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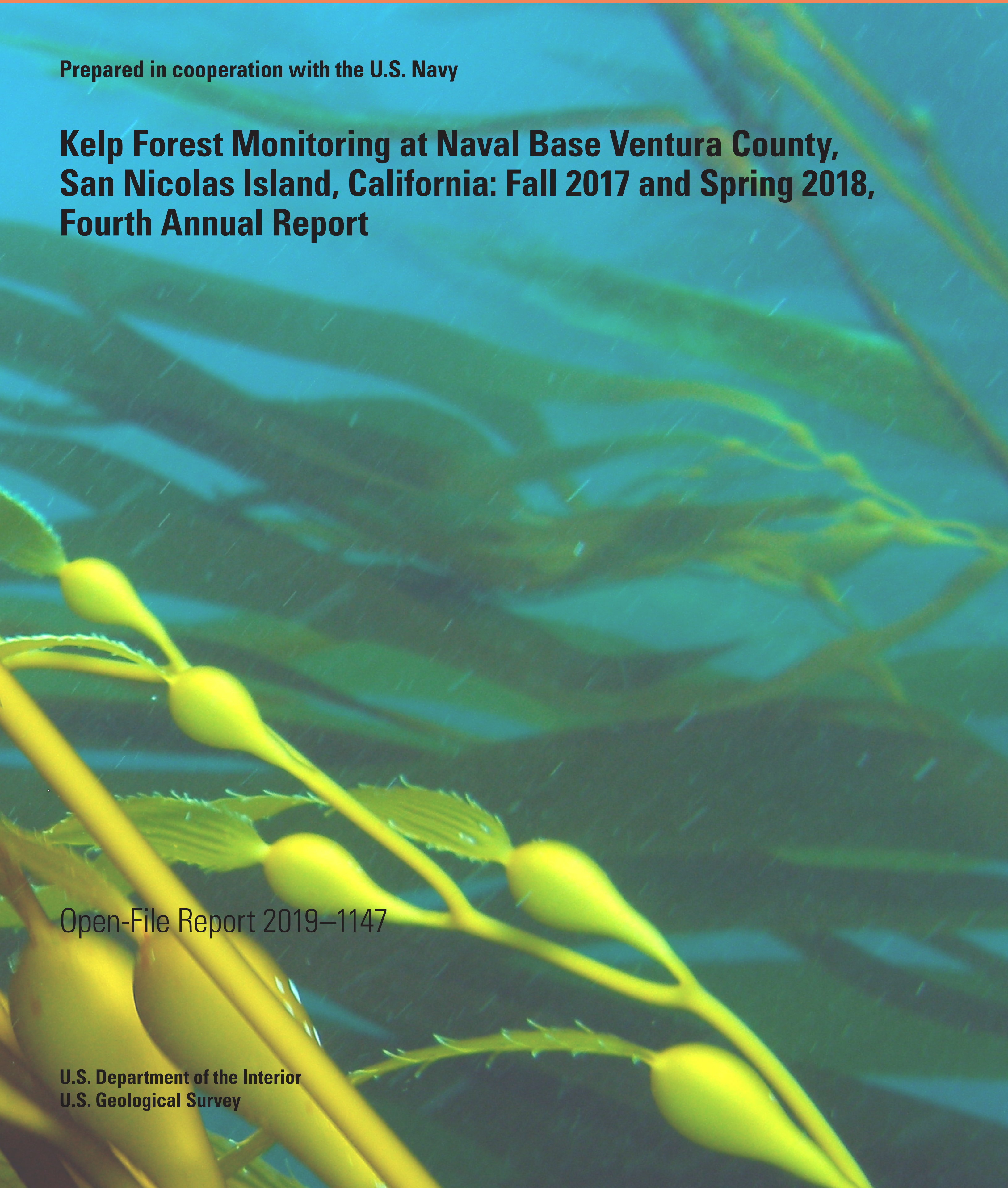
Kelp Forest Monitoring at Naval Base Ventura County, San Nicolas Island, California: Fall 2017 and Spring 2018, Fourth Annual Report



Open-File Report 2019–1147

U.S. Department of the Interior
U.S. Geological Survey

Cover: *Norrisia norrisi* on *Macrocystis pyrifera* at west end of San Nicolas Island, California, photograph taken by Michael Kenner, U.S. Geological Survey, October 21, 2006.

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U.S. Geological Survey
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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Datum

Horizontal coordinate information is referenced to the World Geodetic System of 1984 (WGS84).

Abbreviations

CO_2	carbon dioxide
GPS	Global Positioning System
INRMP	Integrated Natural Resources Management Plan
RPC	random point contact
SNI	San Nicolas Island
SSWS	sea star wasting syndrome
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Kelp Forest Monitoring at Naval Base Ventura County, San Nicolas Island, California: Fall 2017 and Spring 2018, Fourth Annual Report

By Michael C. Kenner[1,2] and Joseph Tomoleoni[1]

Abstract

To assess and track changes to the rocky subtidal communities surrounding San Nicolas Island, the U.S. Navy entered into an agreement with the U.S. Geological Survey (USGS) in 2014 to conduct an ecological monitoring program at several sites around the island. Four permanent sites—Nav Fac 100, West End, Dutch Harbor, and Daytona 100—were established. The sites were based on ones that had been monitored since 1980 by USGS and were combined or expanded for better comparability with monitoring programs conducted at the other California Channel Islands. At the sites, scientists from USGS and our cooperator, the University of California, Santa Cruz, measured bottom cover of algae and sessile invertebrate species in quadrats, counted and sized fish on swimming transects, and counted a suite of kelps and invertebrates on benthic band transects. Holdfast diameter and number of stipes of giant kelp (*Macrocystis pyrifera*) were recorded on these transects, and size data were collected for urchins, sea stars, and shelled mollusks. Bottom temperatures were recorded at hourly intervals by archival data loggers that were deployed at the sites. This report focuses primarily on data collected in fall 2017 and spring 2018 and makes comparisons with data collected in previous years, beginning in fall 2014.

Nav Fac 100 is a site with a relatively low benthic profile, situated on the north side of San Nicolas Island. It was previously urchin dominated but underwent a dramatic decline in purple sea urchins in 2015 and 2016. Since then, macroalgae has become more prevalent as both annual brown algae, such as *Dictyota*, and perennials (for example, *Cystoseira*) have become established. The invasive brown alga *Sargassum horneri* has also become established. West End, on the southwest side of the island, also lacks much bottom relief but has more crevice habitat associated with boulders. It remains dominated by kelps and red algae, but red algae have decreased recently. Dutch Harbor, on the south side, has many high relief rocky reefs and had the greatest fish and non-motile invertebrate densities. It remains the most stable of the sites. Daytona 100, on the southeast side, has moderate relief and has remained a patchwork of kelp and urchin dominated areas with moderate fish density.

The main change at the sites during the last 4 years was the decline in urchin numbers at Nav Fac 100. There was storm-related mortality and subsequent recruitment in the *M. pyrifera* population at several of the sites in both 2016 and 2017. The winter of 2018, however, was relatively mild, with less destructive storm-related disturbance. The invasive brown alga *S. horneri*, first seen at San Nicolas Island at Nav Fac 100 in fall 2015, has become firmly established there during the last 2 sampling years. Finally, moderate increases were observed in purple urchin densities at all sites this spring. Long-term data are presented to illustrate trends and changes over the past three decades. Results indicate continued monitoring to evaluate ecosystem effects from perturbations owing to natural processes and anthropomorphic factors, including recovery of the sea otter population, changes in fisheries, invasive species and changing environmental conditions, could be valuable to inform managers' decision-making.

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[2]University of California, Santa Cruz.

Introduction

Kelp forests and rocky reefs are among the most recognized marine ecosystems and provide the primary habitat for several species of fishes, invertebrates, and algal assemblages (Stephens and others, 2006). In addition, kelp forests have been shown to be important carbon dioxide (CO_2) sinks (Wilmers and others, 2012) and are an important source of near-shore marine primary production (Duggins and others, 1989). These highly dynamic ecosystems are extremely variable, and both top-down and bottom-up ecological controls drive this rich trophic environment. Giant kelp (*Macrocystis pyrifera*) forests and the species that inhabit these ecosystems are influenced by several environmental conditions, such as wave exposure, water temperature, water clarity, bottom depth and composition, species composition, and the density of kelp and other algal assemblages (Schiel and Foster, 2015). However, in addition to "normal" variability, kelp forests can undergo extreme regime shifts from kelp canopy forested areas to barrens characterized by high densities of urchins and encrusting coralline algae (Harrold and Reed, 1985).

San Nicolas Island (SNI) is the outermost of the California Channel Islands, is home to a diverse group of terrestrial and marine organisms, and includes both kelp bed and rocky reef habitats (fig. 1). The SNI kelp forests not only provide food and shelter for fishes and invertebrates within the habitat but also support higher trophic level consumers such as marine birds and several marine mammal species including the southern sea otter (*Enhydra lutris nereis*), a major predator on sea urchins and other marine invertebrates. Owing to concern over the vulnerability of the California population, the U.S. Fish and Wildlife Service (USFWS) translocated 140 southern sea otters from the central California coast to SNI between 1987 and 1990. Although only approximately 14 translocated otters are thought to have remained at SNI (U.S. Fish and Wildlife Service, 2012), their population at the island has continued to increase and is currently >90 individuals (Hatfield and others, 2018). Sea otters are a natural part of the kelp forest ecosystem, but their presence has implications for community dynamics as they repopulate a region from which they were extirpated in the 19th century. At SNI, sea otters have been concentrated mostly around the west end of the island, with some use of the south side and very little but expanding use of the northeast side. An ecosystem shift from urchin dominated to kelp dominated, which occurred at a site at the west end of the island, was likely facilitated to some degree by sea otter foraging (Kenner and Tinker, 2018).

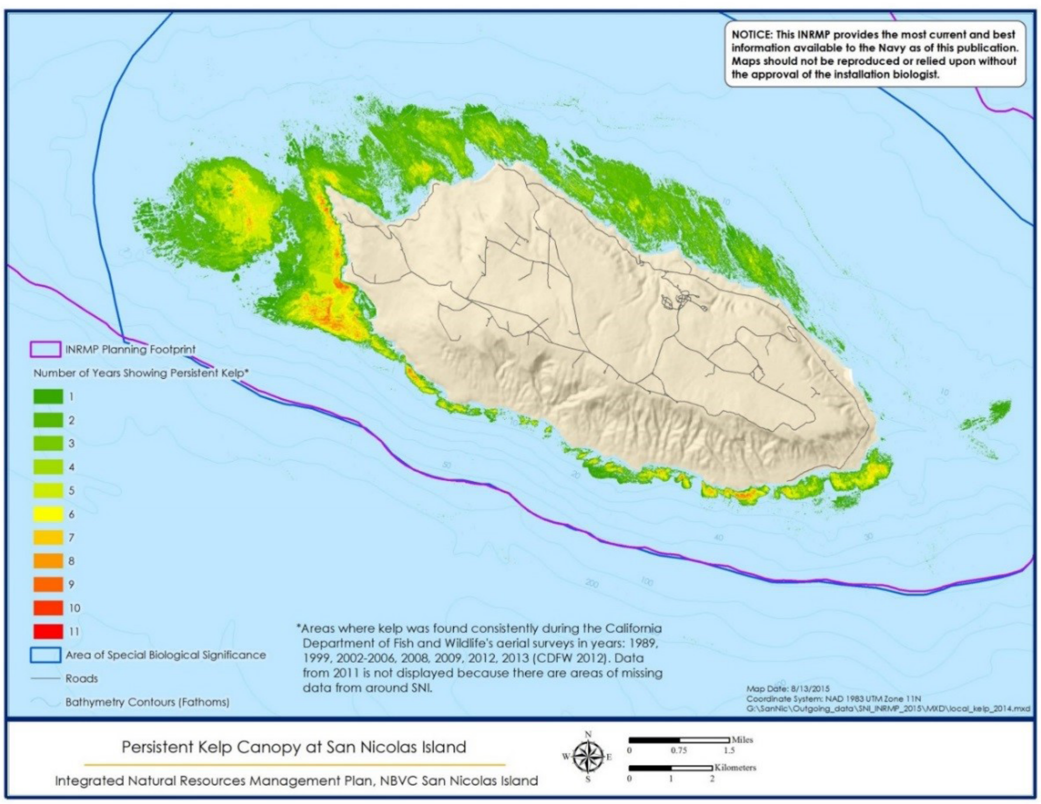

Figure 1. San Nicolas Island, California persistent kelp canopy. Figure from SNI Integrated Natural Resources Management Plan (U.S. Navy, 2015).

These ecosystems are also the target of many fisheries including urchin and lobster. However, owing to the distance from the mainland, SNI kelp forests and reefs have been protected from the degree of exploitation and other anthropogenic impacts experienced by the southern California mainland. Invasive species are another issue, and there are a few subtidal macroalgae of concern in southern California waters. Although the brown alga *Sargassum muticum* has been established at the island for decades, *S. horneri* has only recently been seen there, and so far, the invasive kelp *Undaria pinnatifida* and the green alga *Caulerpa taxifolia* have not been observed there. Because the surrounding kelp forests fall within the management boundary of the SNI Integrated Natural Resources Management Plan (INRMP; U.S. Navy, 2015), surveys of this ecologically important ecosystem are necessary to provide U.S. Navy natural resource managers with knowledge of trends in the population abundance of particular species. In addition, long-term surveys also allow for an understanding of potential changes in species diversity and community composition as a result of trophic or other interactions.

The U.S. Geological Survey (USGS), in cooperation with the University of California, Santa Cruz, implemented a kelp forest monitoring program for the U.S. Navy at San Nicolas Island in 2014, building on sites and methods established by USFWS scientists in 1980 (appendix 1). This report focuses on data collected during sampling expeditions to these sites in fall 2017 (October 7–12) and spring 2018 (April 2–5). Together they will be herein referred to as year 4 because, although the trips were made in different calendar years, they were approximately six months apart and were conducted under the 4th year of this contract. Additionally, the year 4 data are compared with that collected during six trips from fall 2014 through spring 2017. Differences in counts between these expeditions can be due to seasonal factors, stochastic variation, or sampling error, but temporal comparison can reveal population trends. Where appropriate, long-term data collected prior to fall 2014 are presented in order to lend some context to the observations reported here.

Methods

Site Design and Sampling Protocols

Four permanent supersites were sampled at the island, and each is composed of two subunit sites (figs. 2–3). Most of these were set up as part of the USGS SNI Subtidal Baseline project described in appendix 1. Associated with each of these eight subunit sites is a 50-meter (m) main transect with five 10-m x 2-m benthic band transects (swaths) and ten 1-square-meter (m^2) random point contact (RPC) quadrats (see details in the following subsections). Except in the case of Dutch Harbor, where these segments are on adjacent reefs, the 50-m main transects of the two subunit sites are connected in a linear fashion with the 50-m end of one connecting to the 0-m end of the other. As explained in appendix 1, the supersites at West End and Dutch Harbor each have ten 50-m-long fish transects, whereas Nav Fac 100 and Daytona 100 each have only five 50-m fish transects (fig. 2).

At each supersite, a TidbiT® v2 model UTBI-001 (Onset Computer Corporation, Bourne, Massachusetts) archival temperature logger was deployed. These were set to record at 1-hour intervals and were installed on the sea floor at the midpoint of the 100-m main transects at Nav Fac 100, West End, and Daytona 100 and at 0-m at East Dutch Harbor. See figure 2 for a schematic of the sampling layout at Nav Fac 100 supersite as an example and table 1 for site Global Positioning System (GPS) locations.

Swaths/Band Transects

The swath/band transect method was used to determine densities of kelps and benthic macroinvertebrates as well as to gather size data on some of these populations. Ten permanent 10-m x 2-m transects, which run perpendicular to the main 100-m transect, were sampled by divers at each supersite. First, they attached a meter tape at a fixed point on the main transect and ran it out to an eyebolt embedded in the sea floor approximately 10 m away. On each swath, the divers then counted the target organisms (see table 2) that occurred within 1 m on either side of the tape. They measured sea stars and mollusks (millimeters [mm])—maximum arm length from center for sea stars, maximum shell length for mollusks. For giant kelp (*M. pyrifera*) >1 m tall (herein referred to as adults), the divers measured the holdfast diameter at the base (centimeters [cm]) and counted stipes at 1 m above the substrate. Holdfast diameters give an indication of the *M. pyrifera* age structure because the holdfast continues to grow throughout the life of the plant. Stipe counts are more variable with age but give an indication of plant biomass. Kelps of the genus *Laminaria* occur at SNI in a few different forms. Most of them appear to be *L. farlowii* or have a range of forms blending traits of *L. farlowii* (very short stipes and a single entire bullate blade) and *L. setchellii* (a single smooth but divided blade with a longer stiff stipe) but a very few of them are obviously *L. setchellii* (Abbott and Hollenberg, 1976). For this reason, these kelps are tallied and presented as "*Laminaria* spp." Note that in the referenced text, *L. setchellii* is erroneously referred to as *L. dentigera*. See table 3 for swath locations and orientations.

We measured the test diameter (mm) of a subsample of sea urchins (*Strongylocentrotus* spp.)—about 200 per species per supersite. Divers did not measure urchins on swaths but instead measured them in situ near the main transect. The urchins were measured as encountered to avoid size selective bias.

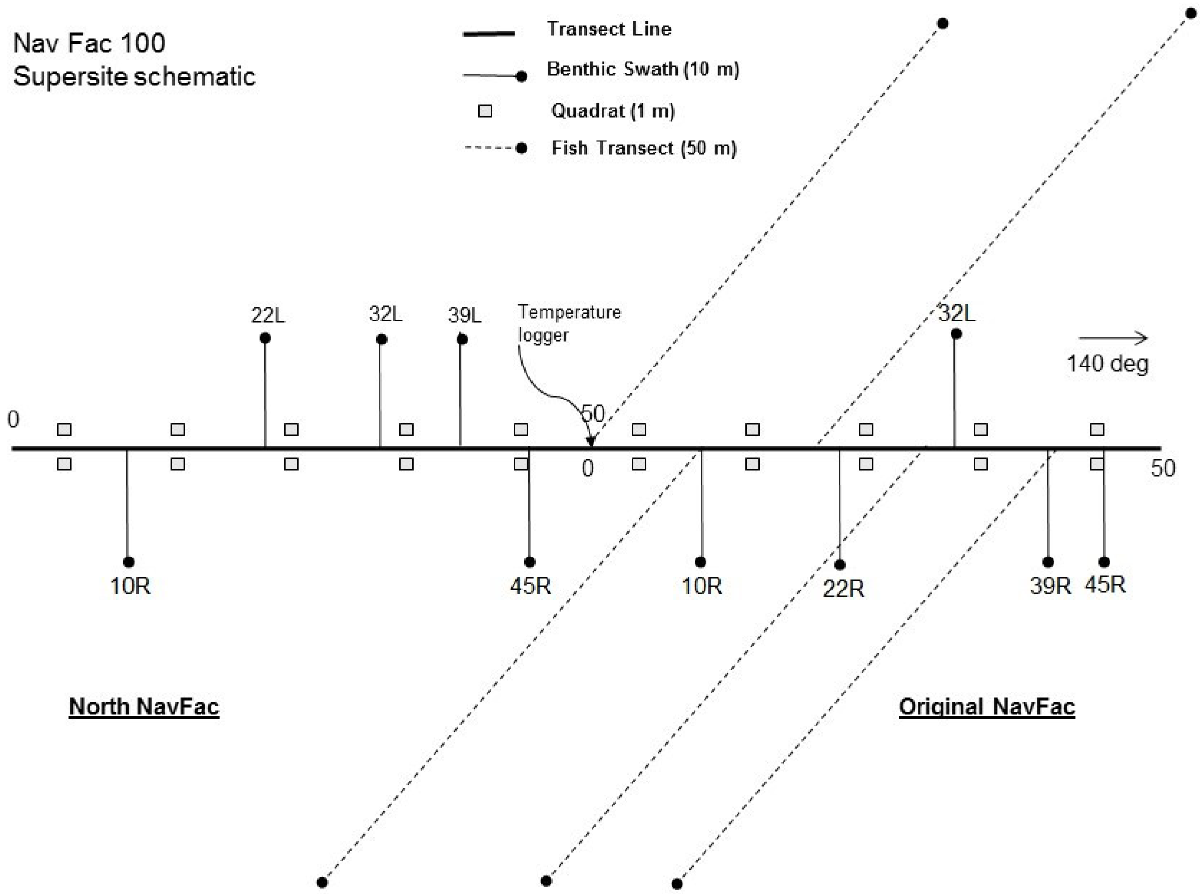

Figure 2. Nav Fac 100 supersite layout.

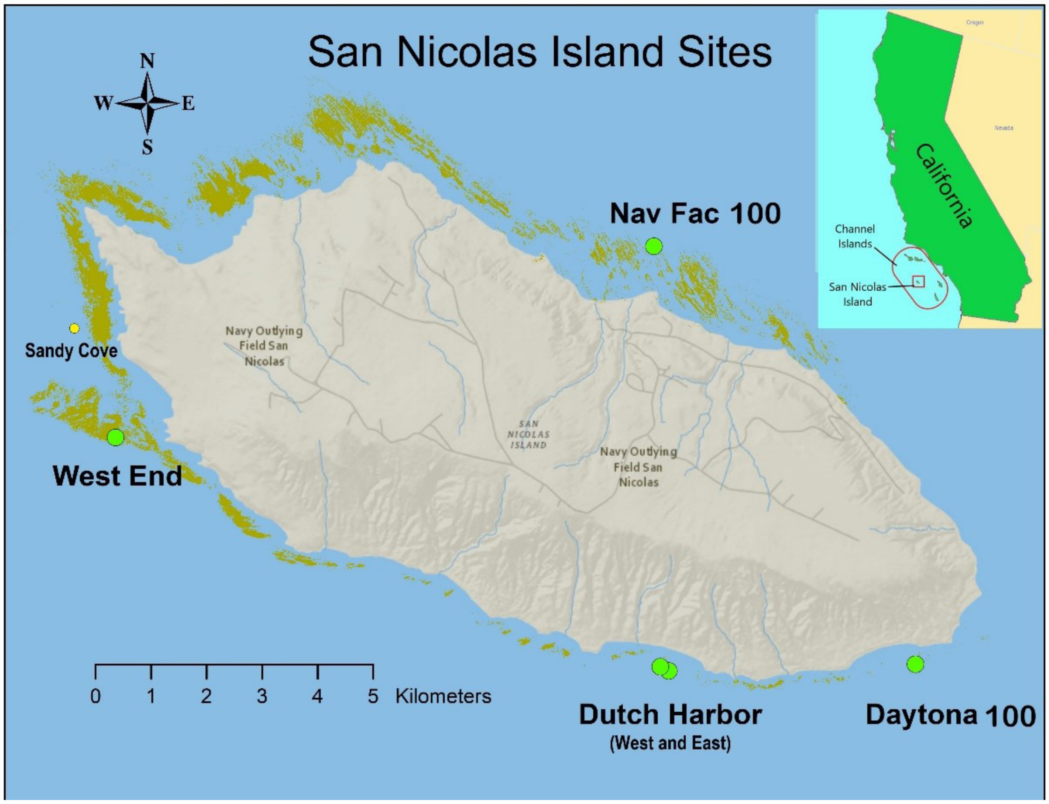

Figure 3. San Nicolas Island, California, and supersite locations.

Table 1. San Nicolas Island subtidal site waypoints (WGS84) and main transect bearings.

[TidbiT® logger location denoted by *. **Abbreviations**: m, meter; N, north; °, degrees; W, west]

Marker name	Latitude	Longitude	Transect bearing
	Nav Fac 100		
North Nav Fac 0m	N33.27385°	W119.48681°	140°
Nav Fac 0m/NNF 50m*	N33.27354°	W119.48647°	140°
Nav Fac 50m	N33.27310°	W119.48626°	
	West End		
WEU 0m	N33.24772°	W119.57419°	100°
WEK 0m/WEU 50m*	N33.24762°	W119.57367°	110°
WEK 50m	N33.24742°	W119.57318°	
	Dutch Harbor		
WDH 0m	N33.21652°	W119.48547°	55°
WDH 50m	N33.21672°	W119.48503°	
EDH 0m*	N33.21598°	W119.48407°	25°
EDH 50m	N33.21630°	W119.48381°	
	Daytona 100		
South Daytona 0m	N33.21643°	W119.44420°	0°
Daytona 0m/SD 50m*	N33.21687°	W119.44412°	0°
Daytona 50m	N33.21731°	W119.44400°	

Table 2. Species and measurements sampled on 10-meter x 2-meter swaths.

[*Measured off swaths. **Abbreviaitions**: mm, millimeter; <, less than; >, greater than; m, meter; cm, centimeter]

Species name	Common name	Measurement
Strongylocentrotus franciscanus	Red urchin	Test diameter (mm)*
Strongylocentrotus purpuratus	Purple urchin	Test diameter (mm)*
Lytechinus anamesus	White urchin	Test diameter (mm)
Parastichopus parvimensis	Warty sea cucumber	None
Pycnopodia helianthoides	Sunflower star	Longest ray length from center (mm)
Patiria miniata	Bat star	Longest ray length from center (mm)
Pisaster giganteus	Giant spined star	Longest ray length from center (mm)
Astrometis sertulifera	Fragile rainbow star	Longest ray length from center (mm)
Dermasterias imbricata	Leather star	Longest ray length from center (mm)
Haliotis corrugata	Pink abalone	Shell length (mm)
Haliotis rufescens	Red abalone	Shell length (mm)
Megathura crenulata	Giant keyhole limpet	Shell length (mm)
Megastraea undosa	Wavy turban snail	Shell base diameter (mm)
Kelletia kelletii	Kellet's whelk	Shell length (mm)
Crassadoma gigantea	Rock scallop	Shell width (mm)
Aplysia californica	California sea hare	None
Urticina lofotensis	White-spotted rose anemone	None
Tethya aurantia	Puffball sponge	None
Cystoseira osmundacea	Bladder-chain kelp	None
Eisenia arborea	Southern sea palm	None
Laminaria spp.	Oar weed	None
Macrocystis pyrifera <1 m	Giant kelp juvenile	None
Macrocystis pyrifera >1 m	Giant kelp adult	Holdfast diameter (cm) and stipe count
Pterygophora californica	California sea palm	None
Sargassum horneri	Devil weed	None
Young Laminariales	Unidentified juvenile kelp	None

Table 3. Benthic swath locations relative to main transect line at each supersite.

[R or L indicates the swath is to the right or left of main transect when facing from 0 meter (m) to 50 m. Note that the 45R swath at Daytona site was lost owing to sand burial in 1983, so the 22L swath was set up 2 years later as a replacement]

Supersite and sites	Swaths				
Nav Fac 100					
Nav Fac	10R	22R	32L	39R	45R
North Nav Fac	10R	22L	32L	39L	45R
West End					
WE Urchin	10L	22L	32R	39L	45L
WE Kelp	10R	22R	32L	39R	45L

Supersite and sites	Swaths				
Dutch Harbor					
W Dutch	10R	22L	32L	39L	45L
E Dutch	10R	22R	32L	39R	45R
Daytona 100					
Daytona	10R	22R	22L	32L	39L
South Daytona	10R	22L	32R	39R	45R

Random Point Contact (RPC) Sampling

Random Point Contact (RPC) sampling was used to estimate cover of exposed substrate as well as cover of algae and (primarily) non-motile invertebrates. Benthic percent cover data were collected in 1-m^2 permanent quadrats placed 1 m to the left or right of the main transect at 20 fixed locations. Within each quadrat, 20 points were distributed in a fixed pattern, each representing an estimate of 5 percent cover. The divers identified all organisms that intersected with an imaginary line running vertically through each point up to 1 meter above the substratum. The divers scored each species only once per point even if multiple individuals of the same species intersected that point. Because of this method of scoring multiple layers, total cover of all species often exceeded 100 percent, but the cover of any individual species could not be greater than 100 percent (20 points). The list of taxa recorded was open and ranged from actual individual species to species groups, for example, "orange encrusting sponge." Substrate type (bare rock or sand) was also scored if exposed. In order to access affixed species or substrate beneath them, motile invertebrate species were removed if possible but were scored in the cases of ophiuroids (brittle stars) and small holothurians (sea cucumbers). See table 4 for quadrat locations and orientations.

1-Meter Quadrats

The 1-m^2 quadrats, which define the location of the point contact sampling, were also used to sample densities of certain smaller species that are difficult to count on swaths. Unlike the RPC sampling, which yields a measure of cover, these were actual counts of individuals. Divers counted Norris's top snails (*Norrisia norrisi*), any *Tegula* species observed, red turban snails (*Astraea gibberosa*), chestnut cowries (*Cypraea spadicea*), stalked tunicates (*Styela montereyensis*), Kellet's whelks (*Kelletia kelletii*), white-spotted rose anemones (*Urticina lofotensis*), orange puffball sponges (*Tethya aurantia*), and the invasive brown alga (*S. horneri*) found in these quadrats. These last four species were also counted on swaths.

Visual Fish Transects

The purpose of the fish transects was to estimate fish density, size, sex (if obviously sexually dimorphic), and vertical distribution in the water column. The fish transects were 50 m long with a fixed beginning point along the main site transect and a permanently chosen compass heading. The midwater and bottom portions of each transect were sampled separately. Midwater transects were 5 m wide and encompassed the entire water column except the bottom 2 m. Bottom transects were 2 m wide and included only the bottom 2 m of the water column. Divers attached a meter tape at the specified location on the main transect line and swam the prescribed compass heading, identifying, counting, and estimating size of all conspicuous fishes on each transect. If sex was visually distinguishable, as in the case of kelp greenling (*Hexagrammos decagrammus*) or California sheephead (*Semicossyphus pulcher*), this was recorded as well.

Table 4. Point contact and 1 square meter (m^2) quadrat locations relative to main transect line at each supersite.

[R or L indicates the swath is to the right or left of main transect when facing from 0 meter (m) to 50 m]

Supersite and sites	Quadrats									
Nav Fac 100										
Nav Fac	R05	L05	R15	L15	R25	L25	R35	L35	R45	L45
North Nav Fac	R05	L05	R15	L15	R25	L25	R35	L35	R45	L45
West End										
WE Urchin	R05	L05	R10	L10	R15	L15	R25	L25	R35	L35
WE Kelp	R05	L05	R10	L10	R20	L20	L25	L40	R45	L45
Dutch Harbor										
W Dutch	R10	R15	L15	L20	R25	L25	L30	R35	L35	R40
E Dutch	R05	L05	R10	L10	R15	L15	R25	L25	R35	L35
Daytona 100										
Daytona	R05	L05	R10	L10	R15	L15	R25	L25	R35	L35
South Daytona	R05	L05	R10	L15	R25	L25	R35	L35	R45	L45

Juveniles were also recorded separately when morphologically distinct. Divers estimated total length (TL) of small fish (<20 cm TL) to the nearest 1 cm and larger fish (>20 cm) to the nearest 5-cm interval. For schools of a species, a size range was recorded. As described above, Nav Fac 100 and Daytona 100 each have 5 fish transects, but West End and Dutch Harbor each have 10. At Dutch Harbor, owing to very high counts typically recorded there, fish were only sized on two midwater and two bottom transects at the West Dutch Harbor site and two of each at the East Dutch Harbor site. Counts only were done on the remaining transects there. See table 5 for fish transect locations and headings.

Table 5. Fish transect locations relative to main transect line at each supersite.

[*Fish not sized on these transects. **Abbreviations**: m, meter; E, east; W, west; N, north; S, south]

Supersite and sites	Transects (start point and bearing); ON means transect is on the main line.				
	1	2	3	4	5
Nav Fac 100					
Nav Fac	0m E	10m W	20m E	30m W	40m W
West End					
WE Urchin	0m N	10m N	20m N	30m N	ON
WE Kelp	0m S	10m N	20m S	30m N	ON
Dutch Harbor					
W Dutch	0m W	10m W	30m W*	45m W*	ON*
E Dutch	0m E	10m W	20m E*	30m W*	40m E*
Daytona 100					
Daytona	0m E	0m W	10m E	20m W	30m E

Site Descriptions

See table 1 for site coordinates and orientations and figure 3 for map of site locations.

Nav Fac 100

The Nav Fac 100 supersite is situated on the north side of the island. It is exposed to the prevailing northwest swell and wind and has a generally flat bottom with a few 1–2 m high ledges and undercuts. The TidbiT® logger was deployed at approximately 12 m in depth. From the time that the original Nav Fac site (the southern 50 m of the supersite) was established in the fall of 1980 until 1989, it was kelp dominated with the bottom largely covered by encrusting and erect coralline algae, the fucoid alga (*Cystoseira osmundacea*), and the tube building snail (*Serpulorbis squamiger*). The understory kelps *Laminaria* spp. and *Pterygophora californica* and the giant kelp *M. pyrifera* were common. By the spring of 1990, a strong recruitment of the purple sea urchin (*Strongylocentrotus purpuratus*) had transformed most of the site to an urchin barren. Though urchin densities fluctuated over time, the west side of the site did not recover to a kelp dominated state. That part of the site is very flat, and the bottom is composed of soft sandstone, which may impede kelp recovery because there is no barrier to urchin movement and storms easily remove kelp holdfasts. The east side of the site has slightly higher relief, and *C. osmundacea*, *P. californica*, and *Laminaria* spp. are common there. Fish densities have generally been low throughout the site. The new part of the supersite (North Nav Fac), which was established in fall 2014, included some kelp dominated and urchin dominated areas and had swaths and quadrats in both states. Urchin densities fell after the spring 2015 sampling trip and have remained low since then. Kelp recovery has been gradual (fig. 4). The invasive brown alga *S. horneri*, which had not been observed at SNI before, first appeared at the site in fall 2015.

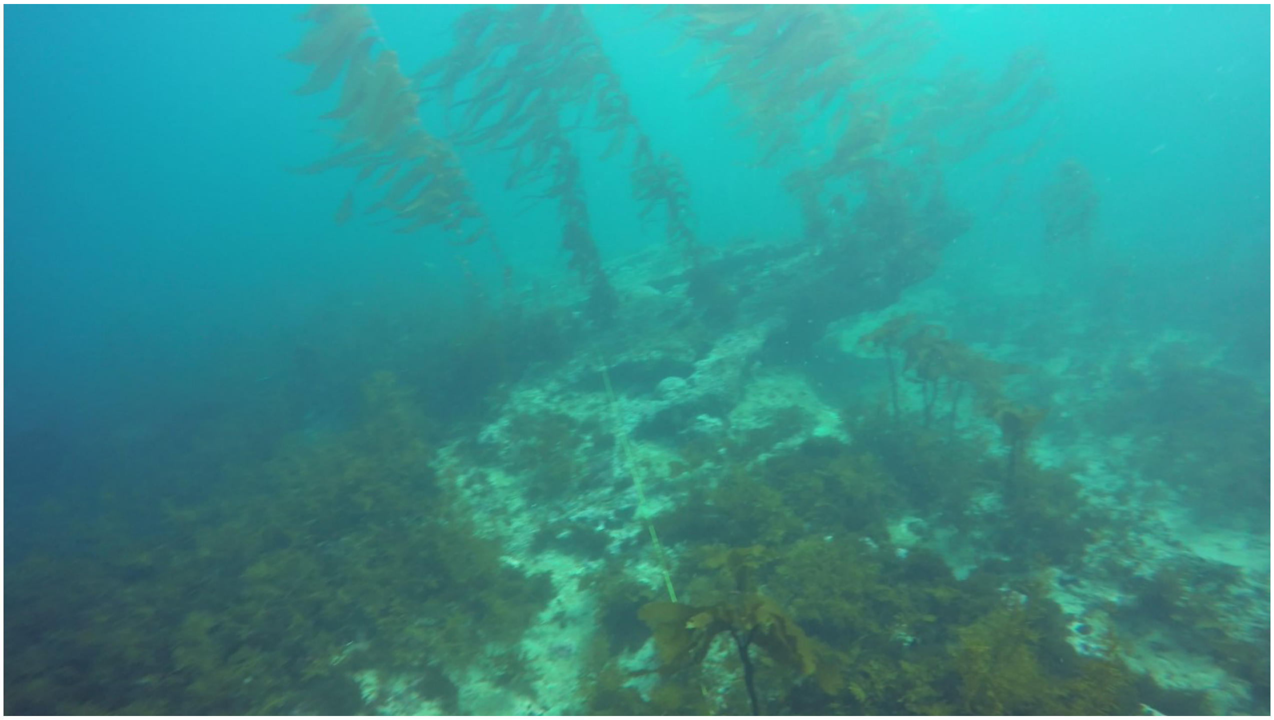

Figure 4. Nav Fac 100 site showing understory brown algae, *Pterygophora californica* and *Macrocystis pyrifera*, April 2018 (captured from video by Shannon Myers).

West End

The West End supersite is located off the southwest shore of the island. The bottom there is generally flat with scattered ~1 m boulders and sand patches. The TidbiT® logger was deployed at a depth of about 11 m. The supersite is very exposed to prevailing NW swell and wind. Originally designed with one 50 m transect installed in an urchin dominated area and one in a kelp dominated area, this dynamic region has undergone several shifts between kelp and urchin states since the sites were established in 1980. In 2001, it underwent a dramatic shift from an entirely urchin dominated state to one in which they were almost entirely absent. The cause of this shift remains unclear but likely was some combination of an undocumented sea urchin disease and the foraging of sea otters that frequent the area. Since that time, the high density of *M. pyrifera*, which recruited early on, has largely given way to high densities of understory kelps and high bottom cover of fleshy red algae (fig. 5). Urchin densities, although higher the last several years than during the first decade following the 2001 crash, remain low at this site, and fish densities are moderate.

Dutch Harbor

The two 50-m transects at the Dutch Harbor supersite are on adjacent, roughly parallel reefs separated by about 140 m of sand. This supersite is located on the south side of the island. Depth along the transects ranges from about 11 to 13 m, and the TidbiT® logger is at approximately 11 m at the East Dutch Harbor subsite. The swaths traverse high-relief reefs up to 4 m in height with abundant cracks and ledges (fig. 6). The area is exposed to occasional south swell and the prevailing west wind. This supersite, remarkable for its high-relief reefs, high densities of filter feeding invertebrates, and high fish densities, has remained the most stable of the sites over the long term (Kenner and Tinker, 2018). It has never exhibited urchin “outbreaks,” and kelp densities have remained moderate and mixed with many encrusting invertebrates and small holothurians.

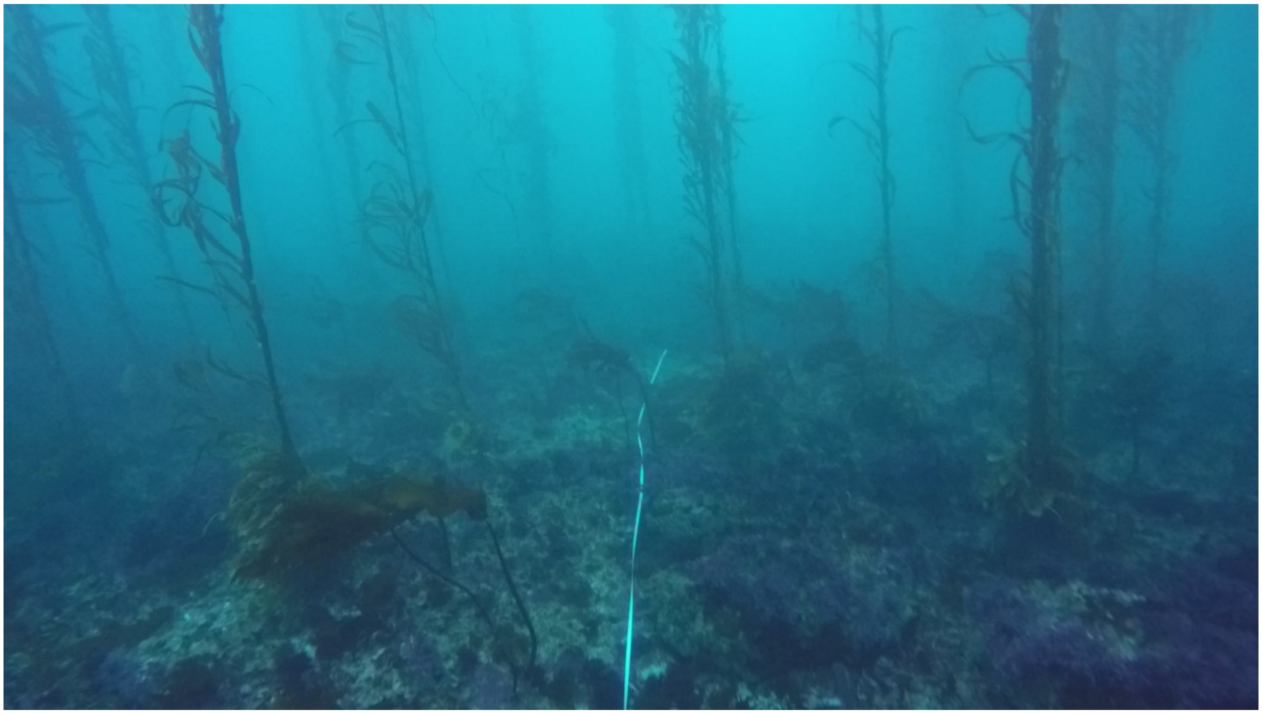

Figure 5. West End supersite showing fleshy red algal cover and understory kelp with *Macrocystis pyrifera*, April 2018 (captured from video by Shannon Myers).

Figure 6. High relief reefs at East Dutch Harbor, April 2018 (captured from video by Shannon Myers).

Daytona 100

Located at the southeast side of the island, depths along the Daytona 100 transect are about 10–12 m with the TidbiT® logger at about 10 m. The supersite is generally flat with some 1–2 m ledges and boulders. The South Daytona site, established in fall 2014, has somewhat higher relief and greater depth than the original Daytona site. The area is exposed to occasional south swell. The prevailing wind blows offshore, so wind waves are usually small. The original Daytona site (northern 50 m) first became a purple urchin barren in the mid-1990s. After a few years, it returned to an algal-dominated state but again changed to an urchin barren soon after. Since that time, it has retained patches of urchin-dominated areas intermixed with patches of kelp-dominated areas (fig. 7). Moderate to high fish densities are typical here. In the early 1980s, there was considerable sand movement in this area probably resulting from the old barge landing operation, which prior to construction of the pier, required heavy equipment to move beach sand to enable vehicles to drive off the barge. Sand movement is less apparent now since completion of the pier in 2005.

Trip Conditions and Accomplishments

The fall 2017 trip took place October 7–12. Light to moderate winds and swell prevailed throughout the trip. Dive conditions were generally good with moderate surge and visibility from 7 to 10 m, but conditions at West End included strong surge associated with large swell and poor visibility (ranging from 3 to 5 m). Water temperatures for the trip were about 16–17 °C. We completed all sampling at the four supersites and downloaded and redeployed the TidbiT® archival temperature logger at each. The *Macrocystis* surface canopy was dense at the West End supersite, sparse at Nav Fac 100 and moderate at the other sites.

The spring 2018 sampling was conducted April 2–5. We had calm, overcast topside conditions. Visibility was better than average, ranging from about 10 to 13 m. Water temperature ranged from about 12 to 13 °C. We were again able to complete all sampling at the four supersites, download and redeploy the temperature loggers, as well as replace some missing marker eyebolts at the sites. Surface kelp canopies were absent at Nav Fac 100, moderate at Daytona 100, and dense at West End and Dutch Harbor.

Figure 7. Daytona 100 supersite, April 2018, showing urchin dominated and kelp dominated areas and male sheephead (captured from video by Shannon Myers).

Results

Island-Wide

In year 4 (fall 2017 and spring 2018), sea temperatures appeared cooler than those recorded in 2015 and 2016, but the range recorded (10–20 °C) was larger than in most previous years (fig. 8). Temperature data recorded at three of the supersites from fall 2014 until spring 2018 and at Nav Fac 100 from fall 2015 until spring 2018 are shown in figure 9 (the temperature logger at Nav Fac 100 was lost and not replaced until fall 2015). As in past years, late spring and early summer temperatures fluctuated on the order of 5 °C during an hour or two, possibly owing to cold water upwelling; this was particularly apparent at Dutch Harbor, perhaps because of its high bottom relief or the proximity of deep water at that site.

There was a slight increase in purple urchin density at Nav Fac 100, West End, and Dutch Harbor in year 4, but no destructive grazing was observed at these supersites. Nav Fac 100 continued its recovery from an urchin to a kelp dominated state. At this location, purple urchin numbers decreased substantially in 2015 after nearly 25 years of overgrazing, and the site has since supported more macroalgae. This year, *M. pyrifera* densities were low in the spring, but *P. californica* counts recovered, and *C. osmundacea* numbers reached all-time highs. The invasive brown alga *S. horneri* returned in high numbers in spring 2018. West End continued as the most macroalgal dominated supersite, although the cover of fleshy red algae declined somewhat there. Dense *M. pyrifera* surface canopy returned there in fall 2017 (fig. 10). Dutch Harbor, historically most-stable of the supersites, remained relatively unchanged. Finally, Daytona 100 continued on as a hodgepodge of urchin and kelp dominated areas. *Strongylocentrotus purpuratus* densities remained high there, particularly at the northern subunit, and large patches remained free of fleshy algae.

The invasive brown alga *S. horneri* was first observed in California in 2003 and at Catalina Island 3 years later (Miller and others, 2007). By the spring of 2015, it had been observed at five of the Channel Islands and at several areas along the California coast from Santa Barbara south to Isla Natividad in Baja California (Marks and others, 2015). It was first seen at SNI in low numbers at Nav Fac 100 in fall 2015 (Kenner, 2016) and has been recorded on every subsequent visit there. In spring 2017, and again in spring 2018, high densities of reproductive plants were present (fig. 11), but our data do not show much change in numbers or distribution. *Sargassum horneri* has not been observed at any of the other SNI monitoring sites.

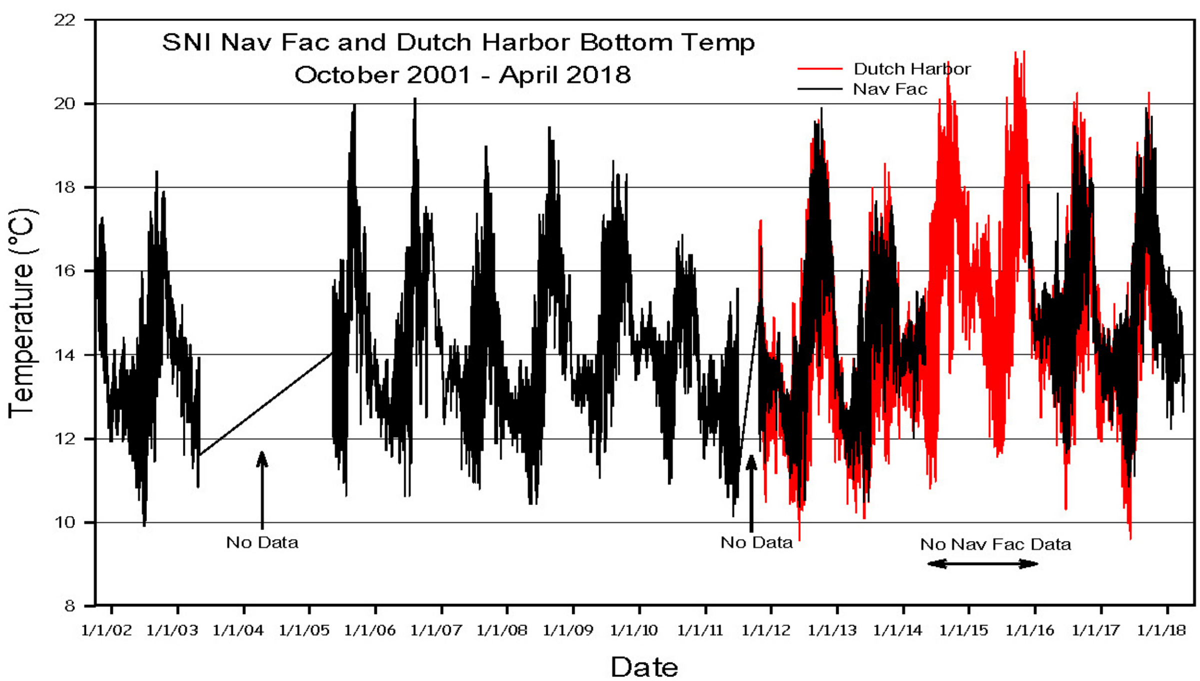

Figure 8. Fifteen-year temperature record from subtidal readings at San Nicolas Island subtidal sites. Hourly temperature data from Nav Fac at 12-meter (m) depth from October 2001–April 2018 (in black)—but note periods of missing data—and East Dutch Harbor (in red) at 11-m depth from October 2011–April 2018.

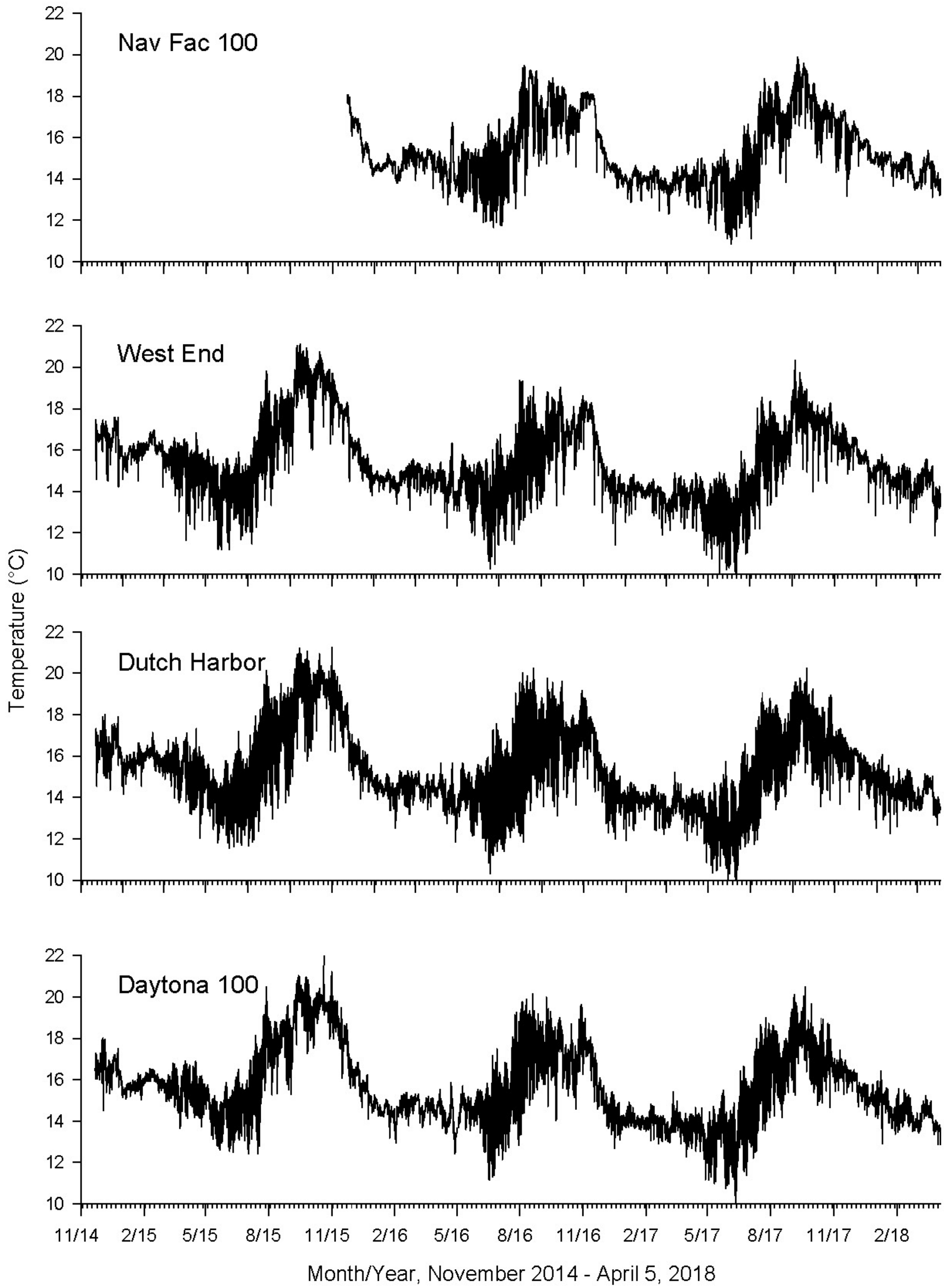

Figure 9. Hourly bottom temperature data for Nav Fac 100 from November 22, 2015–April 5, 2018, and the other three supersites from November 22, 2014–April 5, 2018.

Figure 10. Dense *Macrocystis pyrifera* surface canopy at West End site, October 2017 (photo by Zach Randell).

Figure 11. Expansive view of the invasive alga *Sargassum horneri* at Nav Fac 100 site, April 2018 (captured from video by Shannon Myers).

No abalone (*Haliotis* spp.) were counted in year 4 at any of the sites, and only five have been counted since 2002 (four *H. rufescens* and one *H. corrugata*). Prior to the mid-1990s, island-wide total abalone counts of both species at the original six USGS sites were usually in the teens to low twenties. Although the timing of their decline corresponded with the decimation of the intertidal black abalone population on SNI by withering syndrome (VanBlaricom and others, 1993), the disease was not observed in subtidal habitats at SNI, and fishing pressure or other factors may have contributed to the decline. Although sea otters could have played a part in the decline of *H. rufescens* and *H. corrugata*, sea otter numbers and distribution at the time make that unlikely.

Sea star numbers were still low, apparently as a result of sea star wasting syndrome (SSWS). The bat star (*Patiria miniata*), however, continued to increase at most sites from low densities recorded in 2016 and by the last sampling trip had reached the median density for counts since 1980 (2.29 per 20-m^2 swath). The giant sea star (*Pisaster giganteus*) was the only other asteroid counted. Although their density was higher in spring 2018 than in the previous 4 years, it was still only about 5 percent of the long-term average. No sign of SSWS or of sea star recruitment was observed.

During the two trips in year four, divers estimated the sizes of 5,747 fish and counted 8,593. Both trips yielded lower total fish counts than those from the last few years. The fall 2017 total of 3,688 was less than the long-term average of 4,410, but the spring 2018 count of 4,905 exceeded it. Table 6 shows minimum, maximum, and mean size and the number of fishes sized for each species, pooled from all the sites in fall 2017, and table 7 shows these data for spring 2018. As usual, two schooling species, blacksmith (*Chromis punctipinnis*) and señorita (*Oxyjulius californica*), comprised most of these counts.

There was no recruitment of sheephead (*S. pulcher*) observed at the sites in year 4. An important predator on sea urchins, but targeted by sport anglers, sheephead typically only recruit to SNI during warm water years (Cowen, 1985). Estimated sizes of all sheephead from around the island during the 4-year period are plotted by sex in figure 12. This figure shows recruitment during the first few surveys when warm water (averaging about 16.5 °C and reaching above 21.0 °C) was prevalent. In fall 2017 and spring 2018, there were no individuals <10 cm, and no juveniles were recorded. This is consistent with a return to cooler water conditions.

Kelp bass (*Paralabrax clathratus*) also recruited in fall 2014–fall 2015 (fig. 13). The size structure of the island-wide population has remained stable throughout the last three periods.

Table 6. Summary of fall 2017 fish size estimates (total length, centimeters) for all sites combined.

[Schooling fish were typically recorded in size-bins and the midpoints of bins were used for these calculations. **Abbreviations**: f, female; m, male]

Species name	Common name	Minimum size	Maximum size	Mean size	Number sized
Atherinops affinis	Topsmelt	15	22.5	18.8	120
Brachyistius frenatus	Kelp perch	10	29	18.2	5
Caulolatilus princeps	Ocean whitefish	27	45	35.1	8
Chromis punctipinnis	Blacksmith	2.5	25	13.0	780
Coryphopterus nicholsii	Blackeye goby	5	11	8.3	11
Embiotoca jacksoni	Black perch	9	35	16.7	72
Embiotoca lateralis	Striped seaperch	10	29	19.2	11
Girella nigricans	Opaleye	20	50	32.6	64
Halichoeres semicinctus	Rock wrasse	16	16	16.0	1
Hypsurus caryi	Rainbow seaperch	12	20	15.2	13
Hypsypops rubicundus	Garibaldi	12	27	18.8	25
Medialuna californiensis	Halfmoon	17	29	22.1	43
Mycteroperca xenarcha	Broomtail grouper	61	61	61.0	1
Neoclinus spp.	Fringehead	15	15	15.0	1
Oxyjulis californica	Señorita	7.5	17.5	11.9	644
Oxylebius pictus	Painted greenling	8	25	13.7	19
Paralabrax clathratus	Kelp bass	11	45	24.7	96
Rhacochilus toxotes	Rubberlip seaperch	30	35	32.5	2
Rhacochilus vacca	Pile perch	15	38	28.0	6
Sebastes atrovirens	Kelp rockfish	9	25	16.7	26
Sebastes auriculatus	Brown rockfish	28	28	28.0	1
Sebastes chrysomelas	Black and yellow rockfish	11	24	18.2	5
Sebastes mystinus	Blue rockfish	7.5	30	17.2	155
Sebastes serranoides	Olive rockfish	9	40	24.7	36
Sebastes serriceps	Treefish	12	24	17.7	3
Semicossyphus pulcher (f)	California sheephead (f)	10	60	28.9	113
Semicossyphus pulcher (m)	California sheephead (m)	50	80	63.3	16
Stereolepis gigas	Giant sea bass	150	150	150.0	1
Total Sized	—	—	—	—	2,278

Table 7. Summary of spring 2018 fish size estimates (total length, centimeters) for all sites combined.

[Where a range of sizes was recorded for schooling fish, the midpoint of the range was used for these calculations. **Abbreviations**: f, female; m, male]

Species name	Common name	Minimum size	Maximum size	Mean size	Number sized
Brachyistius frenatus	Kelp perch	10	15	12.6	10
Chromis punctipinnis	Blacksmith	2.5	17.5	10.0	1,046
Coryphopterus nicholsii	Blackeye goby	6	12	9.3	13
Embiotoca jacksoni	Black perch	10	29	17.9	58
Embiotoca lateralis	Striped seaperch	13	30	19.1	13
Girella nigricans	Opaleye	20	38	29.5	5
Halichoeres semicinctus	Rock wrasse	16	25	20.5	2
Hypsurus caryi	Rainbow seaperch	12	20	15.4	6
Hypsypops rubicundus	Garibaldi	16	25	19.8	15
Medialuna californiensis	Halfmoon	18	35	27.8	7
Oxyjulis californica	Señorita	2.5	17.5	8.0	1,857
Oxylebius pictus	Painted greenling	10	15	12.5	10
Paralabrax clathratus	Kelp bass	8	40	23.1	53
Rhacochilus vacca	Pile perch	16	42	28.4	5
Sebastes atrovirens	Kelp rockfish	13	26	18.9	16
Sebastes carnatus	Gopher rockfish	40	40	40.0	1
Sebastes mystinus	Blue rockfish	8	35	19.3	102
Sebastes rastrelliger	Grass rockfish	30	35	32.5	2
Sebastes serranoides	Olive rockfish	15	41	27.7	57
Sebastes serriceps	Treefish	9	9	9.0	1
Semicossyphus pulcher (f)	California sheephead (f)	12	65	29.6	147
Semicossyphus pulcher (m)	California sheephead (m)	30	75	57.1	42
Stereolepis gigas	Giant sea bass	150	150	150	1
Total Sized	—	—	—	—	3,469

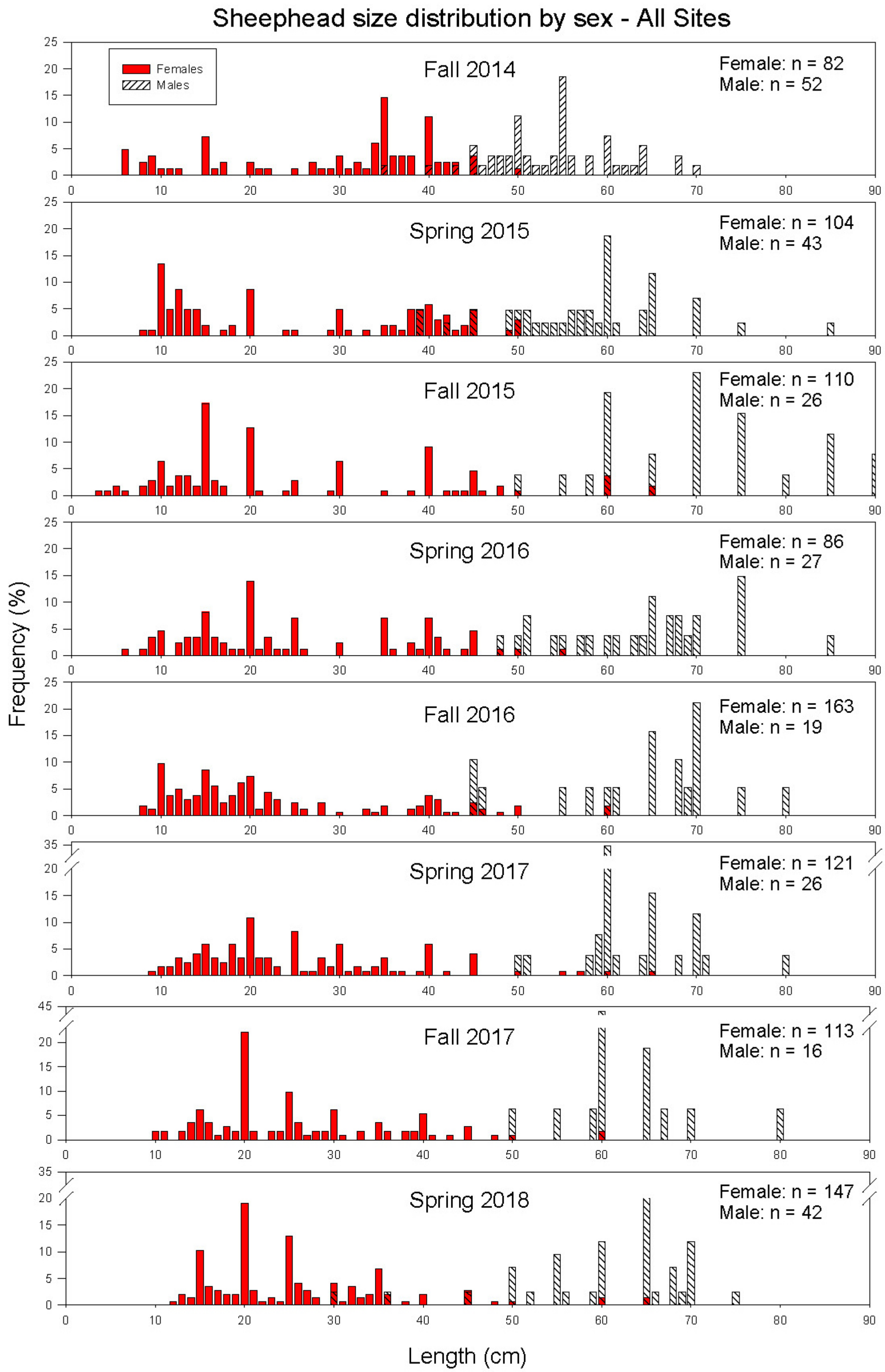

Figure 12. Size distribution by sex of sheephead (*Semicossyphus pulcher*), fall 2014–spring 2018.

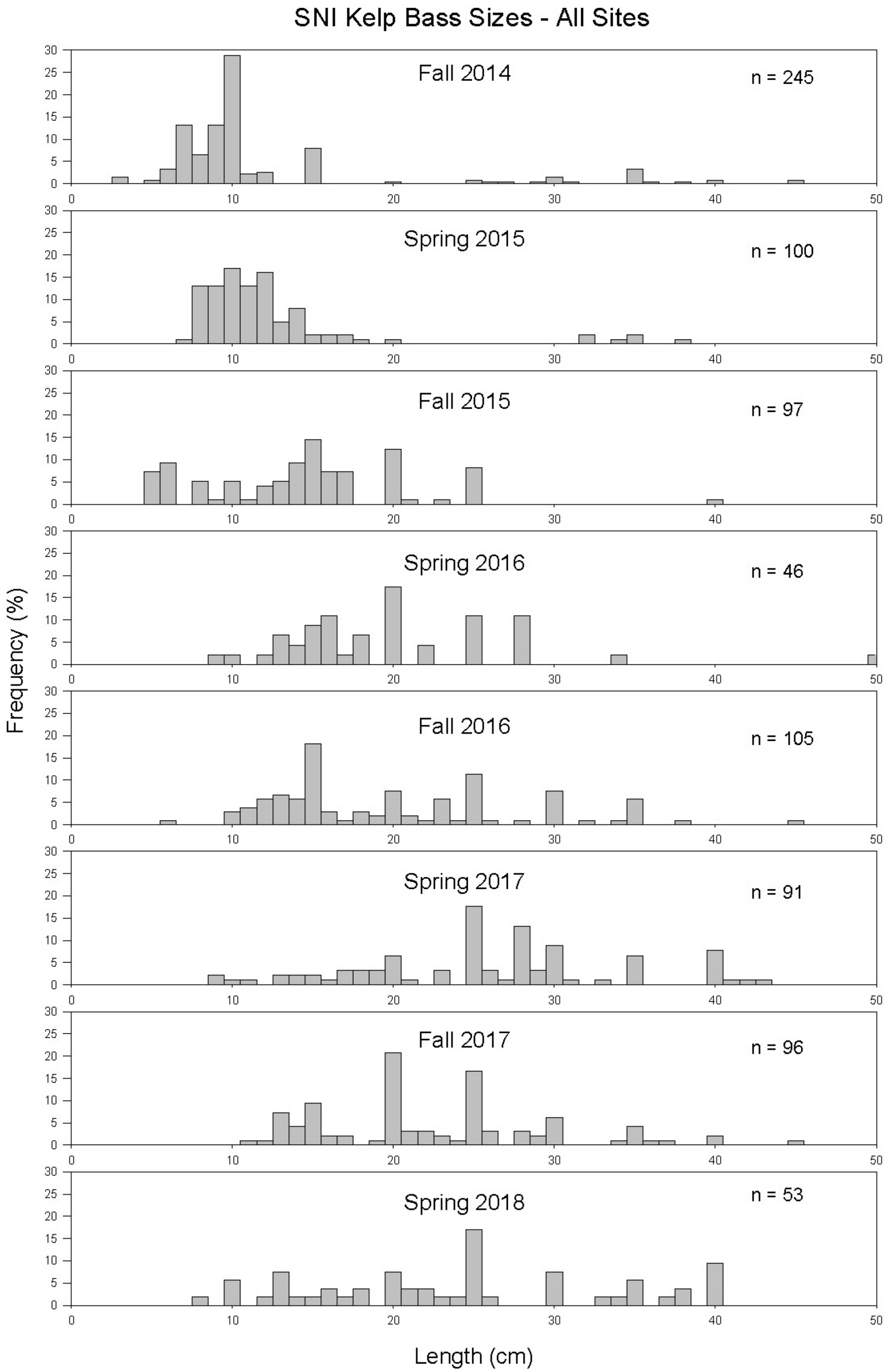

Figure 13. Size distribution of kelp bass (*Paralabrax clathratus*), fall 2014–spring 2018.

Nav Fac 100

Nav Fac 100 continued its recovery from an urchin to a kelp dominated state. Purple urchin numbers declined substantially there in 2015 (table 8) after nearly 25 years of overgrazing, and the supersite has since been supporting more macroalgae. Although *M. pyrifera* densities were low in the spring, *P. californica* counts recovered. *Cystoseira osmundacea* numbers reached all-time highs, and again it was the most common organism counted on swaths. Spring counts of the invasive algae *S. horneri* returned in high numbers in 2018, but not much higher than in 2017 (fig. 11). The numbers counted on swaths increased from 699 in spring 2017 to 775 in spring 2018. The number of swaths on which it was counted increased from eight to nine. Numbers of *S. purpuratus* increased during year 4 but remained well below 2015 counts. They were the second most common swath-counted organism. The red urchin (*S. franciscanus*), although at much lower numbers, showed a similar trend. Counts of the wavy turban snail (*Megastraea undosa*) were again higher this year. Table 8 shows the mean and standard deviation of swath counted organisms for this site in fall 2014 through spring 2018.

Figures 14 and 15 show the number of stipes and the holdfast diameters of each *M. pyrifera* counted on Nav Fac 100's permanent swaths for the last eight sampling periods. Both metrics indicate there was good survival of plants over the summer from spring 2017 to fall 2017 as well as a small amount of recruitment. There was poor survival and very little recruitment apparent between fall 2017 and spring 2018, and loss of larger plants with holdfasts >20 cm was about 94 percent over the winter.

A summary of the invertebrate sizes measured on swaths during the last eight sampling trips is presented in table 9. Most of these species were not common enough to result in useful numbers of measurements. The small sample sizes make any generalizations about most of them difficult. In contrast, the number of wavy turban snails (*M. undosa*), which has continued to increase at the site since urchins declined there, more than doubled between spring and fall 2017. Their counts were down somewhat in spring 2018, but still higher than the previous spring. Their size structure (fig. 16) indicates that most of the fall 2017 increase was in the portion of the population in the 40–60 mm shell diameter size range. The subsequent decline is not attributable to any size class, but it appears that there were a few smaller (20–30 mm) individuals entering the population.

After five periods of relatively constant low numbers, there was a significant increase in the density of purple sea urchins (*S. purpuratus*) in the spring 2018, but they remained at about one-third the density measured in spring 2015. Their size distribution showed little change in the last two sampling periods other than a slight increase in the proportion of individuals <25 mm (fig. 17). Though there was a slight increase in the density of *S. franciscanus* over the last year, their size distribution changed little other than the loss of most individuals >100 mm in test diameter (fig. 18).

The mean numbers of organisms counted in 1-m^2 quadrats are shown in table 10. The orange puffball sponge (*T. aurantia*) continued to be present at low but consistent densities. The invasive brown alga *S. horneri* declined somewhat, showing a slightly different trend than that in the swath counts. Total counts in quadrats declined from a total of 130 in spring 2017 to 83 in spring 2018, but the number of quadrats in which *S. horneri* was found remained the same, at 11 of 20 sampled. Additionally, the number of cover points scored was almost identical for these two periods (93 and 95 respectively), apparently resulting from somewhat more robust plants at lower density.

Data collected from RPC quadrats are summarized in figure 19 as categories of cover species at the different supersites over time. Nav Fac 100 was still higher in "bare" cover than the other sites, but the trend since urchin densities fell in spring 2015 was toward less exposed bare rock. Conversely, the cover that was due to various brown algae (*Dictyota binghamiae*, *Dictyopteris undulata*, *C. osmundacea*, *Taonia lennabackerae*, and *S. horneri*) increased. In the springs of 2017 and 2018, *S. horneri* was the third highest cover species behind encrusting coralline algae and *D. binghamiae* (table 11). The sand castle worm (*Phragmatopoma californica*) replaced the scaled tube snail (*S. squamiger*) as the most common invertebrate cover.

Nav Fac 100 continued to have the least number of fish species of any of the supersites, but the densities of fish exceeded those measured at West End (table 12). The schooling species señorita (*O. californica*) and blacksmith (*C. punctipinnis*) made up most of the count, but kelp bass (*P. clathratus*) and sheephead (*S. pulcher*) are regular members of the fish assemblage at the site (table 13). A giant sea bass (*Stereolepis gigas*) was observed here in spring 2017 and spring 2018.

Table 8. Nav Fac 100 mean (standard deviation) swath counts for fall 2014 through spring 2018 expressed as individuals per 20 square meters (m²).

[>, greater than; m. meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Aplysia californica	0.3 (0.48)	2.4 (2.41)	0 (0.00)	0.8 (1.03)	1.3 (2.26)	0 (0.00)	0.7 (1.64)	0 (0.00)
Astrometis sertulifera	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Crassadoma gigantea	0 (0.00)	0 (0.00)	0.6 (1.07)	0 (0.00)	0.1 (0.32)	0.3 (0.67)	0.3 (0.95)	0.5 (0.85)
Cystoseira osmundacea	30.1 (52.18)	18.2 (30.33)	56.4 (82.24)	101.2 (117.87)	75.6 (61.55)	76.5 (80.20)	127.7 (122.83)	188.4 (125.3)
Dermasterias imbricata	0.1 (0.32)	0.1 (0.32)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Eisenia arborea	1.7 (3.09)	0.7 (1.06)	1.3 (2.00)	2.7 (5.74)	3.7 (2.98)	3.7 (3.68)	4 (4.08)	2.1 (3.18)
Haliotis corrugata	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Haliotis rufescens	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Kelletia kelletii	0.3 (0.48)	0.3 (0.67)	4.1 (6.72)	0.6 (0.97)	0.5 (1.08)	1.2 (1.40)	0.9 (1.29)	5.7 (4.3)
Laminaria spp.	1.2 (3.79)	0.5 (1.58)	0 (0.00)	1.6 (1.35)	0.3 (0.67)	0.4 (0.70)	15.4 (14.88)	0.4 (0.7)
Lytechinus anamesus	1.9 (4.09)	0 (0.00)	0.2 (0.42)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Macrocystis pyrifera <1 m	2.1 (3.11)	0.1 (0.32)	0.4 (1.26)	5.2 (4.47)	2.7 (1.95)	5.6 (11.02)	5.7 (7.53)	0.1 (0.32)
Macrocystis pyrifera >1 m	1.6 (3.72)	0.8 (1.87)	0.5 (1.27)	3.7 (4.60)	9 (8.04)	5.7 (5.56)	6.1 (3.28)	0.9 (0.99)
Megastraea undosa	1.6 (2.01)	2.8 (2.25)	9.3 (10.20)	9.1 (7.50)	10.8 (9.40)	15.4 (9.12)	37 (16.61)	26.5 (15.41)
Megathura crenulata	0.1 (0.32)	0.2 (0.42)	0.6 (1.58)	0.1 (0.32)	0 (0.00)	0 (0.00)	0 (0.00)	0.1 (0.32)
Parastichopus parvimensis	0.2 (0.42)	0.8 (1.32)	1.3 (1.57)	0.6 (0.97)	0.2 (0.42)	0.1 (0.32)	0.2 (0.42)	0 (0.00)
Patiria miniata	1 (1.33)	0.6 (0.84)	0.3 (0.67)	0.1 (0.32)	0.1 (0.32)	0.1 (0.32)	0.1 (0.32)	0 (0.00)
Pisaster giganteus	0 (0.00)	0.1 (0.32)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0.2 (0.63)
Pterygophora californica	9.6 (18.47)	7.3 (22.04)	1.2 (3.79)	1.4 (3.44)	0.6 (1.35)	1.1 (1.60)	7.9 (10.51)	28.9 (27.7)
Pycnopodia helianthoides	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Sargassum horneri	0 (0.00)	0 (0.00)	0.7 (0.95)	0.5 (0.85)	18.3 (41.15)	69.9 (90.31)	19.8 (30.56)	77.5 (98.63)

Table 8. Nav Fac 100 mean (standard deviation) swath counts for fall 2014 through spring 2018 expressed as individuals per 20 square meters (m^2).—Continued

[>, greater than; m. meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Strongylocentrotus franciscanus	12.4 (21.48)	11 (11.03)	7.9 (22.22)	6.3 (14.77)	5.5 (17.39)	4.9 (11.36)	7 (18.7)	9.1 (20.94)
Strongylocentrotus purpuratus	680.1 (383.40)	447.1 (362.63)	70.1 (41.37)	40.9 (42.96)	30.5 (42.20)	53.4 (44.54)	59.4 (44.12)	147.3 (109.35)
Tethya aurantia	5.1 (3.67)	3.7 (2.16)	2.5 (2.01)	2.9 (2.13)	3.9 (3.25)	2.9 (1.73)	3.3 (2.45)	3 (2.36)
Urticina lofotensis	0.2 (0.42)	2 (2.11)	0 (0.00)	0.1 (0.32)	0 (0.00)	0 (0.00)	0.4 (0.52)	0 (0.00)
Young Laminariales	0.7 (1.64)	0.3 (0.67)	0.1 (0.32)	2.6 (5.32)	0.8 (1.55)	12.1 (19.34)	4.5 (4.79)	5.5 (3.92)

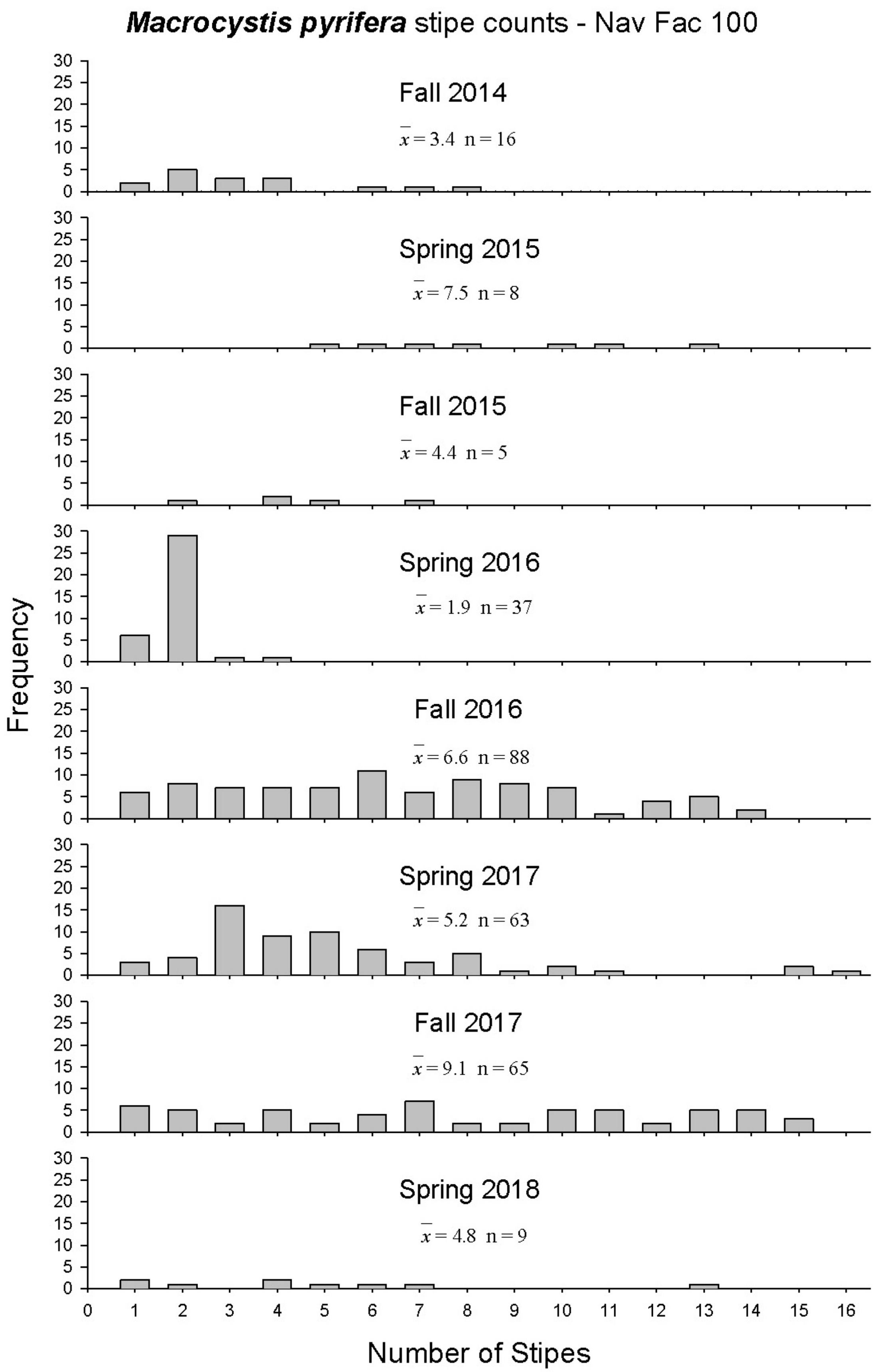

Figure 14. Nav Fac 100 *Macrocystis pyrifera* stipe counts by season, fall 2014–spring 2018.

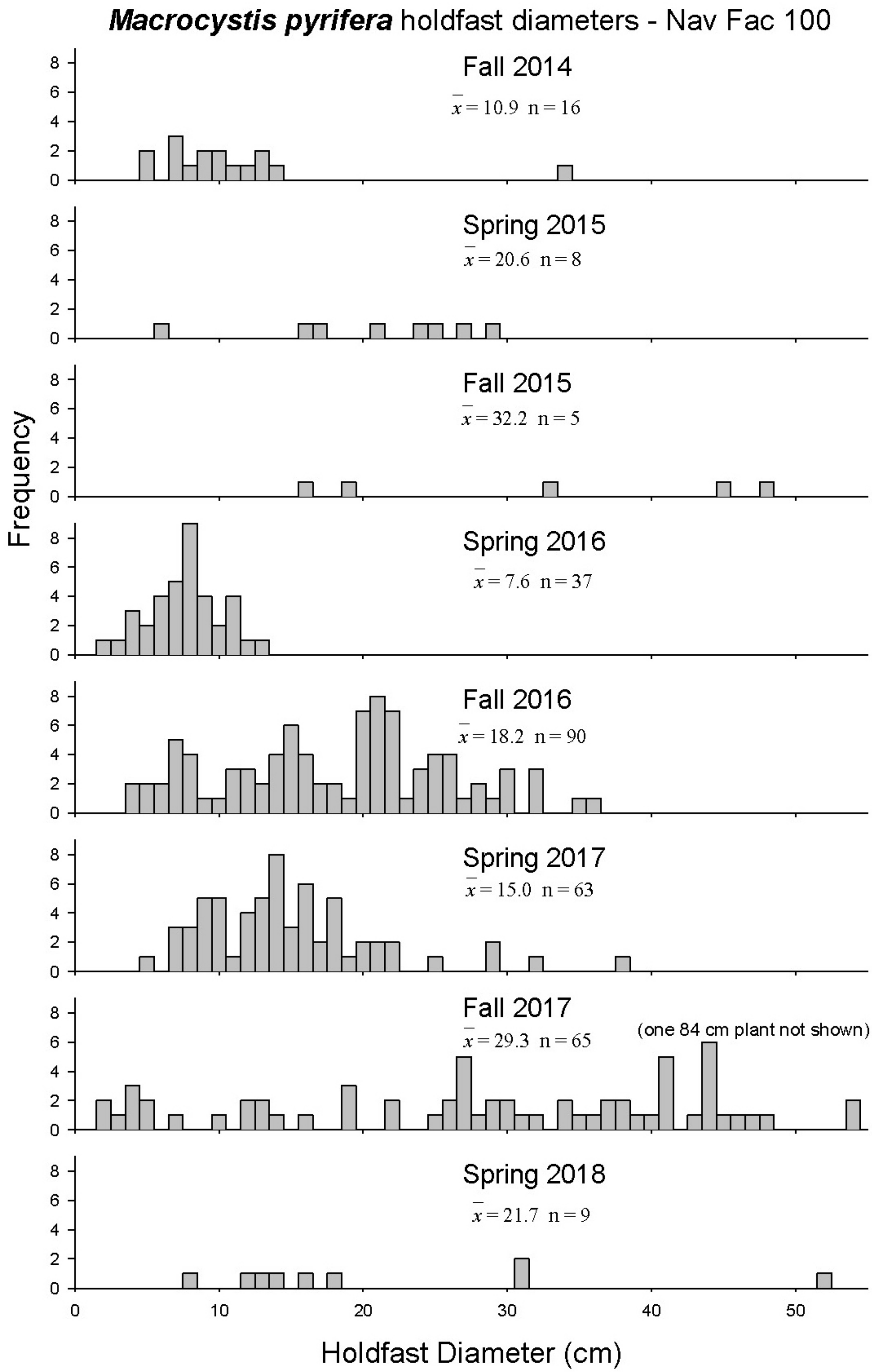

Figure 15. Nav Fac 100 *Macrocystis pyrifera* holdfast diameters by season, fall 2014–spring 2018.

Table 9. Sizes of non-echinoid invertebrates measured on swaths at Nav Fac 100, fall 2014 through spring 2018.

[Strongylocentrotus spp. excluded. See figures 17 and 18 for red and purple urchin size data. **Abbreviations**: N, sample size; —, no data; Min, minimum; Max, maximum]

Size	Species name							
	Crassadoma gigantea	***Dermasterias imbricata***	***Kelletia kelletii***	***Lytechinus anamesus***	***Megastraea undosa***	***Megathura crenulata***	***Patiria miniata***	***Pisaster giganteus***
				Fall 2014				
N	0	1	3	0	16	1	11	0
Min	—	80	30	—	15	52	60	—
Max	—	80	130	—	100	52	109	—
Mean	—	80.0	63.3	—	54.7	52.0	74.5	—
				Spring 2015				
N	0	1	4	0	28	2	6	1
Min	—	52	103	—	22	100	60	180
Max	—	52	150	—	170	180	90	180
Mean	—	52.0	123.5	—	83.1	140.0	70.0	180.0
				Fall 2015				
N	6	0	41	2	98	1	3	0
Min	19	—	6	8	14	112	60	—
Max	130	—	55	13	130	112	72	—
Mean	57.2	—	28.0	10.5	55.3	112.0	64.7	—
				Spring 2016				
N	0	0	6	0	92	1	1	0
Min	—	—	20	—	18	72	30	—
Max	—	—	40	—	115	72	30	—
Mean	—	—	31.7	—	52.9	72.0	30.0	—
				Fall 2016				
N	1	0	5	0	108	0	1	0
Min	77	—	40	—	18	—	120	—
Max	77	—	124	—	108	—	120	—
Mean	77.0	—	59.4	—	47.8	—	120.0	—
				Spring 2017				
N	1	0	15	0	155	0	1	0
Min	60	—	11	—	15	—	27	—
Max	60	—	130	—	101	—	27	—
Mean	60.0	—	57.9	—	50.1	—	27.0	—
				Fall 2017				
N	3	0	9	0	370	0	1	0
Min	48	—	32	—	26	—	70	—
Max	70	—	138	—	114	—	70	—
Mean	58.0	—	68.0	—	54.3	—	70.0	—
				Spring 2018				
N	5	0	57	0	265	1	0	2
Min	42	—	18	—	22	51	—	70
Max	75	—	135	—	99	51	—	80
Mean	57.6	—	58.5	—	52.0	51.0	—	75.0

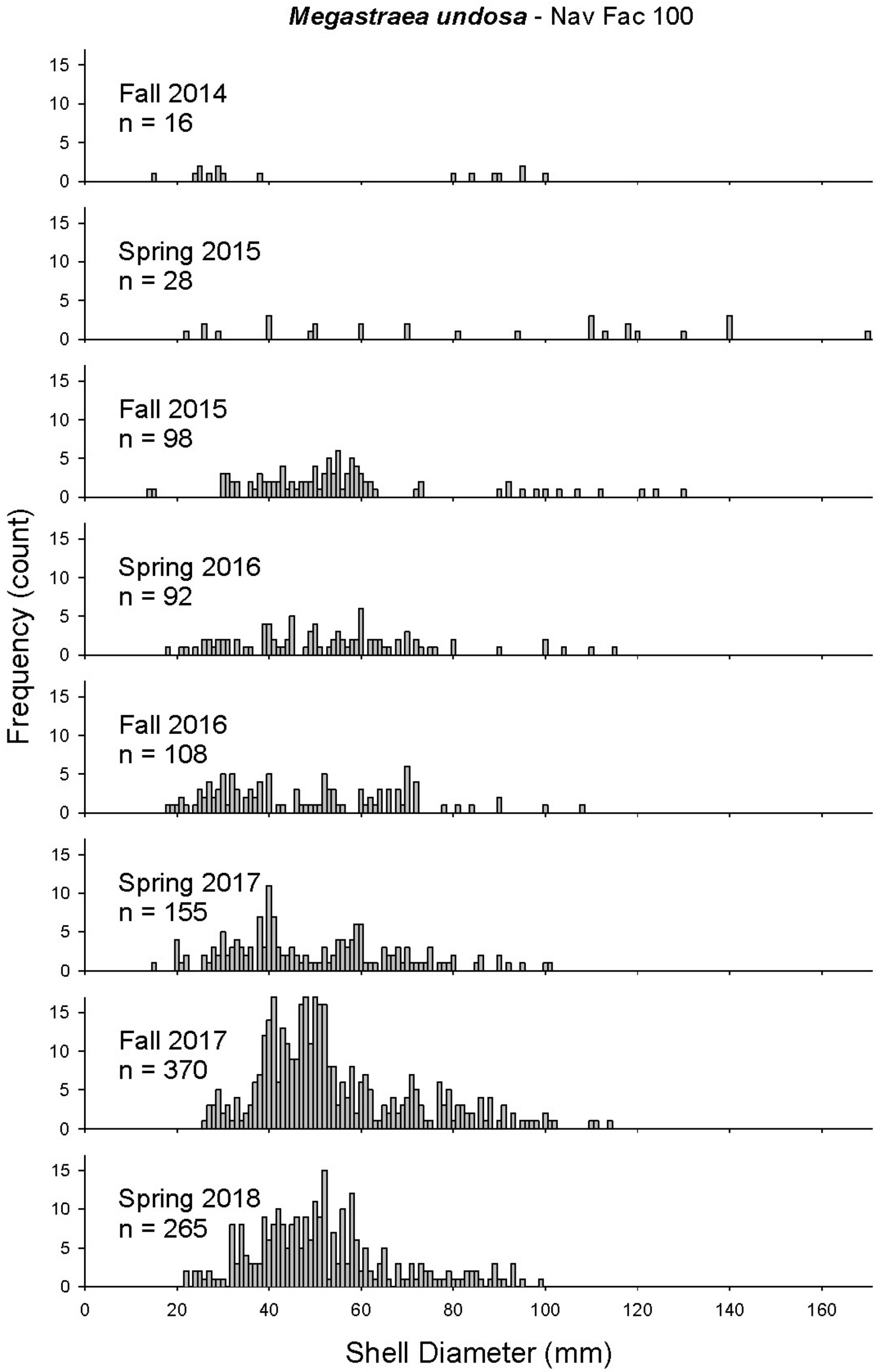

Figure 16. Nav Fac 100 size structure of wavy turban snails (*Megastraea undosa*) in fall 2014 through spring 2018.

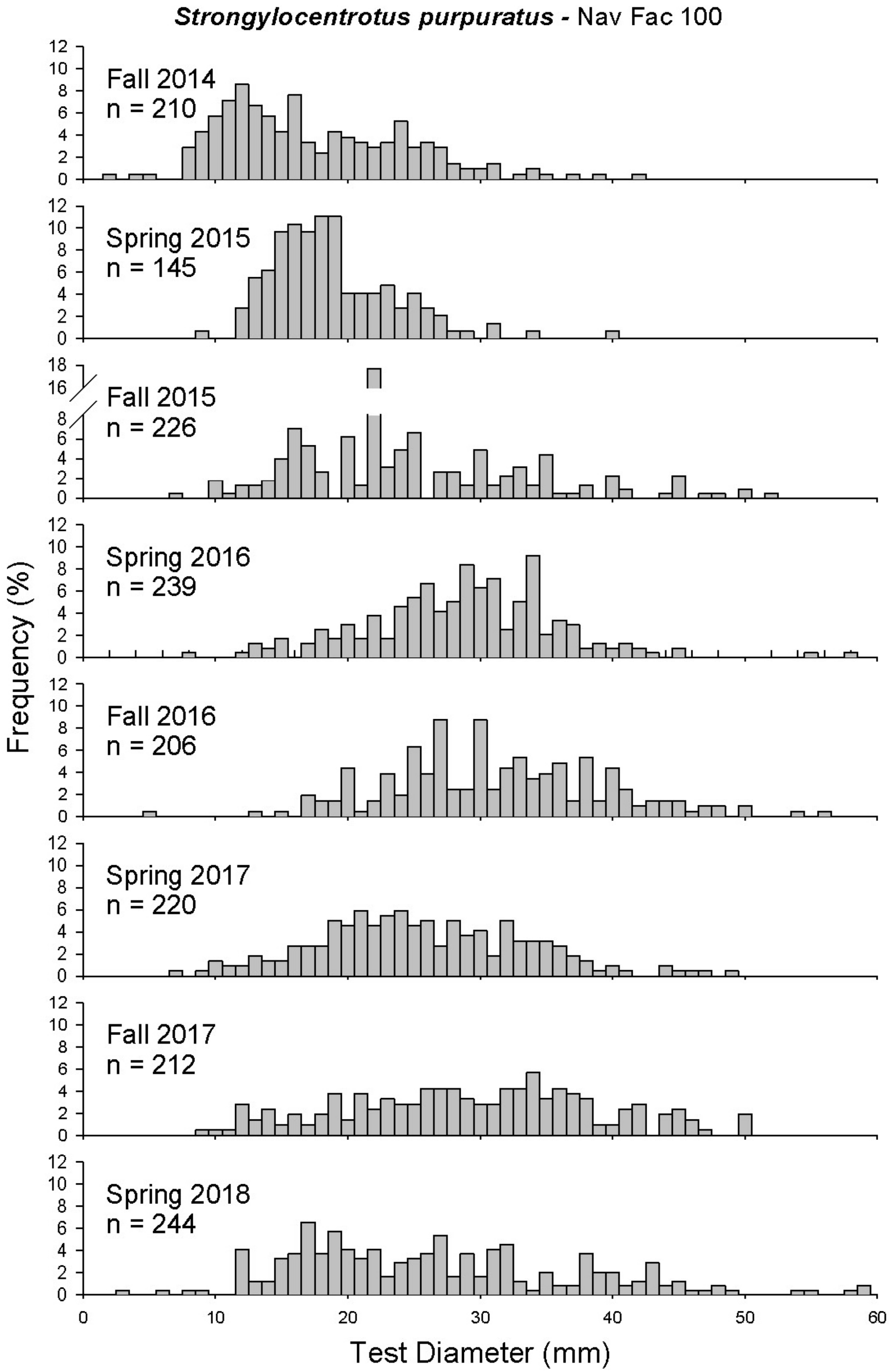

Figure 17. Nav Fac 100 size structure of purple urchins (*Strongylocentrotus purpuratus*) in fall 2014 through spring 2018.

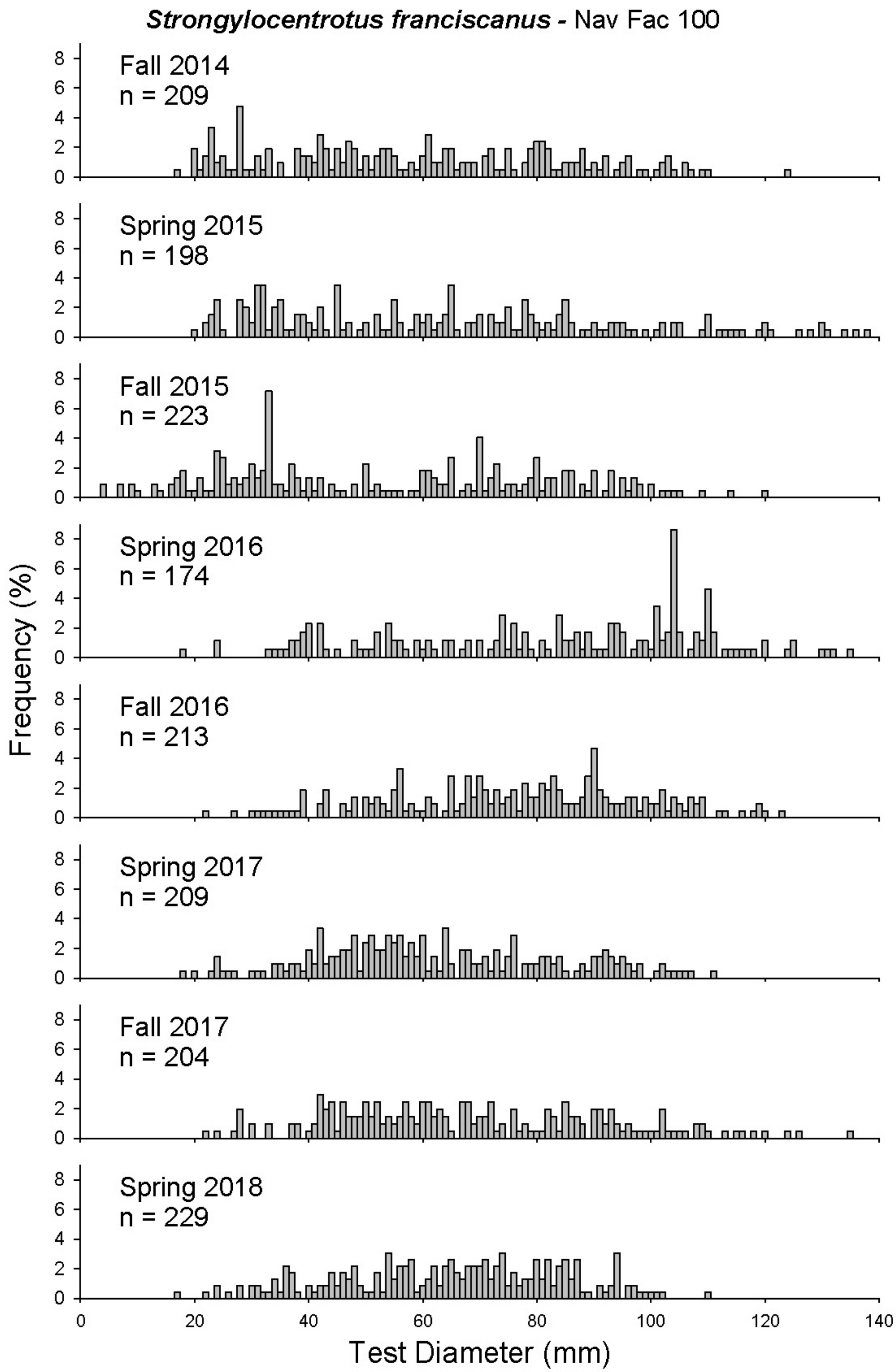

Figure 18. Nav Fac 100 size structure of red urchins (*Strongylocentrotus franciscanus*) in fall 2014 through spring 2018.

Table 10. Nav Fac 100 mean (and standard deviation) of twenty 1-square-meter (m^2) quadrat counts for fall 2014 through spring 2018.

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Astraea gibberosa	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Cypraea spadicea	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0.1 (0.22)	0.1 (0.22)	0.1 (0.22)
Kelletia kelletii	0 (0.00)	0 (0.00)	0.3 (0.80)	0 (0.00)	0.1 (0.31)	0.1 (0.45)	0 (0.00)	0.1 (0.22)
Norrisia norrisi	0 (0.00)	0 (0.00)	0 (0.00)	0.2 (0.49)	0.1 (0.22)	0.1 (0.31)	0 (0.00)	0.2 (0.37)
Sargassum horneri	0 (0.00)	0 (0.00)	0.05 (0.22)	0 (0.00)	4.7 (11.78)	6.5 (10.02)	3.3 (6.73)	4.2 (5.35)
Styela montereyensis	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0.2 (0.49)	0.1 (0.22)	0 (0.00)	0 (0.00)
Tegula regina	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Tethya aurantia	0.5 (0.69)	0.3 (0.55)	0.4 (0.59)	0.2 (0.52)	0.4 (0.67)	0.3 (0.44)	0.3 (0.44)	0.2 (0.37)
Urticina lofotensis	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0.2 (0.89)	0 (0.00)	0 (0.00)	0 (0.00)

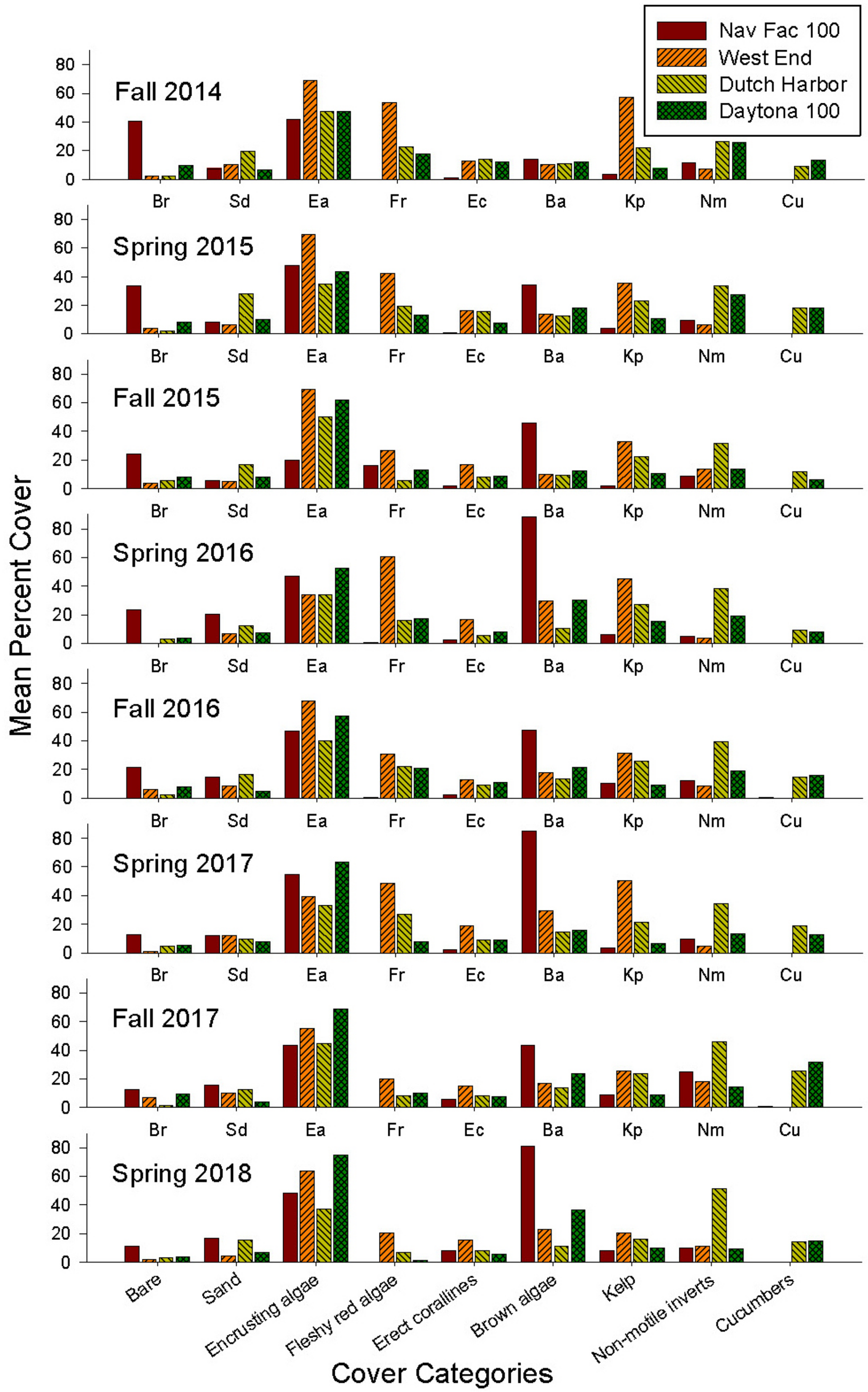

Figure 19. Mean percent cover category by supersite, fall 2014 through spring 2018. Categories are bare rock (Br), sand (Sd), encrusting algae (Ea), fleshy red algae (Fr), erect corallines (Ec), brown algae (Ba), kelp (Kp), non-motile invertebrates (Nm), and sea cucumbers (Cu).

Table 11. Nav Fac 100 point contact “species” for fall 2014 through spring 2018 by number of points.

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Encrusting coralline algae	164	191	79	186	182	218	172	193
Bare substratum	163	134	98	93	85	52	49	46
Dictyota binghamiae	36	33	7	135	70	126	99	111
Cystoseira osmundacea	11	18	39	77	57	68	67	88
Sand	30	34	22	82	60	48	62	67
Dictyopteris undulata	9	84	50	93	45	29	1	22
Sargassum horneri	0	0	1	0	8	93	3	95
Phragmatopoma californica	0	0	0	0	11	21	57	20
Unidentified brown algae	0	0	77	0	0	0	0	0
Serpulorbis squamiger	12	10	9	6	13	8	11	7
Pterygophora californica	7	9	5	17	9	5	9	12
Corallina officinalis	4	2	7	6	7	7	16	23
Filamentous red algae	0	1	63	0	0	0	0	0
Taonia lennebackerae	0	2	0	33	0	23	1	1
Barnacle	23	15	2	0	0	0	0	0
Kelp holdfast	0	0	1	0	10	2	14	6
Mucus tube polychaete	0	2	20	0	9	0	0	0
Eisenia arborea	5	4	0	2	4	4	1	6
Pink encrusting bryozoan	0	0	0	0	2	2	18	3
Macrocystis pyrifera >1 m	0	0	0	0	14	1	7	2
Sargassum muticum	0	0	7	4	8	0	0	1
Astrangia lajollaensis	4	3	0	0	1	3	4	2
Calliarthron spp.	1	0	0	3	2	1	2	7
Laminaria spp.	1	1	1	3	2	1	4	2
Zonaria farlowii	0	0	3	0	1	1	2	6
Encrusting red algae	3	0	0	3	5	0	1	0
Diopatra ornata	1	1	0	0	3	0	3	3
Filamentous brown algae	0	0	0	11	0	0	0	0
Orange encrusting sponge	2	2	1	3	1	0	1	0
Tethya aurantia	2	1	2	3	0	0	0	1
Bossiella spp.	0	1	0	1	0	0	5	2
Diatom film	8	0	0	0	0	0	0	0
Macrocystis pyrifera <1 m	0	1	2	2	1	1	0	1
Balanus spp.	0	0	0	7	1	0	0	0
Codium fragile	0	2	0	0	0	5	0	0
Pholad clam	0	3	0	0	2	1	0	0
Metandrocarpa dura	0	0	0	0	0	0	2	4
Balanophyllia elegans	2	1	1	0	1	0	0	0
Cryptopleura spp.	0	0	1	3	1	0	0	0
Young Laminariales	0	0	0	0	1	0	0	3
Spirobranchus spinosus	0	1	0	0	0	2	0	0
Cucumaria salma	0	1	0	0	0	0	1	0

Table 11. Nav Fac 100 point contact "species" for fall 2014 through spring 2018 by number of points.—Continued

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Cystodytes lobatus	0	0	0	0	1	1	0	0
Unidentified sponge	0	0	0	0	1	0	0	1
Archidistoma psammion	0	0	0	0	0	1	1	0
Lissothuria nutriens	0	0	0	0	0	0	2	0
Pterosiphonia spp.	0	0	1	0	0	0	0	0
Desmarestia ligulata	0	0	0	1	0	0	0	0
Halichondria spp.	0	0	0	1	0	0	0	0
Strongylocentrotus franciscanus	0	0	0	1	0	0	0	0
Anthopleura sola	0	0	0	0	1	0	0	0
Cucumaria fisheri	0	0	0	0	1	0	0	0
Eupentacta quinquesemita	0	0	0	0	1	0	0	0
Lagenocella spp.	0	0	0	0	1	0	0	0
Nienburgia andersoniana	0	0	0	0	1	0	0	0
Boltenia villosa	0	0	0	0	0	0	1	0
Laurencia pacifica	0	0	0	0	0	0	1	0
Stylantheca porphyra	0	0	0	0	0	0	1	0

Table 12. Number of fish species counted, total count, density on benthic and midwater transects, and number of fish sized at each supersite in fall 2014 through spring 2018.

[Densities are given in terms of area rather than volume because the volume of midwater transects is variable. **Abbreviation**: m^2, square meter]

Supersite	Number of species	Total count	Density			Number sized
			Overall / m^2	Benthic / m^2	Midwater / m^2	
Fall 2014						
Nav Fac 100	19	732	0.42	0.84	0.25	732
West End	22	4,022	1.15	1.15	1.15	4,022
Dutch Harbor	25	8,841	2.53	1.67	2.87	3,148
Daytona 100	20	3,592	2.05	1.70	2.19	3,592
Spring 2015						
Nav Fac 100	11	136	0.08	0.27	0.00	136
West End	13	958	0.27	0.05	0.36	958
Dutch Harbor	23	4,503	1.30	1.43	1.23	2,072
Daytona 100	20	990	0.57	0.89	0.44	990
Fall 2015						
Nav Fac 100	12	344	0.20	0.57	0.05	344
West End	17	2,677	0.76	1.41	0.51	2,677
Dutch Harbor	27	4,256	1.22	1.64	1.05	1,673
Daytona 100	17	738	0.42	0.81	0.27	738
Spring 2016						
Nav Fac 100	14	1,067	0.61	1.22	0.37	1,067
West End	17	1,447	0.41	0.26	0.47	1,447
Dutch Harbor	29	2,153	0.62	0.57	0.63	947
Daytona 100	15	336	0.19	0.31	0.15	336
Fall 2016						
Nav Fac 100	17	408	0.23	0.60	0.08	408
West End	18	1,253	0.36	0.81	0.18	1,253
Dutch Harbor	26	3,482	1.0	0.93	1.02	1,587
Daytona 100	18	759	0.43	0.46	0.42	759
Spring 2017						
Nav Fac 100	13	1,135	0.65	0.68	0.64	1,135
West End	17	1,196	0.34	0.43	0.31	1,196
Dutch Harbor	20	2,351	0.67	0.87	0.59	1,031
Daytona 100	15	1,556	0.89	0.68	0.97	1,556
Fall 2017						
Nav Fac 100	10	325	0.19	0.34	0.12	325
West End	18	303	0.09	0.22	0.03	303
Dutch Harbor	25	2,441	0.70	0.70	0.70	1,031
Daytona 100	22	619	0.35	0.48	0.30	619
Spring 2018						
Nav Fac 100	10	702	0.40	0.58	0.33	702
West End	17	653	0.19	0.30	0.14	653
Dutch Harbor	22	2,614	0.75	0.55	0.83	1,178
Daytona 100	15	936	0.53	1.33	0.22	936

Table 13. Nav Fac 100 fish counts—adult (juvenile)—in fall 2014 through spring 2018 by species.

[f, female; m, male]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Artedius spp.	0	1	0	0	0	0	0	0
Brachyistius frenatus	1	0	0	0	1	0	0	0
Caulolatilus princeps	3	0	2	0	0	0	0	0
Chromis punctipinnis	370	40	117 (53)	129	245	345	113	149
Coryphopterus nicholsii	57	1	5	0	4	1	3	9
Embiotoca jacksoni	12	7	4	7	3	11	9	0
Embiotoca lateralis	2	0	0	0	0	0	0	0
Galeorhinus galeus	0	0	0	1	0	0	0	0
Girella nigricans	3	1	2	1	25	1	2	0
Halichoeres semicinctus	0	0 (1)	0	0	1	0	0	1
Heterodontus francisci	0	0	0	0	0	1	0	0
Hypsurus caryi	5	0	0	0	6	0	0	0
Hypsypops rubicundus	1	1	2	1	8	6	4	1
Medialuna californiensis	0	0	35	16	3	1	37	1
Neoclinus spp.	0	0	0	0	1	0	0	0
Oxyjulis californica	119	68	45	864	57	721	116	484
Oxylebius pictus	8	2	0	1	0	0	1	0
Paralabrax clathratus	114	7	26 (16)	22	9	21	18	14
Rhacochilus vacca	4	0	5	0	1	0	0	1
Sebastes atrovirens	4	0	2	1	2	0	2	0
Sebastes chrysomelas	3	0	0	1	0	0	0	0
Sebastes mystinus	4	0	0	1	2	2	0	0
Sebastes rastrelliger	0	0	0	1	0	0	0	0
Sebastes serranoides	0	3	0	0	1	0	0	0
Sebastes serriceps	1	0	0	0	0	1	0	0
Semicossyphus pulcher (f)	17	2 (1)	23 (3)	15 (2)	32 (6)	21	20	35
Semicossyphus pulcher (m)	5	1	4	4	1	1	0	6
Stereolepis gigas	0	0	0	0	0	2	0	1
Torpedo californica	1	0	0	0	0	0	0	0

West End

West End continued to be algal dominated with understory kelps and *C. osmundacea* among the most common components (table 14). The purple urchin was consistently the most common invertebrate counted on swaths. Their numbers have continued to increase recently, and although they have now reached an 18-year high for the site, they are still well below the densities observed to destructively graze in the past. Red urchins also increased slightly to densities not seen since 2001. Although densities were much lower than purple urchins, they were the second most common invertebrate on swaths. The brown alga, *C. osmundacea*, and the understory kelps, *Laminaria* spp. and *P. californica*, were all very abundant at West End, and counts changed little over time. The large recruitment of juvenile *M. pyrifera* observed in the spring 2017 failed to result in a perceivable increase in adult plant density, but by fall 2017, a dense surface canopy had returned (fig. 10).

Stipe counts and holdfast diameters of *M. pyrifera* for eight sampling periods at West End revealed distinct modes of younger plants apparent in spring 2016–spring 2017 that gave way in year four to a more balanced age and size distribution similar to that seen in 2014 and 2015 (figs. 20 and 21). Although a few young plants were represented in the population, half or more of the plants had >10 stipes and holdfast diameters >20 cm.

Table 15 provides a summary of the sizes of invertebrates measured on swaths for all seasons. Again, at West End, only the rock scallop (*Crassadoma gigantea*) and Kellet's whelk (*K. kelletii*) were observed in all sampling periods. Both *K. kelletii* and *M. undosa* increased in abundance.

Except for a slight shift of the mode toward larger sizes and the loss of most individuals larger than 50 mm, the size distributions of purple urchins showed little change between spring 2017 and spring 2018 (fig. 22). It appears that there has been a gradual loss of the largest urchins throughout the last 4 years. Although the presence of a few individuals around 10 mm indicated possible low-level recruitment, it does not explain the 68 percent increase in density observed. Red urchins (*S. franciscanus*) also showed little change in size distribution in recent periods (fig. 23), but similarly, there were fewer larger individuals and some sign of recruitment of individuals in the 10–20 mm size class. We suggest predation by sea otters, which typically have been concentrating near West End for many years (Kenner and Tinker, 2018), is likely responsible for the loss of the larger urchins, which on this site were mostly found in crevices and under boulders. The low densities and generally cryptic habits of these red urchins make it unlikely that commercial harvest would be a factor.

Of the invertebrate species counted in 1-m^2 quadrats at West End, the stalked tunicate (*S. montereyensis*) and the orange puffball sponge (*T. aurantia*) are the only ones to have been observed on all sampling trips (table 16). The gastropods *A. gibberosa*, *C. spadicea*, *K. kelletii*, and *N. norrisi* occurred at the site, but none of these species were present in quadrats in more than a few sampling periods.

Encrusting algae, brown algae, fleshy red algae, and kelp, scored in RPC quadrats, provided the most bottom cover at West End, but there was a decline in the latter two categories during year 4 (fig. 19). Cover continued to be dominated by macroalgae species, but in fall 2017, the sandcastle worm (*P. californica*) joined bare substrate and sand in the top 10 cover "species" (table 17). *Cystoseira osmundacea*, *Dictyota binghamiae,* the articulated coralline *Calliarthron* spp., and several species of fleshy red algae accounted for most of the remaining cover after encrusting corallines. Whereas encrusting red algae was more prominent during year 4, the understory kelp *Laminaria* spp. decreased in percent cover.

Although the number of fish species observed at West End held steady at 17 or 18, the total number of fish counted decreased considerably (table 12). Poor visibility in fall 2017 probably contributed to the low count at that time, but conditions were quite good during spring 2018 and counts remained low. West End's ranking for overall fish density has fallen to last place since spring 2017. The most common fish were the schooling species señorita (*O. californica*), blacksmith (*C. punctipinnis*), and blue rockfish (*Sebastes mystinus*), but black perch (*Embiotoca jacksoni*) and sheephead (*S. pulcher*) remained important (table 18).

Table 14. West End mean (standard deviation) swath counts for fall 2014 through spring 2018 expressed as individuals per 20 square meter (m^2).

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Aplysia californica	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Astrometis sertulifera	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Crassadoma gigantea	0.2 (0.42)	0.4 (0.70)	0.2 (0.42)	0.4 (0.70)	0.4 (0.97)	0.1 (0.32)	0.2 (0.42)	0.2 (0.63)
Cystoseira osmundacea	49.3 (25.77)	53.6 (31.16)	53 (32.55)	55.9 (28.36)	42.7 (28.37)	49.2 (26.77)	41.6 (23.93)	55.5 (37.89)
Dermasterias imbricata	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Eisenia arborea	4.4 (5.19)	2.7 (1.77)	1.9 (2.42)	1.9 (1.66)	2.2 (2.62)	2.7 (2.06)	2 (2.00)	1.4 (1.51)
Haliotis corrugata	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Haliotis rufescens	0 (0.00)	0 (0.00)	0.1 (0.32)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Kelletia kelletii	0.1 (0.32)	0.3 (0.67)	0.2 (0.63)	1.2 (2.20)	0.7 (1.49)	0.3 (0.67)	0.6 (1.58)	2.4 (2.50)
Laminaria spp.	45.2 (43.33)	64.4 (32.85)	64 (39.99)	56.4 (25.83)	56.4 (20.78)	41.5 (17.18)	42.1 (40.50)	37.3 (43.13)
Lytechinus anamesus	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Macrocystis pyrifera <1 m	4.4 (3.17)	3.8 (4.10)	2.7 (4.03)	152 (88.49)	5.3 (9.17)	256.9 (151.48)	5.1 (9.43)	1 (0.94)
Macrocystis pyrifera >1 m	4.7 (2.83)	4.1 (2.64)	3.5 (2.37)	10.2 (7.74)	18.6 (10.47)	11.7 (6.96)	7.4 (2.99)	5.6 (2.84)
Megastraea undosa	0 (0.00)	0.1 (0.32)	0.1 (0.32)	0 (0.00)	0.7 (1.06)	0.1 (0.32)	3.9 (3.63)	5.8 (3.16)
Megathura crenulata	0 (0.00)	0 (0.00)	0.1 (0.32)	0.3 (0.67)	0.5 (0.53)	0.6 (0.84)	0.3 (0.67)	0.8 (0.79)
Parastichopus parvimensis	0 (0.00)	0.1 (0.32)	0 (0.00)	0.4 (0.97)	0.1 (0.32)	0.4 (0.52)	0 (0.00)	0.1 (0.32)
Patiria miniata	0.3 (0.95)	0.3 (0.48)	0 (0.00)	0.1 (0.32)	0.1 (0.32)	0.9 (0.99)	0.8 (1.03)	0.9 (0.88)
Pisaster giganteus	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0.1 (0.32)	0.2 (0.42)	0 (0.00)	0.5 (0.97)
Pterygophora californica	51 (26.72)	47 (18.57)	52.6 (39.29)	25.8 (17.86)	31.5 (21.71)	24.3 (18.86)	17.4 (13.99)	29.3 (24.94)
Pycnopodia helianthoides	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Sargassum horneri	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)

Table 14. West End mean (standard deviation) swath counts for fall 2014 through spring 2018 expressed as individuals per 20 square meter (m^2).—Continued

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Strongylocentrotus franciscanus	18.5 (38.23)	14.2 (24.80)	18.7 (32.55)	16 (20.56)	11.2 (22.16)	21.3 (23.42)	17.8 (33.28)	30 (31.68)
Strongylocentrotus purpuratus	80.7 (87.66)	66.5 (70.44)	99.1 (68.83)	118.1 (80.79)	59.1 (59.25)	126.3 (73.75)	135.3 (67.11)	212.5 (106.35)
Tethya aurantia	2.8 (2.66)	3.8 (2.94)	2.8 (3.58)	2.5 (2.68)	3.2 (2.90)	2.5 (3.10)	2.2 (2.78)	2.9 (3.14)
Urticina lofotensis	0.9 (1.91)	2 (2.05)	0.4 (0.97)	0.5 (0.71)	0.8 (0.92)	0.9 (1.20)	0.9 (1.29)	0.2 (0.63)
Young Laminariales	7.3 (8.59)	5.9 (8.60)	6.4 (6.57)	67.3 (115.67)	5.4 (6.93)	39.2 (54.47)	41.6 (62.39)	38.4 (32.20)

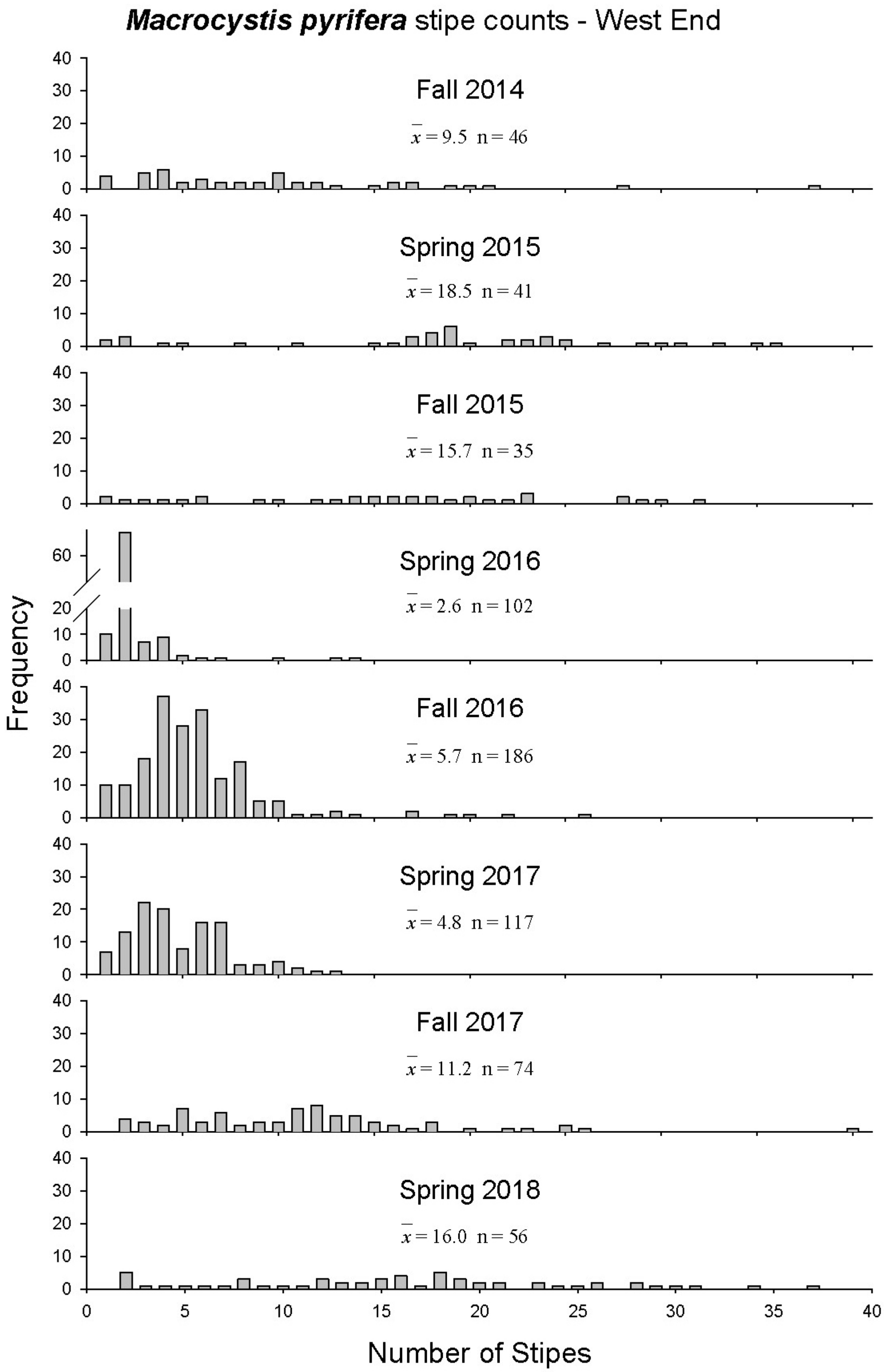

Figure 20. West End *Macrocystis pyrifera* stipe counts by season, fall 2014–spring 2018.

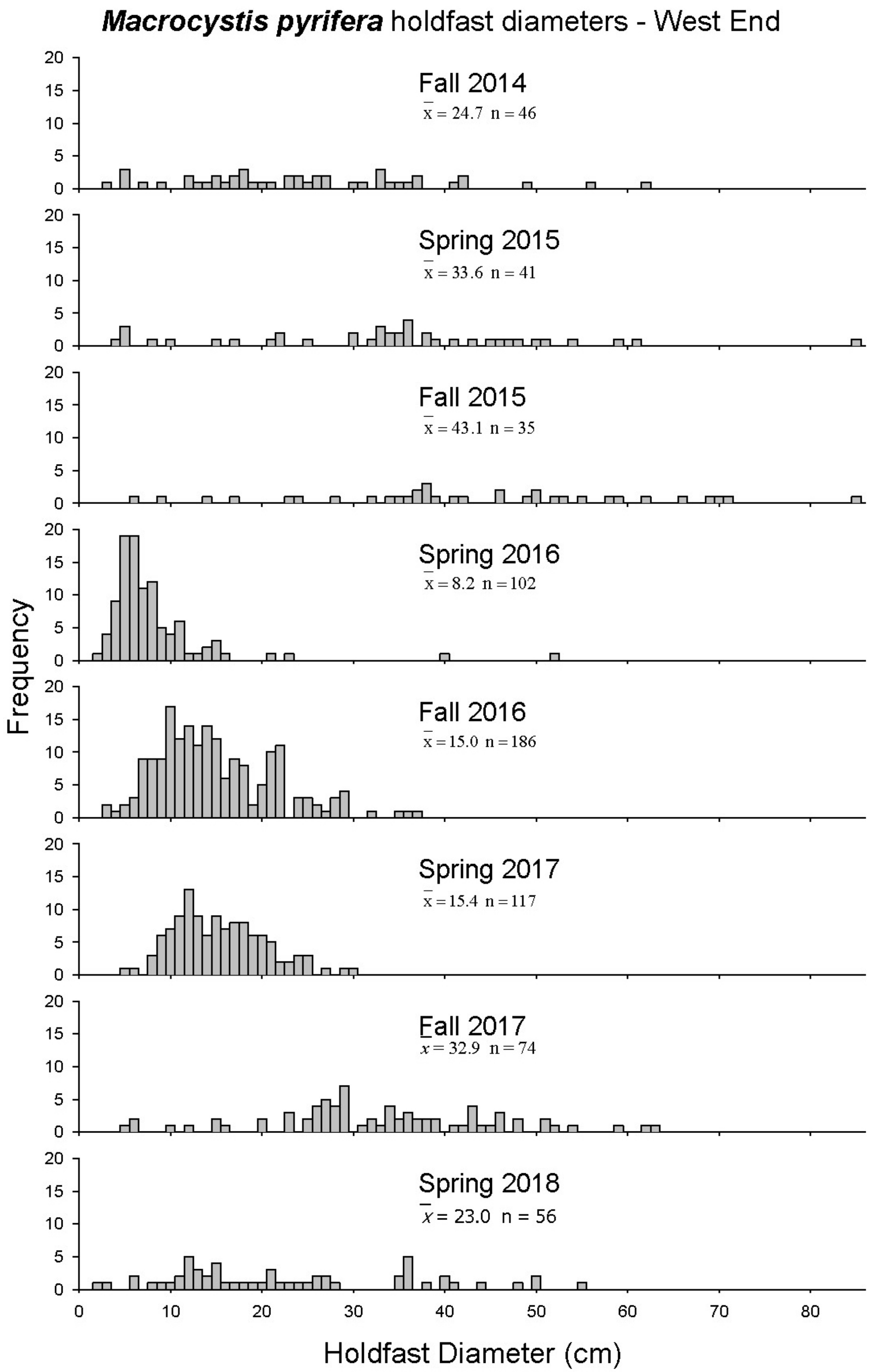

Figure 21. West End *Macrocystis pyrifera* holdfast diameters by season, fall 2014–spring 2018.

Table 15. Sizes of non-echinoid invertebrates measured on swaths at West End, fall 2014 through spring 2018.

[*Strongylocentrotus* spp. excluded. See figures 22 and 23 for purple and red urchin size data. **Abbreviations**: N, sample size; —, no data; Min, minimum; Max, maximum]

Species name	*Crassadoma gigantea*	*Haliotis rufescens*	*Kelletia kelletii*	*Megastraea undosa*	*Megathura crenulata*	*Patiria miniata*	*Pisaster giganteus*
Fall 2014							
N	2	0	1	0	0	3	0
Min	23	—	32	—	—	22	—
Max	51	—	32	—	—	50	—
Mean	37.0	—	32.0	—	—	39.0	—
Spring 2015							
N	4	0	3	1	0	3	0
Min	18	—	25	30	—	42	—
Max	52	—	43	30	—	61	—
Mean	41.3	—	34.3	30.0	—	49.7	—
Fall 2015							
N	2	1	2	1	1	0	0
Min	35	66	45	43	95	—	—
Max	40	66	47	43	95	—	—
Mean	37.5	66.0	46.0	43.0	95.0	—	—
Spring 2016							
N	4	0	12	0	3	1	0
Min	35	—	30	—	70	41	—
Max	55	—	48	—	122	41	—
Mean	48.0	—	38.3	—	95.7	41.0	—
Fall 2016							
N	4	0	7	7	5	1	1
Min	40	—	29	42	88	20	54
Max	53	—	39	96	170	20	54
Mean	47.5	—	33.9	63.4	117.0	20.0	54.0
Spring 2017							
N	1	0	3	1	6	9	2
Min	64	—	38	50	68	21	65
Max	64	—	61	50	125	49	66
Mean	64.0	—	46.7	50.0	96.7	39.9	65.5
Fall 2017							
N	2	0	6	39	3	8	0
Min	46	—	39	23	69	25	—
Max	71	—	54	89	96	50	—
Mean	58.5	—	46.0	55.7	84.0	32.9	—
Spring 2018							
N	2	0	25	58	8	9	5
Min	38	—	30	35	45	8	50
Max	41	—	52	92	138	46	110
Mean	39.5	—	39.7	52.6	99.8	34.3	84.4

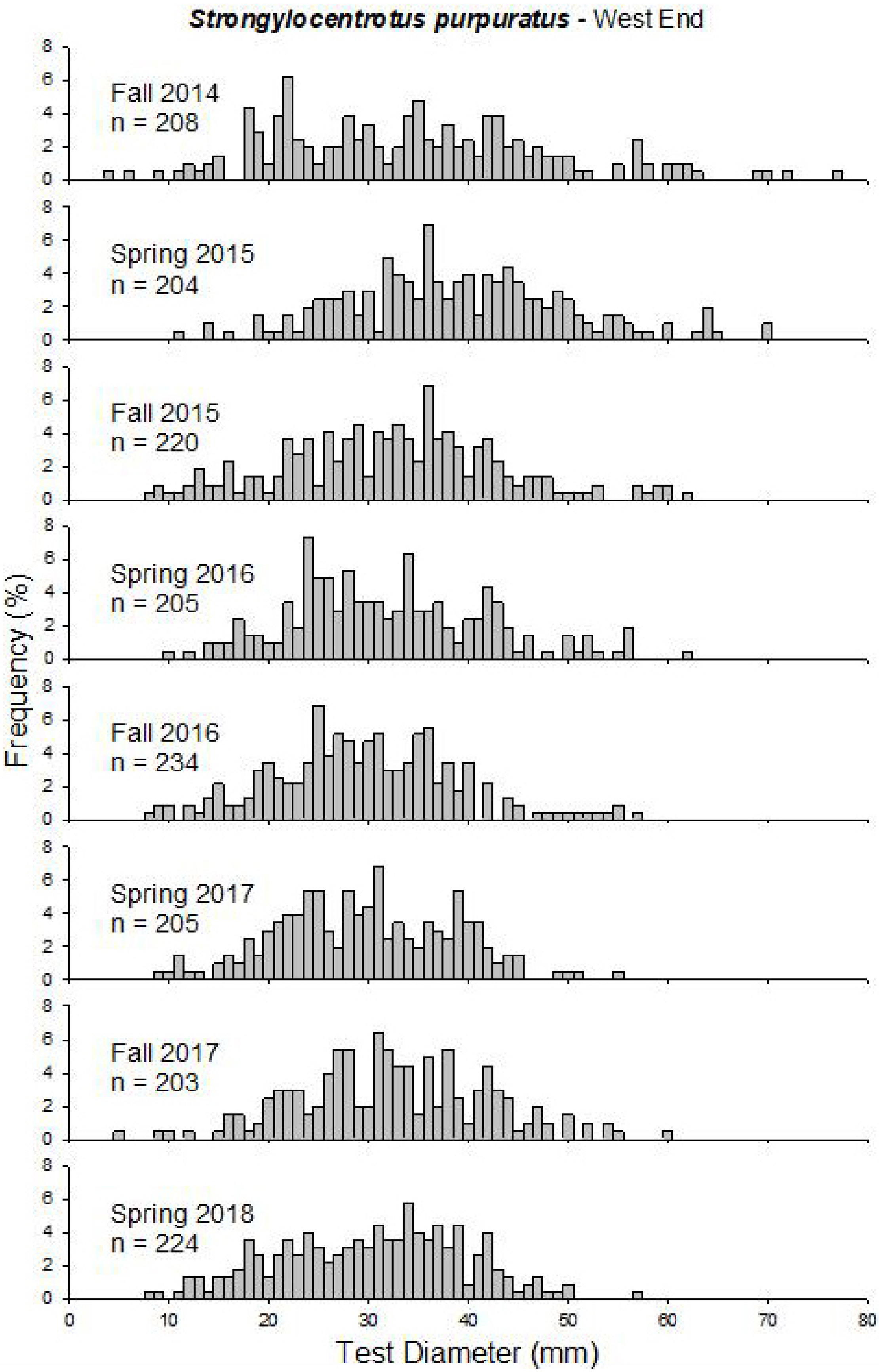

Figure 22. West End size structure of purple urchins (*Strongylocentrotus purpuratus*) in fall 2014 through spring 2018.

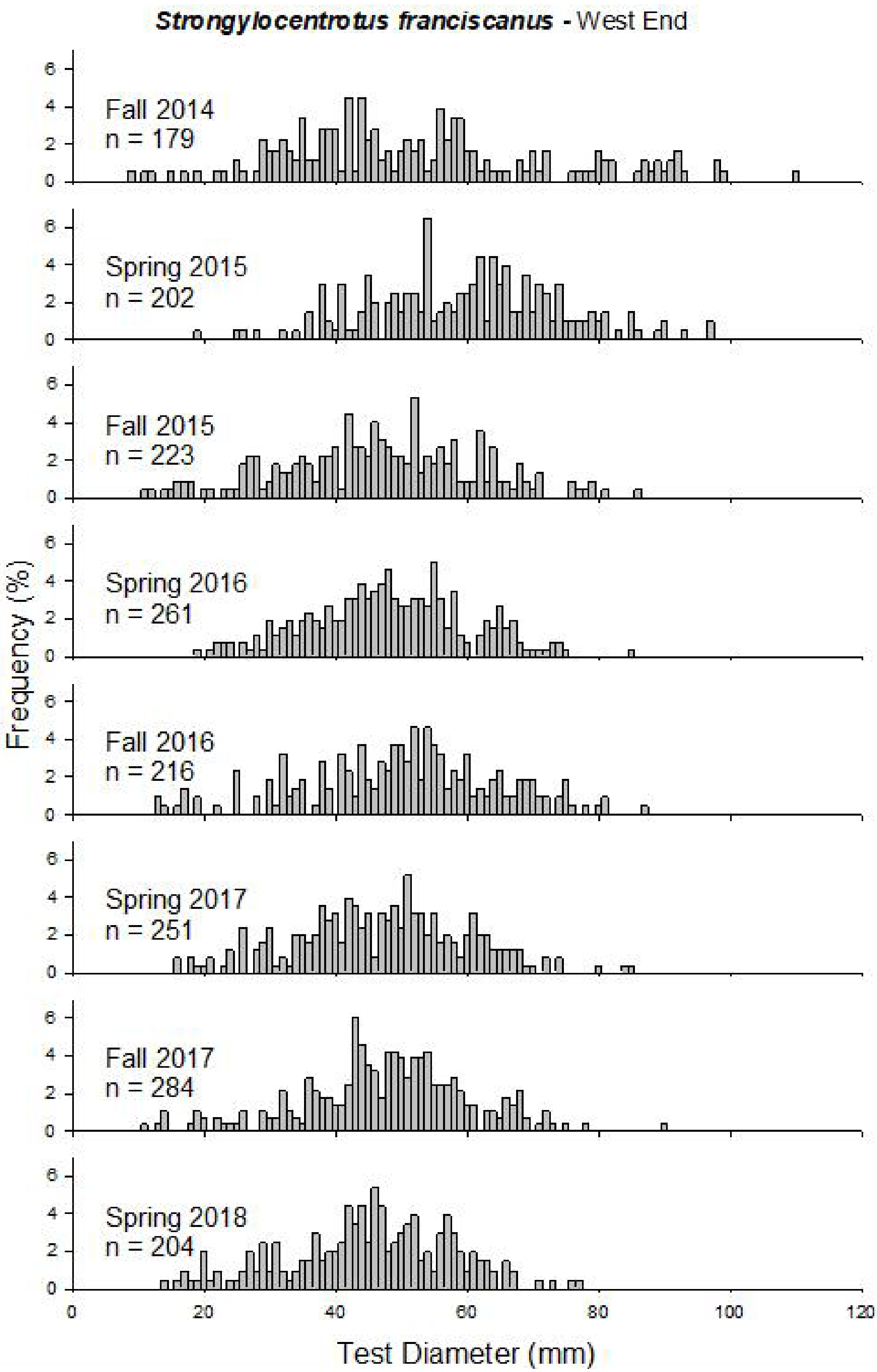

Figure 23. West End size structure of red urchins (*Strongylocentrotus franciscanus*) in fall 2014 through spring 2018.

Table 16. West End mean (and standard deviation) of twenty 1-square-meter (m²) quadrat counts for fall 2014 through spring 2018.

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Astraea gibberosa	0.0 (0.00)	0.0 (0.00)	0.1 (0.31)	0.0 (0.00)	0.1 (0.22)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Cypraea spadicea	0.1 (0.22)	0.0 (0.00)	0.0 (0.00)	0.1 (0.22)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Kelletia kelletii	0.0 (0.00)	0.1 (0.22)	0.1 (0.22)	0.0 (0.00)	0.1 (0.22)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Norrisia norrisi	0.0 (0.00)	0.1 (0.22)	0.0 (0.00)	0.0 (0.00)	0.2 (0.37)	0.1 (0.31)	0.1 (0.22)	0.1 (0.22)
Sargassum horneri	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Styela montereyensis	0.2 (0.41)	0.3 (0.55)	0.1 (0.31)	0.1 (0.22)	0.2 (0.52)	0.1 (0.31)	0.3 (0.73)	0.2 (0.37)
Tegula regina	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Tethya aurantia	0.2 (0.37)	0.1 (0.22)	0.1 (0.31)	0.1 (0.22)	0.1 (0.31)	0.1 (0.31)	0.1 (0.31)	0.1 (0.31)
Urticina lofotensis	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)

Table 17. West End point contact "species" for fall 2014 through spring 2018 by number of points.

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Encrusting coralline algae	267	257	249	125	257	140	196	203
Laminaria spp.	102	67	60	57	56	88	28	20
Calliarthron spp.	48	59	67	65	49	69	58	57
Rhodymenia californica	83	47	41	67	73	68	30	31
Cystoseira osmundacea	38	52	39	51	46	58	32	43
Pterygophora californica	89	51	45	25	26	29	21	28
Sand	41	25	21	26	35	49	40	17
Dictyota binghamiae	4	4	2	67	21	58	36	49
Cryptopleura spp.	43	10	21	69	4	40	9	25
Encrusting red algae	9	20	29	10	15	18	25	53
Kelp holdfast	21	8	15	10	15	19	27	20
Chondracanthus exasperata	32	24	13	17	17	14	8	3
Macrocystis pyrifera <1 m	3	5	5	71	2	31	2	1
Pink encrusting bryozoan	13	10	28	4	19	10	14	12
Bare substratum	8	17	15	1	25	5	28	8
Nienburgia andersoniana	3	27	5	43	0	23	0	1
Macrocystis pyrifera >1 m	12	3	6	8	16	15	20	11
Prionitis lanceolata	7	16	9	13	11	6	16	4
Gelidium robustum	15	20	10	7	5	6	7	7
Phragmatopoma californica	0	0	2	1	3	1	31	11
Cryptopleura ruprechtiana	16	12	0	6	0	3	0	0
Young Laminariales	0	0	0	6	4	21	1	3
Botryocladia pseudodichotoma	2	0	1	2	2	11	5	5

Table 17. West End point contact “species” for fall 2014 through spring 2018 by number of points.—Continued

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Eisenia arborea	2	8	1	4	7	0	4	0
Serpulorbis squamiger	2	0	3	1	1	1	5	8
Metandrocarpa dura	2	2	0	3	5	0	9	0
Bossiella spp.	3	4	1	0	0	6	1	5
Neoptilota densa	6	2	1	7	1	1	2	0
Pterosiphonia spp.	0	2	3	0	0	7	0	4
Callophyllis flabellulata	0	0	0	0	7	8	0	0
Orange encrusting sponge	4	2	1	0	2	0	3	0
Diademnum carnulentum	1	2	1	0	2	0	4	1
Plocamium pacificum	2	2	1	2	1	2	0	1
Corallina officinalis	1	2	0	3	3	0	1	1
Unidentified sponge	1	5	2	0	0	0	1	1
Kallymenia pacifica	3	0	2	1	1	1	0	2
Acanthacora cyanocrypta	1	0	7	0	0	0	0	1
Anthopleura sola	1	2	0	1	0	2	1	1
Synoicum spp.	0	0	0	0	0	0	0	8
Aglaophenia spp.	0	0	0	2	0	5	0	0
Barnacle	0	0	7	0	0	0	0	0
Filamentous red algae	3	2	0	0	0	0	1	0
Laurencia pacifica	0	2	0	1	0	2	1	0
Opuntiella californica	0	2	0	0	1	0	2	0
Epiactis prolifera	0	0	2	0	0	0	2	0
Polyneura spp.	0	1	0	3	0	0	0	0
Balanophyllia elegans	0	1	0	1	0	0	0	1
Tethya aurantia	1	0	0	1	0	0	0	1
Dictyopteris undulata	0	0	0	0	3	0	0	0
Diopatra ornata	0	1	0	0	0	0	1	0
Crisia spp.	0	0	1	0	0	0	0	1
Dodecaceria spp.	0	0	1	0	0	0	1	0
Styela montereyensis	1	1	0	0	0	0	0	0
Red algae	0	0	0	2	0	0	0	0
Bryopsis corticulans	0	0	0	0	0	0	0	2
Desmarestia ligulata	0	0	0	1	0	1	0	0
Pikea spp.	0	1	1	0	0	0	0	0
Corynactis californica	1	0	0	0	0	0	0	0
Eupentacta quinquesemita	0	0	0	0	0	1	0	0
Pachythyone rubra	0	0	0	0	0	0	1	0
Archidistoma psammion	0	0	0	0	1	0	0	0
Stylantheca porphyra	0	0	0	0	1	0	0	0
Leucosolenia eleanor	0	0	0	0	0	0	1	0
Polyclinum planum	0	0	1	0	0	0	0	0
Laurencia spp.	0	0	0	0	0	1	0	0
Fauchea laciniata	0	0	0	0	0	1	0	0
Red algal turf	0	0	0	1	0	0	0	0
Prionitis spp.	0	0	0	0	0	1	0	0

Table 18. West End fish counts—adult (juvenile)—in fall 2014 through spring 2018 by species.

[f, female; m, male]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Artedius spp.	0	0	1	1	0	0	0	0
Brachyistius frenatus	40	6	1	0	29	1	1	1
Chromis punctipinnis	1,030	305 (27)	788	214	385	232	26	168
Coryphopterus nicholsii	2	0	1	0	0	0	0	0
Embiotoca jacksoni	43	6	17	10	36	17	33	37
Embiotoca lateralis	61	7	7	1	10	5	4	7
Gibbonsia spp.	3	0	0	0	0	0	0	0
Girella nigricans	7	1	3	5	7	9	6	1
Gymnothorax mordax	0	0	0	1	0	0	0	0
Halichoeres semicinctus	0	0	0	0	0	0	0	1
Heterostichus rostratus	1	0	0	0	0	0	0	0
Hypsurus caryi	6	0	2	3	8	0	7	3
Hypsypops rubicundus	1	0	0	0	3	3	1	5
Medialuna californiensis	0	0	1	2	0	3	0	3
Neoclinus spp.	0	0	0	0	0	0	1	0
Ophiodon elongatus	0	0	0	0	0	1	0	0
Oxyjulis californica	2,613	286	1,751	1,146	529	792	159	305
Oxylebius pictus	8	8	10	7	1	5	1	2
Paralabrax clathratus	11	2 (2)	22	5	15	18	3	5
Rhacochilus toxotes	0	0	0	0	2	0	0	0
Rhacochilus vacca	4	1	0	1	1	0	1	0
Scorpaenichthys marmoratus	0	1	0	0	0	0	0	0
Sebastes atrovirens	16	1	7	0	3	3	4	1
Sebastes auriculatus	0	0	0	1	0	0	1	0
Sebastes carnatus	0	0	0	0	0	2	0	0
Sebastes caurinus	0	0	0	0	0	0 (1)	0	0
Sebastes chrysomelas	12	0	9	4	1	1	1	0
Sebastes mystinus	126	278 (12)	14	21	123	59	33	60
Sebastes rastrelliger	2	0	0	0	1	0	0	2
Sebastes serranoides	0	0	4	10	48 (25)	4	2	6
Sebastes serriceps	1	0	0	0	0	0	0	0
Sebastes spp.	0	0	0	0	0	0 (1)	0	0
Semicossyphus pulcher (f)	20	10 (2)	32 (3)	15	20	28	16	31
Semicossyphus pulcher (m)	13	3	4	0	6	11	3	15
Stereolepis gigas	1	0	0	0	0	0	0	0
Torpedo californica	1	0	0	0	0	0	0	0

Dutch Harbor

Purple urchins remained the most common swath-counted organism at Dutch Harbor. In fact, both purple and red sea urchins doubled in density since the previous year (table 19). The spotted rose anemone, *U. lofotensis*, fell third behind red urchins. *Laminaria* spp. again became the most common kelp after *M. pyrifera* numbers decreased.

Figures 24 and 25 show the stipe counts and holdfast diameters of *M. pyrifera* throughout the eight sampling periods at Dutch Harbor. These plots resemble those from West End in that at Dutch Harbor, there was also no recruitment pulse detected in year 4. Other than a few recruits, the population was made up primarily of survivors from the previous year. The survival of several larger plants with many stipes supports the conclusion that overwinter conditions were relatively calm in 2018.

Counts of the rock scallop (*C. gigantea*) reached new maxima in fall 2017 with only a slight decrease evident in spring, but the mean size remained quite consistent (table 20). Counts of the wavy turban snail (*M. undosa*) increased slightly here, as did those of the giant keyhole limpet (*Megathura crenulata*). The sea star, *P. miniata*, reached the highest density in three years. Kellet's whelk (*K. kelletii*) counts increased markedly during the last period.

As mentioned above, *S. purpuratus* density increased considerably in year 4, but the size distribution showed little change other than a broadening of the mode (fig. 26). Similar to West End, there was no evidence of a recruitment event that could explain the increase in density. In contrast, red urchins not only showed an increase in the proportion less than 40 mm but also a decrease among individuals >60 mm in the last period (fig. 27).

Urticina lofotensis continued to be relatively stable in density and remained the most common species in the 1-m^2 quadrat counts (table 21). The orange puffball sponge (*T. aurantia*) and the tunicate *S. montereyensis* remained present at lower numbers.

Dutch Harbor RPC quadrats again had the same even mix of non-bare categories with encrusting algae and non-motile invertebrates as the most common categories (fig. 19). There was a slight decrease in the cover of fleshy red algae and a corresponding increase in invertebrate cover. Of the taxa recorded, encrusting coralline algae dominated, followed by the small sea cucumber *Pacythyone rubra* in fall 2017, and pink encrusting bryozoans in spring 2018 (table 22). The tube-building polychaete *Diopatra ornata*, another small sea cucumber (*Cucumaria fisheri*), and various understory algae including *C. osmundacea* and *Laminaria* spp. add to the diverse cover at Dutch Harbor. More than at any of the other sites, cover here is a diverse mix of algae and invertebrates.

Dutch Harbor continued to have the greatest number of fish species and the highest overall fish density of all sites (table 12). Most fishes encountered at Dutch Harbor were blacksmith (*C. punctipinnis*) and señorita (*O. californica*), but a suite of rockfishes, including blue (*S. mystinus*) and olive rockfish (*S. serranoides*), as well as sheephead (*S. pulcher*), were regular members of the overall site assemblage (table 23). No juveniles of the latter species were observed this year because warm-water associated recruitment (Cowen, 1985) came to an end with the switch to cooler ocean conditions in 2016.

Table 19. Dutch Harbor mean (SD) swath counts for fall 2014 through spring 2018 expressed as individuals per 20 square meter (m^2).

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Aplysia californica	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Astrometis sertulifera	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Crassadoma gigantea	1.5 (1.78)	1.7 (1.64)	10.8 (6.97)	3 (2.16)	6.8 (5.75)	6 (4.83)	15.9 (11.15)	13 (9.85)
Cystoseira osmundacea	6.8 (9.58)	7.7 (9.46)	8.2 (6.81)	5.5 (8.42)	6.9 (7.19)	9.8 (11.81)	6.6 (7.21)	6.7 (11.43)
Dermasterias imbricata	0 (0.00)	0 (0.00)	0 (0.00)	0.1 (0.32)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Eisenia arborea	9.7 (8.30)	14.7 (10.06)	9.7 (8.11)	8.9 (5.07)	12.4 (9.01)	12.7 (7.29)	9.1 (10.09)	5.8 (5.77)
Haliotis corrugata	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Haliotis rufescens	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Kelletia kelletii	0.5 (1.58)	0.9 (1.29)	0.7 (1.57)	0.7 (1.06)	0.5 (0.85)	0 (0.00)	0.1 (0.32)	2.3 (2.16)
Laminaria spp.	16.6 (20.07)	18 (18.21)	23.2 (24.05)	10 (6.78)	17.8 (19.40)	9.5 (10.61)	11.5 (17.93)	10.5 (15.39)
Lytechinus anamesus	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Macrocystis pyrifera <1 m	7.3 (9.71)	6.7 (7.17)	0.7 (1.49)	16.1 (25.56)	37.8 (26.08)	16 (27.26)	2 (2.98)	0 (0.00)
Macrocystis pyrifera >1 m	8.2 (3.58)	7.9 (7.49)	4.5 (3.92)	2.8 (4.24)	16.8 (16.34)	10.8 (4.71)	6.3 (2.91)	5.8 (3.33)
Megastraea undosa	0.4 (0.84)	0.3 (0.48)	0.3 (0.67)	0.5 (0.71)	0.4 (0.70)	0.4 (0.70)	0.7 (0.95)	1.6 (1.26)
Megathura crenulata	1.1 (1.29)	1.1 (1.60)	0.4 (0.70)	0.3 (0.48)	0.6 (0.70)	0.5 (0.71)	1.1 (1.10)	0.9 (1.29)
Parastichopus parvimensis	0.3 (0.67)	1 (1.49)	0.1 (0.32)	1.8 (1.40)	0.9 (1.10)	3.9 (3.48)	0.3 (0.67)	2.9 (3.31)
Patiria miniata	2 (2.36)	2.8 (3.12)	0.7 (0.82)	0.8 (0.92)	2 (1.49)	0.8 (1.03)	2 (2.36)	2.3 (1.57)
Pisaster giganteus	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0.3 (0.48)
Pterygophora californica	3.1 (8.12)	1.9 (2.85)	4.1 (7.14)	1.7 (4.03)	3.3 (4.22)	2.6 (4.97)	1 (2.21)	2.6 (4.88)
Pycnopodia helianthoides	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Sargassum horneri	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)

Table 19. Dutch Harbor mean (SD) swath counts for fall 2014 through spring 2018 expressed as individuals per 20 square meter (m^2).
—Continued

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Strongylocentrotus franciscanus	39.8 (27.74)	52.9 (36.80)	47 (21.59)	42.3 (24.01)	38 (20.80)	29.8 (14.95)	59.8 (31.08)	62.9 (31.09)
Strongylocentrotus purpuratus	161 (79.38)	238.8 (126.53)	228 (118.44)	190.6 (99.64)	209 (90.74)	198.7 (99.72)	341.4 (149.43)	401.5 (204.87)
Tethya aurantia	12.3 (9.32)	7.4 (5.99)	5.4 (6.59)	6.1 (5.99)	6.6 (4.14)	7 (5.23)	5.2 (4.39)	7.4 (5.38)
Urticina lofotensis	27.2 (15.02)	41.5 (20.45)	28.5 (16.26)	28.1 (18.04)	35.9 (19.49)	34.6 (18.37)	35 (25.62)	40.8 (25.93)
Young Laminariales	3.9 (3.45)	6.9 (6.51)	3.9 (6.38)	9.9 (18.88)	5.6 (11.95)	2.3 (3.80)	1 (2.16)	5.3 (8.41)

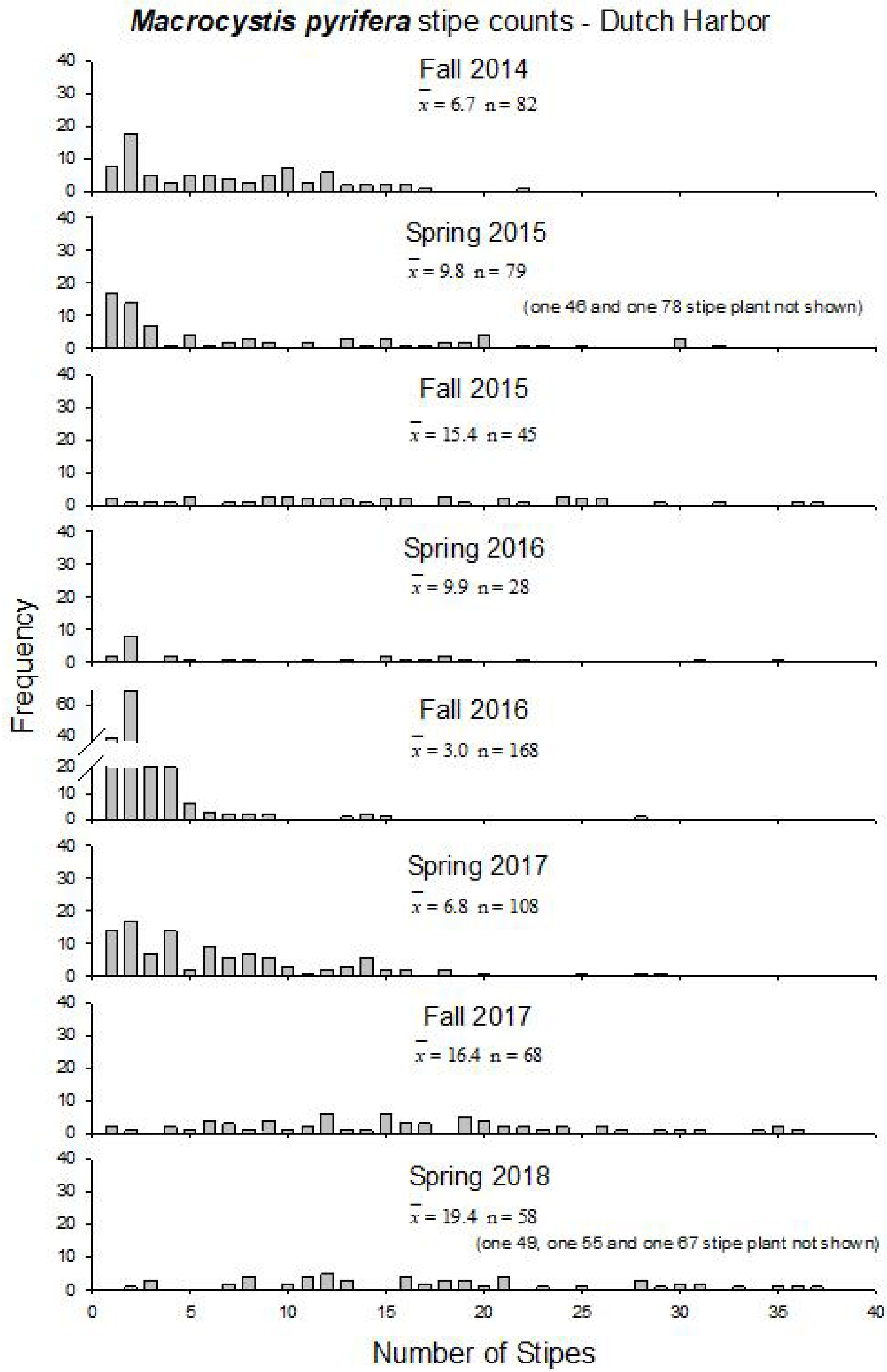

Figure 24. Dutch Harbor *Macrocystis pyrifera* stipe counts by season, fall 2014–spring 2018.

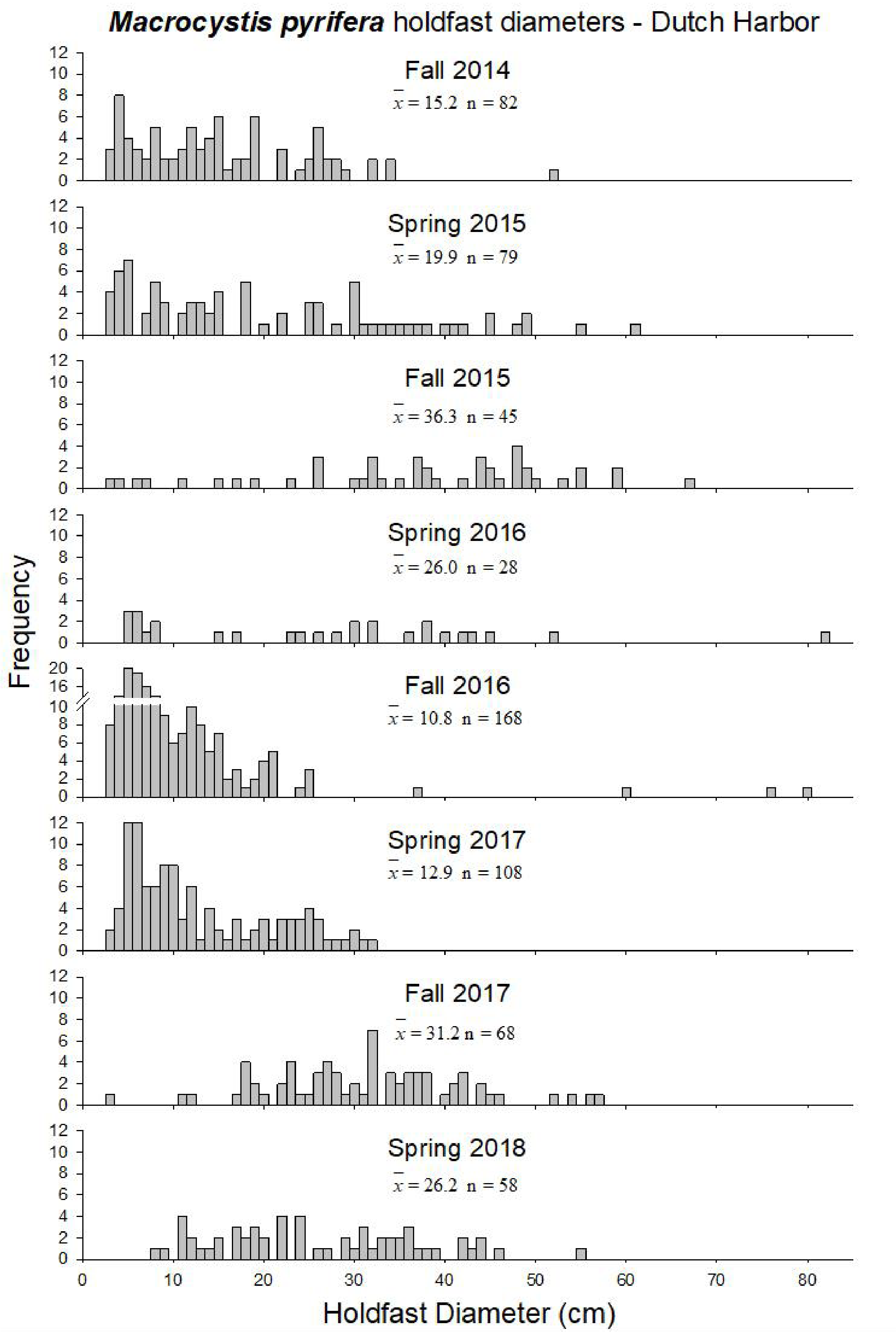

Figure 25. Dutch Harbor *Macrocystis pyrifera* holdfast diameters by season, fall 2014–spring 2018.

Table 20. Sizes of non-echinoid invertebrates measured on swaths at Dutch Harbor, fall 2014 through spring 2018.

[*Strongylocentrotus* spp. excluded. See figures 26 and 27 for purple and red urchin size data. **Abbreviations**: N, sample size; Min, minimum; —, no data; Max, maximum]

Species name	*Crassadoma gigantea*	*Dermasterias imbricata*	*Kelletia kelletii*	*Megastraea undosa*	*Megathura crenulata*	*Patiria miniata*	*Pisaster giganteus*
Fall 2014							
N	16	0	5	4	11	20	0
Min	19	—	65	25	66	27	—
Max	113	—	75	90	117	94	—
Mean	59.2	—	71.4	63.8	100.0	60.3	—
Spring 2015							
N	17	0	9	3	11	28	0
Min	25	—	40	39	90	36	—
Max	115	—	98	75	162	90	—
Mean	60.9	—	76.3	52.0	124.8	62.0	—
Fall 2015							
N	108	0	7	3	4	4	0
Min	20	—	31	28	54	40	—
Max	100	—	108	99	148	70	—
Mean	58.8	—	55.3	54.0	102.3	56.8	—
Spring 2016							
N	30	1	7	5	3	8	0
Min	15	80	30	45	109	21	—
Max	95	80	90	120	115	85	—
Mean	67.4	80.0	56.7	77.0	111.3	55.5	—
Fall 2016							
N	68	0	5	4	6	16	0
Min	19	—	27	17	102	24	—
Max	112	—	80	80	125	80	—
Mean	61.0	—	49.8	49.0	116.3	56.4	—
Spring 2017							
N	60	0	0	4	5	8	0
Min	15	—	—	40	75	23	—
Max	110	—	—	50	120	73	—
Mean	63.0	—	—	45.0	101.4	56.4	—
Fall 2017							
N	158	0	1	8	11	20	0
Min	26	—	47	37	28	20	—
Max	113	—	47	81	125	91	—
Mean	65.1	—	47.0	52.0	95.8	61.3	—
Spring 2018							
N	130	0	23	16	9	23	3
Min	21	—	24	24	70	7	55
Max	120	—	113	82	115	92	110
Mean	59.9	—	51.4	50.3	91.9	60.1	77.3

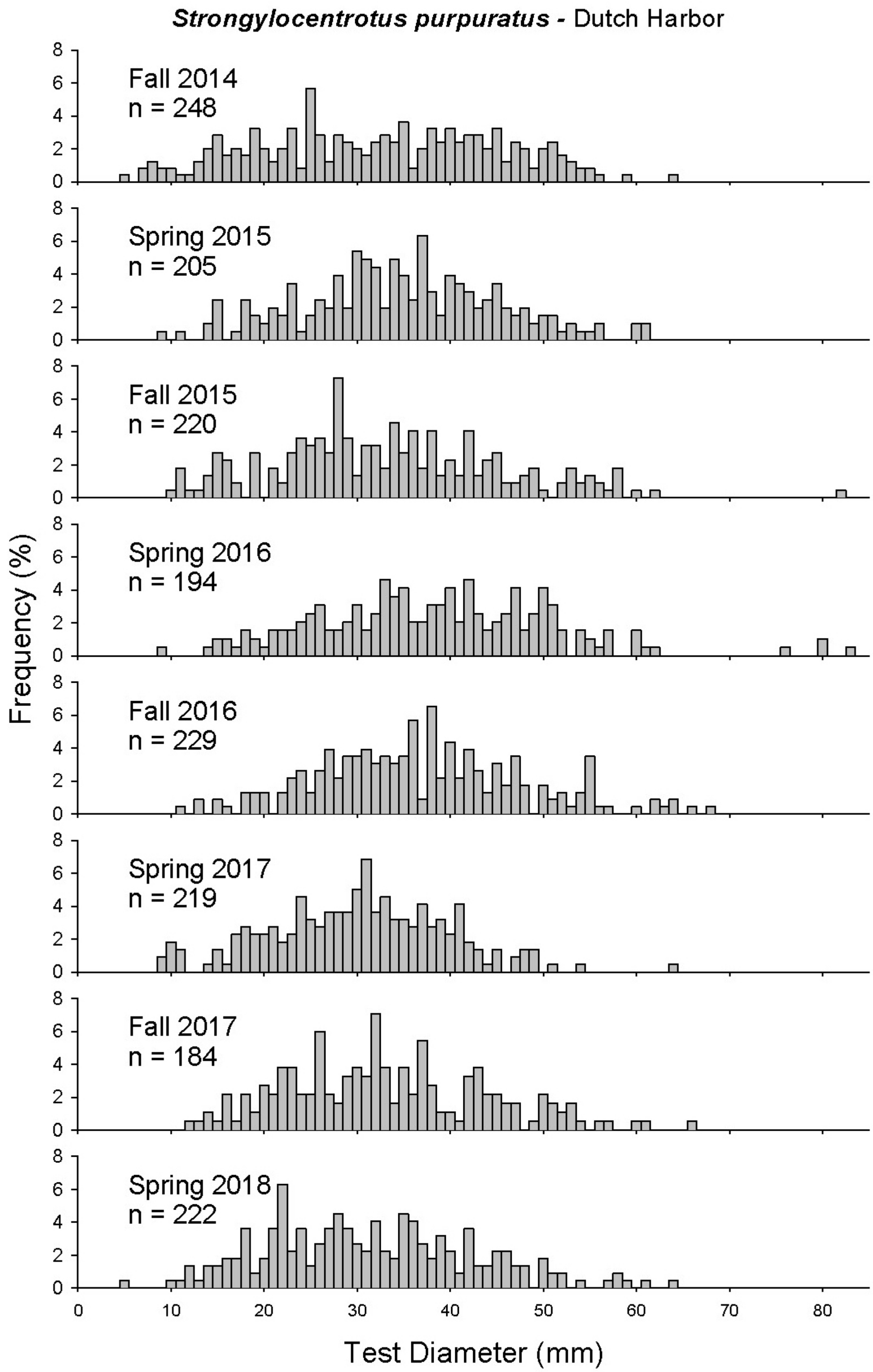

Figure 26. Dutch Harbor size structure of purple urchins (*Strongylocentrotus purpuratus*), fall 2014 through spring 2018.

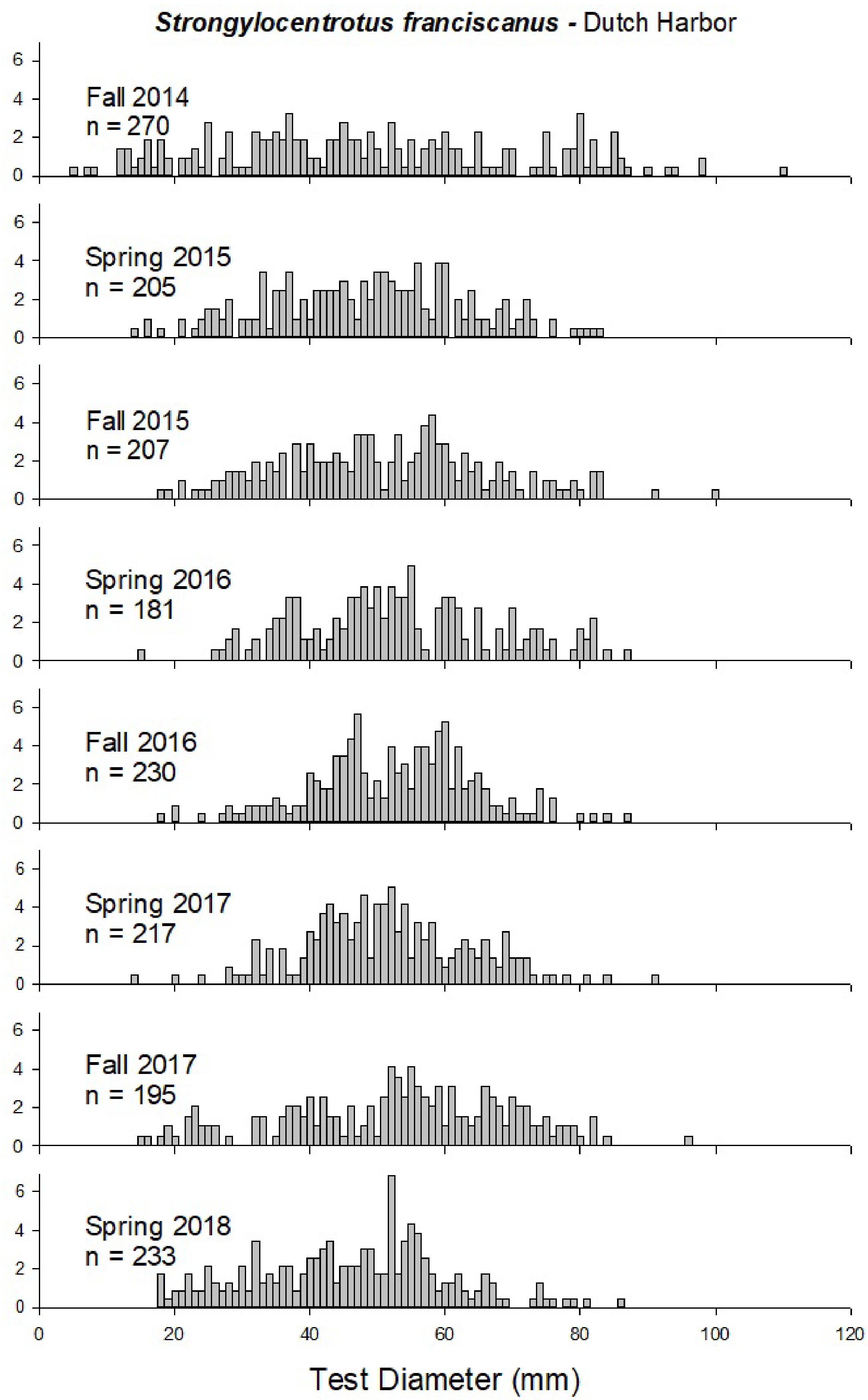

Figure 27. Dutch Harbor size structure of red urchins (*Strongylocentrotus franciscanus*) in fall 2014 through spring 2018.

Table 21. Dutch Harbor mean (and standard deviation) of twenty 1 square meter (m^2) quadrat counts for fall 2014 through spring 2018.

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Astraea gibberosa	0.1 (0.22)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.1 (0.22)	0.0 (0.00)	0.0 (0.00)
Cypraea spadicea	0.0 (0.00)	0.1 (0.45)	0.1 (0.22)	0.1 (0.31)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.1 (0.22)
Kelletia kelletii	0.0 (0.00)	0.1 (0.45)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Norrisia norrisi	0.1 (0.45)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.1 (0.22)	0.1 (0.22)	0.0 (0.00)	0.0 (0.00)
Sargassum horneri	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Styela montereyensis	0.1 (0.31)	0.0 (0.00)	0.0 (0.00)	0.1 (0.45)	0.2 (0.67)	0.2 (0.49)	0.2 (0.49)	0.1 (0.31)
Tegula regina	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Tethya aurantia	0.3 (0.57)	0.4 (0.68)	0.1 (0.31)	0.2 (0.41)	0.1 (0.22)	0.2 (0.37)	0.1 (0.31)	0.2 (0.41)
Urticina lofotensis	0.4 (0.75)	0.6 (0.89)	0.7 (1.03)	0.6 (0.94)	0.6 (1.05)	0.7 (0.93)	0.8 (0.85)	0.5 (0.76)

Table 22. Dutch Harbor point contact "species" for fall 2014 through spring 2018 by number of points.

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Encrusting coralline algae	182	129	187	128	151	122	167	139
Sand	79	112	67	50	67	39	50	62
Laminaria spp.	45	57	46	47	43	40	58	50
Cystoseira osmundacea	38	27	38	27	33	43	56	45
Pink encrusting bryozoan	5	16	23	40	33	33	58	66
Pachythyone rubra	13	29	25	19	35	44	69	36
Diopatra ornata	33	43	19	26	42	22	18	41
Rhodymenia californica	64	42	14	24	29	44	19	5
Cucumaria fisheri	24	39	23	17	19	30	31	22
Calliarthron spp.	27	34	18	19	18	16	15	9
Cryptopleura spp.	13	16	2	27	42	34	9	1
Corallina officinalis	27	20	12	2	16	19	15	24
Eisenia arborea	16	15	9	14	23	19	17	4
Bare substratum	10	8	23	13	9	19	7	12
Crisia spp.	6	11	5	16	3	13	15	18
Encrusting red algae	8	11	14	9	8	11	13	9
Kelp holdfast	5	2	18	21	13	10	8	6
Dictyota binghamiae	5	24	0	14	21	14	0	1
Aglaophenia spp.	6	1	6	3	14	16	16	10
Corynactis californica	12	9	7	6	13	9	7	4
Macrocystis pyrifera >1 m	8	0	9	16	5	7	8	5
Plocamium pacificum	2	13	3	10	4	8	3	10
Cellaria spp.	0	5	10	5	7	0	13	12
Balanophyllia elegans	4	6	7	12	6	3	4	7
Astrangia lajollaensis	4	8	3	5	7	6	6	9
Barnacle	12	6	29	0	0	0	0	0
Pterygophora californica	8	15	8	3	4	4	2	0
Macrocystis pyrifera <1 m	6	1	0	7	14	5	2	0
Acarnus erithacus	9	3	3	4	2	3	3	4
Nienburgia andersoniana	1	4	1	2	4	9	1	4
Hippodiplosia insculpta	1	1	1	5	0	4	9	3
Orange encrusting sponge	0	4	1	2	6	1	4	3
Bossiella spp.	3	8	3	1	3	0	3	0
Lagenocella spp.	1	1	2	6	4	0	3	2
Serpulorbis squamiger	2	2	2	1	0	4	2	5
Anthopleura sola	2	4	0	3	4	2	0	1
Abietinaria spp.	0	1	2	0	3	5	3	2
Urticina spp.	3	1	0	7	2	2	0	0
Bugula spp.	2	3	3	4	1	0	2	0
Eupentacta quinquesemita	0	5	0	0	5	2	2	0
Filamentous red algae	6	1	1	1	1	4	0	0
Phidolopora pacifica	0	3	1	3	2	1	2	1
Acanthacora cyanocrypta	1	2	0	0	0	1	2	6

Table 22. Dutch Harbor point contact "species" for fall 2014 through spring 2018 by number of points.—Continued

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Phragmatopoma californica	0	1	1	0	3	0	4	1
Chondracanthus exasperata	4	0	0	0	3	2	1	0
Botryocladia pseudodichotoma	0	0	0	0	2	2	1	3
Unidentified sponge	0	1	0	2	1	0	2	1
Stylantheca porphyra	0	0	0	1	0	3	2	1
Diademnum carnulentum	0	0	0	0	0	3	2	1
Young Laminariales	1	3	0	1	1	0	0	0
Kallymenia pacifica	0	0	0	0	2	1	0	3
Strongylocentrotus purpuratus	1	1	2	0	0	0	0	0
Epiactis prolifera	0	0	1	0	0	3	0	0
Archidistoma psammion	0	0	0	0	0	0	4	0
Tethya aurantia	1	1	0	0	0	0	1	1
Plumularia spp.	0	0	0	0	0	0	0	4
Synoicum spp.	0	0	0	0	3	0	0	0
Gelidium robustum	0	0	0	0	2	0	0	1
Spheciospongia confoederata	1	0	0	1	0	0	0	0
Anthopleura spp.	0	0	1	0	0	1	0	0
Laurencia pacifica	0	2	0	0	0	0	0	0
Pterosiphonia spp.	0	0	0	0	0	2	0	0
Dictyopteris undulata	0	0	0	1	0	1	0	0
Strongylocentrotus franciscanus	0	1	0	0	0	0	0	0
Balanus spp.	0	0	0	0	1	0	0	0
Pholad clam	0	0	0	0	0	1	0	0
Styela montereyensis	0	0	0	0	0	0	1	0
Leucetta losangelensis	0	1	0	0	0	0	0	0
Boltenia villosa	0	0	0	0	0	1	0	0
Clavelina huntsmani	0	0	0	0	0	1	0	0
Crassadoma gigantea	0	0	0	0	0	0	0	1
Urticina lofotensis	0	0	0	0	0	0	0	1
Prionitis lanceolata	0	0	1	0	0	0	0	0
Codium setchellii/hubbsii	0	0	0	0	1	0	0	0
Codium fragile	1	0	0	0	0	0	0	0
Bryopsis corticulans	0	0	0	0	0	1	0	0
Callophyllis flabellulata	0	0	0	0	0	1	0	0
Desmarestia ligulata	0	0	0	0	1	0	0	0
Filamentous green algae	0	0	0	0	1	0	0	0

Table 23. Dutch Harbor fish counts—adult (juvenile)—in fall 2014 through spring 2018 by species.

[f, female; m, male]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Atherinops affinis	0	0	0	0	185	0	145	0
Brachyistius frenatus	52	5	18	2	0	0	3	10
Caulolatilus princeps	0	0	0	1	0	0	4	0
Cephaloscyllium ventriosum	0	0	0	4	0	0	0	0
Chromis punctipinnis	4,044	1,435 (405)	1,581	1,461	1,711 (70)	1,110	976	1,193
Coryphopterus nicholsii	36	12	11	1	8	10	8	2
Embiotoca jacksoni	40	22 (2)	62	25	43	27	67	64
Embiotoca lateralis	43	21 (3)	27	15	19	12	24	26
Gibbonsia spp.	1	0	0	0	0	0	0	0
Girella nigricans	53	27	39	18	28	48	105	23
Halichoeres semicinctus	0	0	4	2	0	0	2	0
Hypsurus caryi	0	0	3	2	8	3	33	10
Hypsypops rubicundus	17 (4)	14	23 (1)	18	26 (1)	17	28	18
Medialuna californiensis	43	55	70	13	14	31	9	8
Mycteroperca xenarcha	0	0	0	0	0	0	1	0
Neoclinus spp.	0	0	0	0	1	0	0	0
Ophiodon elongatus	3	0	1	2	0	0	0	0
Oxyjulis californica	3,742	1,816 (57)	1,068	237	622 (125)	548	239	683
Oxylebius pictus	74	50 (1)	46	13	25	11	46	12
Paralabrax clathratus	111	41 (29)	69	3	40	48	38	26
Rhacochilus toxotes	7	0	1	1	1	0	7	1
Rhacochilus vacca	17	6	27	8	17	10	13	13
Sardinops sagax	0	0	170	0	0	0	130	0
Scomber japonicus	40	0	0	5	0	0	0	0
Scorpaenichthys marmoratus	6	2	6	1	1	1	0	1
Sebastes atrovirens	49	73 (27)	108	17	64	24	38	23
Sebastes auriculatus	0	1	0	0	0	0	0	0
Sebastes carnatus	0	3 (2)	1	0	1	0	0	2
Sebastes caurinus	2	1	3	2	3	1	1	0
Sebastes chrysomelas	25	16	22	8	10	5	6	2
Sebastes melanops	0	0	0	2	0	0	0	0
Sebastes mystinus	195	101 (3)	392	144	183	279	177 (120)	190
Sebastes rastrelliger	2	7	2	2	2	0	0	1
Sebastes serranoides	144	100 (28)	272	38	77 (9)	47	96 (95)	115
Sebastes serriceps	6	1	5	4	2 (2)	1	4	0
Semicossyphus pulcher (f)	57 (6)	51 (49)	177 (17)	87 (3)	138 (2)	110 (1)	141	162
Semicossyphus pulcher (m)	22	37	30	14	13	7	15	28

Daytona 100

There have been no remarkable changes in the densities of organisms counted on swaths at Daytona 100 (table 24). With the exception of spring 2016, *S. purpuratus* densities have oscillated between about 600 and the mid-800s per swath throughout the last several years. The distribution is such that the site still appears as a mosaic of urchin dominated and kelp dominated areas. Purple urchins remained the most common swath-counted organism at Daytona 100. Red urchin (*S. franciscanus*) numbers declined somewhat in year 4, but they remained the second most abundant organism counted. *Cystoseria osmundacea* and understory kelps made up most of the remaining counts. Of the latter, although *E. arborea* declined during this period, *P. californica* remained relatively stable. The wavy top snail, *M. undosa,* continued to increase at the site.

Although densities of *M. pyrifera* were lower this year than for several previous years, the stipe counts and holdfast diameters (figs. 28 and 29) showed that unlike the other sites, Daytona 100 had a small but noticeable recruitment pulse this year. In spring 2018, half the sample had ≤5 stipes, and nearly as many had a holdfast diameter of ≤10 cm, indicating a substantial proportion of young plants.

A summary of density and sizes of non-echinoid invertebrate species observed at Daytona 100 is shown in table 25. As mentioned above, wavy turban snail (*M. undosa*) densities increased to record levels in year four. The size frequency distribution of this species indicated that most of the population growth was in the 40–75 mm size range (fig. 30).

The orange puffball sponge (*T. aurantia*) continued to be the only species consistently counted in 1-m^2 quadrats (table 26). The gastropod *N. norrisi* was present at low levels, and *C. spadicea and K. kelletii,* though present at low densities the previous year, were not recorded in year 4.

The size distribution of purple urchins showed little shift in the main mode, but there was a continued low-level influx of small animals in the 7–15 mm size range (fig. 31). We suggest that the increase in *S. purpuratus* density observed resulted from recruitment. The maximum sizes observed at this site for the species remained smaller than the other sites for unknown reasons. By spring 2018, the size distribution for red urchins was truncated on both tails with very few individual <30 mm or >85 mm in diameter (fig. 32). This resulted in a size distribution that had the lowest proportion of small individuals of any of the sites. Most of the sample was 60 to 80 mm with slightly less in the 40 to 60 mm range. There was a substantial decrease in the portion of the population in the 60 to 80 mm range. The maximum size here remained smaller than that at Nav Fac 100, but purple urchins were larger than that found at West End and Dutch Harbor (figs. 18, 23 and 27).

Encrusting coralline algae was again the most common cover species (table 27), with the brown alga *D. binghamiae* and the small holothurian *P. rubra* second and third. Cover categories throughout time as shown in figure 19 indicated that, although there was an increase in brown algae in spring 2018 (primarily *D. binghamiae* and *C. osmundacea*), the cover of fleshy red algae dropped to very low levels.

In year 4 fish surveys, Daytona 100 had the highest benthic fish densities of all the sites and ranked second (after Dutch Harbor) for overall density (table 12). Most of the fish counted were of the schooling species, blacksmith (*C. punctipinnis*) and señorita (*O. californica*), but kelp bass (*P. clathratus*) and sheephead (*S. pulcher*) were common (table 28).

Table 24. Daytona 100 mean (SD) swath counts for fall 2014 through spring 2018 expressed as individuals per 20 square meter (m^2).

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Aplysia californica	0.1 (0.32)	0 (0.00)	0 (0.00)	0.1 (0.32)	1.6 (2.27)	0 (0.00)	0.5 (0.97)	0 (0.00)
Astrometis sertulifera	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Crassadoma gigantea	2.4 (4.65)	0.5 (0.97)	1.7 (2.45)	0.9 (1.73)	1.7 (4.08)	2.2 (3.85)	2.2 (3.46)	2.7 (4.85)
Cystoseira osmundacea	32.3 (32.93)	27.8 (24.41)	26.1 (28.11)	15.1 (14.84)	23.1 (24.87)	23.5 (21.19)	19 (22.16)	34.9 (35.40)
Dermasterias imbricata	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Eisenia arborea	11.2 (7.87)	11.2 (5.98)	14.3 (10.24)	12.8 (9.19)	11.3 (6.29)	9.7 (6.25)	6.5 (4.58)	2.2 (2.04)
Haliotis corrugata	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Haliotis rufescens	0 (0.00)	0 (0.00)	0 (0.00)	0.1 (0.32)	0 (0.00)	0.1 (0.32)	0 (0.00)	0 (0.00)
Kelletia kelletii	0 (0.00)	0.9 (1.91)	0.5 (0.97)	5.5 (13.61)	0.9 (2.02)	0.2 (0.42)	0.4 (0.52)	6.5 (5.08)
Laminaria spp.	8.9 (11.68)	15.1 (20.96)	11.6 (14.36)	8.3 (11.04)	14.4 (18.29)	9.2 (11.29)	12.5 (18.00)	12.6 (13.16)
Lytechinus anamesus	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0.1 (0.32)	0 (0.00)	0 (0.00)	0.8 (0.79)
Macrocystis pyrifera <1 m	3.5 (2.72)	1.3 (1.49)	0.8 (1.32)	1.1 (1.20)	4 (3.27)	3.5 (4.70)	0.8 (1.14)	1 (1.49)
Macrocystis pyrifera >1 m	3.6 (3.50)	3.7 (4.30)	3 (3.20)	2.4 (2.27)	2.1 (2.77)	3 (4.22)	1.9 (1.66)	1.6 (1.26)
Megastraea undosa	0.6 (0.97)	0.8 (1.03)	1 (1.25)	0.4 (0.52)	3.4 (4.27)	2.7 (1.49)	4.6 (5.23)	10.3 (4.40)
Megathura crenulata	0.7 (1.16)	0.3 (0.48)	0.5 (0.71)	0.2 (0.63)	0.8 (0.92)	0.8 (0.79)	1 (1.15)	0.5 (0.97)
Parastichopus parvimensis	0.4 (0.70)	1.9 (1.85)	0 (0.00)	0.9 (1.60)	0.2 (0.42)	1.7 (1.42)	0 (0.00)	0.6 (0.84)
Patiria miniata	1.3 (1.83)	2.9 (3.70)	0.8 (0.79)	0.5 (0.85)	0.4 (0.70)	0.6 (0.70)	0.7 (0.82)	1.9 (1.37)
Pisaster giganteus	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0.1 (0.32)	0 (0.00)	0 (0.00)
Pterygophora californica	2.9 (3.31)	2.2 (2.15)	2.4 (3.66)	1.5 (2.46)	2.2 (2.30)	1.7 (2.26)	1.4 (1.96)	2.1 (2.92)
Pycnopodia helianthoides	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Sargassum horneri	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)

Table 24. Daytona 100 mean (SD) swath counts for fall 2014 through spring 2018 expressed as individuals per 20 square meter (m^2). —Continued

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Strongylocentrotus franciscanus	143.3 (119.12)	105.5 (75.93)	130.9 (111.10)	85.8 (83.22)	102 (100.96)	89.9 (83.83)	73.3 (85.76)	78.4 (79.56)
Strongylocentrotus purpuratus	639.5 (448.46)	867.2 (533.56)	631.7 (362.31)	388 (201.25)	578.8 (335.58)	885.7 (460.31)	683 (295.60)	841.5 (376.79)
Tethya aurantia	6.9 (4.70)	6.2 (3.19)	4 (2.21)	5.5 (3.31)	4.9 (4.18)	6 (3.40)	4.7 (3.89)	5.8 (4.73)
Urticina lofotensis	0.2 (0.42)	1.5 (2.01)	0.4 (0.97)	0.1 (0.32)	0.1 (0.32)	0.4 (0.84)	0.8 (1.62)	0.2 (0.63)
Young Laminariales	2.7 (4.30)	4.3 (5.72)	0.7 (1.25)	2.2 (3.05)	0.9 (1.29)	2.1 (3.21)	0.4 (1.26)	1.7 (3.74)

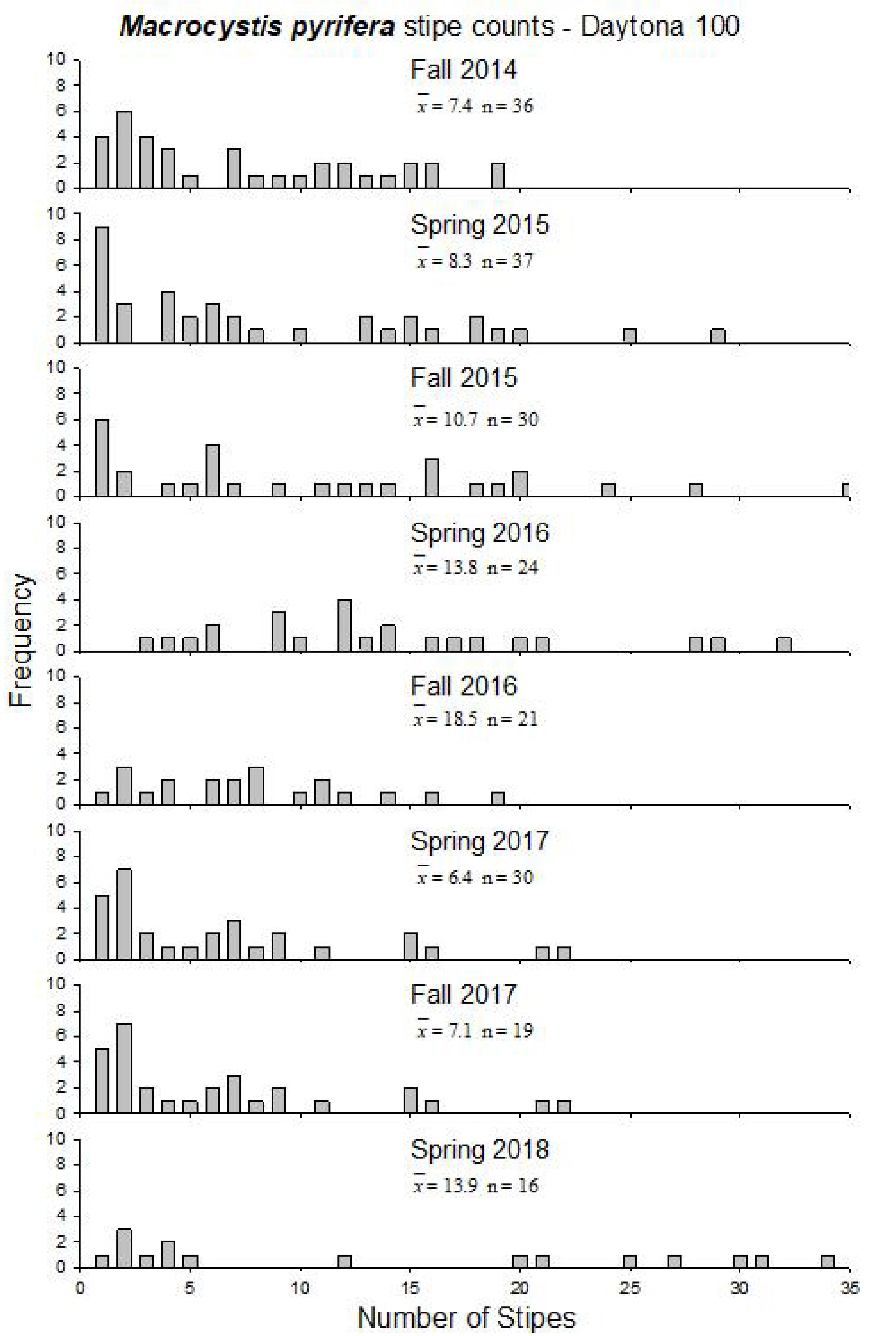

Figure 28. Daytona 100 *Macrocystis pyrifera* stipe counts by season, fall 2014–spring 2018.

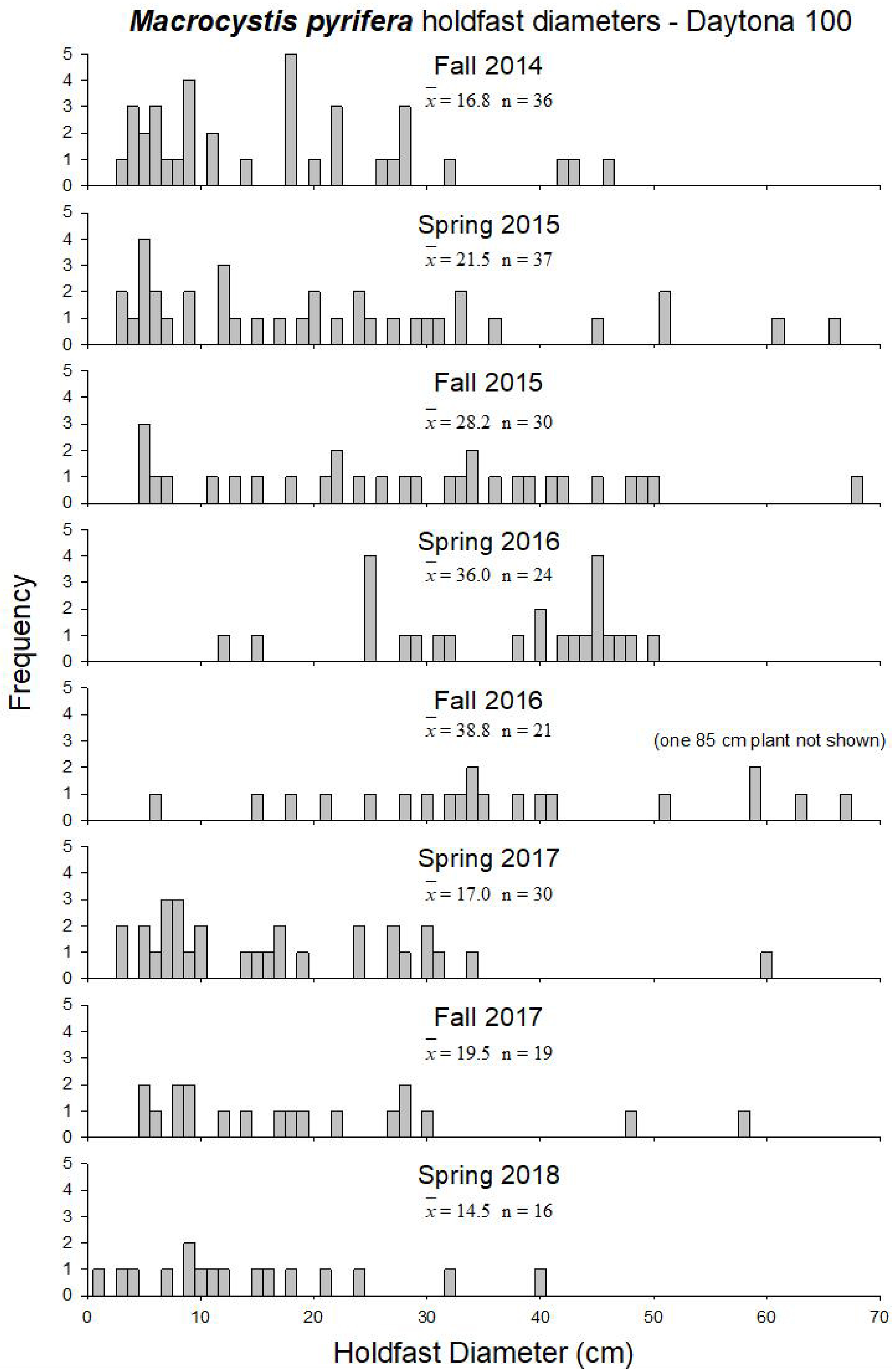

Figure 29. Daytona 100 *Macrocystis pyrifera* holdfast diameters by season, fall 2014–spring 2018.

Table 25. Sizes of non-echinoid invertebrates measured on swaths at Daytona 100, fall 2014 through spring 2018.

[*Strongylocentrotus* spp. excluded. See figures 31 and 32 for purple and red urchin size data. **Abbreviations**: N, sample size; Min, minimum; —, no data; Max, maximum]

Species name	*Crassadoma gigantea*	*Haliotis rufescens*	*Kelletia kelletii*	*Lytechinus anamesus*	*Megastraea undosa*	*Megathura crenulata*	*Patiria miniata*	*Pisaster giganteus*
Fall 2014								
N	23	0	0	0	6	6	13	0
Min	22	—	—	—	38	18	48	—
Max	101	—	—	—	90	100	101	—
Mean	52.3	—	—	—	65.0	80.3	64.0	—
Spring 2015								
N	5	0	9	0	8	3	29	0
Min	60	—	35	—	30	120	32	—
Max	180	—	110	—	130	193	94	—
Mean	97.0	—	60.8	—	86.1	151.0	59.8	—
Fall 2015								
N	17	0	5	0	10	5	7	0
Min	24	—	38	—	44	50	37	—
Max	170	—	135	—	85	120	86	—
Mean	74.7	—	68.6	—	59.3	86.0	66.7	—
Spring 2016								
N	9	1	34	0	4	2	5	0
Min	42	50	25	—	45	70	25	—
Max	95	50	120	—	68	80	70	—
Mean	67.7	50.0	46.1	—	56.8	75.0	49.8	—
Fall 2016								
N	17	0	9	0	34	8	4	0
Min	27	—	21	—	16	82	50	—
Max	88	—	123	—	106	130	80	—
Mean	65.6	—	50.3	—	56.6	100.6	67.0	—
Spring 2017								
N	23	1	2	0	27	8	7	1
Min	30	40	22	—	23	78	36	75
Max	140	40	50	—	120	110	61	75
Mean	78.4	40.0	36.0	—	57.6	96.5	52.3	75.0
Fall 2017								
N	22	0	5	0	47	10	9	0
Min	38	—	38	—	38	43	35	—
Max	154	—	112	—	93	103	100	—
Mean	83.3	—	73.8	—	62.7	88.2	62.3	—
Spring 2018								
N	27	0	65	8	103	5	20	0
Min	28	—	4	16	21	68	22	—
Max	110	—	81	38	108	114	82	—
Mean	60.4	—	42.7	25.6	64.3	92.4	53.7	—

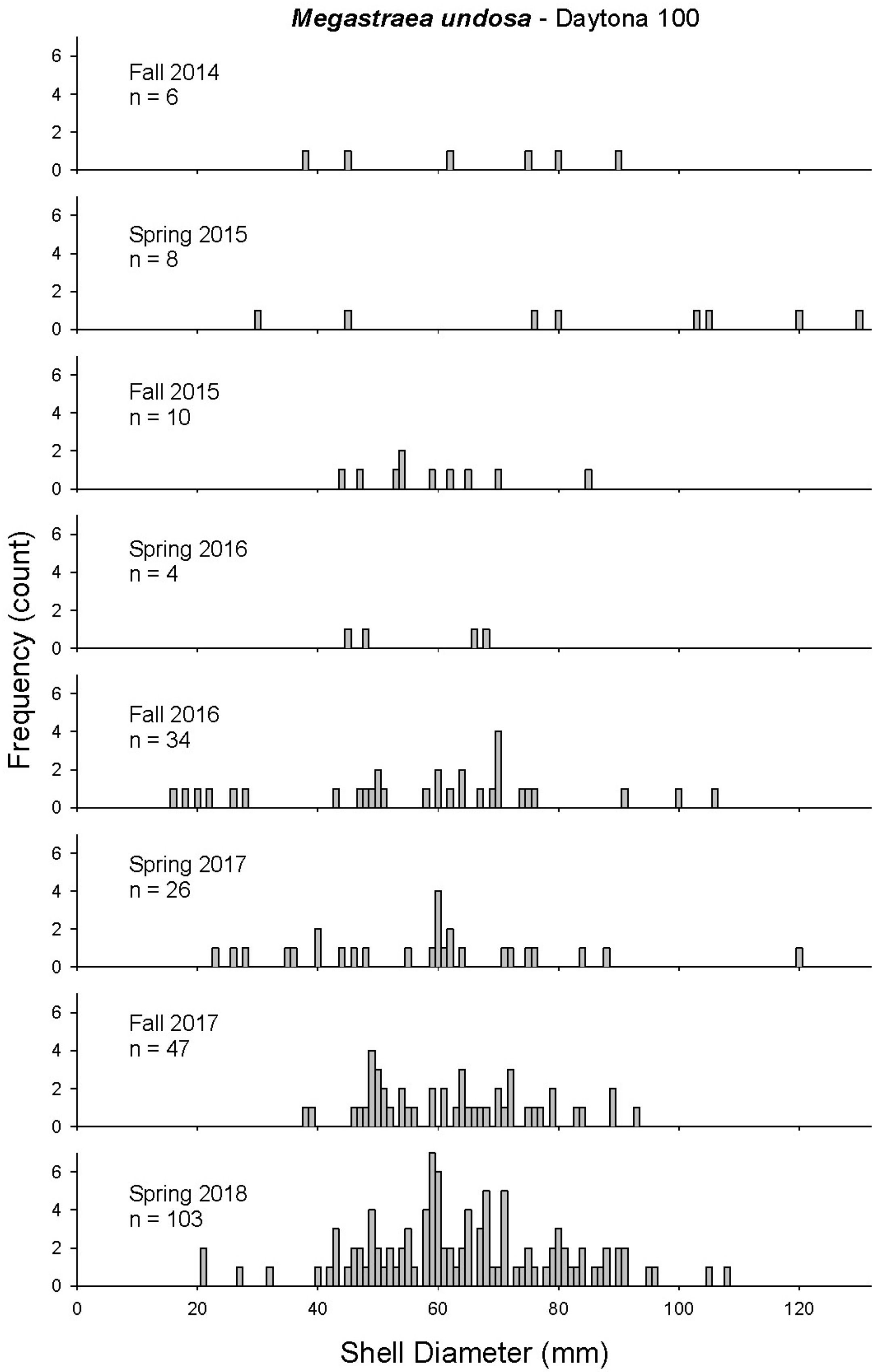

Figure 30. Daytona 100 size structure of wavy turban snails (*Megastraea undosa*) in fall 2014 through spring 2018.

Table 26. Daytona 100 mean (and standard deviation) of twenty 1-square-meter (m^2) quadrat counts for fall 2014 through spring 2018.

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Astraea gibberosa	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Cypraea spadicea	0.0 (0.00)	0.0 (0.00)	0.1 (0.22)	0.0 (0.00)	0.2 (0.37)	0.0 (0.00)	0.1 (0.22)	0.0 (0.00)
Kelletia kelletii	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.1 (0.31)	0.1 (0.22)	0.0 (0.00)	0.0 (0.00)
Norrisia norrisi	0.0 (0.00)	0.1 (0.22)	0.0 (0.00)	0.1 (0.22)	0.0 (0.00)	0.1 (0.22)	0.2 (0.49)	0.1 (0.31)
Sargassum horneri	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Styela montereyensis	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.1 (0.22)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Tegula regina	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)
Tethya aurantia	0.1 (0.31)	0.3 (0.57)	0.3 (0.64)	0.5 (0.83)	0.2 (0.37)	0.3 (0.64)	0.2 (0.37)	0.3 (0.55)
Urticina lofotensis	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)

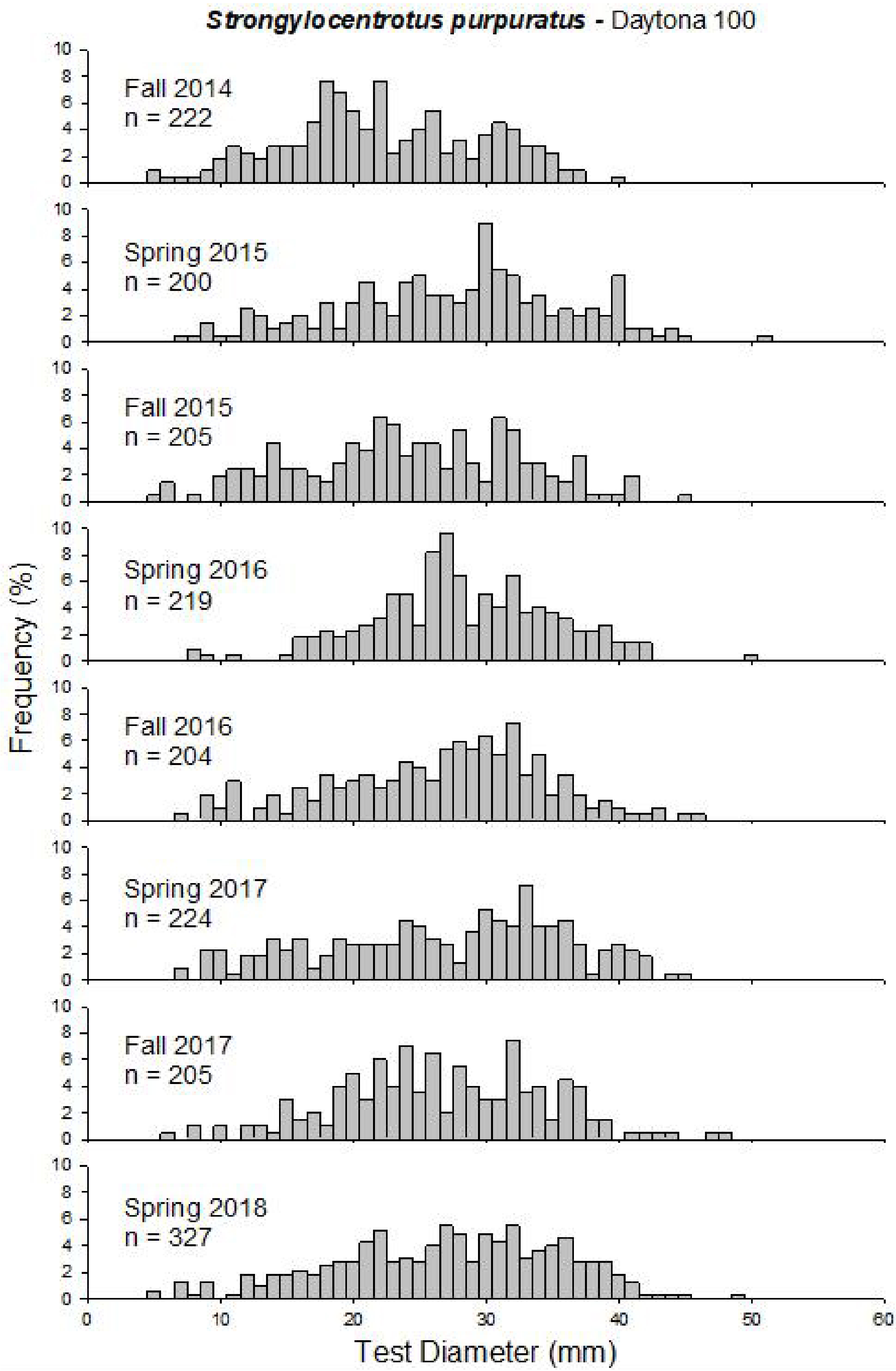

Figure 31. Daytona 100 size structure of purple urchins (*Strongylocentrotus purpuratus*) in fall 2014 through spring 2018.

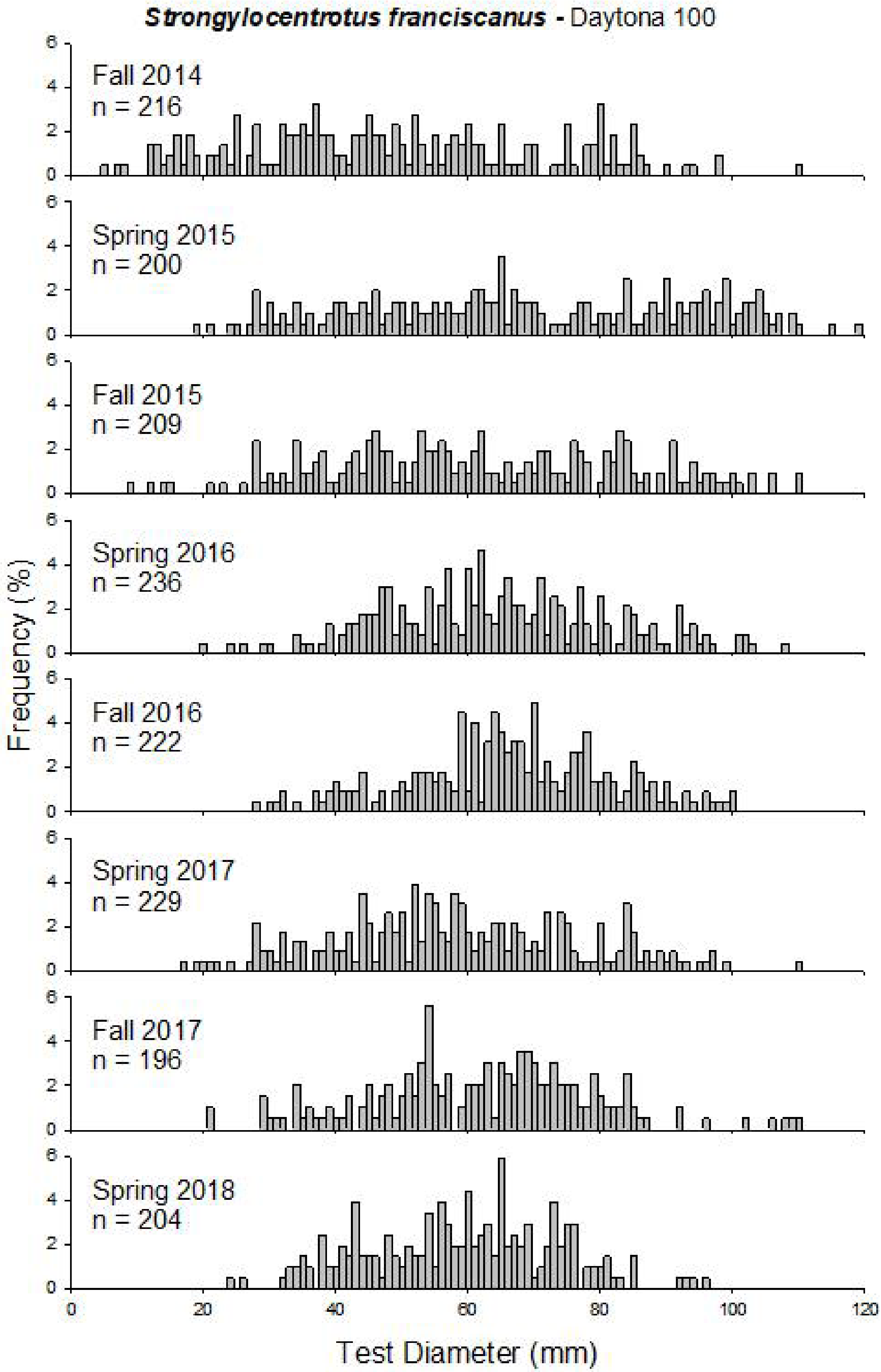

Figure 32. Daytona 100 size structure of red urchins (*Strongylocentrotus franciscanus*) in fall 2014 through spring 2018.

Table 27. Daytona 100 point contact "species" for fall 2014 through spring 2018 by number of points.

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Encrusting coralline algae	188	173	241	206	225	249	269	292
Dictyota binghamiae	26	42	27	90	59	38	75	115
Pachythyone rubra	23	41	13	16	23	37	113	35
Cryptopleura spp.	27	25	31	46	66	25	18	0
Bare substratum	39	34	33	15	32	21	37	15
Sand	26	40	32	30	19	30	15	27
Calliarthron spp.	29	12	23	26	30	16	21	17
Cucumaria fisheri	29	28	12	15	40	12	13	24
Cystoseira osmundacea	19	27	20	24	24	15	17	24
Pink encrusting bryozoan	1	5	12	22	34	21	15	12
Barnacle	59	51	4	0	0	2	0	0
Laminaria spp.	8	16	14	8	12	6	26	24
Rhodymenia californica	32	16	18	21	16	0	9	1
Corallina officinalis	13	18	11	6	12	20	9	6
Eisenia arborea	13	14	15	17	15	5	4	5
Balanophyllia elegans	14	15	11	6	2	7	4	6
Kelp holdfast	3	3	8	19	5	12	3	6
Serpulorbis squamiger	7	9	7	4	6	2	5	8
Orange encrusting sponge	13	10	5	2	3	1	2	2
Encrusting red algae	2	2	6	4	4	5	6	8
Dictyopteris undulata	1	5	2	6	3	9	2	7
Macrocystis pyrifera >1 m	2	1	5	14	2	3	0	2
Crisia spp.	0	0	5	15	6	0	1	1
Astrangia lajollaensis	1	4	4	0	4	5	5	2
Bugula spp.	2	3	0	8	4	0	8	0
Macrocystis pyrifera <1 m	4	8	1	3	1	0	1	1
Filamentous red algae	7	0	3	0	0	0	8	0
Strongylocentrotus purpuratus	6	2	2	1	0	5	0	1
Aglaophenia spp.	0	2	3	0	0	3	6	2
Lagenocella spp.	0	1	0	4	3	6	1	0
Laurencia pacifica	1	9	0	0	0	4	0	0
Bossiella spp.	6	0	1	1	2	0	0	0
Eupentacta quinquesemita	1	2	1	1	1	1	2	0
Mucus tube polychaete	0	0	0	0	7	1	0	0
Cellaria spp.	0	0	1	1	1	1	3	0
Kallymenia pacifica	2	0	0	0	0	1	1	3
Strongylocentrotus franciscanus	1	0	3	0	1	0	0	1
Dodecaceria spp.	1	2	1	1	0	0	1	0
Tethya aurantia	0	1	1	1	0	1	0	2
Filamentous green algae	1	0	1	3	1	0	0	0
Nienburgia andersoniana	0	1	0	2	1	0	1	0
Corynactis californica	0	3	0	1	0	0	0	0
Hippodiplosia insculpta	0	0	0	3	0	1	0	0

Table 27. Daytona 100 point contact "species" for fall 2014 through spring 2018 by number of points.—Continued

[>, greater than; m, meter; <, less than]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Archidistoma psammion	0	0	0	0	0	1	3	0
Metandrocarpa dura	0	0	0	4	0	0	0	0
Diademnum carnulentum	1	1	0	2	0	0	0	0
Pterygophora californica	0	0	0	0	2	0	1	1
Diopatra ornata	1	0	0	0	1	0	1	0
Acarnus erithacus	0	1	0	0	2	0	0	0
Spheciospongia confoederata	2	1	0	0	0	0	0	0
Abietinaria spp.	0	0	1	0	0	0	0	1
Cystodytes lobatus	0	0	0	1	0	0	0	1
Pholad clam	0	0	0	0	1	1	0	0
Colpomenia spp.	1	0	0	0	0	0	1	0
Plocamium pacificum	0	1	0	0	0	0	1	0
Bryopsis corticulans	0	0	0	0	0	2	0	0
Sargassum muticum	0	0	1	0	0	0	0	1
Anthopleura sola	0	0	0	0	0	0	1	0
Phragmatopoma californica	0	0	0	0	0	0	0	1
Acanthacora cyanocrypta	0	0	0	0	0	1	0	0
Cucumaria salma	0	1	0	0	0	0	0	0
Stylantheca porphyra	0	0	0	1	0	0	0	0
Phidolopora pacifica	0	1	0	0	0	0	0	0
Spirobranchus spinosus	0	0	0	0	0	0	1	0
Crassadoma gigantea	0	0	0	0	1	0	0	0
Taonia lennebackerae	1	0	0	0	0	0	0	0
Polysiphonia spp.	0	0	0	0	0	0	1	0
Codium setchellii/hubbsii	0	1	0	0	0	0	0	0
Pterosiphonia spp.	0	0	0	0	1	0	0	0
Red algal turf	0	0	0	0	0	1	0	0
Opuntiella californica	0	0	0	0	0	0	1	0
Chondracanthus exasperata	1	0	0	0	0	0	0	0

Table 28. Daytona 100 fish counts—adult (juvenile)—in fall 2014 through spring 2018 by species.

[f, female; m, male]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018
Atherinops affinis	0	0	0	0	0	300	35	0
Brachyistius frenatus	3	5	5	0	10	0	4	0
Caulolatilus princeps	0	0	0	0	5	0	4	0
Chromis punctipinnis	1,611	331 (105)	322	120	333	440	168	177
Coryphopterus nicholsii	43	10	2	2	6	3	2	3
Embiotoca jacksoni	9	26	11	7	18	4	7	0
Embiotoca lateralis	9	18	2	1	4	0	1	2
Girella nigricans	6	3	1	22	5	0	4	2
Halichoeres semicinctus	0	0	0	0	6	0	1	0
Hypsurus caryi	0	0	0	0	2	0	0	0
Hypsypops rubicundus	9 (2)	13 (1)	7 (1)	4	15	2	11	6
Medialuna californiensis	2	6	10	0	7	12	4 (25)	1
Oxyjulis californica	1,448	216	225	92	164	707	240	643
Oxylebius pictus	35	21	7	2	5	4	2	1
Paralabrax clathratus	91	47	21	18	62	26	59	27
Rhacochilus vacca	4	7	1	0	0	1	3	1
Scorpaena guttata	0	1	0	0	0	0	0	0
Scorpaenichthys marmoratus	0	2	0	0	0	0	0	0
Sebastes atrovirens	36	59	7	4	13	2	10	7
Sebastes caurinus	1	0	0	0	0	0	0	0
Sebastes chrysomelas	9	1	0	1	0	1	3	0
Sebastes mystinus	203	22	59	14	17	8	8	9
Sebastes serranoides	25	33	24	5	18	4	13	11
Sebastes serriceps	2	0	0	0	0	0	1	0
Semicossyphus pulcher (f)	15 (2)	35 (3)	22 (2)	25 (1)	62	32	32	35
Semicossyphus pulcher (m)	27	25	9	18	7	10	6	11
Stereolepis gigas	0	0	0	0	0	0	1	0

Long-Term Patterns

At the end of the fourth year of monitoring the four supersites, we found purple urchin densities have again increased at all sites. Likewise, red urchin densities rose slightly at all sites but Daytona 100. These increases appear minor, and it is surprising that urchin densities have not risen enough to trigger a phase change at any of the three kelp dominated sites, given that this has occurred through much of northern and central California following the loss of sea stars to SSWS throughout this region. However, a phase change occurred at Sandy Cove (3 kilometers [km] north of West End), a long-term SNI site not included in this study. Despite its proximity, Sandy Cove has undergone a complete transformation to an urchin dominated phase with mean purple urchin densities exploding from 0 to over 1,100 individuals per swath during the last 3 years.

Figure 33 shows mean *S. purpuratus* and *S. franciscanus* densities since the original monitoring project was established in 1980 (appendix 1). In this figure, Daytona 100 and Nav Fac 100 are represented only by their long-established segments (original 50-m transect), and urchin data collected on the additional 50-m transect that was added under the current project are not included. It is clear from these long-term plots that the recent increases in urchin density are dwarfed by the high numbers of the past at Nav Fac and West End. Even at Daytona, densities of urchins have been higher several times in the past. The current densities of purple urchins at Dutch Harbor, however, are the highest we have recorded there in nearly four decades of sampling.

Both Nav Fac and Daytona first became heavily grazed by sea urchins in the 1990s, Nav Fac in 1991 and Daytona in 1995. The corresponding precipitous loss of kelps can be seen in figures 34 and 35. