001-6/25/2001, 6/5/2005, and 7/12/2014-7/13/2014 (N=3); and once at Cape Meares on 7/23/2013 (N=1).

Quadrat Survey

Quadrat surveys target mobile invertebrates. Along each transect 50 cm x 50 cm quadrats are randomly placed at three locations: one in the high zone (predominately barnacles

and littorines), one in the mid-zone (includes mussels and rockweeds), and one in the low zone (below the mussels). Within each quadrat all mobile invertebrate species are counted and identified excluding worms and amphipods.

Quadrat surveys were conducted once at Otter Rock on 7/16/15 (N=1); once at Cascade Head on 7/17/2015 (N=1); four times at Fogarty Creek on 6/21/2001-6/22/2001, 7/12/2003, 6/4/2004, and 7/22/2013 (N=4); three times at Bob Creek on 6/23/2001, 5/16/2007, 8/21/2013 (N=3); once at Seal Rock 7/19/2013-7/21/2013 (N=1); three times at Ecola on 6/24/2001-6/25/2001, 6/5/2005, and 7/12/2014 (N=3); and once at Cape Meares on 7/23/2013-7/24/2013 (N=1).

Swath Counts

Swath counts target sea stars since they are usually not spatially common. Along each transect the area within a 2 meter swath centered at each transect is searched for sea stars larger than 5 cm in total length. Species, abundance, and location is recorded. *Leptasterias hexactis* was not counted in the swath surveys until 2014 once the sea star wasting epidemic began.

Swath counts were conducted once at Otter Rock on 7/15/15 (N=1); once at Cascade Head on 7/17/2015 (N=1); six times at Fogarty Creek on 6/22/2001, 7/21/2003, 6/4/2004, 7/22/2013, 7/15/2015, and 7/19/2016 (N=6); five times at Bob Creek on 6/23/2001, 5/16/2007, 8/21/2013, 7/14/2015, and 7/18/2016 (N=5); twice at Seal Rock on 7/21/2013 and 8/9/2014 (N=2); four times at Ecola on 6/25/2001, 6/6/2005, 7/12/2014, and 7/20/2016 (N=4); and twice at Cape Meares on 7/23/2013 and 8/10/2014 (N=2).

Baseline Key Findings

Site Specific

2015 Otter Rock (N=1)

1. Dominated by invertebrates (predominantly sessile) and algae
2. Most dominant mobile invertebrates was *Littorina plena/scutulata*
3. Open rock was somewhat common (~20% coverage) and there was little sand
4. Low densities of sea stars
5. High algal species richness (14 species) in those with percent cover >2%

2015 Cascade Head (N=1)

1. Dominated by invertebrates (about 2/3 sessile and 1/3 mobile)
2. Most dominant mobile invertebrates was *Littorina plena/scutulata*
3. Open substrate was very common (~50% cover) and mostly comprised of open sand with some open rock
4. Low densities of sea stars
5. Almost no seagrass observed and low algal species richness (6 species) in those with percent cover >2%

2001-2013 Cape Perpetua (N=3)*

1. Dominated by invertebrates (predominantly sessile) and algae but the ratios between these two vary from year to year
2. Most dominant mobile invertebrates was *Littorina plena/scutulata*
3. Increase in the percent open substrate in 2013 with slightly more rock than sand (total coverage ~35%)
4. Variable densities of sea stars from 2001-2016 but all years were much higher than Otter Rock and Cascade Head
5. Moderate algal species richness (8 species) in those with percent cover >2%

*for swath surveys additional years were sampled in 2015 and 2016 (N=5)

Cross Site Comparisons

1. Focal algal species are not evenly distributed across the sites monitored
2. Focal invertebrate species had higher percent coverage in the most northern and southern areas and lower coverage in the central sites
3. At 80% similarity in the most abundant species (greater than 2% cover), each site was distinctly different but there was no difference in the multiple years sampled per site. Otter Rock and Cascade Head were less than 60% similar to the rest of the sites but 60% similar to each other.

Potential Environmental Drivers

Upwelling along the coast

Timeline of Anomalies While Sampling

2004: Weak El Nino ($+0.5^{\circ}\text{C}$) during sampling (all three surveys) at Fogarty Creek

2014: The Blob was still off Oregon's coast during sampling at Ecola (all three surveys), Seal Rock (only swath survey), and Cape Meares (only swath survey)

2014: Sea star wasting epidemic spread to Oregon affecting 2014 sampling at Ecola (all three surveys), Seal Rock (only swath survey), and Cape Meares (only swath survey)

2015: Strong El Nino ($+1.2$ - 1.8°C) during sampling at Otter Rock (all three surveys), Cascade Head (all three surveys), Fogarty Creek (only swath survey), and Bob Creek (only swath survey).

2015: All sampling in this year may be affected by the outbreak of sea star wasting in 2014. Sampling in 2015 occurred at Otter Rock (all three surveys), Cascade Head (all three surveys), Fogarty Creek (only swath survey), and Bob Creek (only swath survey).

2016: All sampling in this year may be affected by the outbreak of sea star wasting in 2014. Sampling in 2016 occurred at Fogarty Creek (only swath survey) and Ecola (only swath survey).

Baseline Biodiversity Results

Redfish Rocks Marine Reserve

There is no intertidal site for this reserve

Otter Rock Marine Reserve

There is no monitored intertidal site for the comparison area of Otter Rock: Cape Foulweather has no rocky intertidal to sample

Table 1. Site description of Otter Rock intertidal region.

Site Type	Bench type	Slope	Relief	Orientation	Surrounding Coast Type	Cracks and Folds	Limited Human Visitation
MR	Consolidated Bedrock	Gentle	Moderately Uneven	Northwest	consolidated bedrock, boulder fields, sandy beach	few	No

MR=Marine Reserve

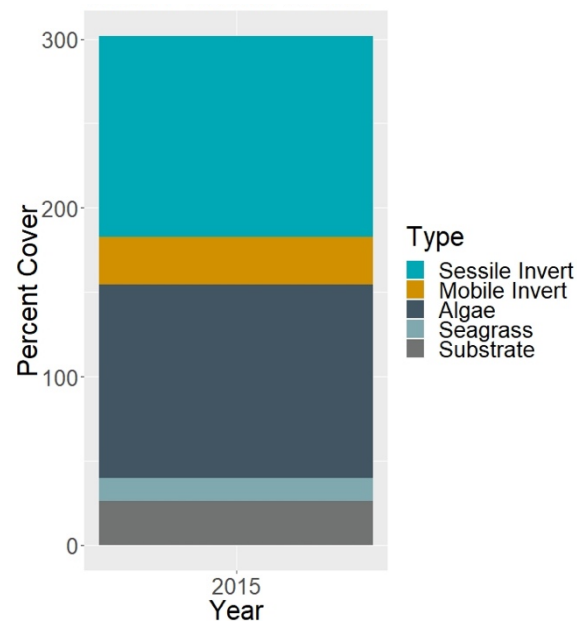


Figure 1. Percent cover of broad groups observed including the major taxa as well as bare substrates at Otter Rock in 2015 from the point count survey.

Otter Rock Marine Reserve is dominated by sessile invertebrates and algae in the surveyed region. Seagrass is present but at low coverage. Additionally, open substrate does occur but not much. These percentages total to greater than 100% since multiple organisms were counted for each point due to species residing on top of each other.

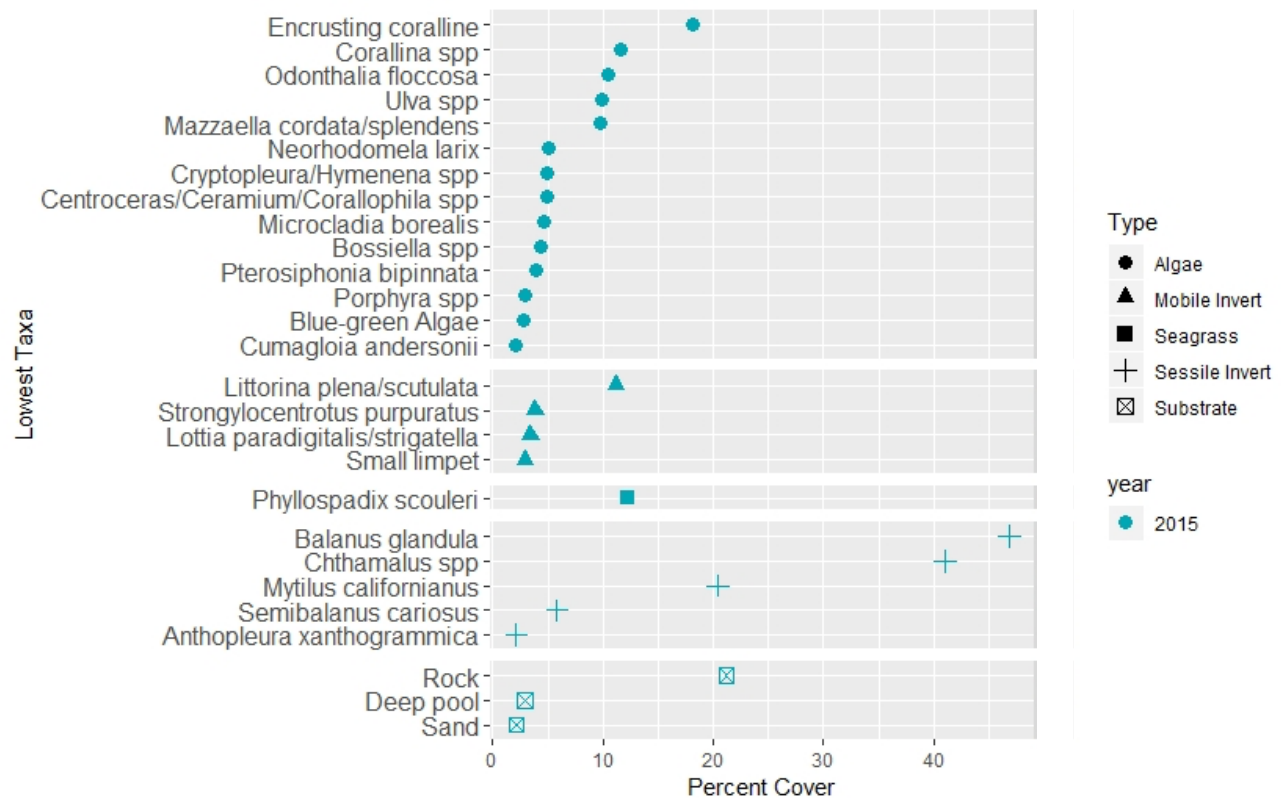


Figure 2. Otter Rock Marine Reserve percent cover of common species and open substrate (>2% cover) for 2015 from the point count survey.

Sessile invertebrates were the most abundant with the top two species being barnacles. The most common algae was encrusting coralline algae. Seagrass was common at this site. Four mobile invertebrates had a percent cover greater than 2%: the black periwinkle, the pacific purple sea urchin, the boreal limpet, and small limpets. Rock comprises of most of the open substrate at Otter Rock. There was a wide diversity of algal species that were in the top 2% of coverage.

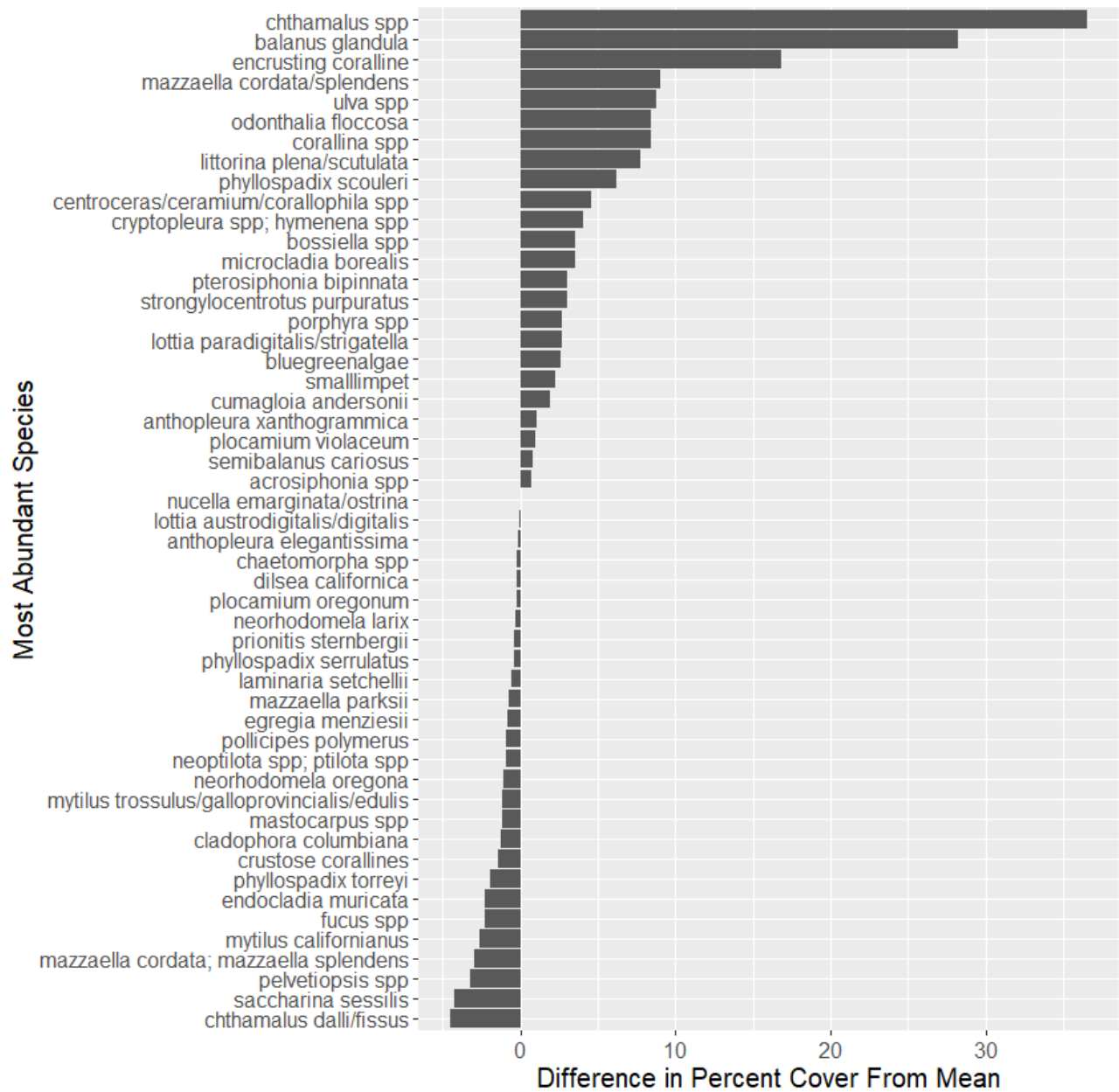


Figure 2. Otter Rock Marine Reserve 2015 point contact survey difference from the mean percent cover of common species and open substrate (>2% cover) across all sites and years of point contact surveys.

