



Rocky Intertidal Monitoring

2016 Results from Redwood National and State Parks

Natural Resource Report NPS/KLMN/NRR—2018/1700



ON THE COVER

Researchers sampling the intertidal community at False Klamath Cove, Redwood National and State Parks.
Photograph by: David Anderson.

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Executive Summary

This report presents the results of the monitoring surveys done in 2016 of the rocky intertidal community at three sites within the Redwood National and State Parks (RNSP) in Del Norte County, California. These sites are part of MARINe (Multi-Agency Rocky Intertidal Network), a regional intertidal monitoring network sponsored by the Bureau of Ocean Energy Management (BOEM), with additional funding and support from local and state governments, universities, and private organizations (see www.marine.gov and www.eeb.ucsc.edu/pacificrockyintertidal/). Funding for RNSP sampling is provided by the National Park Service (NPS) through a collaborative agreement with the University of California at Santa Cruz (UCSC). The 2016 summer and fall crews each consisted of four UCSC biologists and three RNSP staff members.

This monitoring program, adapted from MARINe protocols, was designed to identify and follow temporal trends in populations of the common and/or ecologically important organisms in the rocky intertidal community at three index sites within the Redwood National and State Parks. To accomplish this, sites are sampled twice a year, and data are collected from permanent plots established to monitor changes in sessile invertebrates, algae, and the ochre sea star (*Pisaster ochraceus*), and from permanent transects to monitor surfgrass (*Phyllospadix* spp.). These data are analyzed to determine seasonal and annual changes to the community, and will eventually be used to explore broader spatial and temporal trends.

All of the monitored populations varied to some degree over the course of 2016. However, there were several changes that are noteworthy. For example, disturbances prior to the summer survey caused mussel abundances to decline at Enderts. The numbers started to increase with the appearance of new mussel during the fall; however, abundances were still well below prior sampling. Similarly, the appearance of many new small (<20mm) ochre sea stars caused the populations at Enderts to increase dramatically between the summer and fall surveys. False Klamath Cove showed a similar pattern of increased small individuals from summer to fall, but to a smaller extent.

The rocky intertidal monitoring program, which was initially started in RNSP in 2004, continues to progress successfully. The procedures for data collection, data management, data analysis, and reporting are regularly assessed and have undergone some revisions based on the evolution of the monitoring program. This report and subsequent annual reports for the intertidal monitoring program are intended primarily as administrative reports. More comprehensive trend analyses of the data will be included in the program's five-year reports, the first of which includes data through 2013 (Ammann et al. 2017).

Acknowledgments

We thank the 2016 field crew for their hard work and dedication to the project: Dave Lohse, Maya George, Laura Anderson and Melissa Douglas. We also appreciate the field assistance from Redwood National and State Parks staff including David Anderson, Terry Hines, Kyle Max, Heather Brown and numerous seasonal staff and volunteers. Eric Dinger, Alison Snyder, Sonya Daw and Alice Chung-MacCoubrey from the Klamath Network have provided editorial, technical, and data assistance.

Introduction

Among the many concerns of resource managers is the ability to detect and mitigate the effects of anthropogenic events, like oil spills and climate change, which can alter the structure of natural communities. An important tool needed to accomplish this is long term monitoring programs that establish baseline data and follow changes over time (Davis 2005). Such programs provide important information needed to distinguish natural changes in community structure from those caused by unnatural/anthropogenic events. As such, a consortium of monitoring programs has been established for rocky intertidal habitats.

The U.S. Department of Interior Bureau of Ocean Energy Management (BOEM) and Partnership for the Interdisciplinary Studies of Coastal Oceans (PISCO) have been working in concert with a number of academic and government organizations to monitor intertidal communities along the western coast of North America, from Alaska to California. These Community Structure Surveys have been conducted by members of Multi-Agency Rocky Intertidal Network (MARINe) and PISCO and include over 20 coastwide agencies. Several other coastal parks, including Cabrillo National Monument, Golden Gate National Recreation Area, Point Reyes National Seashore, and Channel Islands National Park, have intertidal monitoring programs to 1) establish baseline datasets of their marine resources, and 2) follow changes in these resources (Davis and Halvorson 1996; Davis 2005). Because such monitoring allows changes to be tracked within and between communities over yearly time scales, it provides critical information needed to make informed management decisions. Further, understanding these patterns is necessary for detecting anthropogenic changes resulting from disturbances such as oil spills or global climate change.

The Community Structure Surveys were initiated in the early 1990s to determine abundance and distributional patterns of intertidal species along the southern California coast (Ambrose et al. 1992). Since then, sites have been added in central and northern California, Oregon, Washington, and recently, Alaska. We have adapted the protocols used in these surveys (i.e., Engle 2005) to monitor the intertidal communities within Redwood National and State Parks (RNSP). This facilitates comparisons between the RNSP sites and those elsewhere along the coast.

The specific monitoring objectives of the RNSP rocky intertidal monitoring program follow:

- Monitor the temporal dynamics of target invertebrate, algal, and surfgrass species across accessible, representative, and historically sampled rocky intertidal sites at Redwood National and State Parks that can feasibly be monitored with the Klamath Inventory and Monitoring Network's intertidal monitoring budget (\$30k/yr) to 1) evaluate potential impacts of visitor use or other park-specific activities, and 2) provide monitoring information to help assess level of impacts and changes outside normal limits of variation due to oil spills, nonpoint source pollution, or other anthropogenic stressors that may come from outside the parks.
- Determine status through time of morphology, disease/condition, and other key parameters describing population status (e.g., size, structure) of the selected intertidal organisms.

- Integrate with and contribute to a monitoring network spanning a broad geographic region in order to evaluate trends at multiple scales, from parkwide to regionwide.
- Detect and document invasions, changes in species ranges, the spread of diseases, and the rates and scales of processes affecting the structure and function of rocky intertidal populations and communities to better understand normal limits of variation.

The specific measurement and analysis objectives of the program follow:

- Provide a photographic record of sessile invertebrates and algae (and potentially oil and other nonpoint source pollutants) using fixed plots (photoplots) as reference.
- Determine the abundance (percent cover) of organisms within select fixed plots (interchangeably called photoplots or photoquadrats).
- Within fixed plots, determine the abundance of sea stars, snails, chitons, limpets, and crabs (mobile invertebrates), which may serve as an indicator of overall or specific ecosystem health.
- Determine surfgrass abundance by measuring cover along fixed point-intercept transects.
- Identify changes that are inconsistent with the established baseline conditions, whether they are park-specific or broader in scale, and whether there are potential management actions needed to mitigate them.
- Prepare annual summary reports and five-year, peer reviewed trend analysis reports showing data relevance following National Park Service reporting guidelines. Reports will display any major (>50%) changes in the abundance of target taxa between sampling intervals as a highlight for potential management actions.

The RNSP rocky intertidal monitoring program uses a selective, scientifically rigorous sampling scheme that integrates with a long-term, spatially extensive program. The national parks are promoting the importance of marine resources by establishing long-term monitoring programs supported by the public and the scientific community. This effort will translate into a greater appreciation of these resources and an awareness of the importance of maintaining them for future generations. See www.eeb.ucsc.edu/pacificrockyintertidal for more information.

This annual report documents the results of data collected in 2016 for the RNSP rocky intertidal monitoring program.

Study Area

Three rocky intertidal sites are monitored within RNSP: Enderts Beach, Damnation Creek, and False Klamath Cove (Figure 1). These index sites are approximately 5 km apart and span the nearly 20 km of rocky intertidal habitat present in RNSP. The sites are all located in an Area of Special Biological Significance (Redwood National Park ASBS).

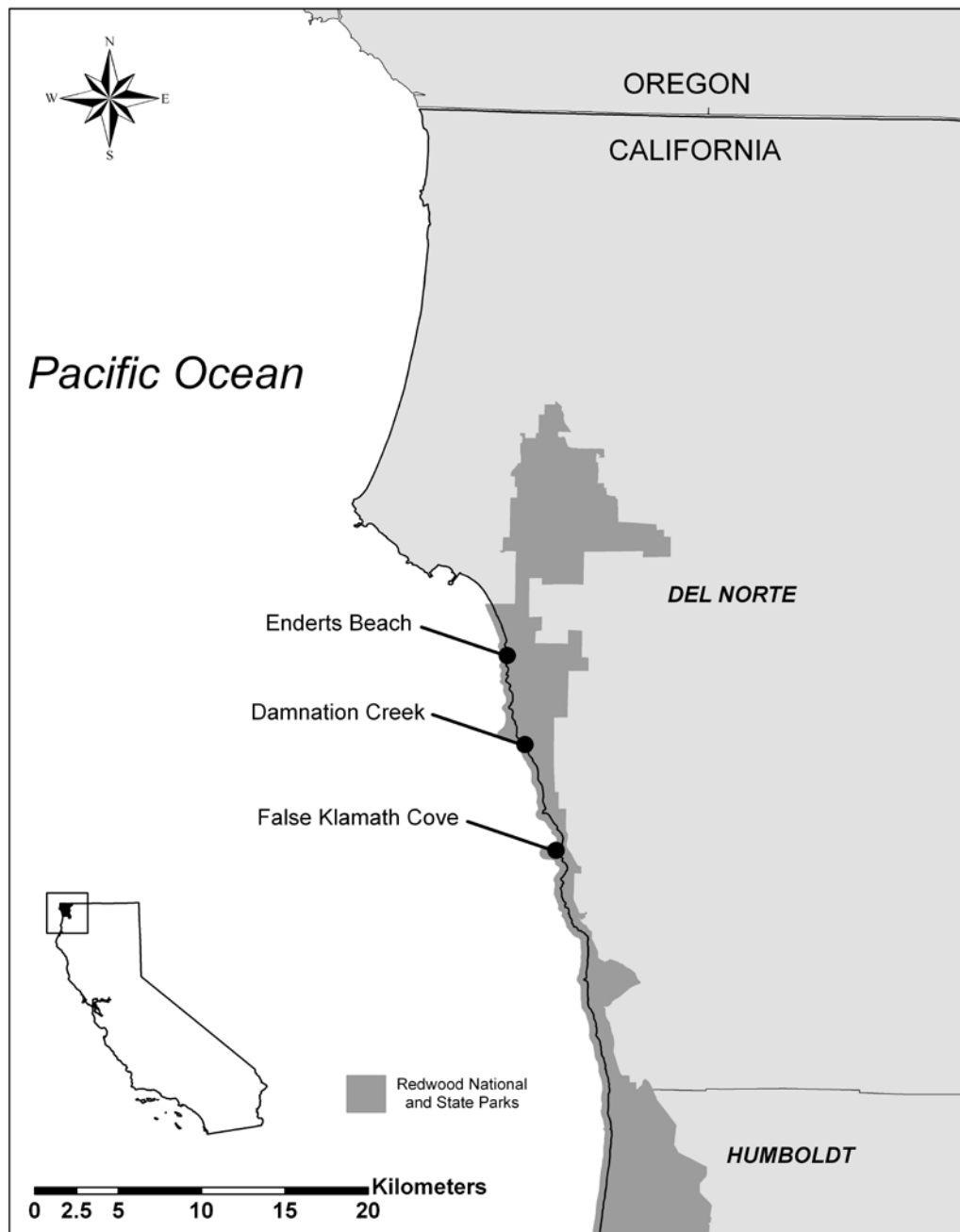


Figure 1. Map of northern California showing the locations of the study sites sampled in the spring and fall of each year within Redwood National and State Parks.

Enderts Beach, located at the southern end of Crescent Beach, is at the northern edge of RNSP. The site consists of a large, gently sloping bench (approximately 100 m wide) and a series of three smaller benches separated by surge channels, a few scattered boulders and cobble beds. Rocky intertidal monitoring occurs on the three rocky benches. Visitation is relatively low due to obstructed access through a cave. Enderts is dominated by consolidated bedrock (greywacke mudstone/sandstone with calcite intrusions), and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and sandy beach. The primary coastal orientation of this site is west.

Damnation Creek is 5 km south of Enderts Beach and 6.5 km north of False Klamath Cove. It is an extensive rocky bench cut by channels, with a few large sedentary boulders at its seaward edge. To access this site a 45 min steep hike is required and then Damnation Creek must be crossed. This site receives very low visitation by hikers. Damnation Creek is dominated by a mixture of consolidated bedrock, boulders, and cobble beach, and the area surrounding the site is comprised of a mixture of consolidated bedrock, boulder fields, and cobble beach. The primary coastal orientation of this site is south/southwest. Although the site is near the mouth of Damnation Creek, most of the monitoring plots are established far enough away from the creek's outflow to avoid direct freshwater input. The exception to this are a series of mussel plots established within the path of the creek's outflow.

False Klamath Cove is located just south of Wilson Creek, about 8 km north of the Klamath River. This site has variable substrata ranging from coarse sand to large boulders. There is potential for temporal variation in sand scour and boulder movement. The intertidal study site is peninsula-like with the ocean to the north and south and a sea stack (approximately 75 m tall and 100 m wide) at the west end. The primary coastal orientation of this site is west. The peninsula stretches approximately 250 m long with a width of approximately 100 m. The site consists of a gently sloping field of boulders and small benches dominated by a mixture of consolidated bedrock, boulder fields, and cobble beach, and the area surrounding the site comprises a mixture of consolidated bedrock, boulder fields, and sandy beach. The vast majority of the sampling takes place on variously sized boulders.

Methods

Sample Design

The methods used for monitoring algal and invertebrate species in RNSP during the 2016 monitoring year and since monitoring began in 2004 are based on the protocols developed by MARINe (www.marine.gov), and are explained in detail in Ammann and Raimondi (2008). In brief, the abundance of ecologically important organisms is measured in discrete, fixed plots that have been established in targeted assemblages. Using fixed plots allows the dynamics of species to be monitored with reasonable sampling effort, and provides greater statistical power (as opposed to random sampling) to detect changes over time. Smaller (50 × 75 cm) plots are used to monitor sessile (or relatively nonmotile) algae and invertebrates, while larger, irregular plots are used to sample more mobile species and 10 m. transects are used to sample surfgrass.

Field Log

Field logs were kept to provide a record of general observations made during the surveys at the monitoring sites including weather conditions, participants, changes to or deviations from the protocols, and any unique or unusual occurrences. Physical and weather-related conditions were collected initially upon reaching the site, as were counts of birds, marine mammals, and humans. These data included: tidal information, temperature, wind, and levels of rain, sand scour, trash, plant wrack, dead animals and trash. Presence/absence was also noted for a set list of species, including some not targeted in the permanent plots. Researchers for MARINe recorded abundance or presence/absence for the same list of core species at all sites from San Diego to Washington (see definition of core species in Appendix A). This standard species list allows monitoring groups to consistently make general observations about species not targeted in specific plots.

Photoplots

At each site, photoplots (50 × 75 cm) were used to record changes in abundance (measured as percent cover) of conspicuous, abundant, and ecologically important species, including mussels (*Mytilus californianus*), barnacles (*Chthamalus dalli*/*Balanus glandula*), and three species of algae (turfweed [*Endocladia muricata*], dwarf rockweed [*Pelvetiopsis limitata*], and rockweed [*Fucus gardneri*]) (Figure 2). The natural history of target organisms is referenced in Appendix B.



Figure 2. Photographs depicting the 5 target species sampled in permanent photo plots in Redwood National and State Parks.

Five photoplots were established for each species (Table 1), and the location of each plot was chosen to maximize the abundance of the targeted species. Because the rockweed (*Fucus*) was not abundant at Enderts Beach, and dwarf rockweed (*Pelvetiopsis*) was not abundant at Damnation Creek, no plots were set up to monitor these species at those sites. At Damnation Creek, five additional mussel plots were established in the outflow of Damnation Creek, where salinity is often much lower than in the other mussel plots (Cox and McGary 2006). At low tide the salinity of the water surrounding the mussel plots near Damnation Creek has been recorded to be as low as 22 ppt (parts per thousand) compared to the average ocean salinity between 32 and 35 ppt.

Table 1. Summary of species monitored in photoplots at Redwood National and State Park sites, including number of replicate plots.

Site	Mussels	Barnacles	Rockweeds/Sessile algae species		
	<i>Mytilus</i> spp.	<i>Chthamalus</i> / <i>Balanus</i>	<i>Pelvetiopsis</i> <i>limitata</i>	<i>Endocladia</i> <i>muricata</i>	<i>Fucus</i> <i>gardneri</i>
Enderts Beach	5 plots	5 plots	5 plots	5 plots	–
Damnation Creek	10 plots*	5 plots	–	5 plots	5 plots
False Klamath Cove	5 plots	5 plots	5 plots	5 plots	5 plots

*Five mussel plots are located away from creek outflow and 5 plots are located near the outflow of Damnation Creek.

The photoplots were marked by three permanent bolts and were photographed using a digital camera mounted on a PVC photo-framer. The abundances (percent cover) of all sessile species in the

photoplots were determined using a rectangular grid of 100 uniformly spaced points. This grid was placed over the plot, and the taxon under each point was identified. In 2014 a new layering protocol was implemented that allowed more than one taxon to be recorded per point whenever multiple layers were present. Palm pilots were used to record these data in the field.

Mobile Invertebrates

The photoplots were also used to measure the abundance (density) of mobile invertebrates. With the exception of burrowing organisms and amphipods, all mobile invertebrates within each photoplot were counted. For select species, such as black turban snails *Chlorostoma* (= *Tegula*) *funeralis*) and dogwinkles (*Nucella emarginata* and *N. canaliculata*), the sizes (measured at the organism's longest axis using calipers) of 10 individuals per plot were recorded. This information was used to determine size distributions.

Barnacle Recruitment

To monitor the recruitment of the barnacles *Balanus glandula* and *Chthamalus dalli* (Figure 3), small clearings (10 × 10 cm) were established near the barnacle photoplots. Each year (measured in summer) the new recruits into these plots were counted with a hand lens, after which the plots were scraped clean. These plots were established at the sites in the summer of 2006, and were first sampled in the summer of 2007.

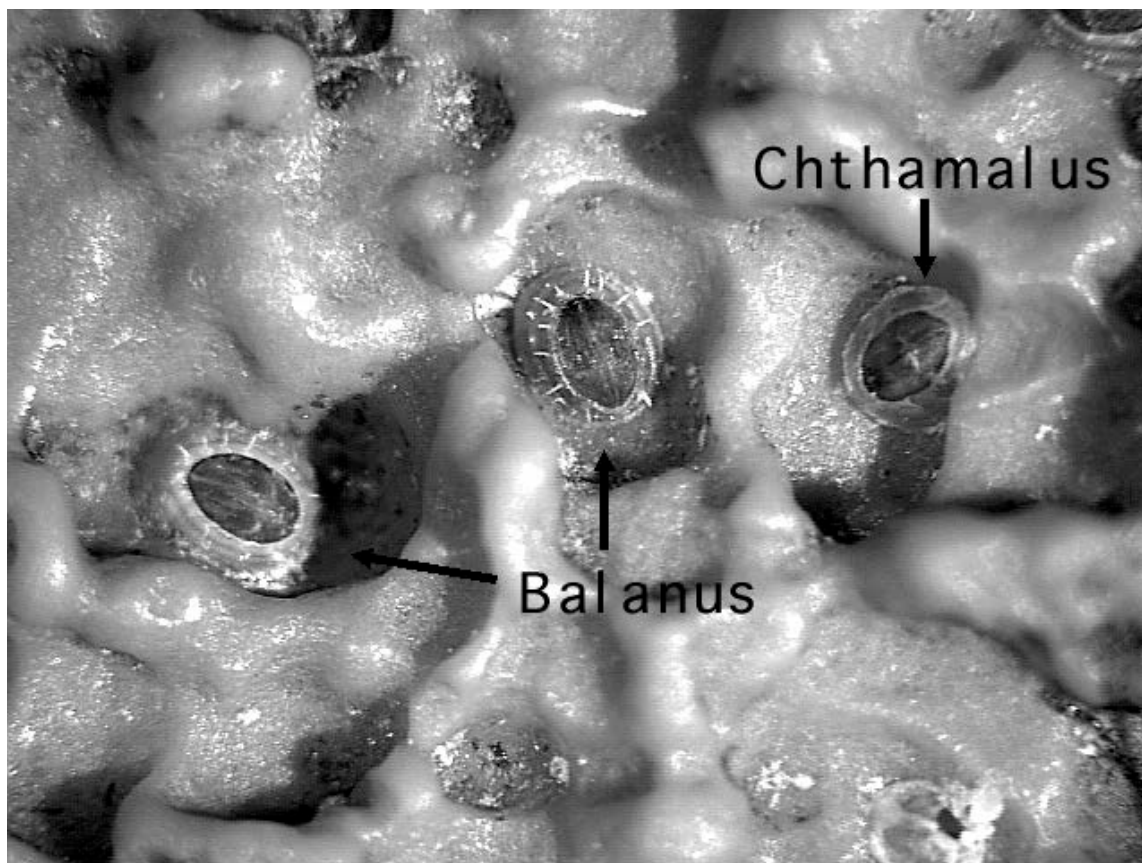


Figure 3. Image (10x) of barnacle recruits (*Balanus glandula* and *Chthamalus dalli*) taken through a microscope.

Sea Stars

Large, permanent plots were used to monitor the size and abundance of the ochre sea star. Three plots were monitored at Damnation Creek and False Klamath Cove, and two plots were sampled at Enderts Beach. These plots were established in areas where sea stars were abundant and were thus not intended to quantify the overall density of sea stars at the site. Each ochre sea star encountered was counted and measured. Other rarer sea stars, such as the bat star (*Patiria miniata*), the giant sea star (*Pisaster giganteus*), the sunflower star (*Pycnopodia helianthoides*), the six-armed star (*Leptasterias hexactis*), and leather sea star (*Dermasterias imbricate*), were also counted when encountered. *Kathrina tunacata*, the leather or Katy chiton, was also monitored in these plots. Since the onset of Sea Star Wasting Syndrome (SSWS) in 2013, monitoring groups have been recording the disease category of each sea star noted. More information and detailed sampling protocols for tracking SSWS can be found at seastarwasting.org.

Surfgrass and Sea Palm Abundance

To measure the abundance (percent cover) of surfgrass (*Phyllospadix scouleri/torreyi*), permanent line transects were established at Damnation Creek (note that surfgrass is not abundant at the other sites). Each transect was 10 m long, and was sampled by noting the species under each 10 cm mark. Thickness of the surfgrass bed was measured every meter along the transects.

Starting in 2014, permanent line transects were established to measure the abundance (counts) of sea palm (*Postelsia palmaeformis*), at False Klamath Cove (note that sea palms are not present at the other sites). Each transect was 6 m long, and was sampled on both the onshore and offshore direction by noting the number of individuals in each 1 meter swath along the transect.

Mussel Measurement

Starting in 2011, mussel (*Mytilus californianus*) sizes and bed/patch thickness were measured within each mussel photoplot. Ten length measurements (more if the mussel bed is multilayered) and five mussel bed/patch depth measurements were recorded in each plot. When combined with measures of mussel spatial cover and density (# individuals per m²), these measurements can provide estimates of site-wide mussel biomass.

Sea Surface Temperature

Sea-surface temperature was measured at each site using small Tidbit Temperature data loggers (Onset Computer Corporation). These units were attached to the rock below the mussel zone, and were set to record temperatures every 15 minutes. The units were changed out during each site visit, downloaded, and then reset for use again. Only those times of the day when the probe was underwater were used to calculate sea-surface temperature.

Data Collection and Entry

The RNSP intertidal sites were sampled twice each year (spring/summer and fall/winter) during times when there were good negative low tides. The spring/summer survey occurs in May or June (referred to as summer sample in report), and the fall/winter survey sometime between November and January (referred to as fall sample). All data for this report were collected between May 22, 2016 (SU16) and December 13, 2016 (FA16) (Table 2). Each site required a full low-tide sequence to

sample, by a team of four to six experienced intertidal field biologists with two to four extra field biologists and/or volunteers assisting. Summer 2016 crew consisted of four UCSC biologists: Maya George, Melissa Redfield, Karah Ammann, and Laura Anderson with three RNSP crew: David Anderson, Terry Hines and alternating Kyle Max, Heather Brown, and Steve Bustamante. Fall 2016 crew consisted of four UCSC biologists: Karah Ammann, Maya George, Melissa Redfield and David Lohse with two RNSP crew: Dave Anderson and Heather Brown.

After the completion of each survey, researchers reviewed the data forms for missing or incorrectly recorded data. Once complete, the data from field logs, photoplots, sea star plots, and surfgrass transects were entered into the MARINe Data Management System (MDMS), a system that provides uniform data information storage and retrieval for all MARINe institutions. Data for mobile invertebrate counts and sizes were entered into a Microsoft Excel spreadsheet.

Data Analysis

Basic summary statistics were used to examine variations in abundance for the key species found in the photoplots (e.g., barnacles (*Chthamulus*, *Balanus*, etc.); mussels (*Mytilis spp.*), and rockweed species (e.g., *Pelvetiopsis limitata*), and in the line transects (e.g., surfgrass [*Phyllospadix spp.*]). Mean percent cover values are presented for each site (based on pooled values for all plots in each zone) in summer and fall sampling periods. This report covers 1 year of data; any analysis of trends should be based on a longer time series (>5 years). Trend graphs are available at www.eeb.ucsc.edu/pacificrockyintertidal/sites/index.html.

Table 2. 2016 sampling locations and dates for rocky intertidal monitoring at Redwood National and State Parks.

Site	Site Code	Latitude ¹	Longitude ¹	Summer 2016	Fall 2016
False Klamath Cove	FKC	41.59476	124.10643	22- May	11- Dec
Damnation Creek	DMN	41.65249	124.12784	23 -May	12 -Dec
Enderts Beach	END	41.69000	124.14257	25 -May	13- Dec

¹ Site coordinates are in decimal degrees, NAD83 datum (source Bureau of Land Management).

Results

Raw data used to create this report are available upon request through MARINe or the National Park Service. Please contact the authors with requests.

Field Log

Species List and Conditions

The general observations of conditions for each survey are presented in Table 3. Estimates of the site-wide presence/absence (absence = not observed) of the core and optional species for the field logs are presented in Table 4. Due to the protocol being implemented by MARINe co-operators, a change in the SOPs outside the normal process occurred with abundance categories for general observations being phased out and replaced with presence/absence.

Shorebirds and Mammals

The only marine mammals seen at the sites during the 2016 sampling surveys were an occasional harbor seal swimming offshore of site. Summaries of the common shorebirds observed during the RNSP surveys are presented in Table 5. These data represent the greatest number of each species observed at any one time on or near the sampled reef. They are not intended as census data, but rather as field observations. Table 5 summarizes the common list of birds that all rocky intertidal MARINe monitoring groups recorded along the California and Oregon coast. A list of the additional bird species that were noted on the reef or flying over the sampling sites at one or more occasions during 2016 follows Table 6.

Table 3. Field conditions for sampling trips in 2016 at three intertidal sites within Redwood National and State Parks. Codes for levels indicated are 0=Zero, L = Relatively few or low levels, M = Medium or moderate levels, H = High numbers or high levels, ND = No Data. Tide level is relative to Mean Low Low Water (MLLW).

Site ID	Season Code	Start Time	End time	Low Tide Level (ft)	Low Tide Time	Swell Surge	Wind	Rain	Recent Rain	Sedi-ment Level	Scour	Rock Move-ment	Plant Wrack	Drift-wood	Shell Debris	Dead Animals	Trash
END	SU16	7:00	11:00	-0.7	08:50	L	L	0	L	L	L	L	L	L	M	L	0
END	FA16	13:45	18:00	-1.7	17:11	L	L	0	L	L	L	L	L	L	L	0	L
DMN	SU16	5:30	10:30	-0.8	07:34	L	L	0	L	L	L	L	L	L	L	0	0
DMN	FA16	13:00	18:00	-1.2	16:23	L	L	0	M	L	L	L	L	L	L	0	L
FKC	SU16	5:00	10:00	-0.7	7:00	L	L	L	L	M	L	L	L	L	L	0	0
FKC	FA16	13:00	18:15	-0.6	15:34	L	L	L	M	M	M	M	L	L	L	0	L

Table 4. Status (Present = X; Not Observed = 0) of core and optional species at Enderts Beach (E), Damnation Creek (D) and False Klamath Cove (F) during the 2016 summer and fall surveys at Redwood National and State Parks.

Group	Core Species	Common Names	Summer 2016 Present/Not Obs.			Fall 2016 Present/Not Obs.		
			E	D	F	E	D	F
Red Algae	<i>Caulacanthus ustulatus</i>	–	0	0	0	0	0	0
	<i>Endocladia muricata</i>	turfweed	x	x	x	x	x	x
	<i>Mastocarpus papillatus</i>	Turkish washcloth	x	x	x	x	x	x
	<i>Mazzaella</i> spp. (=Iridaea spp.)	iridescent weed	x	x	x	x	x	x
	<i>Neorhodomela larix</i>	blackpine	x	x	x	x	x	x
	<i>Odonthalia</i> spp. (optional)	tooth branch	x	x	x	x	x	x
	<i>Porphyra</i> spp.	nori	x	x	x	x	x	x
Green Algae	<i>Ulva/Enteromorpha</i>	sea lettuce	x	x	x	x	x	x
Brown Algae	<i>Egregia menziesii</i>	feather boa kelp	x	x	x	x	x	x
	<i>Fucus gardneri</i>	rockweed	x	x	x	x	x	x
	<i>Hesperophycus californicus</i>	western alga	x	x	x	x	x	x
	<i>Pelvetiopsis limitata</i>	dwarf rockweed	0	0	x	0	0	x
	<i>Postelsia palmaeformis</i>	sea palm	0	0	x	0	0	0
	<i>Sargassum muticum</i>	wireweed	x	x	x	x	x	x
	<i>Scytosiphon</i> spp	leather tube	0	0	0	0	x	0
	<i>Silvetia compressa</i>	slender rockweed	x	x	x	x	x	x
Surfgrass	<i>Phyllospadix scouleri/torreyi</i>	surfgrass	x	x	x	x	x	x
Gastropods	<i>Acanthinucella</i> spp.	unicorn snail	0	0	0	0	0	0
	<i>Haliotis cracherodii</i>	black abalone	0	0	0	0	0	0
	<i>Katharina tunicata</i>	black leather chiton	x	x	x	x	x	x
	<i>Littorina</i> spp.	periwinkle snail	x	x	x	x	x	x
	<i>Lottia gigantea</i>	owl limpet	0	0	0	0	0	0
	<i>Nucella canaliculata</i>	channeled dogwinkle	x	0	x	x	0	x
	<i>Nucella emarginata/ostrina</i>	striped dogwinkle	x	x	x	x	x	x
	<i>Ocenebra circumtexta</i>	circled rocksnail	0	0	0	0	0	0
	<i>Chlorostoma</i> (=Tegula) <i>funeralis</i>	black turban snail	x	x	x	x	x	x

Table 4 (continued). Status (Present = X; Not Observed = 0) of core and optional species at Enderts Beach (E), Damnation Creek (D) and False Klamath Cove (F) during the 2016 summer and fall surveys at Redwood National and State Parks.

Group	Core Species	Common Names	Summer 2016 Present/Not Obs.			Fall 2016 Present/Not Obs.		
			E	D	F	E	D	F
Bivalves	<i>Mytilus californianus</i>	California mussel	x	x	x	x	x	x
	<i>Mytilus trossulus/gallo complex</i>	bay mussel	x	x	x	x	x	x
Crustaceans	<i>Balanus glandula</i>	acorn barnacle	x	x	x	x	x	x
	<i>Chthamalus dalli/fissus</i>	small acorn barnacle	x	x	x	x	x	x
	<i>Pachygrapsus crassipes</i>	lined shore crab	x	x	x	x	x	x
	<i>Pollicipes polymerus</i>	gooseneck barnacle	x	x	x	x	x	x
Crustaceans	<i>Semibalanus cariosus</i>	thatched barnacle	x	x	x	x	x	x
	<i>Tetraclita rubescens</i>	red thatched barnacle	0	0	0	0	0	0
Anemones	<i>Anthopleura elegantissima/sola</i>	sea anemone	x	x	x	x	x	x
	<i>Anthopleura xanthogrammica</i>	giant green anemone	x	x	x	x	x	x
Echinoderms	<i>Pisaster ochraceus</i>	ochre sea star	x	x	x	x	x	x
	<i>Strongylocentrotus purpuratus</i>	purple urchin	x	0	x	x	0	x
Polychaete worms	<i>Phragmatopoma</i> complex	sand castle worm	x	0	0	x	0	0

Table 5. Common shorebirds observed at Redwood National and State Parks monitoring sites during intertidal sampling trips in 2016 (maximum seen at any one time).

Site ID	Season	Cormorant (<i>Phalacrocorax</i> spp.)	Gull (<i>Larus</i> spp.)	Oyster-catcher (<i>Haematopus bachmani</i>)	Small Shorebirds (various species)	Pelican (<i>Pelecanus</i> spp.)
END	FA16	0	2	2	0	0
END	SU16	2	0	1	0	0
DMN	FA16	1	0	3	0	0
DMN	SU16	0	25	1	0	30
FKC	FA16	0	3	3	0	0
FKC	SU16	3	5	2	0	14
2016 Totals		6	35	12	0	44

Additional bird species (common name (scientific name)) observed at Redwood National and State Parks intertidal sites during 2016 sampling follow:

- Barn swallow (*Hirundo rustica*)
- Black Turnstone (*Arenaria melanocephala*)
- Brandt's Cormorant (*Phalacrocorax penicillatus*)
- Brown Pelican (*Pelecanus occidentalis*)
- Canadian Goose (*Branta Canadensis*)
- Common Murre (*Uria aalge*)
- Common Raven (*Corvus corax*)
- Double-crested Cormorant (*Phalacrocorax auritus*)
- Marbled Murrelet (*Brachyramphus marmoratus*)
- Northern Flicker (*Colaptes auratus*)
- Orange-crowned Warbler (*Vermivora celata*)
- Pelagic Cormorant (*Phalacrocorax pelagicus*)
- Pigeon Guillemot (*Cepphus columba*)
- Red-throated Loon (*Gavia stellate*)
- Swallows (*Tachycineta* spp)
- Swainson's Thrush (*Catharus ustulatus*)
- Song Sparrow (*Melospiza melodia*)
- Turkey Vulture (*Cathartes aura*)
- Western Grebe (*Aechmophorus occidentalis*)
- White-crowned Sparrow (*Zonotrichia leucophrys*)
- Wrentit (*Chamaea fasciata*)
- Wilson's warbler (*Wilsonia pusilla*)

Photoplots

Abundance (percent cover) of species found in the five types of photoplots are presented in Figures 4 to 8 and will be discussed in detail below. The figures include those taxa whose abundance exceeded 5% cover within the photoplots. It is important to note that the following summaries are from only 1 year of observation and, as such, are not intended to represent an analysis of any long term changes. Graphs were created with the interactive map and graphing tool at pacificrockyintertidal.org and can be recreated in various configurations.

Barnacle (*Chthamalus dalli* and *Balanus glandula*) Photoplots

At the time of the summer sample these plots were dominated by barnacles (~55% cover) at False Klamath Cove and Enderts (Figure 4). Cover of barnacles for the summer sample at Damnation was much lower (22%). This was due, in part, to the presence of new mussel recruits. In the fall, barnacle cover was similar at all three sites (~40%) which represented a decrease at False Klamath Cove and Enderts, but an increase at Damnation Creek.

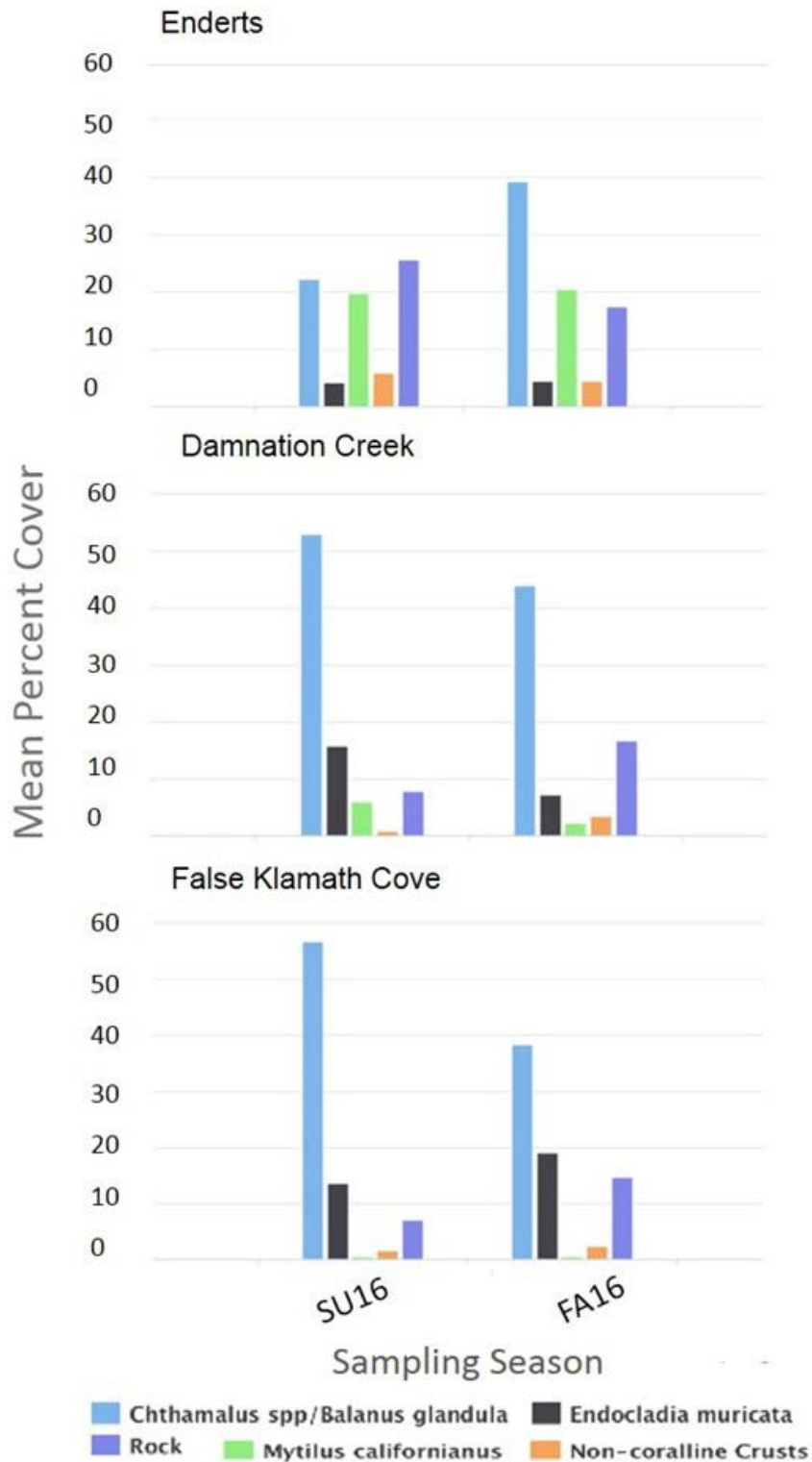


Figure 4. Mean percent cover of the most common taxa in the barnacle (*Balanus/Chthamalus*) photoplots during sampling periods (SU = summer, FA = fall) in 2016.

Turfweed (Endocladia muricata) Photoplots

At False Klamath Cove and Damnation sites, plots were dominated by turfweed (*Endocladia muricata*) during both summer and fall samplings, whereas at Enderts, the plots were dominated by barnacles (summer) or bare space (fall) (Figure 5). At the time of the summer sample at False Klamath Cove, turfweed exceed 70% cover. At all three sites, turfweed cover in the plots decreased from summer to fall (Figure 5).

Rockweed (Fucus gardneri) and Dwarf Rockweed (Pelvetiopsis limitata) Photoplots

In both sets of rockweed plots the dominant species was the targeted taxon. Specifically, cover of *Fucus gardneri* (Figure 6) and *Pelvetiopsis limitata* (Figure 7) was $\geq 45\%$ within the plots. While the abundance of *Fucus* appeared only slightly greater in the fall at False Klamath Cove, it showed a $>20\%$ increase at Damnation Creek from summer to fall (Figure 6). *Pelvetiopsis* cover was lower (by 11%) in the fall at False Klamath Cove in contrast to Enderts which showed an increase (of 13%) from summer to fall (Figure 7).

California Mussel (Mytilus californianus) Photoplots

Overall, mussel (*Mytilus californianus*) cover in plots at Damnation Creek and False Klamath Cove was high (75-90%) during 2016 (Figure 8). In comparison, at Enderts, disturbances, as evidenced by the presence of byssal threads attached to the rock, had created large gaps within the mussel bed prior to the summer survey. Thus, overall mussel cover within the plots at this site was around 25%. By fall, the presence of new mussel recruits increased the cover of mussels to 45% (Figure 8).

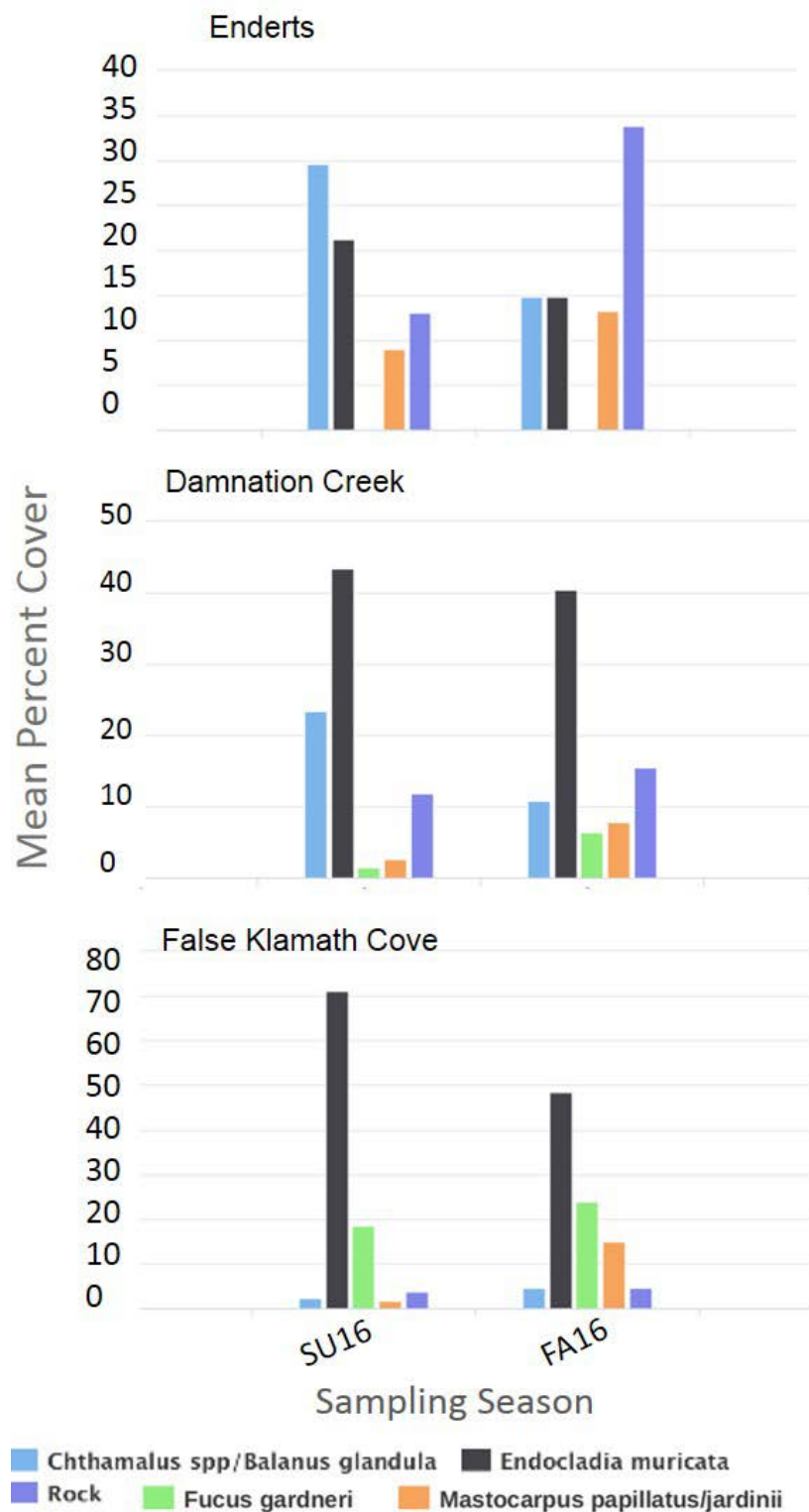


Figure 5. Mean percent cover of most common taxa in turfweed (*Endocladia muricata*) photoplots during sampling periods (SU = summer, FA = fall) in 2016. Note different values on y-axis.

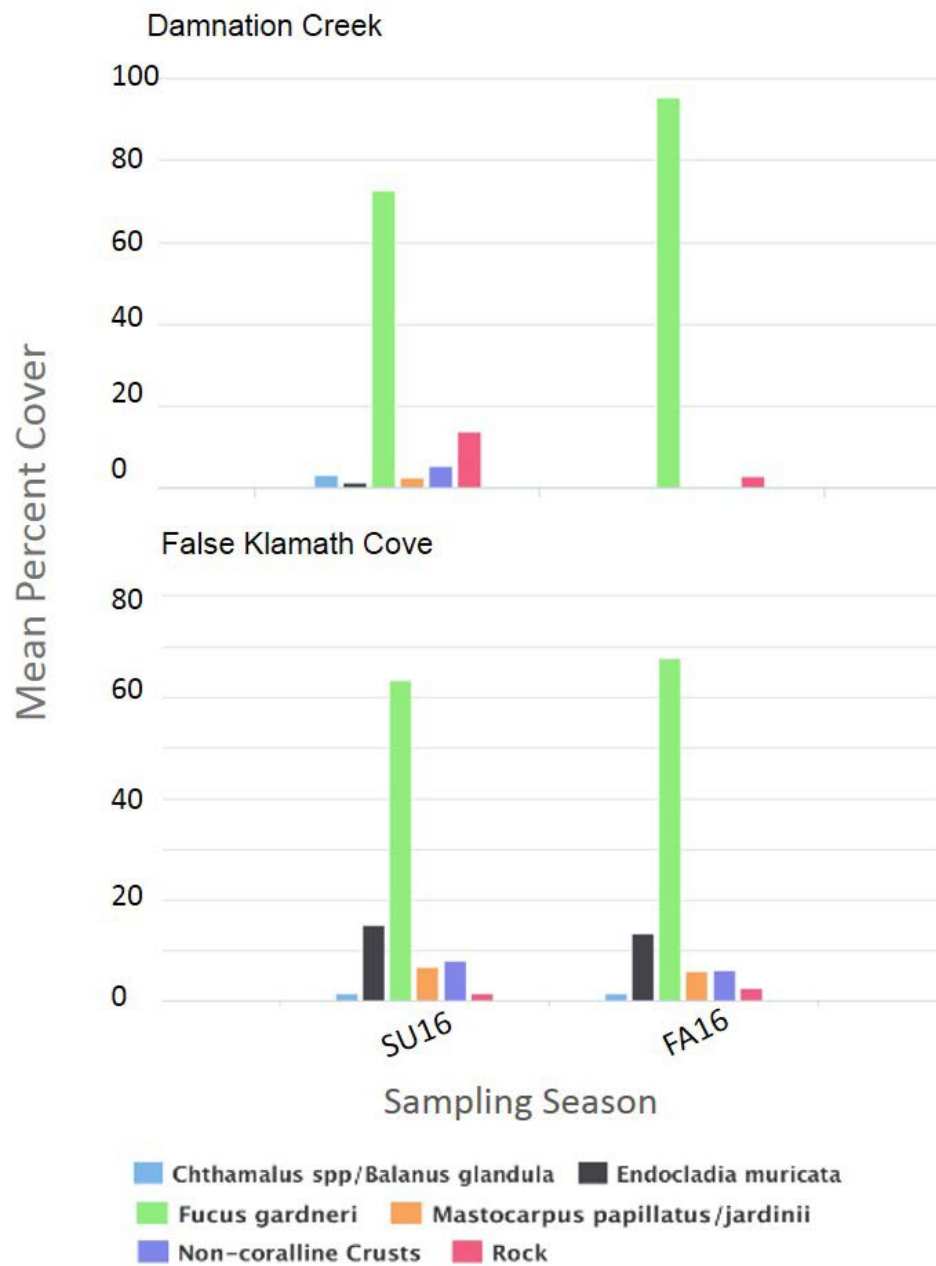


Figure 6. Mean percent cover of most common taxa in the rockweed (*Fucus gardneri*) photoplots during sampling periods (S = summer, FA = fall) in 2016. Note different values on y-axis.

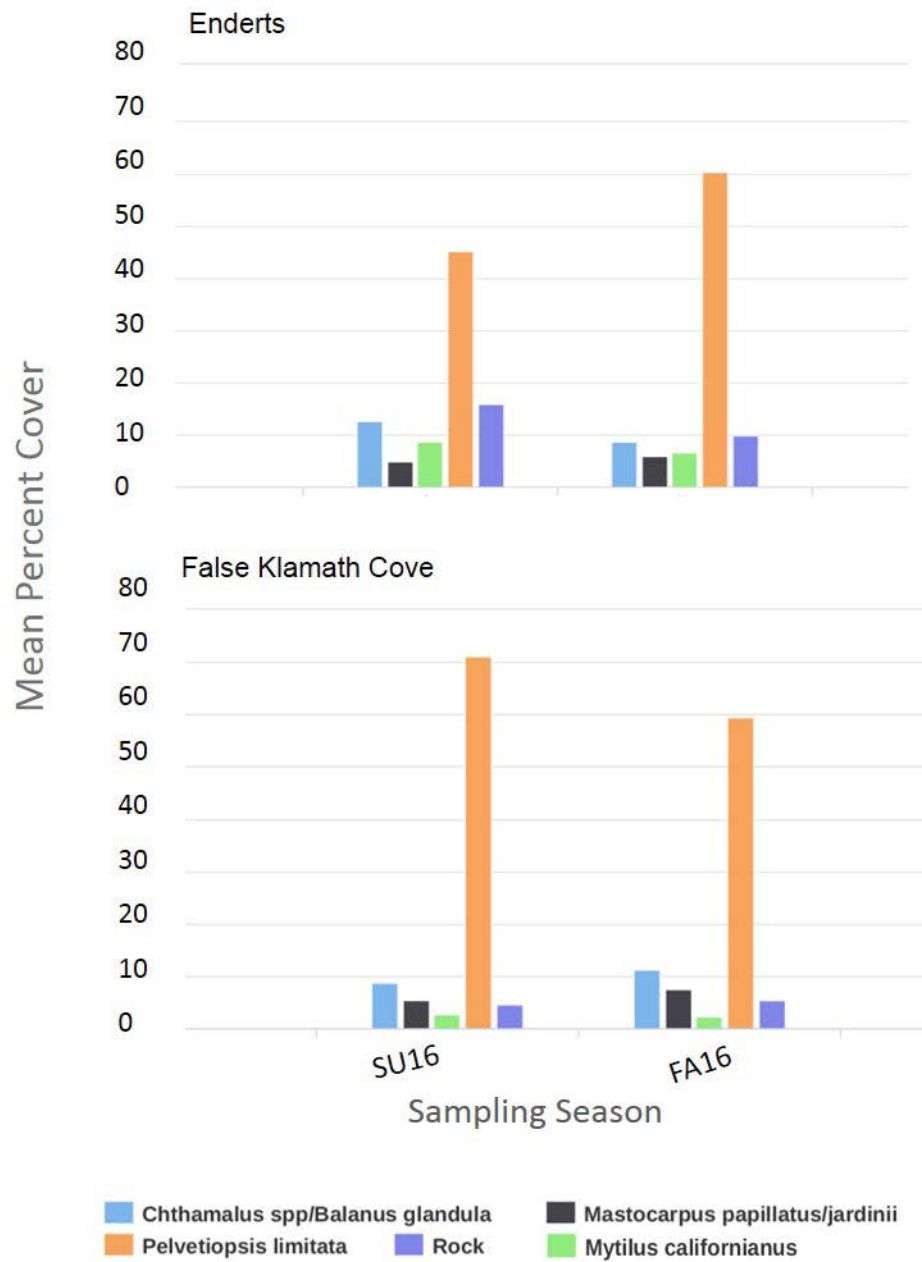


Figure 7. Mean percent cover of most common taxa in dwarf rockweed (*Pelvetiopsis*) photoplots during sampling periods (S = summer, FA = fall) in 2016. There are no dwarf rockweed plots at Damnation Creek.

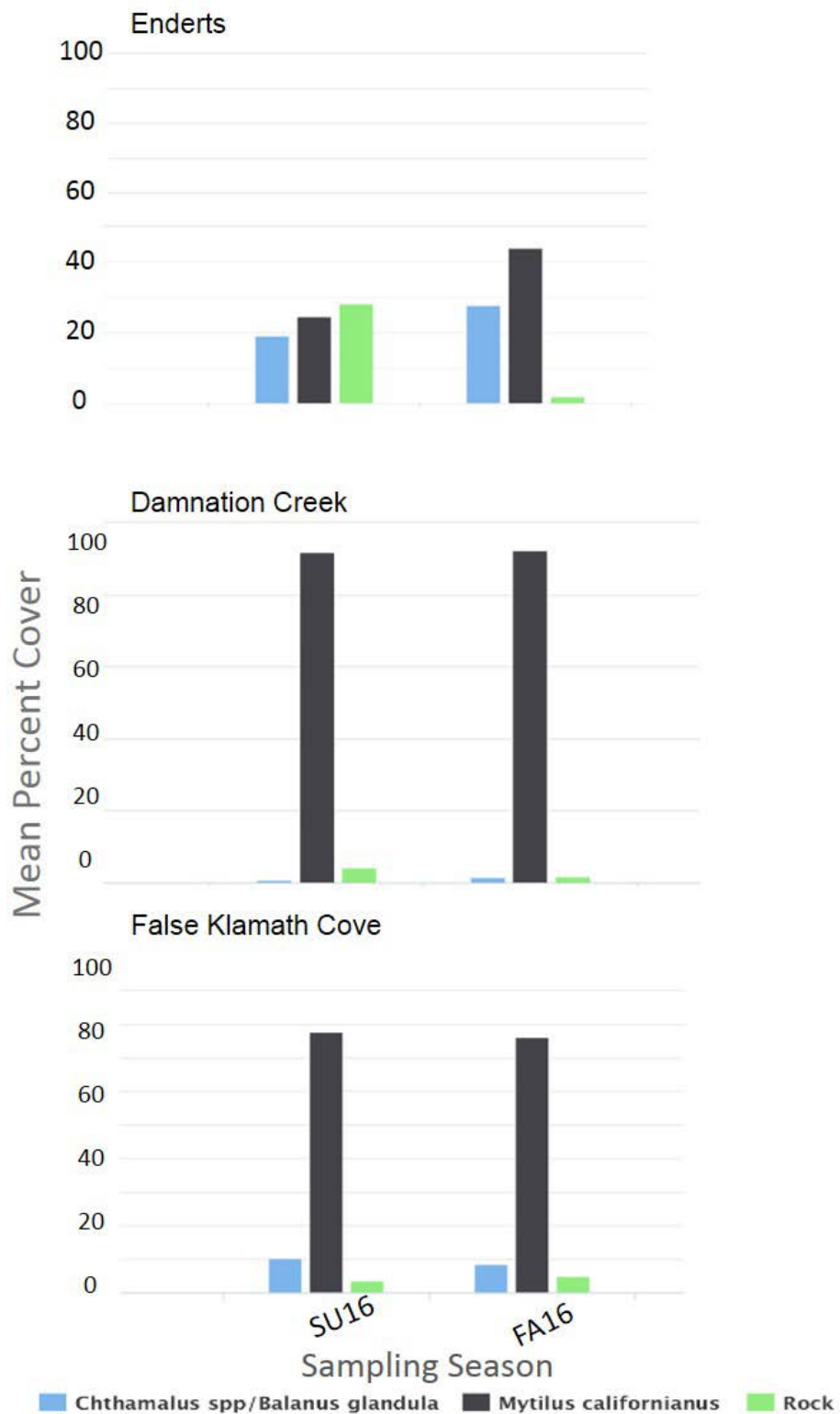


Figure 8. Mean percent cover of most common taxa in mussel (*Mytilus*) photoplots during sampling periods (S = summer, FA = fall) in 2016.

Barnacle Recruitment

The number of *Chthamalus* recruits in the barnacle clearings was approximately 5 to 10 times the number of *Balanus* recruits at all three sites (Figure 9). Recruitment tended to be similar at all three sites for *Chthamalus*, whereas *Balanus* recruitment at Enderts was about twice that of Damnation and False Klamath.

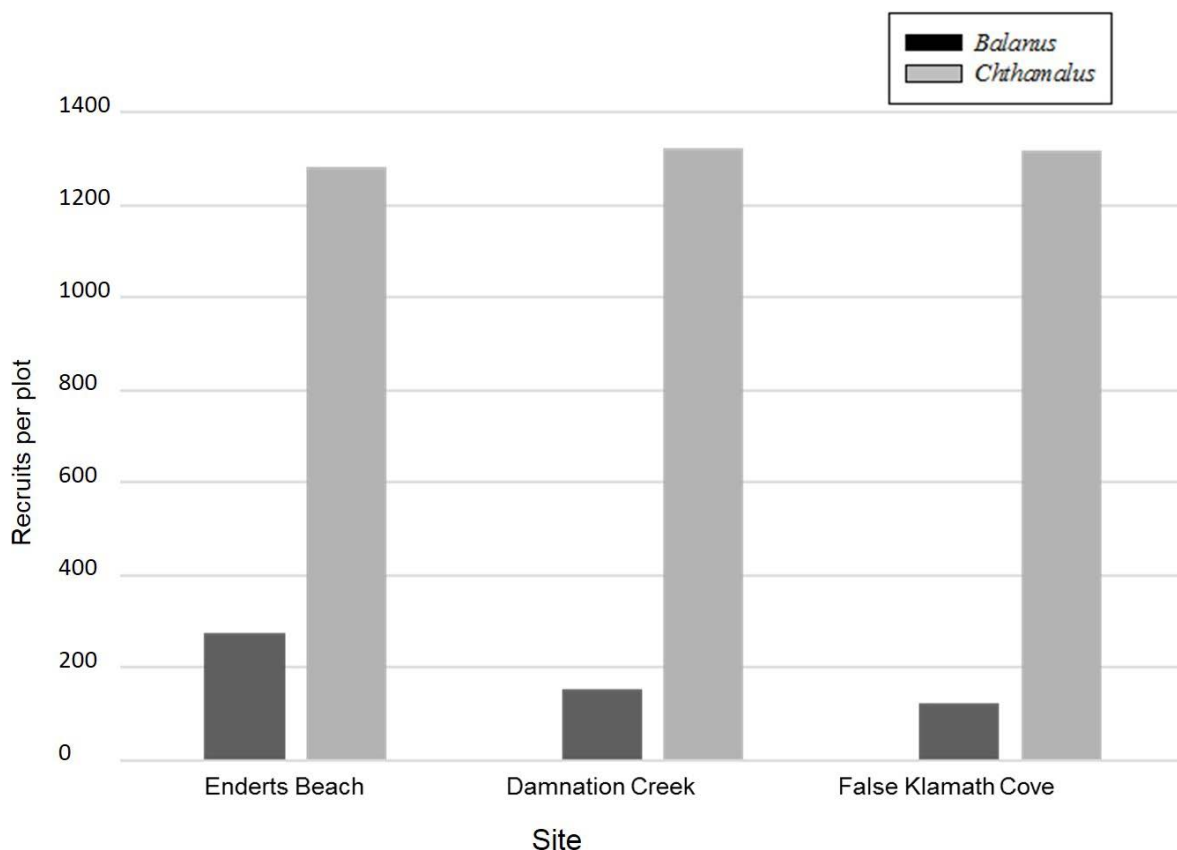


Figure 9. Mean annual recruitment of barnacles in clearings at Redwood National and State Parks sites. These values represent barnacle recruitment from May 2015 to May 2016.

Mobile Invertebrates

A total of 18 mobile invertebrate taxa were found within the photoplots during the surveys in 2016 (Table 6). Due to adverse conditions, the following plots were not sampled in the fall for mobiles: *Pelvetiopsis* plots at False Klamath Cove, *Endocladia* plots at Enderts, and *Mytilus* plots 6-10 at Damnation Creek. Abundances of the more common taxa are presented in Figures 10-14, while the presence/absence of the less common taxa within each type of photoplot is presented in Table 7. With a few exceptions, the abundance of most of these taxa tended to vary among the different types of plot. For example, periwinkle snails (*Littorina scutulata/plena*), which were by far the most common taxa, were particularly abundant in the higher zone barnacle plots (Figures 10) where they often exceeded 1,000 individuals per plot (> 2,500 per m²). Limpets (*Lottia* spp.), the next most common taxa, tended to be more evenly distributed across plot types. The rockweed (*Fucus*) plots

tended to have fewer limpets (averaging less than 50 per plot) than the barnacle, mussel and turfweed plots, which averaged 100 to several hundred limpets per plot (Figures 10-14).

Table 6. Mobile invertebrate taxa found in photoplots at all Redwood National and State Parks sites during 2016 surveys.

Category	Taxa	Common Name
Gastropods	<i>Amphissa</i> spp.	dove snails
	<i>Chlorostoma</i> (= <i>Tegula</i>) <i>funnebralis</i>	black turban
	<i>Epitonium tinctorum</i>	wentletrap
	<i>Lottia</i> spp.	limpets
	<i>Littorina scutulata/plena</i>	periwinkle
	<i>Lacuna</i> spp.	periwinkle
	<i>Nucella canaliculata</i>	channeled dogwinkle
	<i>Nucella emarginata/ostrina</i>	striped dogwinkle
Chitons	<i>Cyanoplax dentiens</i>	Gould's baby chiton
	<i>Kathrina tunicate</i>	Katy chiton
	<i>Mopalia</i> spp.	hairy chiton
Crustaceans	<i>Idotea</i> spp.	Vosnesensky's isopod
	<i>Hemigrapsus nudus</i>	purple shore crab
	<i>Cyanoplax dentiens</i>	lined shore crab
	<i>Pagurus hirsutisculus</i> .	hermit crab
	<i>Pugettia</i> spp.	kelp crab
Echinoderms	<i>Leptasterias hexactis</i>	six-rayed star
	<i>Pisaster ochraceous</i>	ochre star

Dogwinkles (*Nucella emarginata* and *N. canaliculata*), predatory snails, were common at all sites, but were particularly abundant in mussel plots (Figure 11) and in barnacle plots at Enderts Beach (Figure 10).

The black turban snail (*Tegula* [= *Chlorostoma*] *funnebralis*), a grazer, was present at all three sites, but was only common in rockweed (*Fucus*) plots at False Klamath Cove (Figure 13). The Hartweg's chiton (*Cyanoplax hartwegii*), also a grazer, was also present at all three sites, but only seen multiple (>2/plot) times during the summer survey in turfweed (*Endocladia*) plots at Enderts (Figure 14).

The lined shore crab (*Pachygrapsus crassipes*) and the hermit crabs (*Pagurus* spp.) were not very abundant in any of the photoplots in 2016. Although present and scattered throughout the plots at all

three sites, hermit crabs were found mainly in the mid-zone plots (e.g., the rockweed [*Fucus*]) see Figure 13). A majority of the other less common mobile taxa were found in mid-zone plots (Table 7).

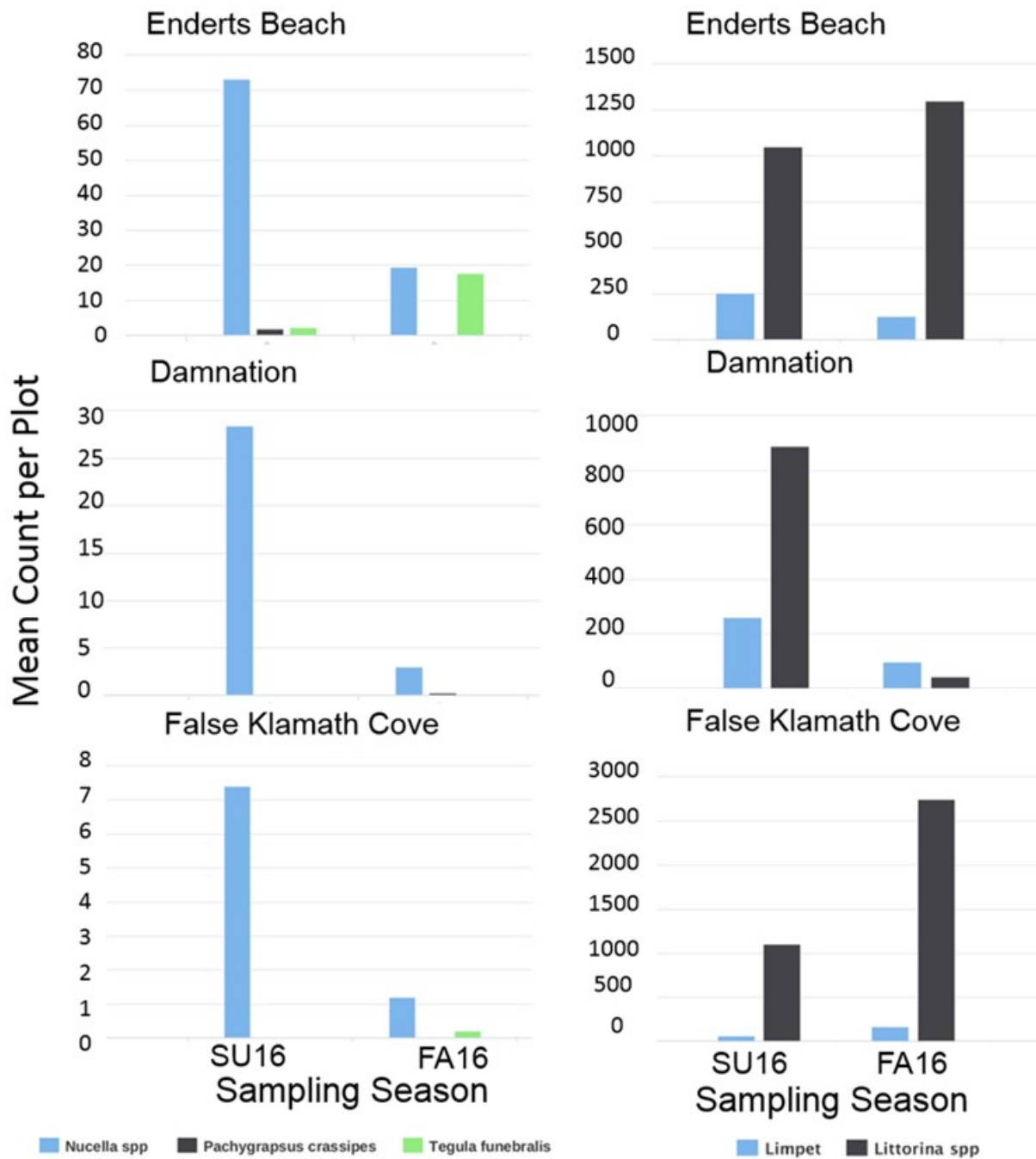


Figure 10. Mean abundance of the most common mobile invertebrates in the barnacle (*Chthamalus/Balanus*) photoplots during the 2016 sampling periods. Note different scales on y axes. Left graphs show dogwinkle whelks (*Nucella* spp.), lined shore crab (*Pachygrapsus crassipes*), and black turban snails (*Tegula funebris*). Right side displays limpet and *Littorina* species.

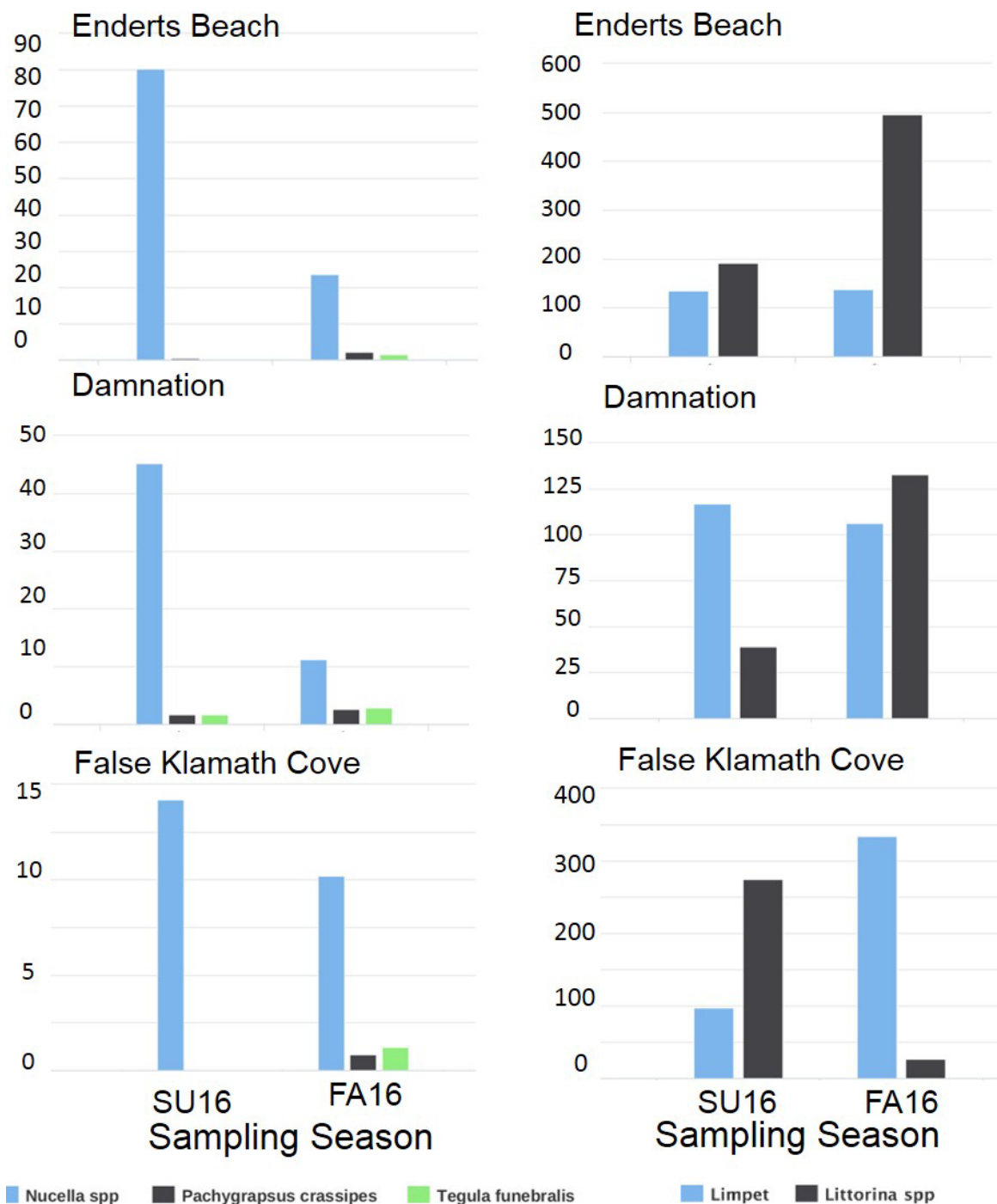


Figure 11. Mean abundances of the most common mobile invertebrates in the mussel (*Mytilus*) photoplots during the 2016 sampling periods. Note different scales on y axes. Left graphs show dogwinkle whelks (*Nucella* spp.), lined shore crab (*Pachygrapsus crassipes*), and black turban snails (*Tegula funebris*). Right side displays limpet and *Littorina* species.

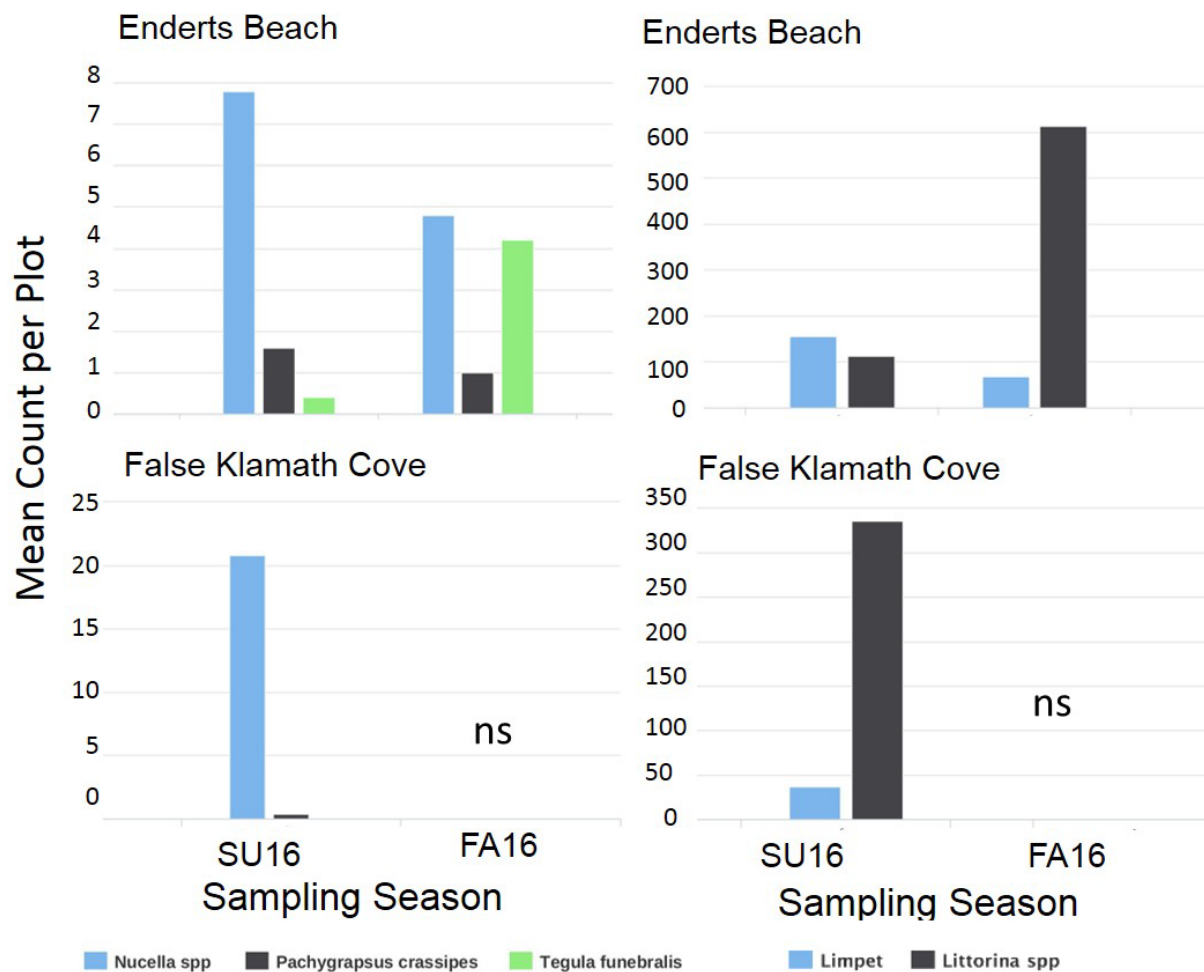


Figure 12. Mean abundances of most common mobile invertebrates in the dwarf rockweed (*Pelvetiopsis*) photoplots during the 2016 sampling periods. Note different scales on y axes. Left graphs show dogwinkle whelks (*Nucella* spp), lined shore crab (*Pachygrapsus crassipes*), and black turban snails (*Tegula funebris*). Right side displays limpet and *Littorina* species. There are no dwarf rockweed (*Pelvetiopsis*) plots at Damnation, and the plots were not sampled at False Klamath Cove in fall 2016.

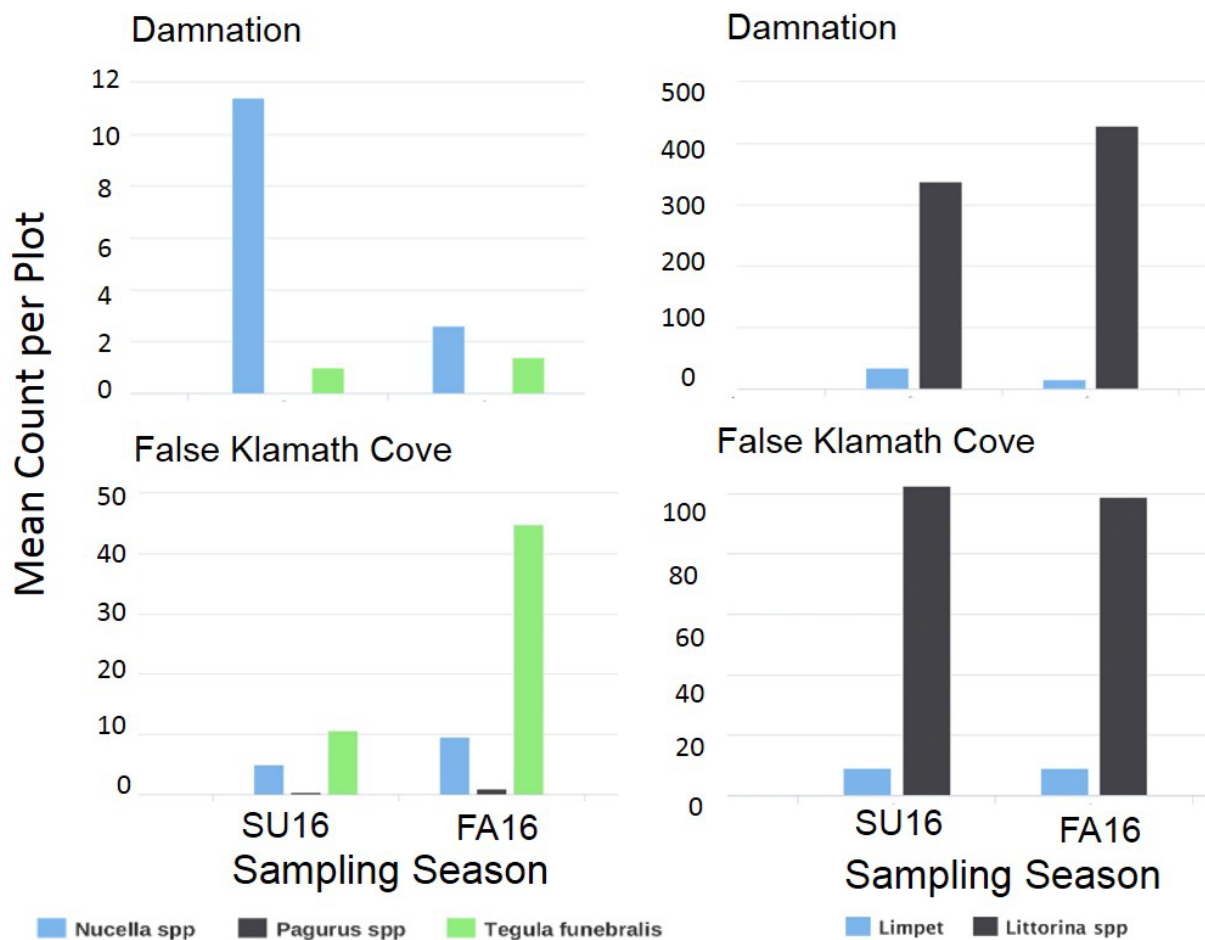


Figure 13. Mean abundances of most common mobile invertebrates in the rockweed (*Fucus*) photoplots during the 2016 sampling periods. Note different scales on y axes. Left graphs show Hermit crabs (*Pagurus* spp.), black turban snails (*Tegula funebris*), and dogwinkle whelks (*Nucella* spp.). Right side displays limpet and *Littorina* species. There are no rockweed (*Fucus*) plots at Enderts. ns = plots not sampled.

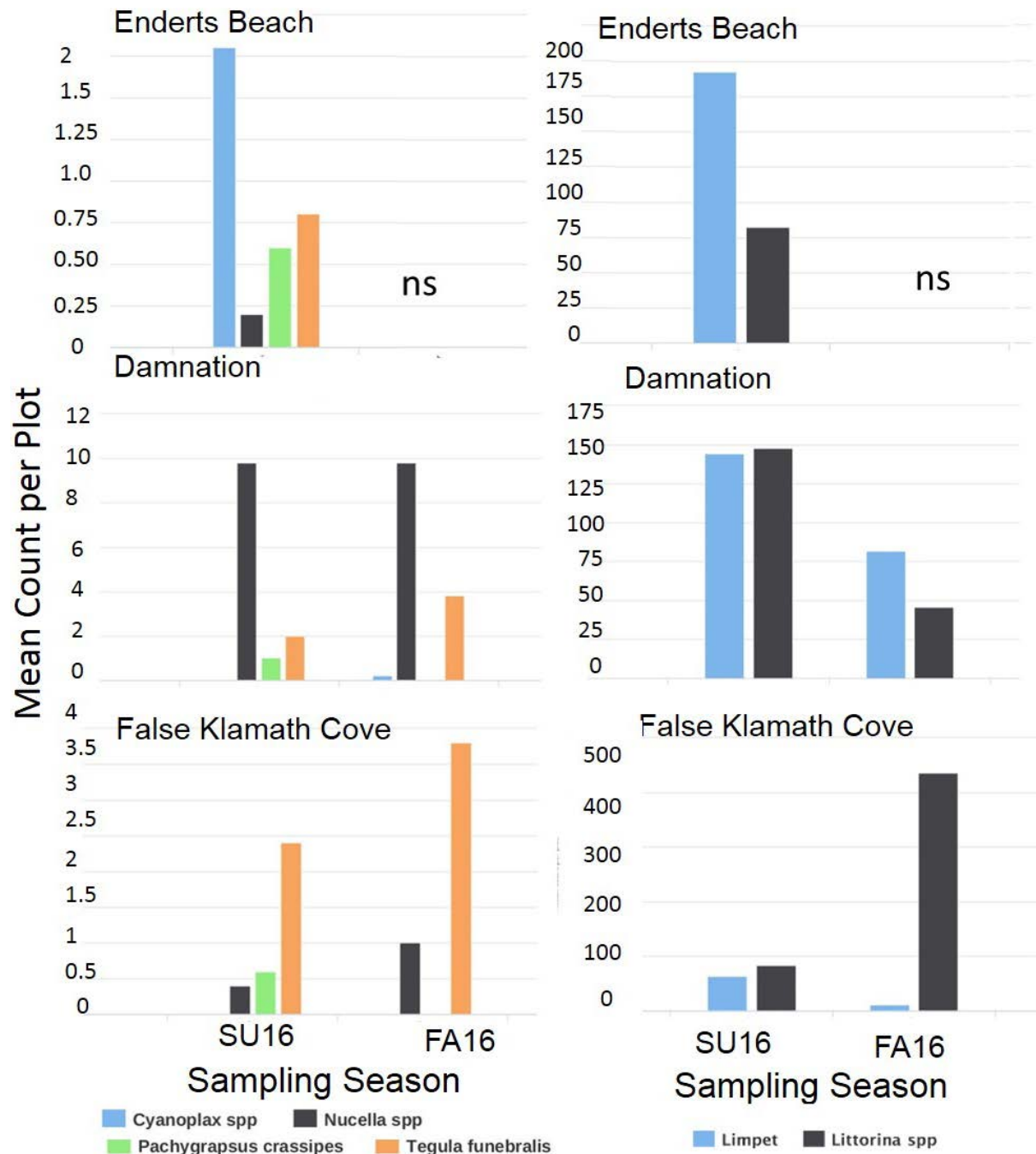


Figure 14. Mean abundances of the most common mobile invertebrates in the turfweed (*Endocladia*) photoplots during the 2016 sampling periods. Note different scales on y axes. Left graphs show black turban snails (*Tegula funebris*), chitons (*Cyanoplax* spp.), dogwinkle whelks (*Nucella* spp.), and lined shore crab (*Pachygrapsus crassipes*). Right side displays limpet and *Littorina* species. ns = plots not sampled.

Table 7. Presence (X) of less common mobile invertebrate species in the different photoplots at Redwood National and State Parks sites during 2016 surveys. Sites: Enderts Beach (E), Damnation Creek (D), and False Klamath Cove (F).

Category	Taxa	Barnacle (<i>Chthamalus/ Balanus</i>)			Dwarf Rockweed (<i>Pelvetiopsis</i>)			Turfweed (<i>Endocladia</i>)			Rockweed (<i>Fucus</i>)			Mussel (<i>Mytilus</i>)		
		E	D	F	E	D	F	E	D	F	E	D	F	E	D	F
Gastropods	<i>Amphissa</i> spp.	X	–	–	X	*	–	–	–	–	*	–	–	X	–	–
	<i>Epitonium tinctum</i>	–	–	X	–	*	–	X	–	X	*	–	–	–	–	–
	<i>Mopalia</i> spp.	–	–	–	–	*	–	X	–	–	*	–	–	–	–	–
	<i>Nucella canaliculata</i>	X	–	–	X	*	–	X	–	X	*	–	–	X	–	X
	<i>Lacuna</i> spp.	–	–	–	–	*	–	X	–	–	*	–	–	–	–	–
Crustaceans	<i>Idotea</i> spp.	–	–	X	X	*	–	X	–	X	*	X	–	X	–	X
	<i>Pagurus hirsutisculus</i>	–	–	–	–	*	–	–	–	–	*	–	X	X	X	–
	<i>Pugettia</i> spp.	–	–	–	–	*	–	–	–	–	*	–	X	–	–	–
	<i>Hemigrapsus nudus</i>	X	–	–	–	*	–	–	–	–	*	–	–	X	–	X
Echinoderms	<i>Leptasterias hexatis</i>	–	–	–	–	*	–	X	–	–	*	–	–	X	–	X
	<i>Pisaster ochraceous</i>	–	–	X	–	*	–	X	–	–	*	–	–	X	–	X
Total taxa		3	0	3	3	*	0	7	0	3	*	1	2	7	1	5

* There are no *Fucus* plots at Enderts Beach and no *Pelvetiopsis* plots at Damnation Creek.

The size distribution of the striped dogwinkle (*Nucella emarginata*) showed some seasonal variation in plots at Enderts and False Klamath Cove. There appeared to be higher numbers of smaller individuals in the fall sample at Enderts, with greater number of larger individuals seen in summer at False Klamath (Figure 15). There were also differences in size structure of the striped dogwinkle among sites. Specifically, overall mean size was similar in the both samples at Enderts and Damnation Creek, with a shift in the size structure toward smaller individuals at False Klamath Cove. The size distribution of the black turban snail showed a similar seasonal pattern at all sites, with more smaller individuals in the fall and larger mean sizes in summer.

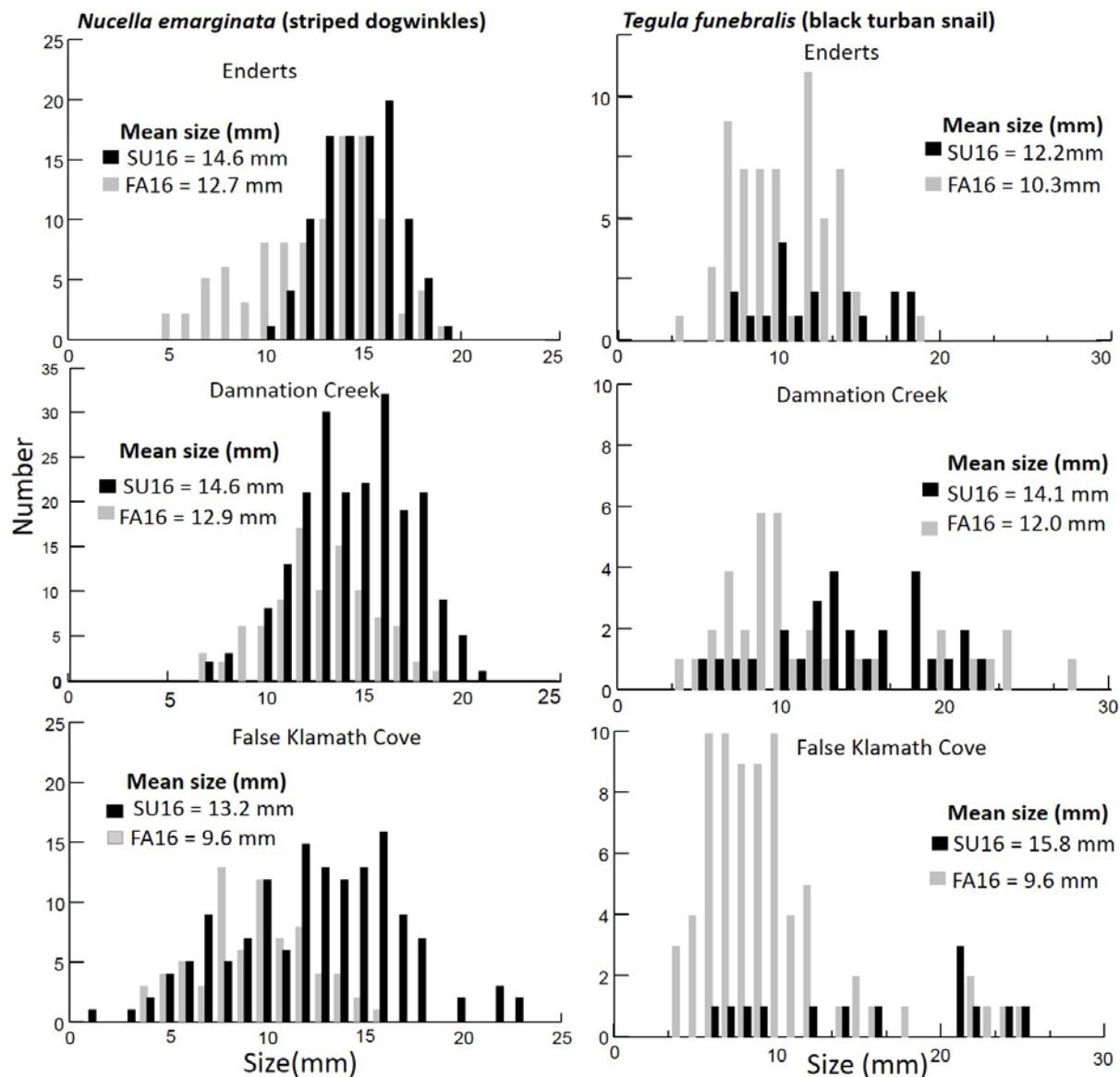


Figure 15. Size frequency distributions of striped dogwinkles and black turban snails and at Redwood National State Parks during 2016 sampling periods. Note difference in x and y scales.

Sea Star Plots

Because the size of the sea star plots varied among the sites, sea star abundances should not be compared across sites. At both Enderts and False Klamath Cove, the number of ochre sea stars (*Pisaster ochraceus*) increased between the summer and fall surveys (Figure 16). This was due to a large increase in the number of small (<20mm) individuals (Figure 18), which suggests a recent recruitment event had occurred. Individuals afflicted with Sea Star Wasting Syndrome were observed at all three sites during fall and summer sampling and accounted for between 0.5-5% of the individuals observed in the plots (Figure 17).

The size structure of the ochre sea star populations differed among the three sites (Figure 18). The range of sizes was greatest at Enderts in 2016, and the size structure of *Pisaster* was similar at Enderts and False Klamath Cove. Mean size was similar between survey periods for each site, but differed between sites. Large recruitment pulses were observed at False Klamath Cove and Enderts especially in the fall surveys. Hundreds of individuals <20mm were observed in plots at these sites. In contrast, at Damnation Creek, *P. ochraceus* numbers decreased in all plots, and fewer than five individuals measuring ≤20mm were observed in the plots.

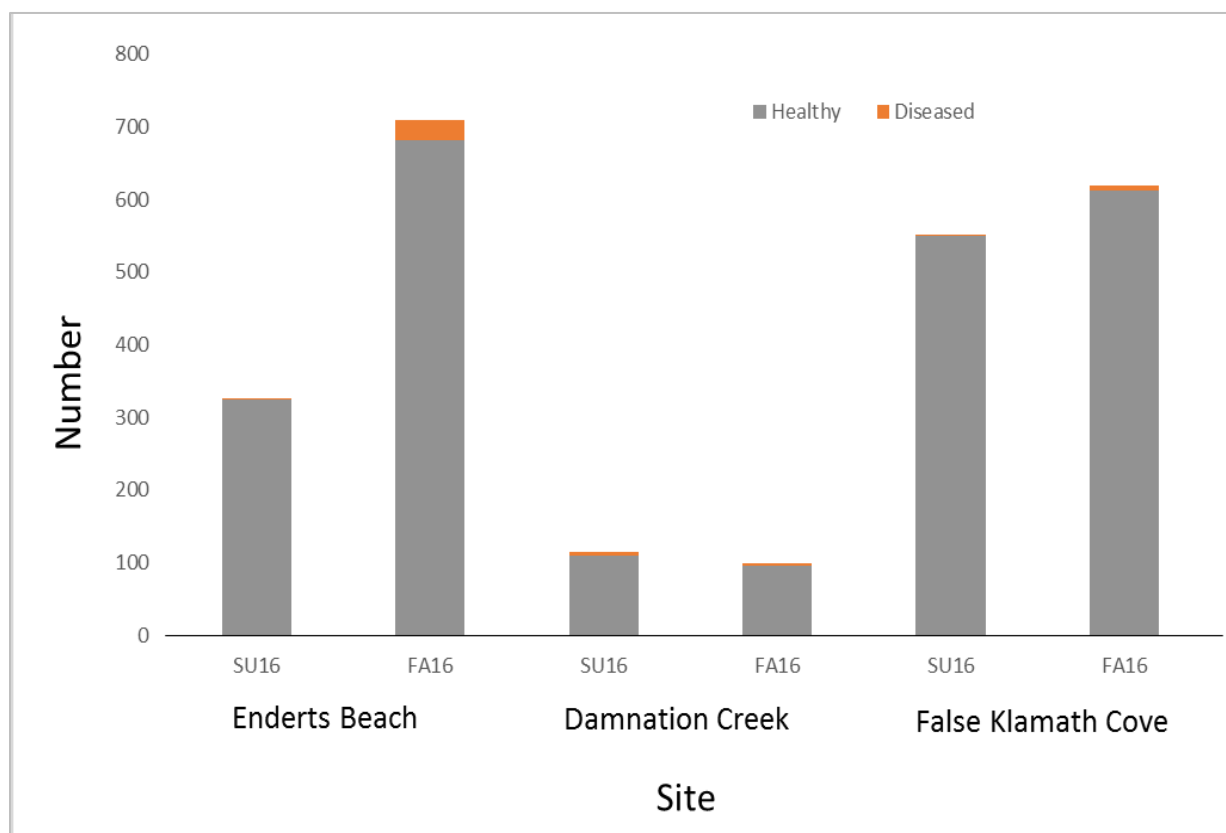


Figure 16. Total number of healthy and diseased ochre sea stars (*Pisaster ochraceus*) at three sites within the Redwood National and State Parks during sampling periods in 2016. Diseased sea stars showed obvious signs of sea star wasting disease.

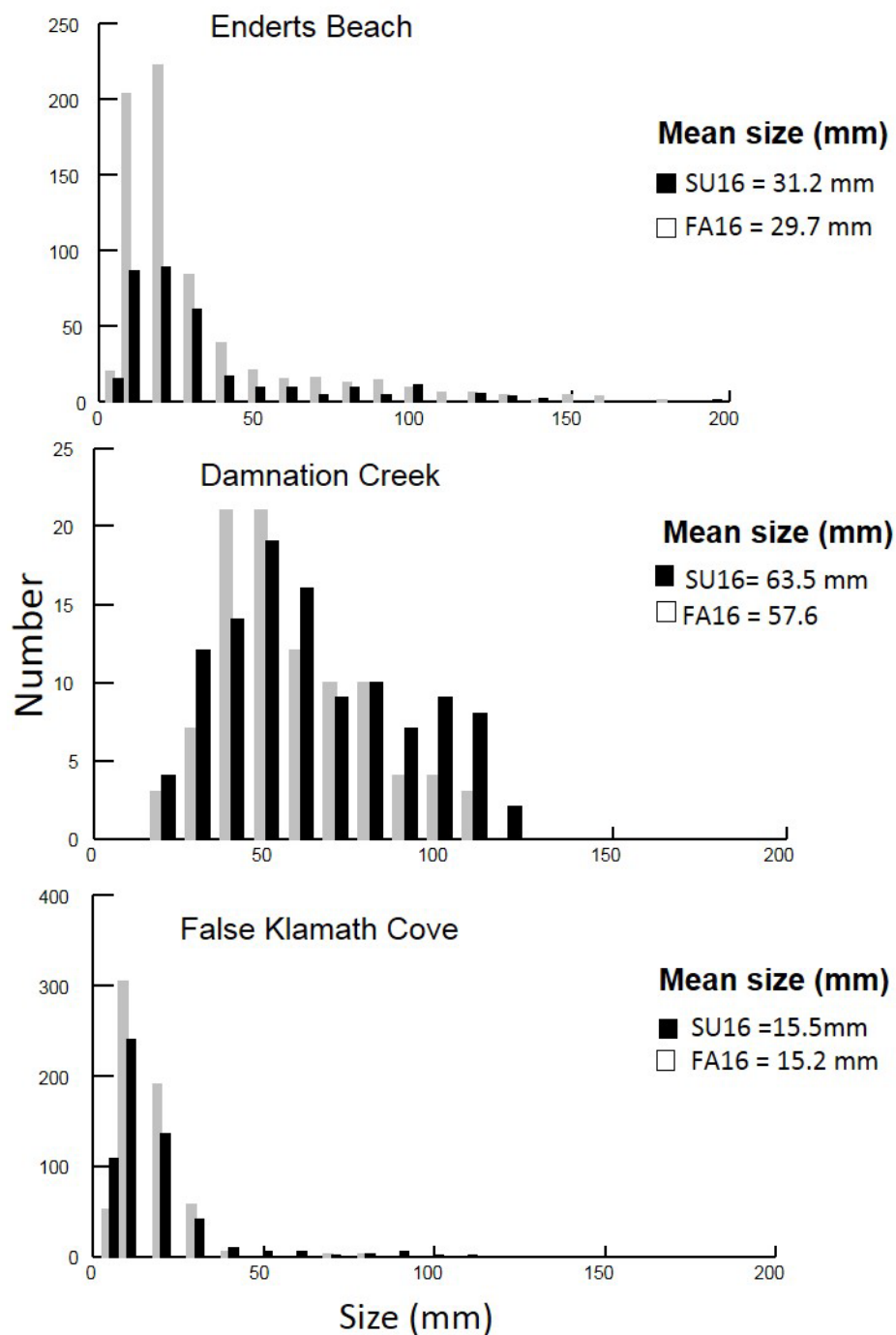


Figure 17. Size structure of ochre sea stars (*Pisaster ochraceous*) at three sites within the Redwood National and State Parks during sampling periods in 2016. Note different y-axis scale for each site.

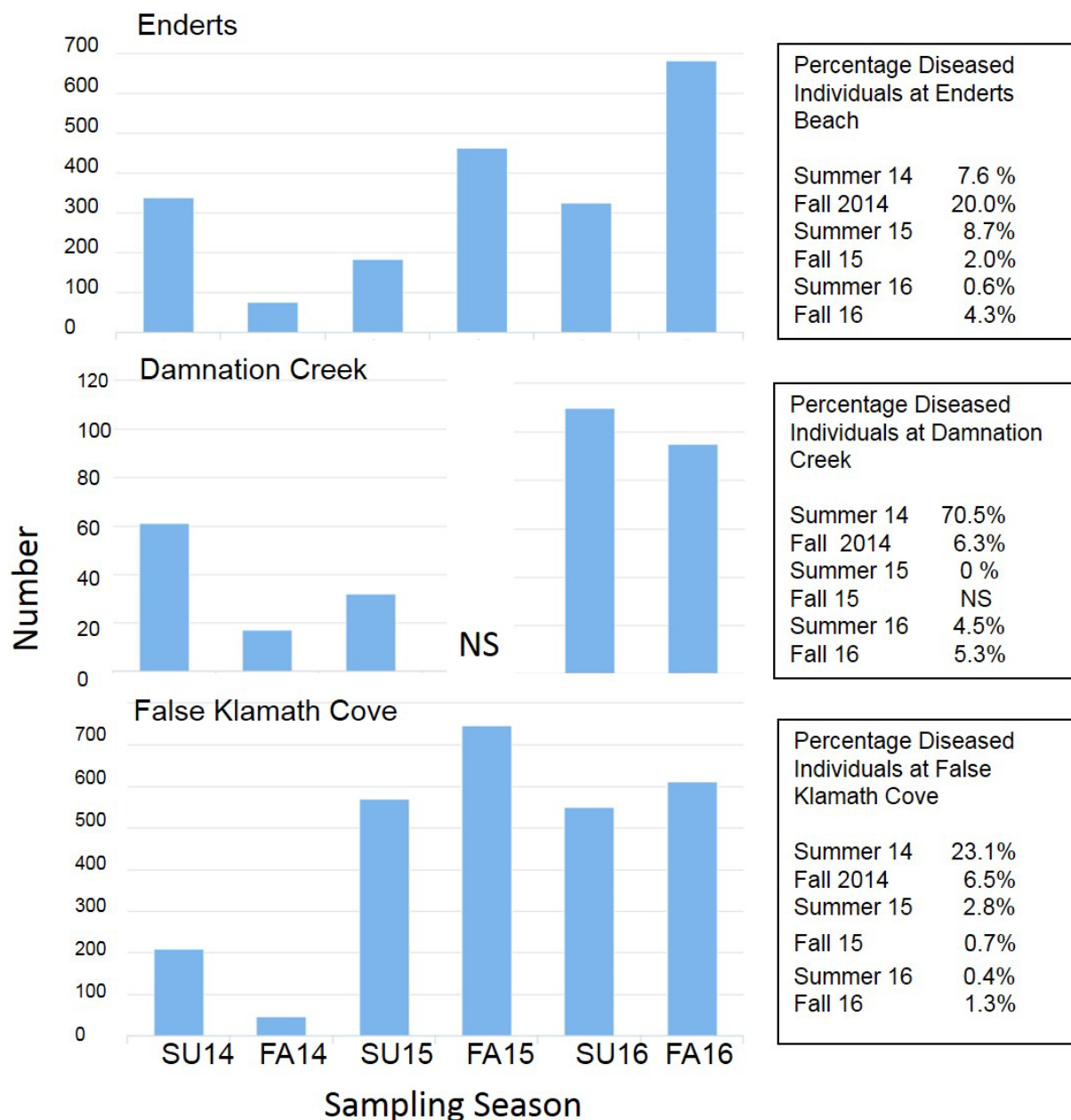


Figure 18. Total number of ochre sea stars (*Pisaster ochraceous*) at three sites within the Redwood National and State Parks during sampling periods in 2014-2016. Graphs created at <http://data.piscoweb.org/marine1/intertidalmap.html>. Percent of individuals displaying signs of sea star wasting disease shown to right of graphs.

Mussel Measurements

Mean size (length) of the mussels appeared similar among the plots at Enderts, Damnation Creek and False Klamath Cove over both summer and fall surveys (Figure 19). The only exception was that the False Klamath Cove mussels were slightly smaller in the summer survey. The mussel beds were approximately two times thicker at Damnation Creek than the other sites (Figure 19). The depth to length ratios of the mussel beds ranged from 1.61/1.22 (summer/fall) at False Klamath Cove to

2.40/2.05 (summer/fall) at Damnation plots #1-5, which indicates that they were multilayered (i.e., the visible surface layer hides additional layers of mussels below them). The depth to length ratio at Enderts, however, was nearly 1 for both seasons, indicating a single layer of mussels at this site.

Surfgrass and Sea Palm Transects

During the 2016 summer survey, surfgrass abundance at Damnation Creek was 83% in plot 1 and 90% in plot 2. Transect 1 had 81% surfgrass cover in fall 2016, and transect 2 was inaccessible during the fall survey. During the 2016 summer survey, sea palm counts at False Klamath Cove were two individuals for plot 1 and 431 individuals for plot 2. Juveniles accounted for a large percentage of these individuals. These numbers dropped in the fall survey to zero for transect 1 and approximately 24 for transect 2. Note: transect 2 could not be sampled safely, so a visual estimate was taken from a location nearby.

Sea Surface Temperature

During 2016, sea surface temperature ranged from lows of around 9.5° C to summer highs of nearly 16° C (Figure 20). There was little temperature variation among the three sites.

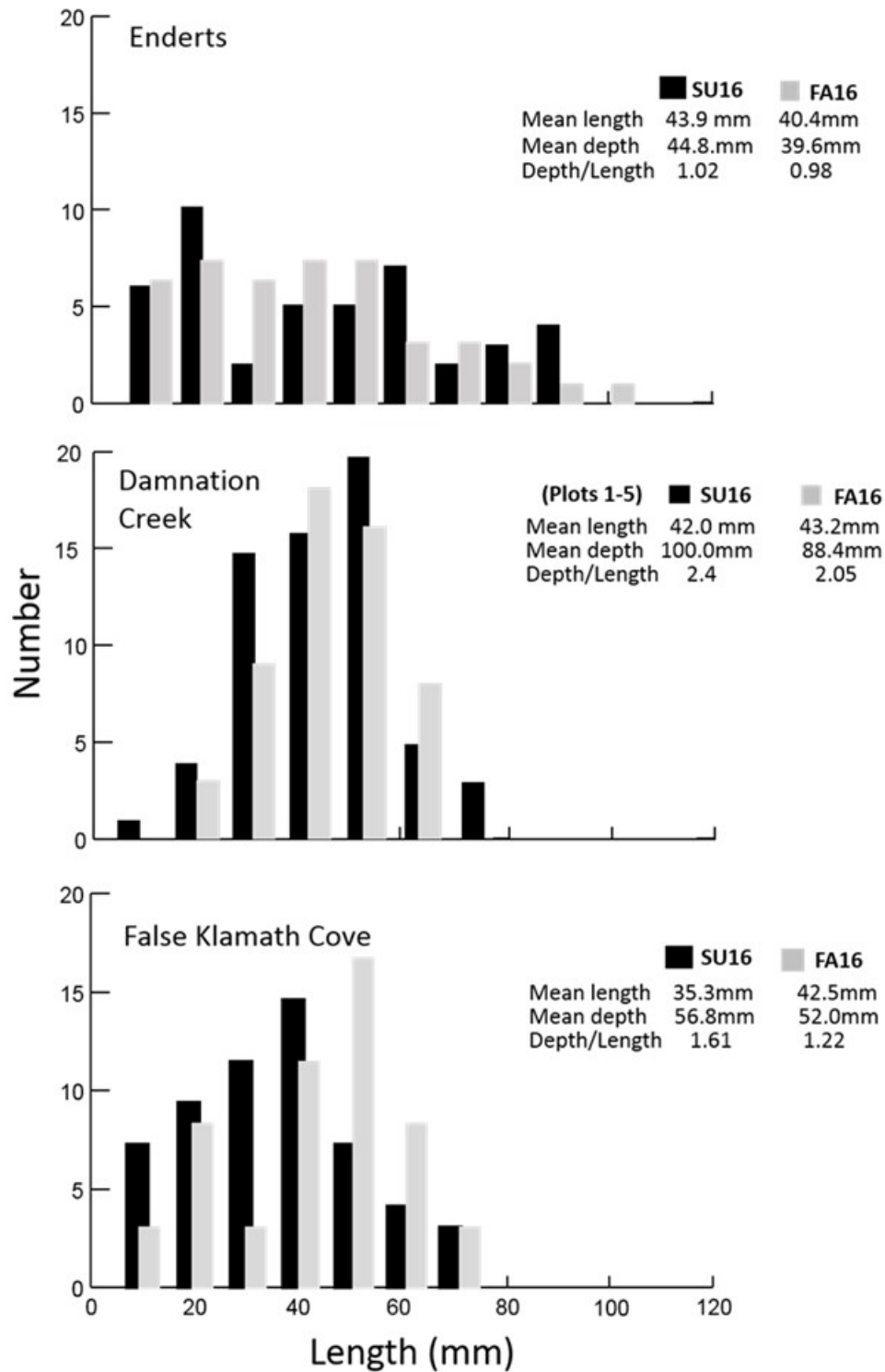


Figure 19. Size distributions of mussels (*Mytilus californianus*) at three sites within the Redwood National and State Parks during summer sampling period in 2016.

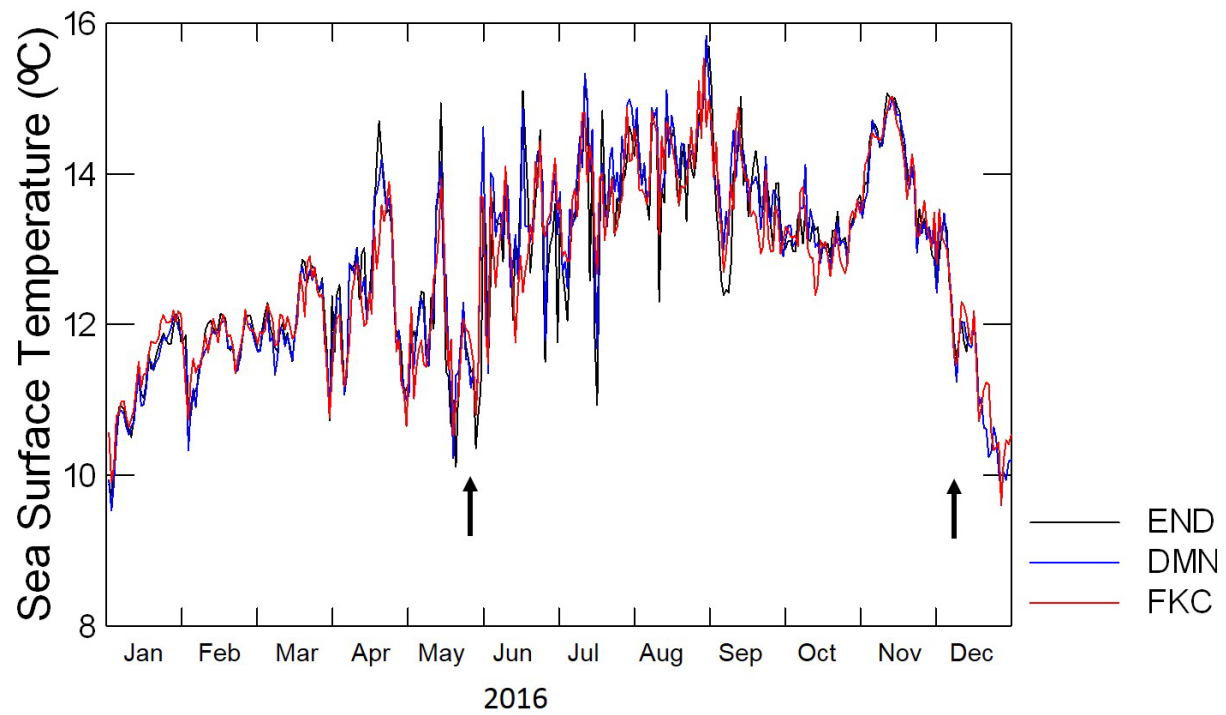


Figure 20. Sea surface temperatures from three Redwood National and State Parks sites in 2016. Arrows denote the two periods when the study sites were sampled. Continuous temperature data collected with Onset brand temperature loggers. FKC = False Klamath Cove, DMN = Damnation Creek, END = Enderts Beach.

Discussion

A primary objective of the RNSP monitoring program is to track changes in the structure of the intertidal community over time. To accomplish this, data on the distribution, abundance, and sizes of species found at several sites within RNSP are being collected. When collected over long periods of time, such data not only help our understanding of the processes that affect intertidal communities, they can enable managers to assess the impacts and determine biological responses of any changes due to natural or anthropogenic drivers (Raimondi et al. 1999). Specifically, such data have been instrumental in detecting shifts in species ranges due to global climate change (Barry et al. 1995, Sagarin et al. 1999) and the introduction of nonnative species (Carlton and Geller 1993).

By gaining an understanding of natural seasonal and annual variations in populations, any deviations from these baseline conditions, like disturbances or long-term changes (e.g., global climate change), will become obvious. For example, data from the photoplots document changes in relative abundance (percent cover) of algae and sessile invertebrates, as well as smaller, mobile species like snails, crabs, and chitons. The sea star plots and surfgrass transects allow us to track changes for these species. See the trends and synthesis section of the Pacific Rocky Intertidal Monitoring website (www.eeb.ucsc.edu/pacificrockyintertidal/interactive-map/index.html) for access to data from the long-term intertidal monitoring program.

All of the monitored populations varied to some degree from previous years and over the course of 2016. While natural variation plays some part in these observations, several changes in 2016 are noteworthy. For example, disturbances prior to the summer survey caused mussel abundances to decline at Enderts, and while the appearance of new mussels during the summer and fall erased some of the decline, numbers remained lower than recorded in the past 12 years at the site. While ochre sea star (*Pisaster ochraceus*) populations within RNSP have shown declines due to Sea Star Wasting Syndrome (see below), a recruitment pulse of new ochre sea stars caused the populations at Enderts and False Klamath Cove to increase between the summer and fall surveys.

To date, observations from the RNSP monitoring program suggest that since its inception (2004), there have been no large changes to the structure of the intertidal community. However, comparisons between the current state of the community and previous observations made by Boyd and DeMartini (1977) indicate a shift from a highly disturbed, early successional community, to a more stable, late successional community. Variations in abundance due to small scale spatial clearance disturbances have also decreased since the earlier study periods. Although such changes may be attributed to decreased sediment loads and lower quantities of driftwood due to decreases in logging activity (e.g., McGary 2005), without long term monitoring data, it is not possible to directly link the changes in community structure to the impacts of logging at these sites. This highlights the need for continued monitoring.

Following the recommendations of the US Commission on Ocean Policy, the Pew Commission Report, and the California Ocean Protection Act, California is rapidly moving towards a new era of marine resource management aimed at dealing with the impacts of humans on marine ecosystems. Long-term monitoring studies, like the one done in RNSP, are vital to this endeavor because they

provide important information not only about the current state of populations and communities, but also about whether and how much they change over time.

The ongoing monitoring program of the rocky intertidal community at RNSP continues to generate data vital to our understanding of the dynamics of rocky intertidal communities along the western coastline of North America. These findings will inform managers and policymakers and facilitate marine conservation through public outreach. As of December 19, 2012, the Marine Protected Areas (MPAs) for the northern coast of California (California/Oregon border to Point Arena) have been designated by the California Fish and Game Commission, and the creation of a monitoring plan is underway. More information about the network of nearly 20 MPAs in this region can be found at <https://www.wildlife.ca.gov/Conservation/Marine/MPAs/Network/Northern-California>. Data from the RNSP intertidal sites and other northern coast MARINe monitoring sites comprise the only existing current intertidal monitoring data for this region. The data from this monitoring program provided essential baseline information for the design of this MPA network and will aid in the assessment of the network's effectiveness.

Sea Star Wasting Syndrome

Ochre sea star (*Pisaster ochraceus*) is considered a keystone species (Paine 1966, 1974). Thus, changes in its abundance may have widespread effects on the structure of rocky intertidal and subtidal communities. In summer 2013, such a change was observed by MARINe researchers when Sea Star Wasting Syndrome struck populations of sea stars along the entire western coast of North America (www.seastarwasting.org). This syndrome is characterized by the formation of white lesions in the ectoderm of the star, decay of tissue surrounding the lesions, fragmentation of the body, and death. The disease can appear and progress rapidly and has the potential to decimate sea star populations. At some MARINe sites, *P. ochraceus* numbers have declined by 90% or more in monitoring plots. Continued monitoring at Redwood National and State Parks and other MARINe sites will allow researchers to further track the progression of the disease and its effects on both sea star populations and rocky intertidal communities as a whole. Furthermore, researchers have observed potential signs of recovery, such as high levels of recruitment and tissue regrowth in surviving stars, at some sites. This includes the appearance of many new small (<20mm) ochre sea stars (*Pisaster ochraceus*) at Enderts and False Klamath Cove, causing the population to increase starting in 2015. The trend continued in 2016 summer and fall surveys, with hundreds of small ochre sea stars recorded at Enderts in 2016. Continued sampling will document the extent of sea star recovery and its effects on the intertidal community.

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Appendix A: Species Monitored

Target, Core, and Optional Species Defined

The definitions for monitored species are adapted from the MARINe handbook (Engle 2005).

Target Species: “Target” species (also called key or indicator species) are species or species groups specifically chosen for long-term monitoring. They dominate particular zones or biotic assemblages in rocky intertidal habitats. The criteria for selecting target species include the following:

- Species ecologically important in structuring intertidal communities.
- Species that are competitive dominants or major predators.
- Species that are abundant, conspicuous or large.
- Species whose presence provides numerous microhabitats for other organisms.
- Species that are slow growing and long-lived.
- Species that have interesting distributions along California coasts.
- Species found throughout California shores.
- Species characteristic of discrete intertidal heights.
- Species that are rare, unique, or found only in a particular intertidal habitat.
- Species approaching their biogeographic limits in California.
- Species that have been well studied, with extensive literature available.
- Species of special human interest.
- Species vulnerable and/or sensitive to human impacts, especially from oil spills.
- Species with special legal status.
- Introduced or invasive species.
- Species harvested by sport or commercial activities.
- Practical species for long-term monitoring.
- Readily identifiable, non-cryptic species.
- Sessile or sedentary species of reasonable size.
- Species located high enough in the intertidal to permit sufficient time to sample.

Currently, there are **18 designated target species monitored by MARINe:**

- *Egregia menziesii*

- *Fucus gardneri*¹
- *Hedophyllum sessile*
- *Hesperophycus californicus*
- *Pelvetiopsis limitata*¹
- *Silvetia compressa*
- *Endocladia muricata*¹
- *Neorhodomela larix*
- *Phyllospadix scouleri/torreyi*¹
- *Anthopleura elegantissima/sola*
- *Mytilus californianus*¹
- *Lottia gigantea*
- *Haliotis cracherodii*
- *Chthamalus dalli/fissus/Balanus glandula*¹
- *Semibalanus cariosus*
- *Tetraclita rubescens*
- *Pollicipes polymerus*
- *Pisaster ochraceus*¹

Designated target species have the highest priority for monitoring. They are monitored at as many sites as possible. If the species is present in sufficient numbers and it is logistically possible, plots or transects are established to monitor it. More information on target species (e.g., photos and how to identify) can be found on the MARINe public website.

Core Species: “Core” species are those **species, species groups, or substrates that are scored using one or more survey methods by everyone in MARINe.** Core species must be reasonably and consistently identifiable using the designated scoring protocol (e.g., from lab-scored photos of fixed plots possibly supplemented by plot sketches/notes). They also must be important enough to warrant scoring for abundance trends. Some of these species only occur at northern sites, or conversely, southern sites, yet to ensure that we notice if they expand their range, we must score everywhere. All target species are core species. It is important that **scorers in all monitoring groups be able to identify and record all core species. Data sheets must include all core species,** though core species that are absent or rarely occur at a site can be deemphasized. Entries for all core species will be required for data submission to the MARINe database.

¹ Species are currently monitored at Redwood National and State Parks (RNSP) sites.

Optional Species: “Optional” species are **non-core species or species groups that one or more monitoring groups choose to score at their sites; however, for various reasons, are not appropriate or feasible for all groups to score.** Since optional species will not be scored by everyone, coast-wide comparisons of trends for these species will be limited or not possible. However, all groups sampling MARINe north sites (NorCal, RNSP and Oregon) use the same list of optional species.

Appendix B: Natural History of Target Species

These brief descriptions provide context for the selection of these target species by including information on life history, ecological importance, and sensitivity to anthropogenic activities. Descriptions of the natural history of the target species monitored in this study have been adapted with permission from the U.S. Bureau of Ocean Energy Management (BOEM) report (Miner et. al. 2005).

Endocladia muricata

Distinctive dark bands of the low-growing red turfweed, *Endocladia muricata*, are characteristic of nearly all high rocky intertidal shores of the northern Pacific Coast. *Endocladia* forms dense 4–8 cm tall, perennial tufts made up of tiny spine-covered branchlets (Abbott and Hollenberg 1976).

Together with spiny-bladed *Mastocarpus papillatus*, the *Endocladia/Mastocarpus* carpet traps sediment and seawater, thus providing a sheltered microhabitat for a host of small organisms, including other algae, worms, crustaceans, and mollusks. Glynn (1965) found over 90 species associated with *Endocladia* clumps in Monterey. Turfweed can also provide habitat for attachment of young mussels. Expanding mussel patches may displace *Endocladia*, but it can then grow on the mussel shells, creating a layered assemblage. Some *Endocladia* clumps appear donut- or crescent-shaped; this condition may be caused by storms tearing out center areas possibly weakened by accumulated anoxic sediment. *Endocladia* is hardy and quite resistant to desiccation, yet vulnerable to oiling from spills. Recovery from natural or human disturbances may vary from 1 to more than 6 years (Kinnetics Laboratories 1992).

***Phyllospadix* spp.**

Surfgrass (*Phyllospadix* spp.) is one of only 2 types of marine flowering plants on the West Coast. Surfgrass attaches by short roots to rock on surf-swept shores from the low intertidal down to 10–15 m depths. The 0.5–2 m tall, bright green grass, commonly occurs in dense perennial beds formed primarily by vegetative growth from spreading rhizomes. Two species (*P. torreyi* and *P. scouleri*) overlap in geographical distribution and morphological characteristics (see Dawson and Foster 1982). *Phyllospadix torreyi* generally has longer (1–2 m), narrower (1–2 mm) leaves, longer flower stems with several spadices, and occurs more in semi-protected habitats as well as at deeper depths. *Phyllospadix scouleri* tends to have shorter (<50 cm), broader (2–4 mm) leaves, shorter flower stems with 1–2 spadices, and is found more often in wave-swept intertidal areas. Surfgrass meadows are highly productive ecosystems, providing structurally complex microhabitats for a rich variety of epiphytes, epibenthos, and infauna. Some organisms, such as the red algae *Smithora naiadum* and *Melobesia mediocris*, are exclusive epiphytes on surfgrass (or eelgrass) (Abbott and Hollenberg 1976). *Phyllospadix* beds provide nursery habitat for various fishes and invertebrates. Surfgrass cannot tolerate much heat or drying; the leaves will bleach quickly when midday low tides occur during hot, calm-water periods. Surfgrass can be particularly sensitive to sewage discharge (Littler and Murray 1975) and oil pollution (see Foster et al. 1988). Recovery can be relatively rapid if the rhizome systems remain functional, but might take many years if entire beds are lost because recruitment is irregular and must be facilitated by the presence of perennial turf algae to which surfgrass seeds attach (Turner 1983, 1985).

Chthamalus dalli* and *Balanus glandula

White acorn barnacles, *Chthamalus dalli* and *Balanus glandula*, typically dominate high intertidal zones along the Pacific North Coast. Acorn barnacle species can be difficult to distinguish, especially in photographic monitoring. *Chthamalus dalli* are smaller (to 8 mm) than *Balanus glandula* (to 22 mm), which are whiter in color and have differing shell plate arrangements. Acorn barnacles spawn often, at variable times throughout the year (Hines 1978), and settle in extremely high densities (to 70,000/m²), forming distinct white bands along the upper intertidal that contain few other invertebrates except littorines and the hardiest limpets. *Balanus* can outcompete *Chthamalus* by crowding or smothering, but *Chthamalus* can occupy higher tide levels than *Balanus* because it is more resistant to desiccation. Slightly lower down, acorn barnacles mix in with the *Endocladia* assemblage, and are common on mussel shells. *Chthamalus* species grow rapidly, but only survive a few months to a few years. *Balanus* can live longer (to 10 years), but its larger size and lower tidal position subject it to higher levels of mortality from predatory gastropods and ochre sea stars.

White acorn barnacles are highly vulnerable to smothering from oil spills because floating oil often sticks along the uppermost tidal levels. Significant, widespread barnacle impacts were reported after the 1969 Santa Barbara oil platform blowout (Foster et al. 1971) and the 1971 collision of 2 tankers off San Francisco (Chan 1973). However, high recruitment rates may promote relatively rapid recovery of acorn barnacles; disturbance recovery times ranging from several months to several years have been reported (see Vesco and Gillard 1980).

A condition referred to as “hummocking” was observed in acorn barnacles at several sites. Hummocking occurs in response to high recruitment densities and growth rates, which intensify competition for primary substrate space (Bertness et al. 1998). This condition causes crowded barnacles to grow up instead of out until they eventually grow so high that they are susceptible to removal by wave action. Evidence of hummocking was observed at all 3 monitored sites within Redwood National and State Parks (RNSP). Frequently, large patches of barnacles would be entirely removed from one sampling period to the next.

Mytilus californianus

The California mussel, *Mytilus californianus*, is abundant at middle to low levels of exposed rocky shores along the entire Pacific Coast. These 10–20 cm black/blue/gray mussels firmly attach to rocks or other mussels by tough byssal threads, forming dense patches or beds. The literature on *Mytilus californianus* is extensive, including key ecological studies on the effects of predation, grazing, and disturbance on succession and community structure (Morris et al. 1980; Ricketts et al. 1985; Kinnetics Laboratories 1992). Thick (>20 cm) beds of California mussels trap water, sediment, and detritus that provide food and shelter for an incredible diversity of plants and animals, including cryptic forms inhabiting spaces between mussels as well as biota attached to mussel shells (Paine 1966, MacGinitie and MacGinitie 1968, Kanter 1980, Lohse 1993). For example, MacGinitie and MacGinitie (1968) counted 625 mussels and 4,096 other invertebrates in a single 25 cm² clump, and Kanter (1980) identified 610 species of animals and 141 species of algae from mussel beds at the Channel Islands. Mussels feed on suspended detritus and plankton. Young mussels settle preferentially into existing beds at irregular intervals, grow at variable rates depending on

environmental conditions, and eventually reach ages of 8 years or more (see Morris et al. 1980; Ricketts et al. 1985). Mussels can tolerate typical rigors of intertidal life quite successfully. However, desiccation likely limits the upper extent of mussel beds, storms tear out various-sized mussel patches, and sea stars prey especially on lower zone mussels. *Mytilus* are adversely affected by oil spills (Chan 1973, Foster et al. 1971). Recovery from disturbance varies from fairly rapid (if clearings are small and surrounded by mussels that can move in) to periods greater than 10 years (if clearings are large and recruitment is necessary for recolonization) (Vesco and Gillard 1980, Kinnetics Laboratories 1992).

Pisaster ochraceus

The ochre sea star, *Pisaster ochraceus*, is found on middle and low tide levels of waveswept, rocky coasts from Alaska to Baja California. Its relatively large size (to 45 cm diameter), variety of colors (yellow, orange, purple, brown), and ability to withstand air exposure (at least 8 hours) attract considerable attention from visitors exploring the shore at low tide. The ochre sea star typically is associated with mussels, which constitute its chief food, but barnacles, limpets, snails, and chitons also may be taken (Morris et al. 1980). Predator-prey interactions involving ochre sea stars have been intensely studied, especially the role of *P. ochraceus* in determining the lower limit of northern mussel beds (Paine 1966, 1974, Dayton 1971). Ochre sea stars are relatively slow-growing, long-lived, and apparently variable in recruitment success. They are tolerant of high surf, using their numerous tube feet to remain firmly in place, often in cracks and crevices. They have few predators, except for curious tidepool visitors. Sensitivity to oil spills is not well known; Chan (1973) saw no obvious effects from a San Francisco oil spill. Recovery time from any major population loss likely would be very long.

Pelvetiopsis limitata

The rockweed, *Pelvetiopsis limitata*, is described as light tan to olive, densely branched, cylindrical at the base becoming flattened to cylindrical in the upper fronds, dichotomous, with thalli 4–8 cm tall (Abbott and Hollenberg 1976). This algae is seen commonly in the upper intertidal of more wave-exposed sites in RNSP. *Pelvetiopsis* ranges on the Pacific coast from Vancouver Island, British Columbia, to Cambria (San Luis Obispo County), California. Little scientific attention has been given to *Pelvetiopsis*, so little is known about its reproductive periodicity, longevity, or ecology.

Fucus gardneri

Another common rockweed in RNSP, *Fucus gardneri*, has similar olive brown, branching, dichotomous thalli morphology to *Pelvetiopsis*. It is distinguished by having taller thalli, 10–25 cm, and prominent midribs in older portions (Abbott and Hollenberg 1976). This conspicuous brown alga is commonly found in the mid to high intertidal on rocks. Many species of invertebrates find vital shelter from the harsh conditions characteristic of the intertidal within the fronds of rockweeds such as *Fucus* and *Pelvetiopsis*. *Fucus* is also a food source for many gastropods (Houghton et al. 1998). Recovery time of *Fucus gardneri* after the Exxon Valdez oil spill of 1989 was studied. Results suggested that the population dynamics and structure did not fully recover 7 years after the spill despite initial biomass recovery (Driskell et al. 2001).

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