There are a lot more *Chthamalus spp.* and *Balanus glandula* (barnacles) at Otter Rock than an average site. Around half of the most abundant species across the sites were present in greater quantities than on average. Around half of the most abundant species across the sites were present in lesser quantities than on average.

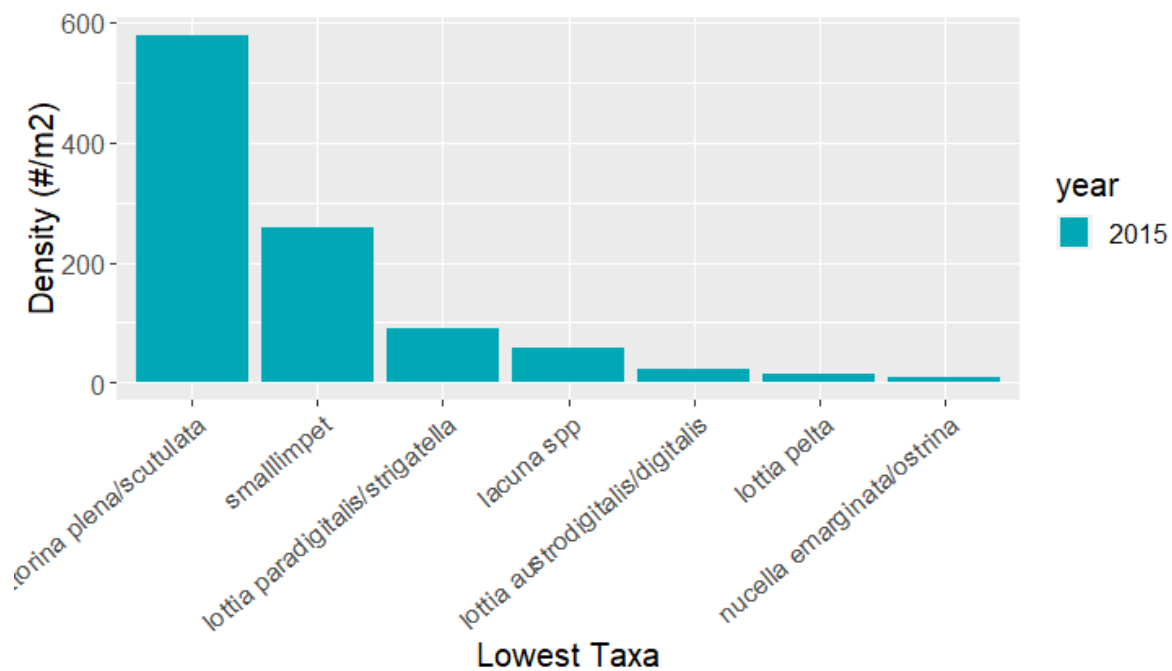


Figure 3. Otter Rock Marine Reserve density of abundant mobile invertebrates (>10/m²) from the 2015 quadrat survey.

The most abundant species, *L. plena/scutulata*, is a type of snail and was observed at a density of 579 individuals/m². Small limpets were also very common at 258 individuals/m².

Table 2. Otter Rock Marine Reserve quadrat total richness and density observed in the 2015 quadrat survey.

Site	Year	Species Richness	Total Density of All Species Observed (#/m ²)
Otter Rock	2015	31	1059

Table 3. Otter Rock Marine Reserve density of sea stars from 2015 swath counts (N=11 per year).

Otter Rock	
2015	
Species	
<i>Pisaster ochraceus</i>	0.022
<i>Leptasterias</i> spp.	0.002
<i>Henricia</i> spp.	0.003

All sea star densities were low at Otter Rock in 2015 with a total sea star density at 0.027 individuals/m² observed during the swath surveys. *P. ochraceus* was the most common

sea star observed, with the density of *Leptasterias spp.* and *Henricia spp.* being very similar to each other and substantially less than *P. ochraceus*.

Cascade Head Marine Reserve

Table 3. Site description of Cascade Head and comparison area's intertidal region.

Site Name	Site Type	Bench type	Slope	Relief	Orientation	Surrounding Coast Type	Cracks and Folds	Limited Human Visitation
Cascade Head	MR	Consolidated bedrock and sandy beach	M	Moderately Uneven	Southwest	Consolidated bedrock sandy beach	few	No
Fogarty Creek	CA	Consolidated bedrock	G	Moderately Uneven	West	Consolidated bedrock, sandy beach	few	Yes

MR= Marine Reserve, CA= Comparison Area, M= Moderate, G=Gentle

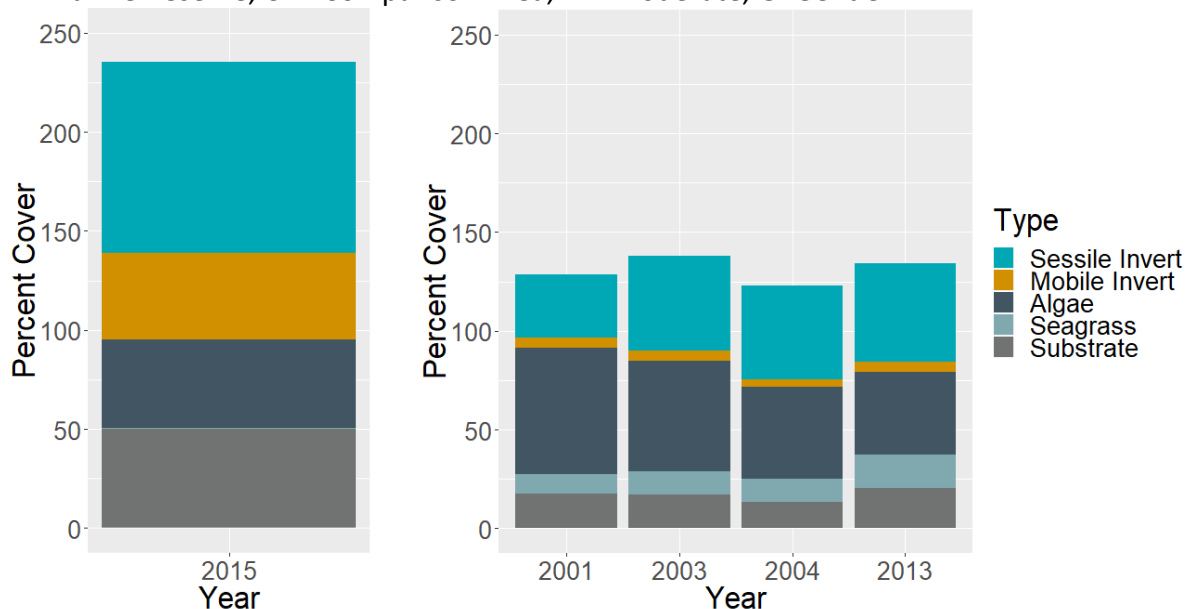


Figure 4. Percent cover of broad groups observed including the major taxa as well as bare substrates at Cascade Head Marine Reserve (left) from the 2015 point count survey and the comparison area (Fogarty Creek) (right) from 2001, 2003, 2004, and 2013 point count surveys.

In Cascade Head Marine Reserve Invertebrates primarily dominate the area with both algae and open substrate equally comprising the rest of the site. No seagrass was present in significant quantities at this site. The comparison area for Cascade Head Marine Reserve is Fogarty Creek. Fogarty Creek was dominated around equally by algae and invertebrates with seagrass and open substrate around equally comprising the rest of the site. These percentages total to greater than 100% since multiple organisms were counted for each point due to species residing on top of each other.

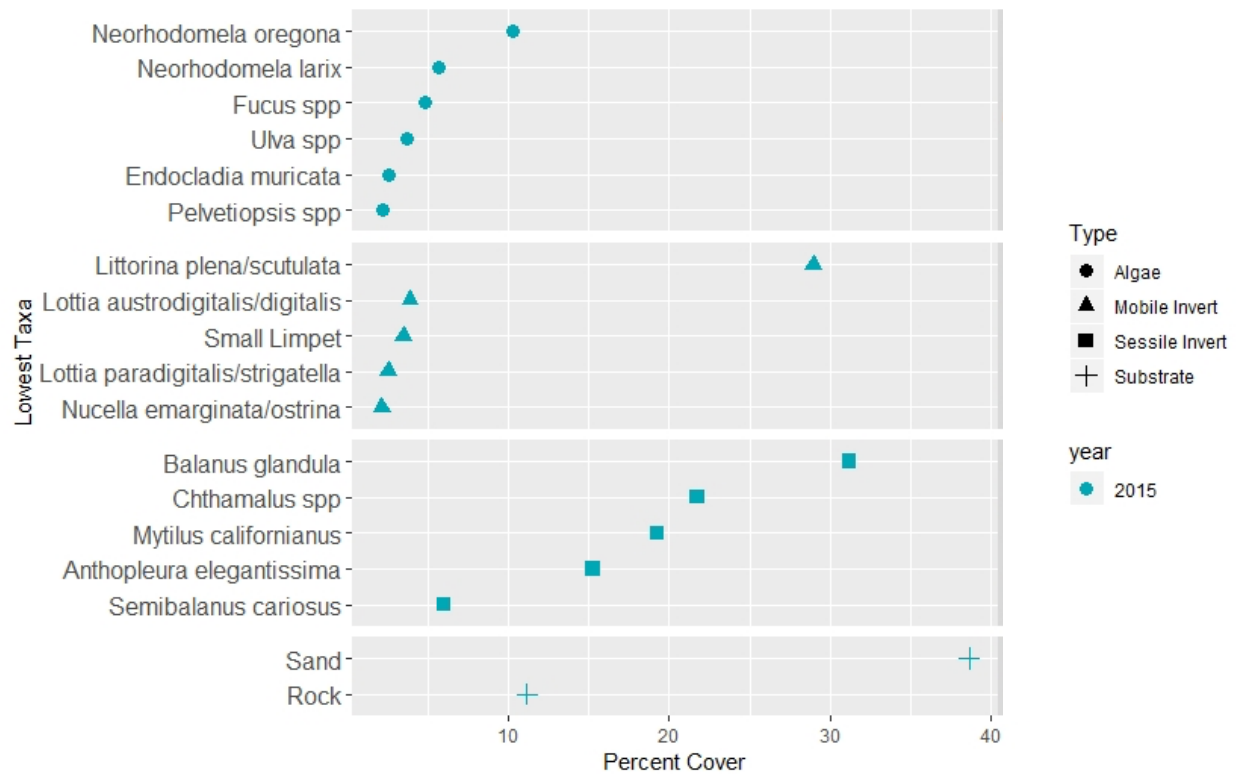


Figure 5. Cascade Head Marine Reserve percent cover of common species and substrate (>2% cover) from the 2015 point count survey.

The figure above shows the percent cover of common intertidal species sorted by the type of taxa observed at Cascade Head Marine Reserve in 2015. The most abundant presence was sand at Cascade Head. The second and third most abundant species at Cascade Head were the acorn barnacle (a sessile invertebrate) and a species of periwinkle (a mobile invertebrate). Three other species of sessile invertebrates were very common (>10% cover) including: a species of barnacle, the California mussel, and a species of clonal anemone.

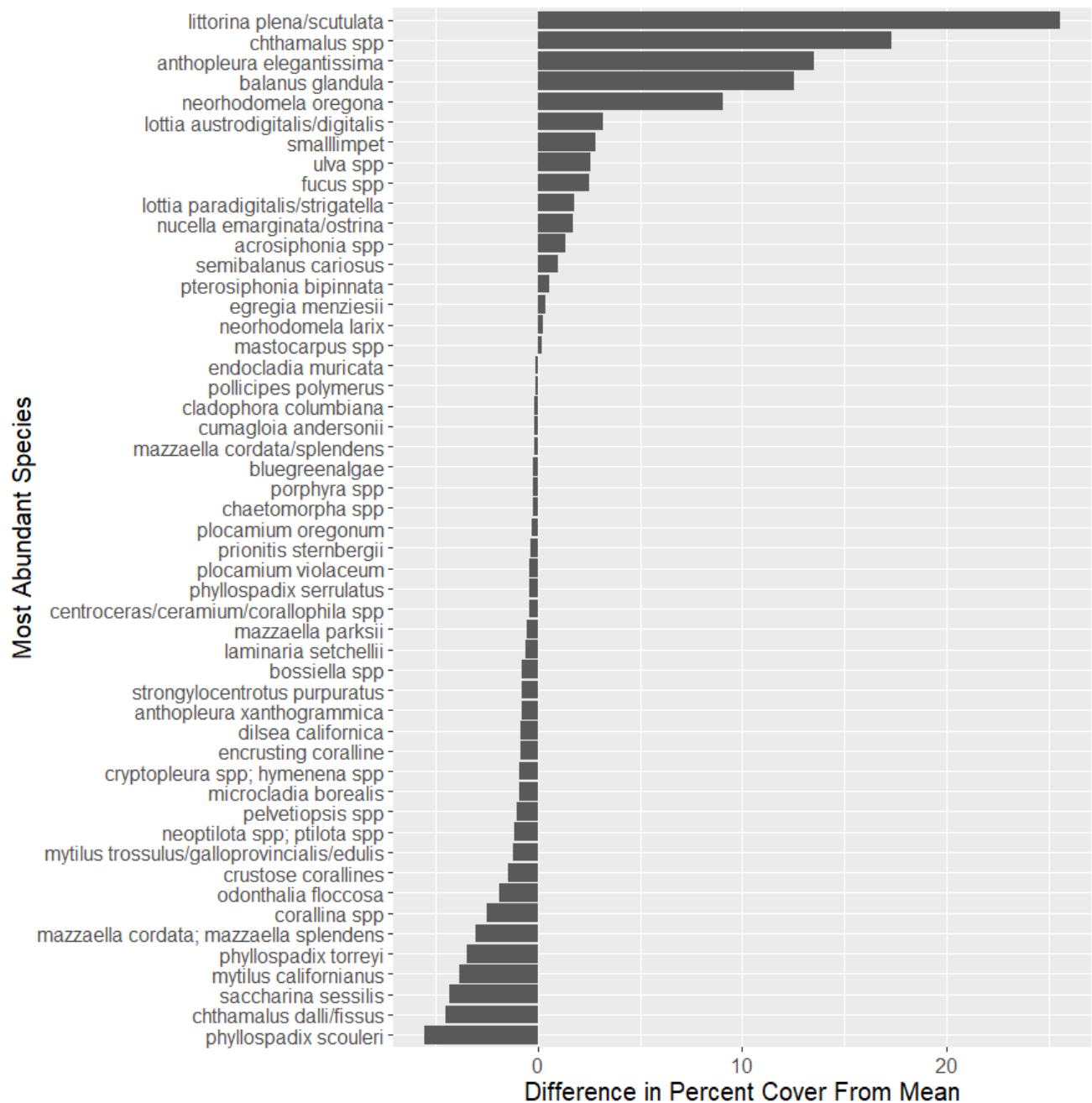


Figure 5. Cascade Head Marine Reserve 2015 point contact survey difference from the mean percent cover of common species and open substrate (>2% cover) across all sites and years of point contact surveys.

At Cascade Head Marine Reserve there were many more *Littorina plena/scutulata* compared with an average site. About 1/3rd of the most abundant species across the sites were more abundant than on average. About 2/3rd of the most abundant species across the sites were less abundant than on average.

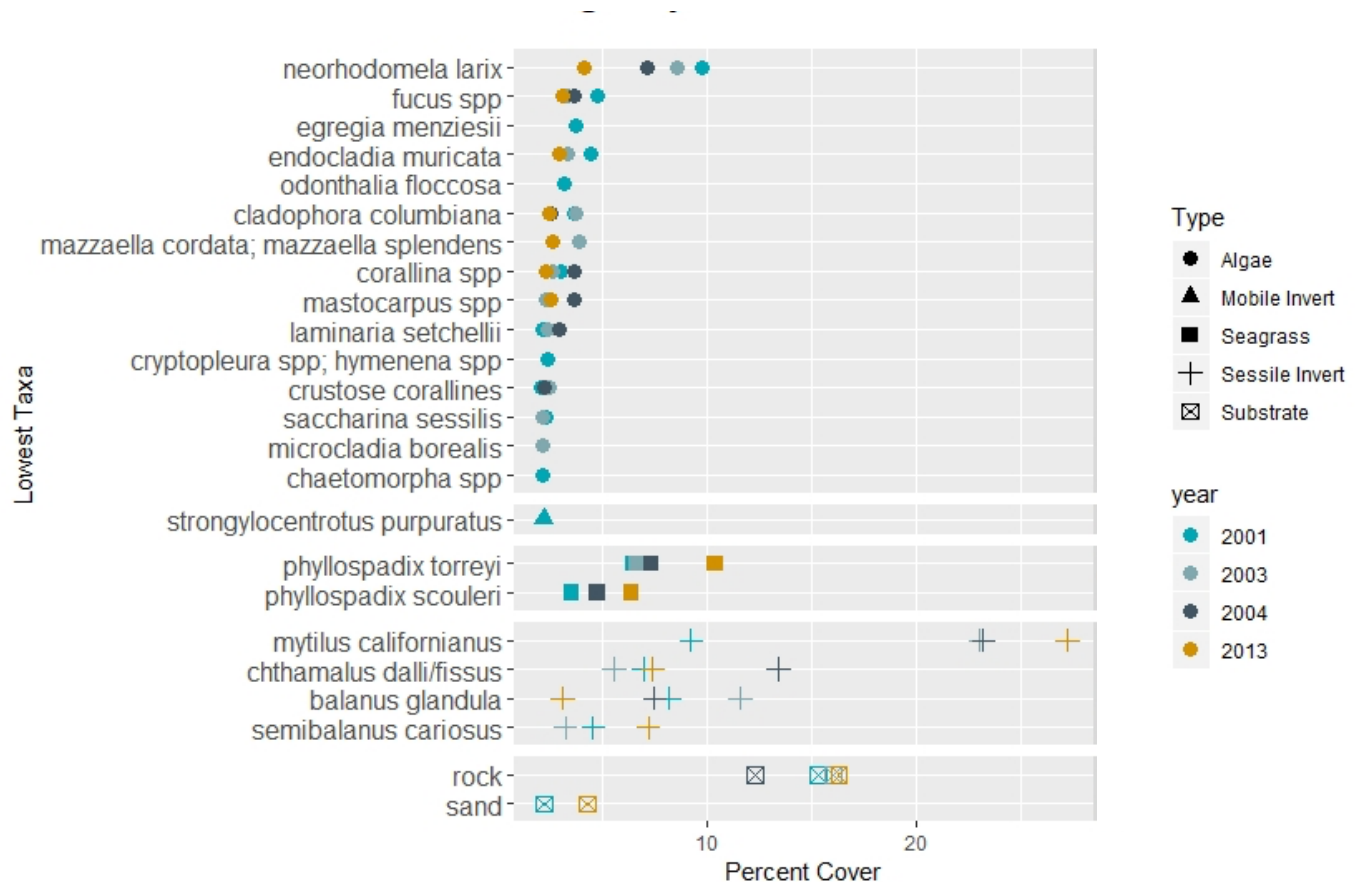


Figure 6. Fogarty Creek (CHMR CA) percent cover of common species and substrate (>2% cover) from 2001, 2003, 2004, and 2013 point count surveys.

The figure above shows the percent cover of common intertidal species sorted by the type of taxa observed at the comparison area to Cascade Head Marine Reserve, Fogarty Creek over 4 years: 2001, 2003, 2004, and 2013. The abundances of some species changes quite a bit. In 2003, 2004, and 2013 the most abundant presence was the California mussel. However in 2001 the most abundant was an open substrate, rock. Another big change is that mobile invertebrates were only commonly found in 2001. Additionally the number of commonly found alga species decreases over the years with few common species in 2004 and 2013. Seagrass increases over the years with 2013 having the highest percent coverage for both species.

Fogarty Creek with 15 species has a greater richness in the species of algae commonly found compared with Cascade Head at 6 species. However at both sites the most common species of algae is in the genus *Neorhodomela*. At Cascade Head both mobile invertebrates and sessile invertebrates dominate the area but at Fogarty Creek only sessile invertebrates do. Fogarty Creek also has a large amount of seagrass coverage but Cascade Head does not. For open substrate, rock is more common than sand at Fogarty Creek but the reverse is true for Cascade Head.

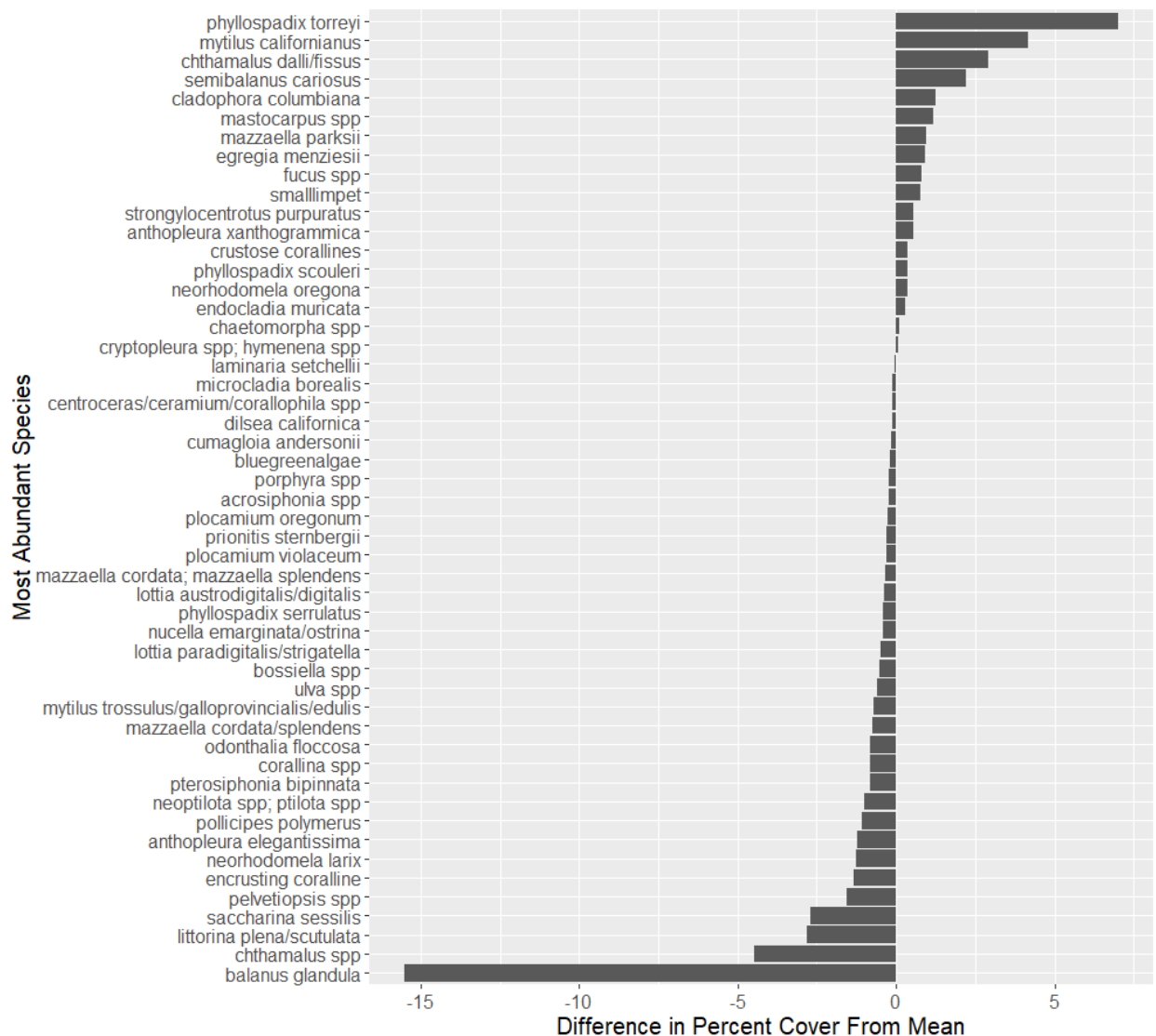


Figure 5. Fogarty Creek (Cascade Head comparison area) point contact survey most recent year (2013) difference from the mean percent cover of common species and open substrate (>2% cover) across all sites and years of point contact surveys.

There was more seagrass than at an average site at Fogarty Creek (Cascade Head's comparison area). There were a lot less *Balanus glandula* than at an average site. About 1/3rd of the most abundant species across the sites were more abundant than on average. About 2/3rd of the most abundant species across the sites were less abundant than on average.

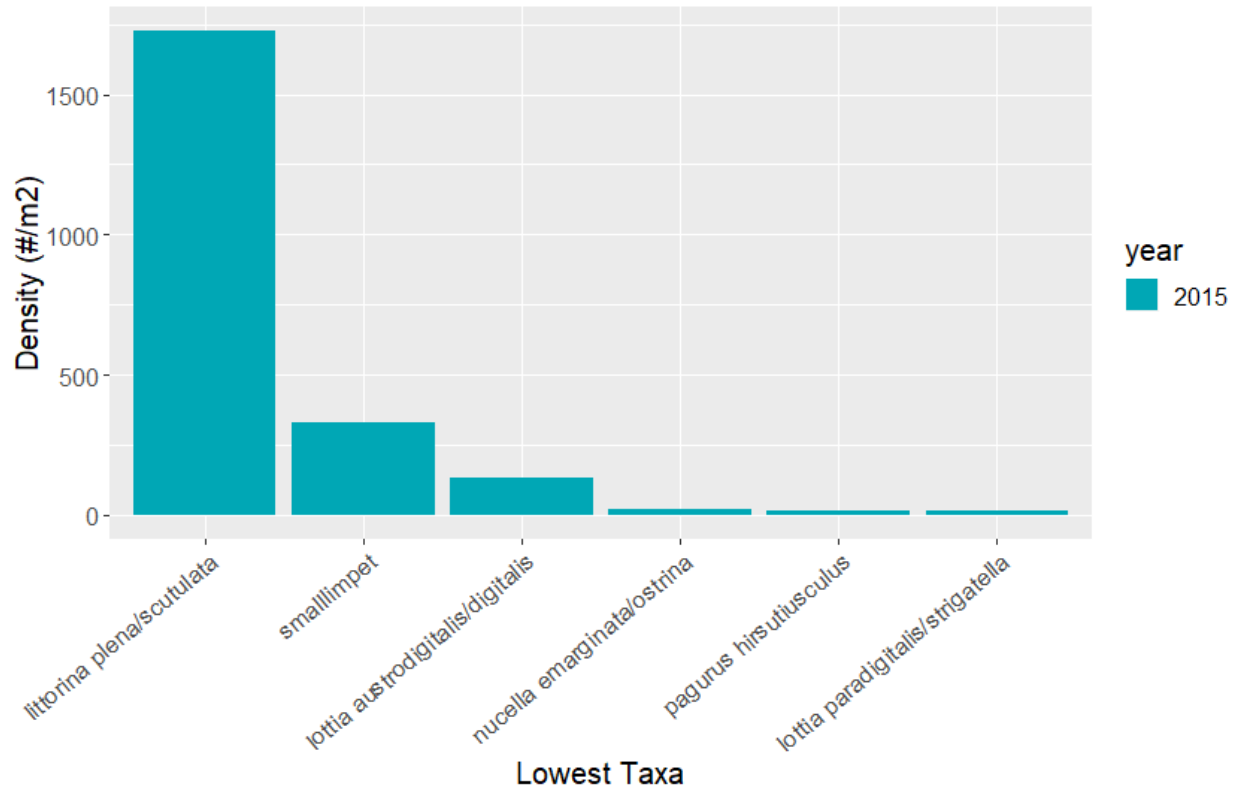


Figure 7. Cascade Head Marine Reserve density of abundant mobile invertebrates (>10/m²) from the 2015 quadrat survey.

The most abundant species was *L. plena/scutulata* at a density of 1,726 individuals/m². Small limpets and *Lottia austrodigitalis/digitalis* were also very abundant with densities of 327 individuals/m² and 130 individuals/m² respectively.

Table 7. Cascade Head Marine Reserve species richness and total density observed in the 2015 quadrat survey.

Site	Year	Species Richness	Total Density of All Species Observed (#/m²)
Cascade Head	2015	27	2266

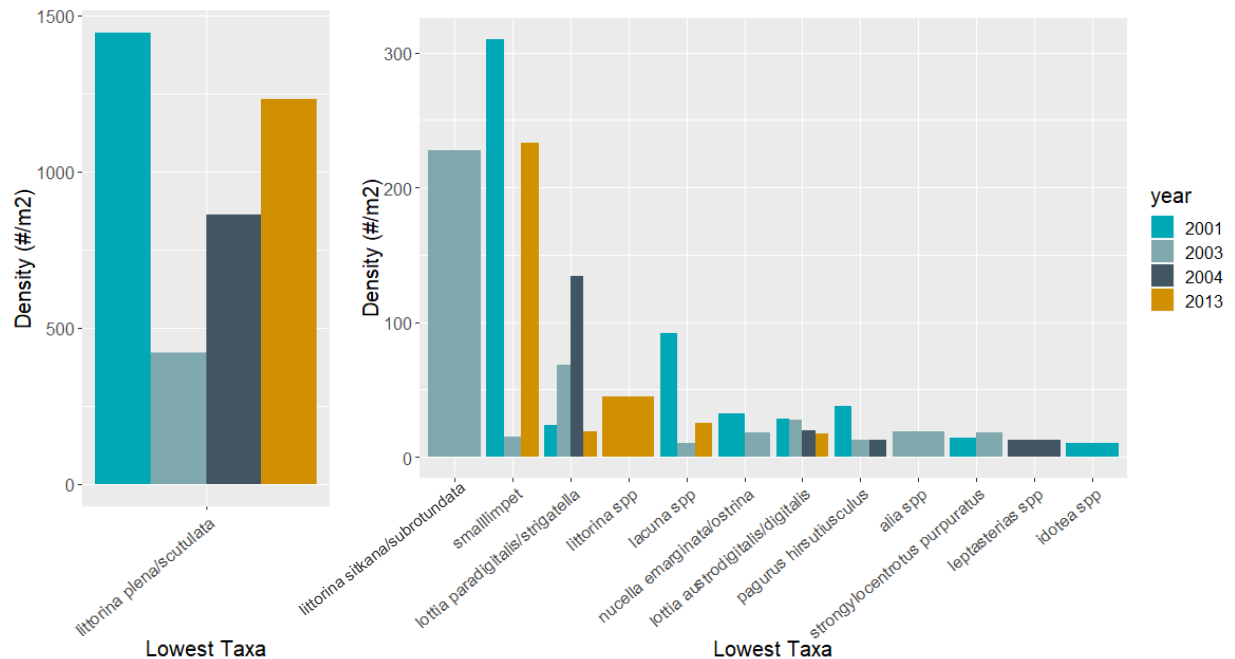


Figure 8. Fogarty Creek (CHMR CA) density of abundant mobile invertebrates (>10/m²) from 2001, 2003, 2004, and 2013 quadrat surveys. There are two separate scales because *Littorina plena/scutulata* is so abundant that the other species could not be seen.

The overall density of mobile invertebrates observed in quadrat surveys peaked in 2001 then drastically decreased in 2003 and then continued to rise to 2013. While 2003 had the lowest overall density of mobile invertebrates, 2003 had the highest species richness. In all four years sampled, *Littorina plena/scutulata* is the most abundant species ranging from 1,444 individuals/m² in 2001 to the lowest in 2003 at 421 individuals/m². A second species of *Littorina*, *L. sitkana/subrotundata*, was only commonly present in 2003.

There were slightly less species observed at Cascade Head compared to Fogarty Creek but Cascade Head had a higher density for the totaled number of species. At both sites the most common mobile invertebrate species was *Littorina plena/scutulata*.

Table 8. Fogarty Creek (CHMR CA) species richness and total density observed in 2001, 2003, 2004, and 2013 quadrat surveys.

Site	Year	Species Richness	Total Density of All Species Observed (#/m ²)
Fogarty Creek	2001	33	2030
	2003	37	885
	2004	31	1085
	2013	31	1625

Table 4. Cascade Head and comparison area (Fogarty Creek) density of sea stars from swath counts (N=11 per year).

	Cascade Head	Fogarty Creek					
	2015	2001	2003	2004	2013	2015	2016
Species							
<i>Pisaster ochraceus</i>	0.073	0.293	0.518	0.326	0.264	0.06	0.179
<i>Leptasterias spp.</i>	0.001	0	0	0	0	0.054	0.57
<i>Henricia spp.</i>	0	0	0.003	0.002	0.006	0.001	0.005
<i>Pycnopodia helianthoides</i>	0	0	0.001	0	0	0	0
<i>Evasterias troschelii</i>	0	0	0	0	0	0	0.002

P. ochraceus density in Cascade Head were low in 2015 in the swath survey. *Leptasterias spp.* was present in 2015 but in very low densities.

P. ochraceus density in Fogarty Creek shows the impacts of sea star wasting disease over the years sampled with swath surveys. *P. ochraceus* density fluctuates between 2001 and 2013 but always remains above 0.25/m². This changes drastically in 2015, one year after the epidemic began, with the density of *P. ochraceus* as low as 0.060/m². Interestingly, *Leptasterias spp.* was not observed until after sea star wasting hit. In 2015 *Leptasterias spp.* density was similar to *P. ochraceus* but in 2016 *Leptasterias spp.* density was over three times greater than *P. ochraceus* density. *Henricia spp.* was present every year except 2001 but in very low densities. In two years rare species were observed in low densities: *Pycnopodia helianthoides* in 2003 and *Evasterias troschelii* in 2016.

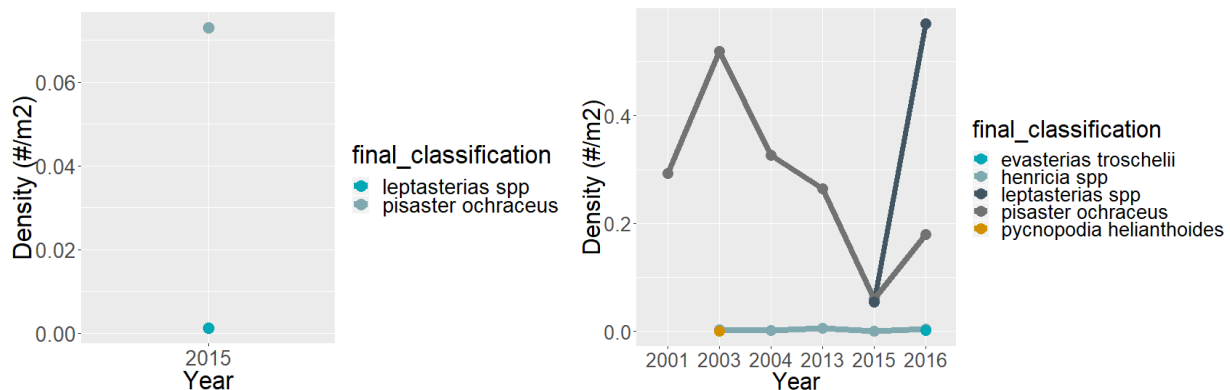


Figure 9. Cascade Head (left) in 2015 and comparison area (Fogarty Creek, right) in 2001, 2003, 2004, 2013, 2015, 2016) density of sea stars from swath counts (N=11 per year).

Cascade Head has much lower densities of *P. ochraceus* compared with Fogarty Creek. In Fogarty Creek *Leptasterias spp.* was only counted in 2015 and 2016.

Cape Perpetua Marine Reserve

Table 5. Site description of Cape Perpetua and comparison area's intertidal region.

Site Name	Site Type	Bench type	Slope	Relief	Orientation	Surrounding Coast Type	Cracks and Folds	Limited Human Visitation
Bob Creek	CP MR	Consolidated bedrock	M	Moderately Uneven	West/Southwest	Consolidated bedrock, boulder fields, sandy beach	few	No
Seal Rock	CA	Consolidated basalt	Steep	Moderately Uneven	West	Consolidated bedrock, sandy beach	few	No

CP MR= Cape Perpetua Marine Reserve, CA= Comparison Area, M=Moderate

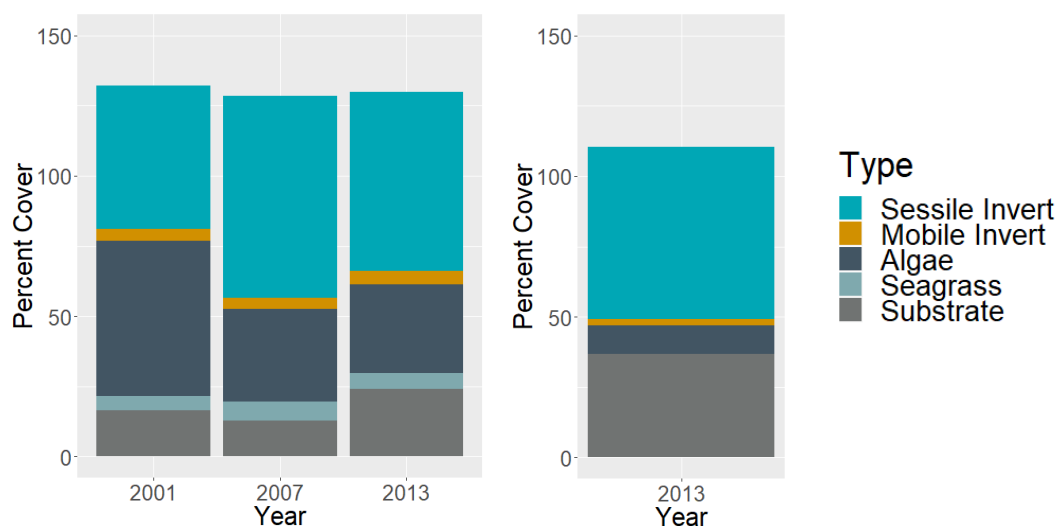


Figure 10. Percent cover of broad groups observed including the major taxa as well as bare substrates at Cape Perpetua Marine Reserve (left) from 2001, 2007, and 2013 point count surveys and the comparison area (Seal Rock) (right) from 2013 point count surveys.

Bob Creek is located inside the Cape Perpetua Marine Reserve. At this site invertebrates dominate over half of the area with algae also a significant portion of the area. Open substrate is present but not in large quantities. Seagrass occupies a very small area, less than 5%. Cape Perpetua Marine Reserve's comparison area, Seal Rock, was also dominated by invertebrates covering over half of the area but the second most abundant presence was open substrate covering a third of the area. Algae was minimally present, less than 10%. No seagrass was present at this site. These percentages total to greater than 100% since multiple organisms were counted for each point due to species residing on top of each other.

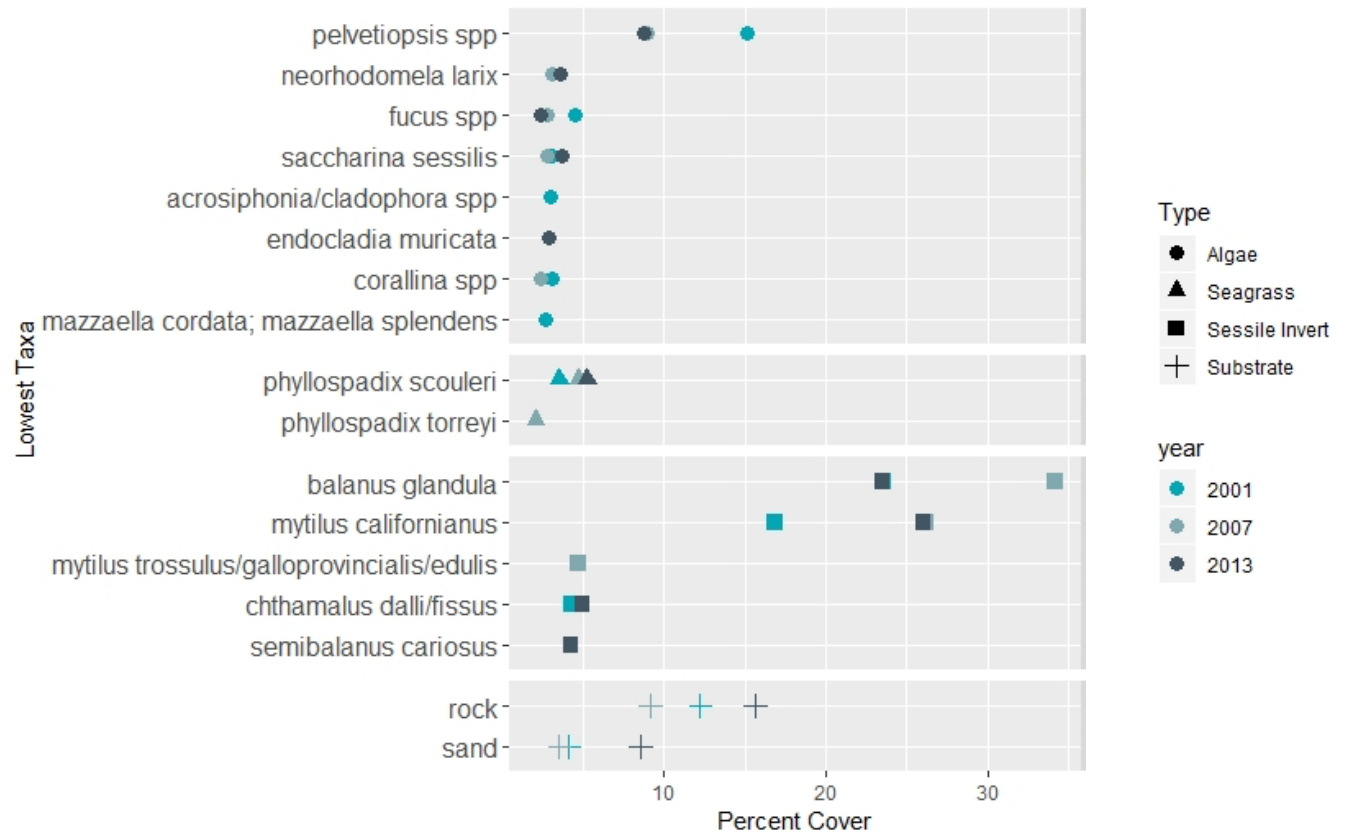


Figure 11. Cape Perpetua Marine Reserve percent cover of common species and substrate (>2% cover) from 2001, 2007, and 2013 point count surveys.

The figure above shows the percent cover of common intertidal species sorted by the type of taxa observed at Cape Perpetua Marine Reserve in 2001, 2007, and 2013. Cape Perpetua is dominated by sessile invertebrates in all three years sampled. The most common species present at Cape Perpetua are the acorn barnacle and the California mussel. An algae, dwarf rockweed (*Pelvetiopsis spp.*) was very abundant in 2001 at this site. No mobile invertebrates were commonly found at this site. Of the types of open substrate, rock always covers more area compared with sand. Two species are present at this site but only one species is commonly found in all three years.

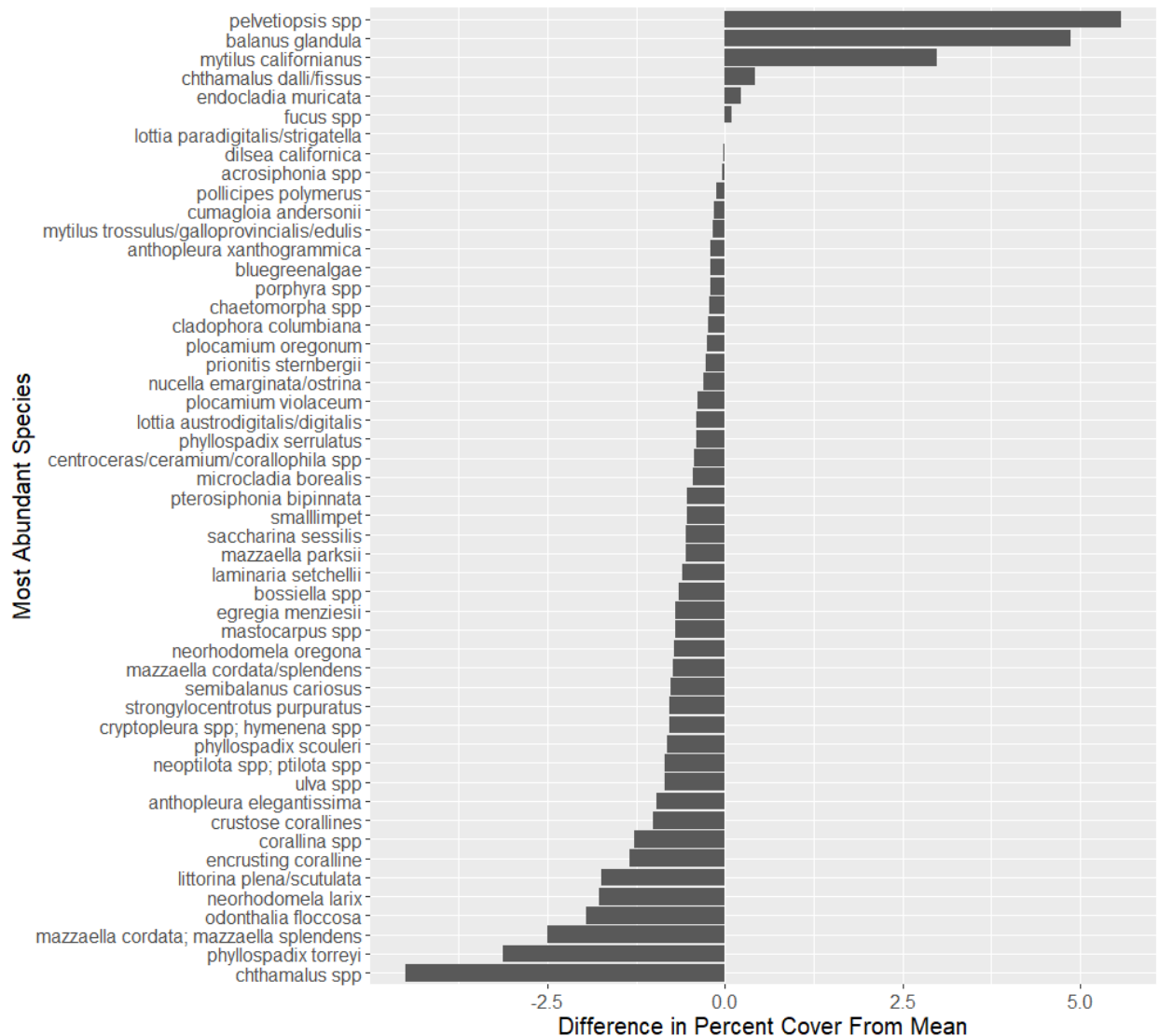


Figure 5. Cape Perpetua Marine Reserve point contact survey most recent year (2013) difference from the mean percent cover of common species and open substrate (>2% cover) across all sites and years of point contact surveys.

There were more *Pelvetiopsis spp.* (algae) and *Balanus glandula* (barnacles) at Cape Perpetua Marine Reserve than at an average site. There were also less *Chthamalus spp.* (barnacles) and *Phyllospadix torreyi* (seagrass) at Cape Perpetua Marine Reserve than at an average site. About 1/10th of the most abundant species were more common at Cape Perpetua than on average. About 9/10th of the most abundant species were less common at Cape Perpetua than on average.

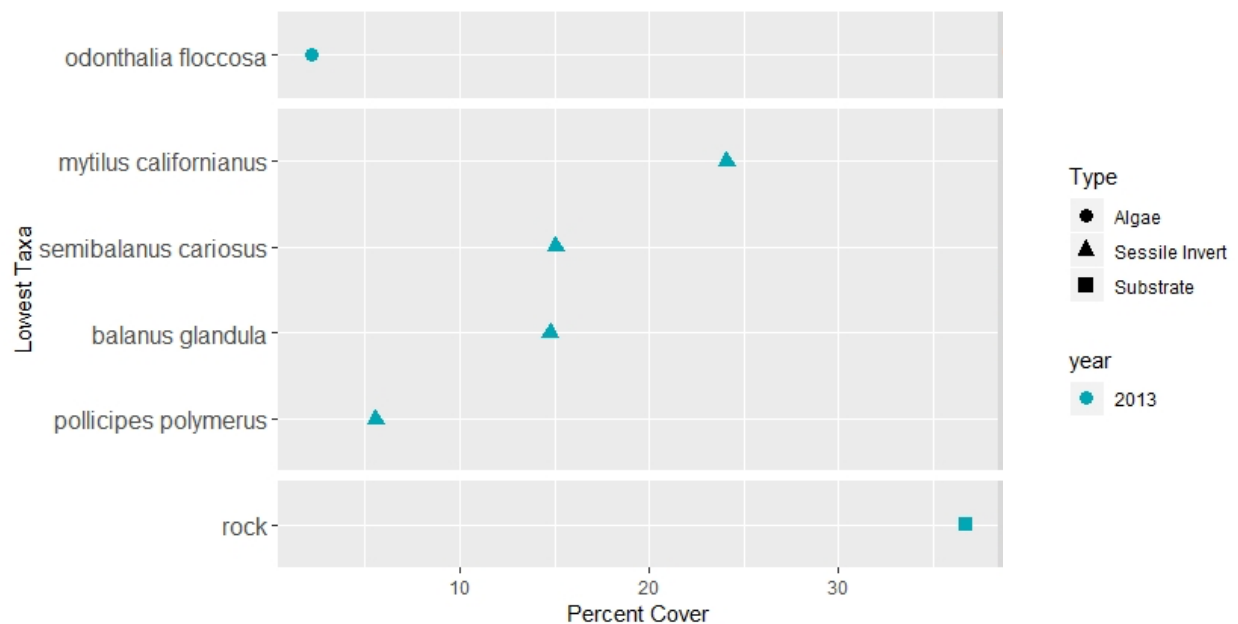


Figure 12. Cape Perpetua comparison area (Seal Rock) percent cover of common species and substrate (>2% cover) from the 2013 point count survey.

The figure above shows the percent cover of common intertidal species sorted by the type of taxa observed at Seal Rock, the comparison area for Cape Perpetua Marine Reserve, in 2013. The most abundant presence was an open substrate, rock. Sessile invertebrates also dominated this site. Three species were very abundant (>10%): the California mussel, the thatched barnacle, and the acorn barnacle. Both seagrass and mobile invertebrates were not commonly observed at this site. Only one species of algae was commonly found and only a small amount.

There were a lot fewer commonly found species at this site compared with Cape Perpetua. Additionally open rock covered much more area at Seal Rock compared with Cape Perpetua. While Cape Perpetua had 8 species of common algae, Seal Rock only had 1.

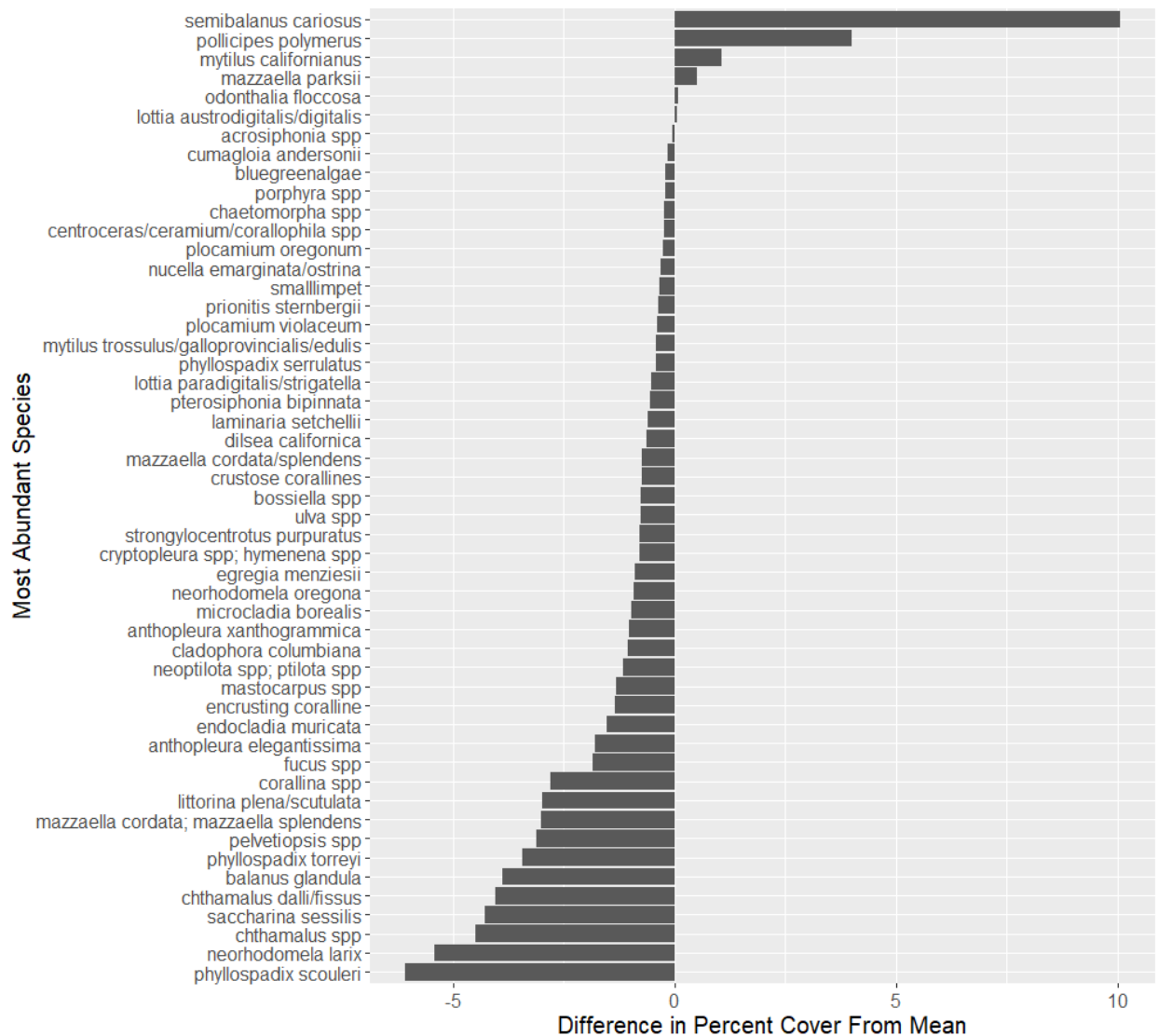


Figure 5. Cape Perpetua comparison area (Seal Rock) 2013 point contact survey difference from the mean percent cover of common species and open substrate (>2% cover) across all sites and years of point contact surveys.

At Seal Rock (Cape Perpetua's comparison area) there were more *Semibalanus cariosus* (barnacles) but less *Phyllospadix scouleri* (seagrass) than at an average site. About 1/10th of the most abundant species were more common at Cape Perpetua than on average. About 9/10th of the most abundant species were less common at Cape Perpetua than on average.

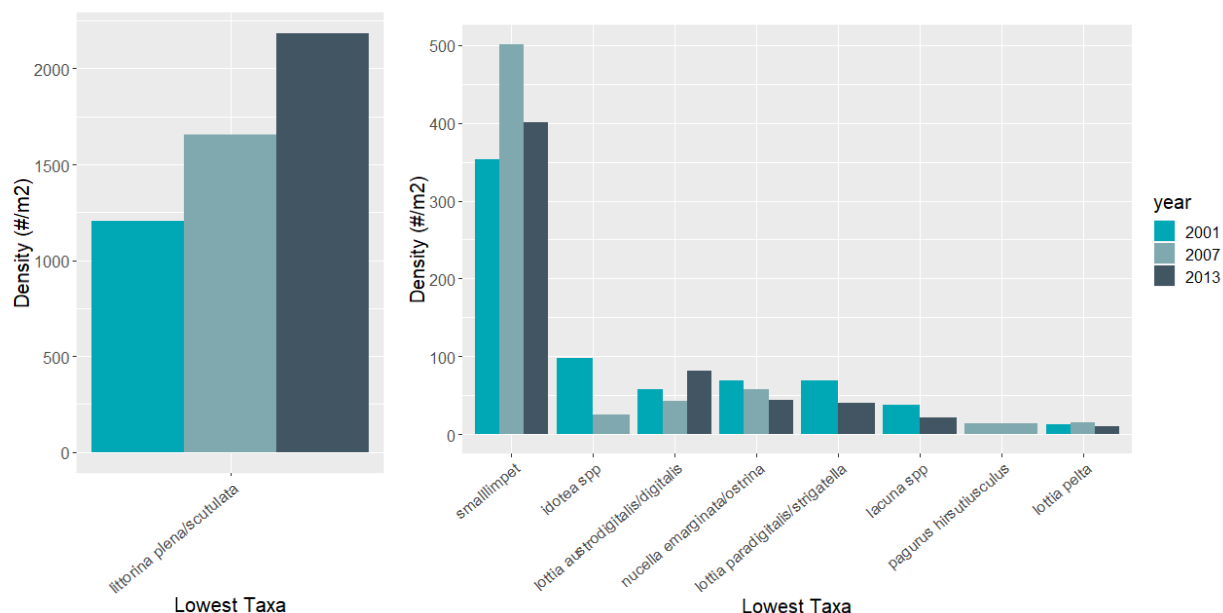


Figure 13. Cape Perpetua Marine Reserve density of abundant mobile invertebrates (>10/m²) from 2001, 2007, and 2013 quadrat surveys. There are two separate scales because *Littorina plena/scutulata* is so abundant that the other species could not be seen.

The overall density of mobile invertebrates from quadrat surveys in Cape Perpetua Marine Reserve peaked in 2013 but the mobile invertebrate species richness peaked in 2001. For all three years the most abundant species was *Littorina plena/scutulata* with densities ranging from the lowest in 2001 at 1,203 individuals/m² to the highest in 2013 at 2,184 individuals/m². Small limpets were also very prevalent in all three years ranging from 353 individuals/m² in 2001 to 501 individuals/m².

Table 13. Cape Perpetua Marine Reserve species richness and total density observed in the 2001, 2007, and 2013 quadrat surveys.

Site	Year	Species Richness	Total Density of All Species Observed (#/m ²)
Bob Creek	2001	23	1922
	2007	17	2331
	2013	18	2800

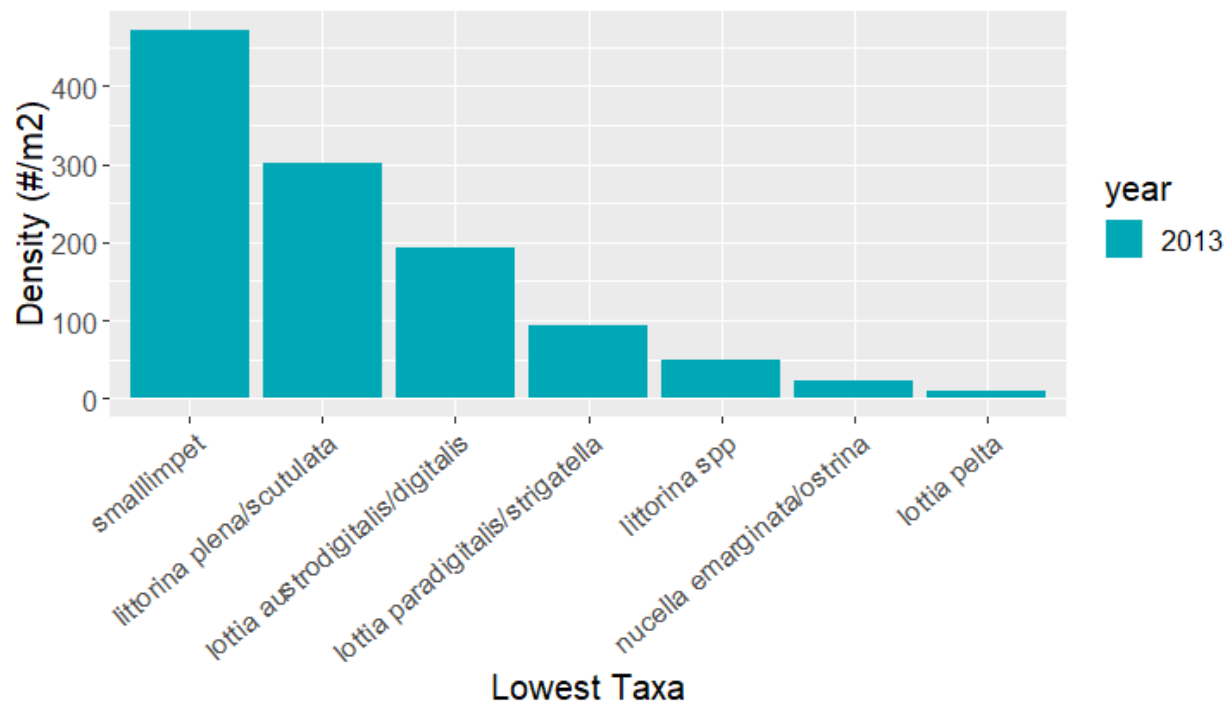


Figure 14. Cape Perpetua comparison area (Seal Rock) density of abundant mobile invertebrates (>10/m²) from the 2013 quadrat survey.

At Seal Rock we observed 18 species totaling to a density of 1,161 individuals/m² in the quadrat survey. The most abundant species were small limpets at a density of 472 individuals/m². *Littorina plena/scutulata* and *Lottia austrodigitalis/digitalis* were also very abundant with densities of 301 individuals/m² and 193 individuals/m² respectively.

While both Cape Perpetua and its comparison area, Seal Rock, observed a similar number of species of mobile invertebrates, the density of these organisms was much greater at Cape Perpetua.

Table 14. Cape Perpetua comparison area (Seal Rock) species richness and total density observed in the 2013 quadrat survey.

Site	Year	Species Richness	Total Density of All Species Observed (#/m ²)
Seal Rock	2013	18	1161

Table 6. Cape Perpetua Marine Reserve (Bob Creek) and comparison area (Seal Rock) sea star densities (N=11 per year).

	Bob Creek					Seal Rock
	2001	2007	2013	2015	2016	2014
Species						
<i>Pisaster ochraceus</i>	0.679	0.223	0.417	0.244	0.219	0.033
<i>Leptasterias spp.</i>	0	0	0	0	0.001	0.062

Cape Perpetua (Bob Creek) does not show a downward trend in *P. ochraceus* densities associated with sea star wasting disease. In 2007 *P. ochraceus* densities were similar to those after sea star wasting hit in 2015 and 2016 indicating that at this site there may be natural large fluctuations in sea star densities.

Seal Rock observed very low densities of *P. ochraceus* in 2014 from the swath surveys. The density of *Leptasterias spp.* was higher than that of *P. ochraceus*.

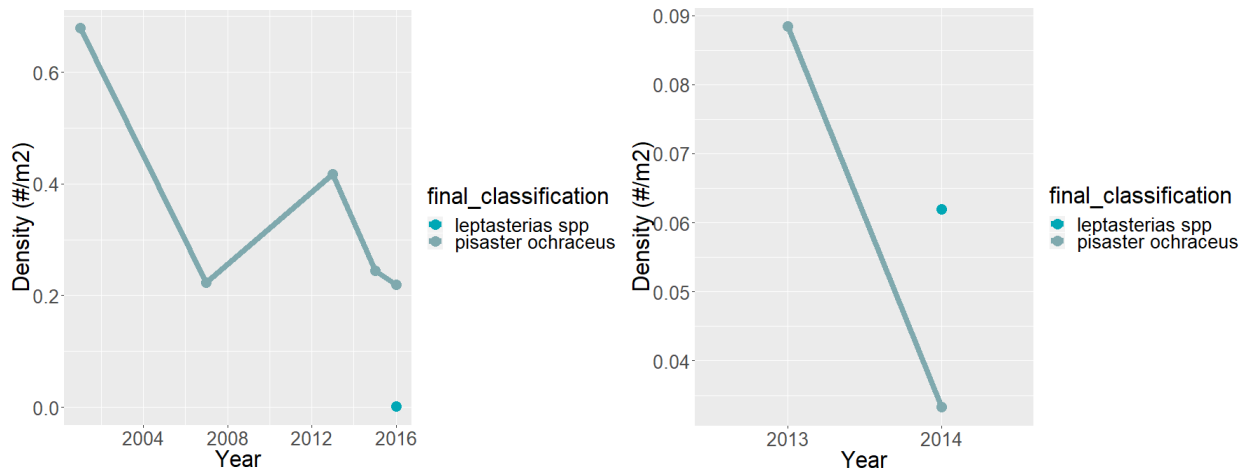


Figure 15. Cape Perpetua Marine Reserve (Bob Creek, left) in 2004, 2008, 2012, 2016 and comparison area (Seal Rock, left) in 2013 and 2014 for sea star densities from swath surveys (N=11 per year).

Densities of *P. ochraceus* were much higher at Cape Perpetua compared with Seal Rock. However densities of *Leptasterias spp.* were higher at Seal Rock (*Leptasterias spp.* not counted at Cape Perpetua until 2016 and at Seal Rock not until 2014).

Cross Site Comparison Results

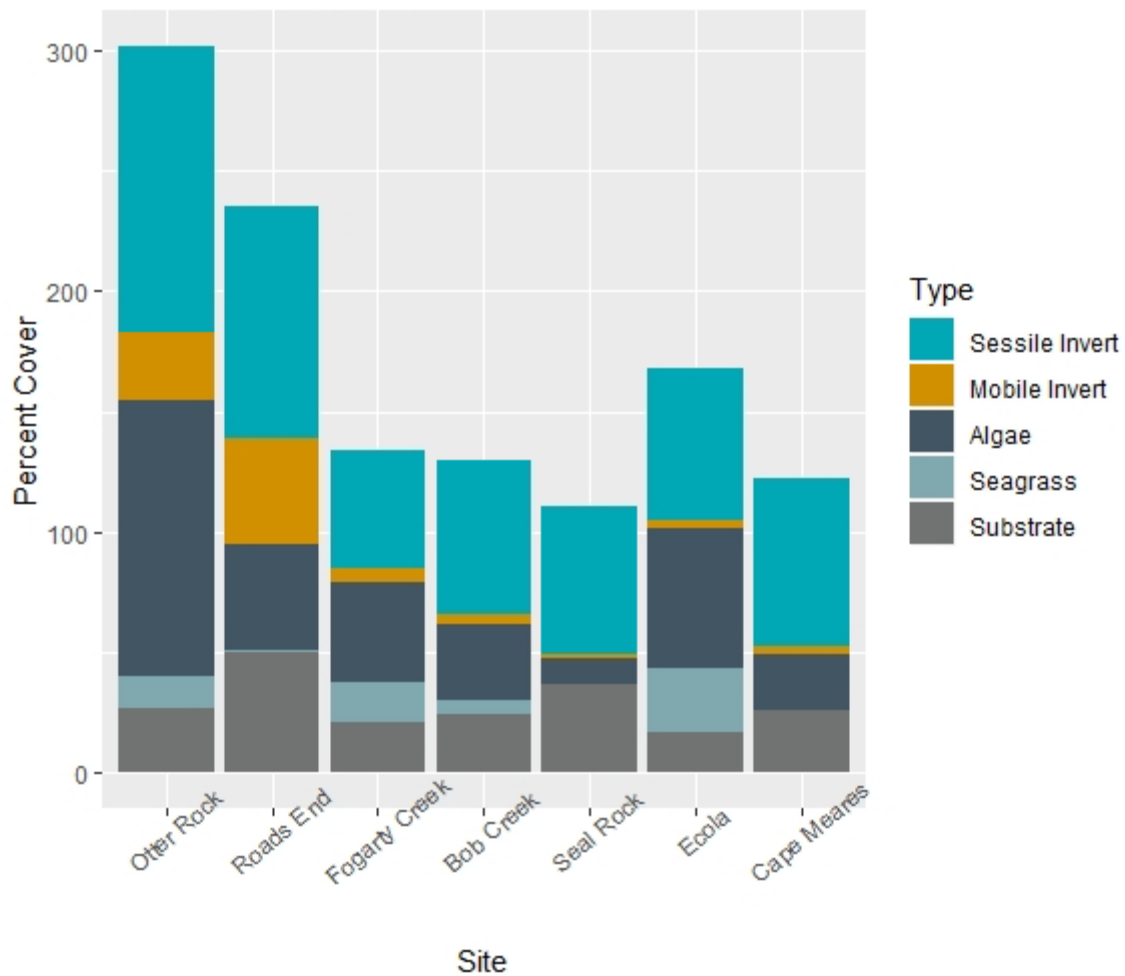


Figure 16. Percent Cover of broad groups observed including the major taxa as well as bare substrates from the most recent year's point count survey for each site.

Otter Rock had much more overlapping species causing the total percent cover to be much higher than other sites. Otter Rock, Fogarty Creek, and Ecola were dominated by both invertebrates and algae. Cascade Head (Roads End), Bob Creek, Seal Rock, and Cape Meares were dominated by invertebrates. Cascade Head was also the site with the highest percent cover of mobile invertebrates, Otter Rock was not too far behind, and all the other sites had very low percent cover for mobile invertebrates. Seagrass was covered the highest percent at Ecola. Roads End and Seal Rock had the highest percentages of open substrate.

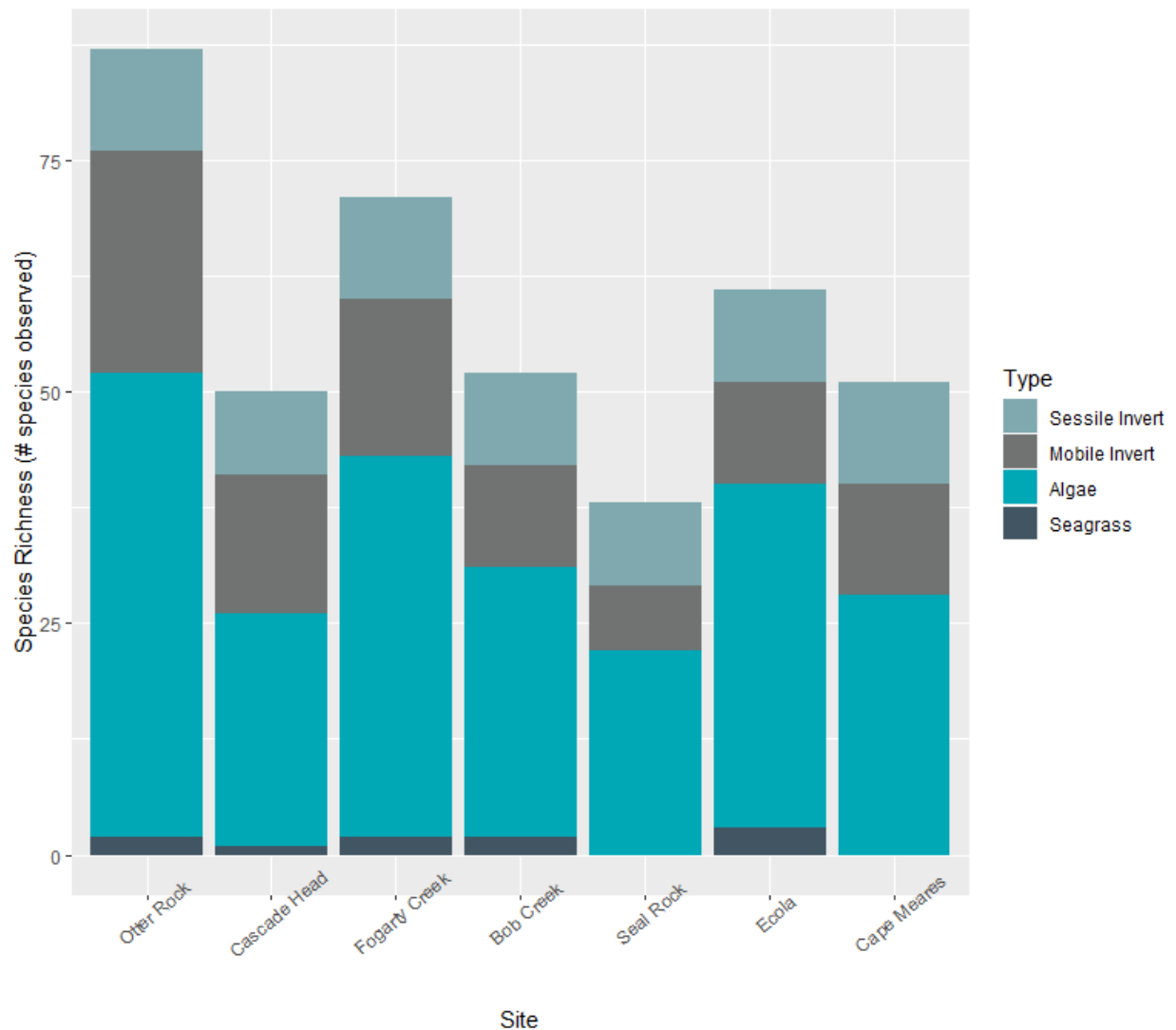


Figure 17. Species richness of broad groups observed including the major taxa as well as bare substrates from the most recent year's point count survey for each site.

Otter Rock had the highest total species richness, followed by Fogarty Creek and Ecola. Cascade Head, Bob Creek, and Cape Meares all had very similar total species richness. It is interesting to note that while mobile invertebrates always had smaller percent cover compared with sessile invertebrates, for species richness mobile invertebrates are very similar in numbers to sessile invertebrates. Additionally there are many more algae species than invertebrate species despite algae generally covering less compared with invertebrates.

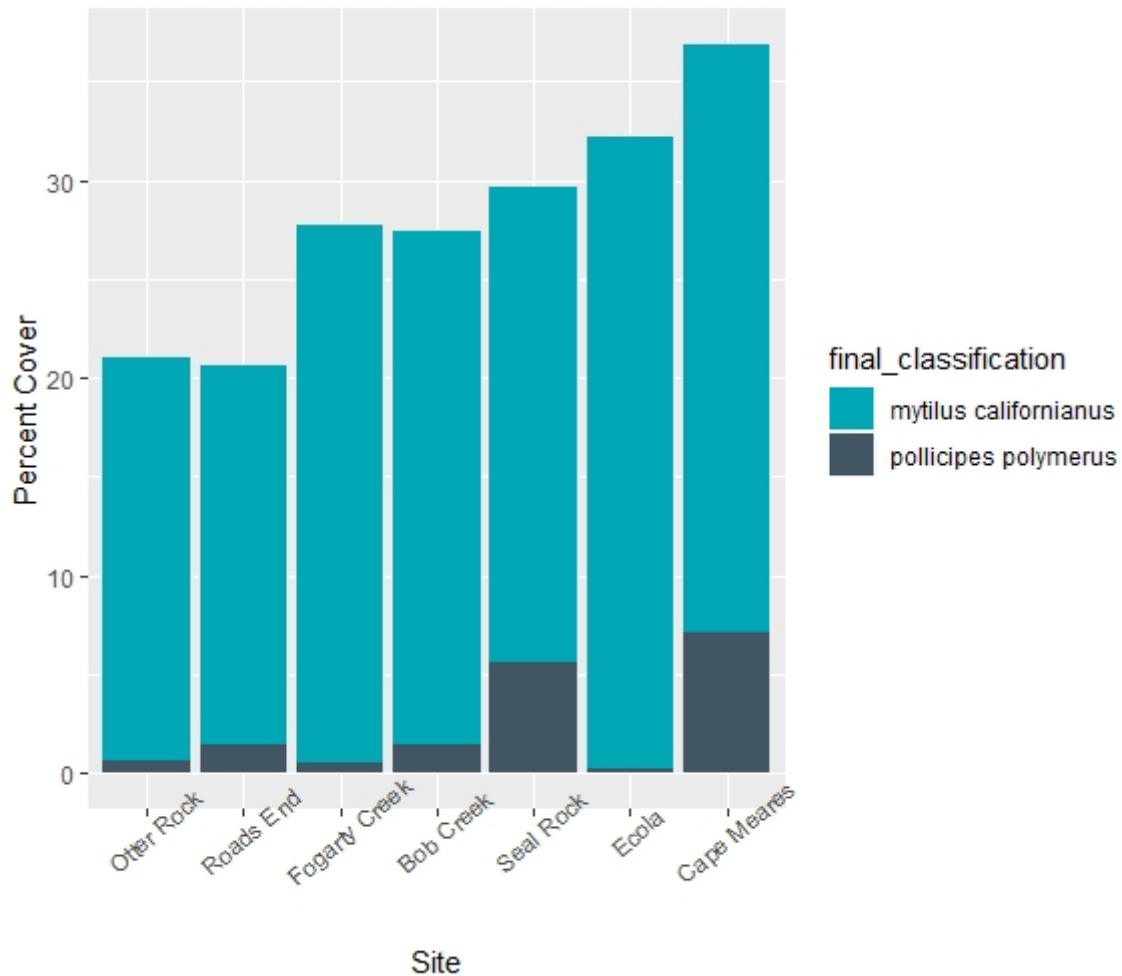


Figure 18. Percent cover of ODFW Marine Reserves' intertidal focal invertebrate species from the most recent year's point count survey for each site.

The California mussel (*Mytilus californianus*) makes up a significant coverage of all site varying from 19% to 32%. Gooseneck barnacles (*Pollicipes polymerus*) cover much less of the intertidal zone for all site varying from 0.2% to 7.1%. Additionally the sites north and south of Otter Rock and Cascade Head (Roads End) have higher percent cover for the California mussel. However there is no pattern to the distribution of gooseneck barnacles.

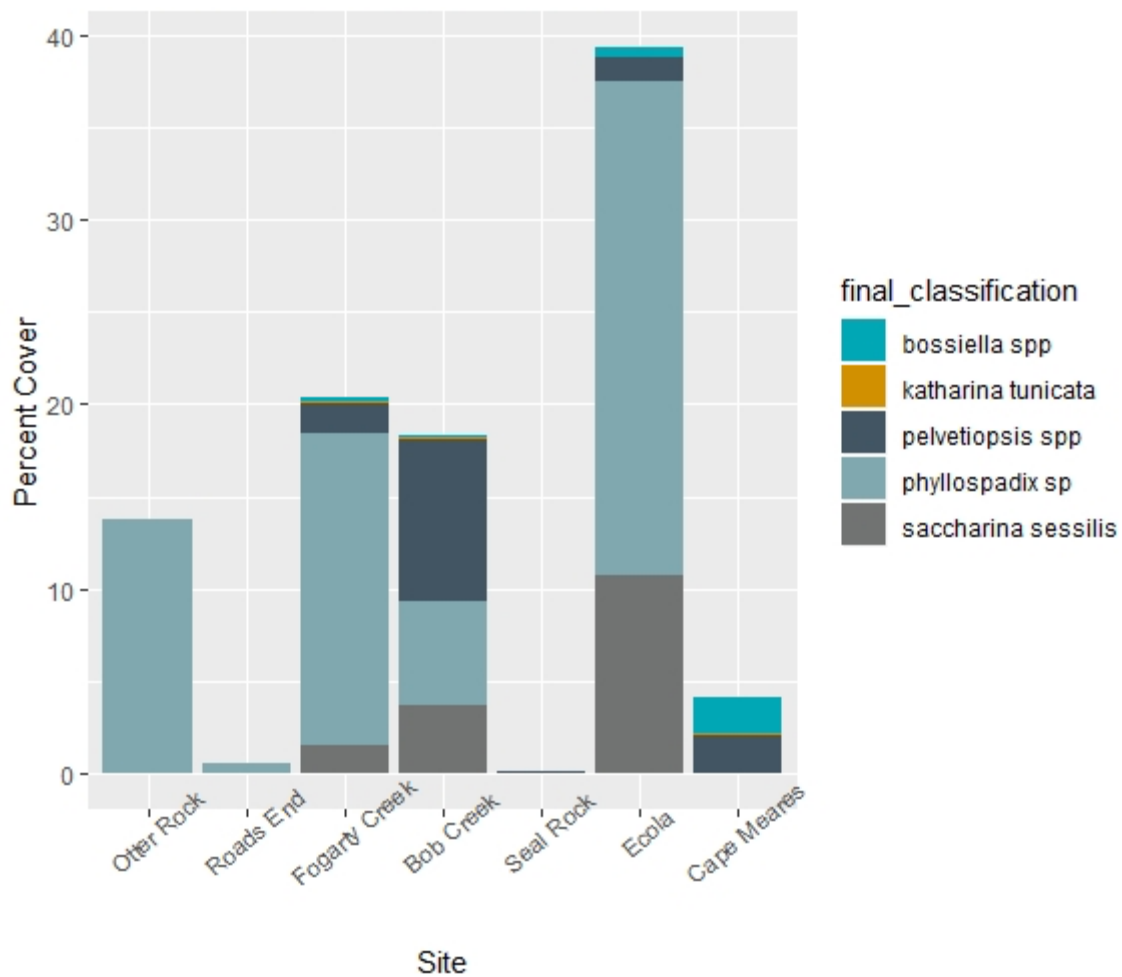


Figure 19. Percent cover of ODFW Marine Reserves' intertidal focal algae, seagrass, and grazer species from the most recent year's point count survey for each site.

There is no pattern for the distribution of focal algal and seagrass species along Oregon's coast. Additionally it does not appear that the predator *Katharina tunicata* has a large influence on algal composition for these sites since *Katharina tunicata* percent cover remains low at all sites. Of these species seagrass (*Phyllospadix sp.*) is the most common.

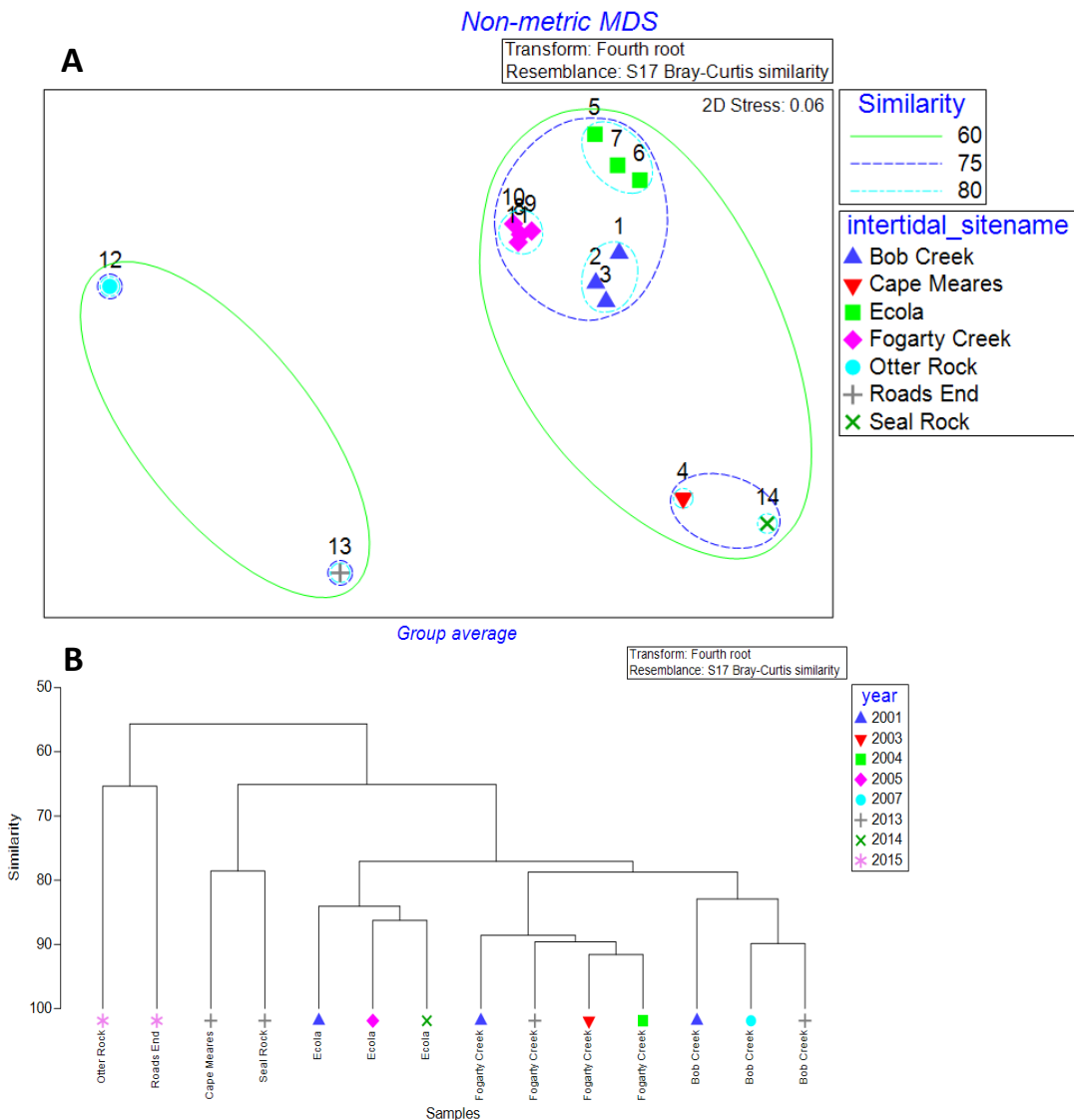


Figure 20 A. NMDS from Bray-Curtis resemblance matrix with fourth root transformation on most abundant species from point count surveys (>2% cover at least one sampling event) for all years and all sites clustered by 60%, 75%, and 80% similar community assemblages.

Figure 20 B. Clustering based on Bray-Curtis resemblance matrix with fourth root transformation on the most abundant species from point count surveys (>2% cover at least one sampling event) for all years and all sites.

At 60% similarities the community structure separates into two distinct groups with Otter Rock and Cascade Head (Roads End) in one group and all other sites in the other group. The grouping of these sites does not correlate with geographic location at 60% or 75% similarity. When considering 80% similarity, each site is distinct.

Otter Rock and Cascade Head were sampled the same year after sea star wasting occurred which may be influencing the substantial difference between the two sites and all other sites. One of the sampling times at Ecola was conducted a couple months after sea star wasting but the community composition of the most abundant species was still 80% similar to the years before wasting occurred.

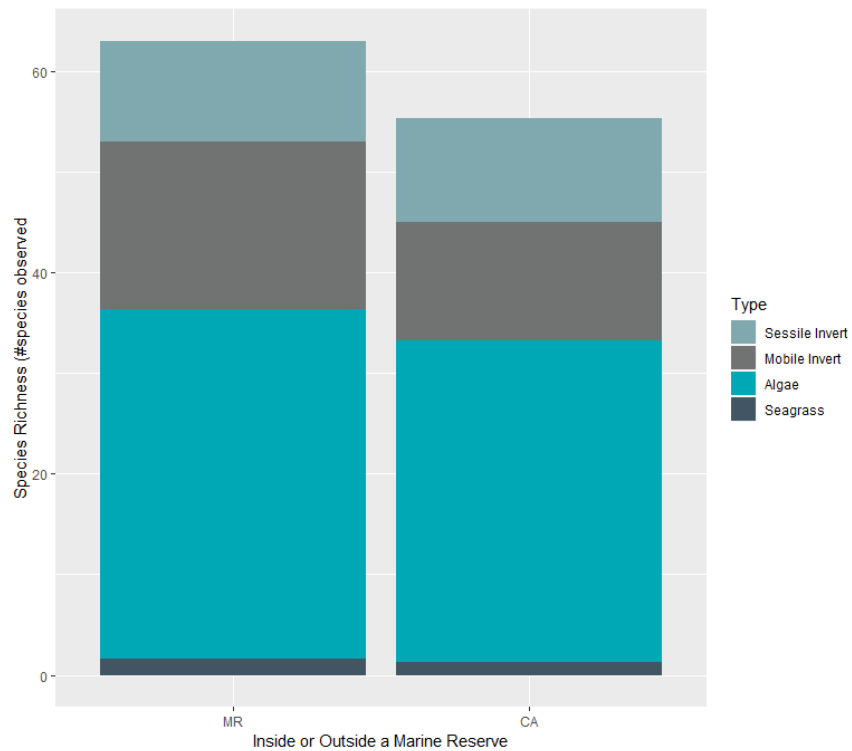


Figure 21. Species richness by broad taxa from the most recent year's point count survey averaged for sites in marine reserves (MR) and site in comparison areas (CA).

The species richness inside and outside marine reserves are not significantly different. Additionally the proportion of species richness for each broad group (sessile and mobile invertebrates, algae, and seagrass) are similar inside and outside marine reserves. While there is no difference from the most recent surveys, it has only been a couple of years since the marine reserves went into effect so it is unlikely to see a change on such a short time scale. However the similarity between the comparison areas and marine reserves currently is a good sign. It indicates that these comparison areas are great to use in the future to investigate if there is change within the marine reserves occurring. This is because the sites chosen currently have relatively similar community compositions to each other so the primary change will be the protection of the marine reserve.

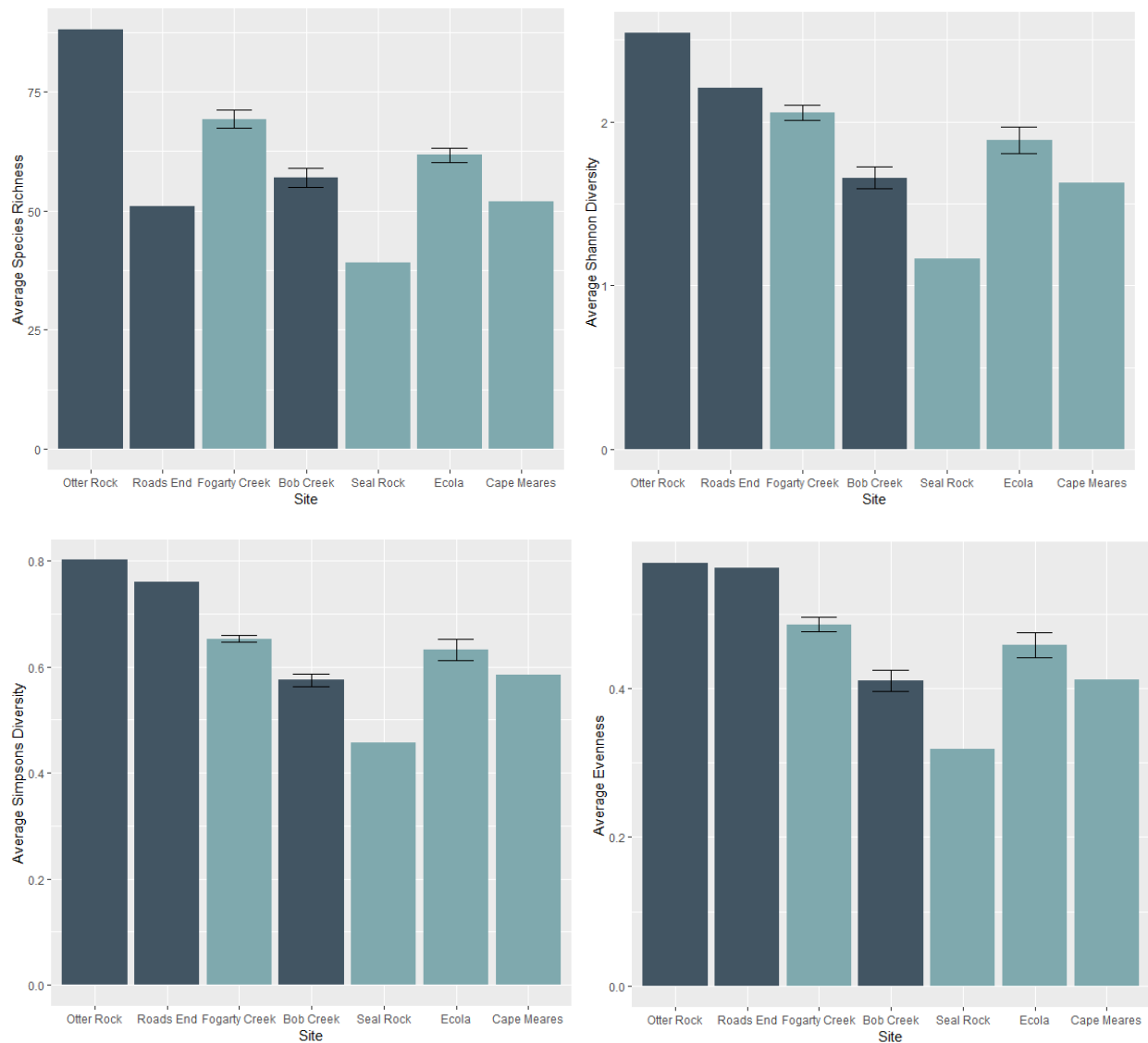


Figure 22. Diversity metrics from point contact surveys for all sites and averaged (\pm SE) when multiple years were sampled (dark blue: marine reserve, light blue: comparison area).

There was no significant difference between inside and outside marine reserves for all four variables (average species richness, average Shannon diversity index, average Simpson's diversity index, and average evenness).

Otter Rock had the highest richness, diversity (both Shannon and Simpson's), and evenness of all sites. Seal Rock had the lowest richness, diversity (both Shannon and Simpson's), and evenness of all sites.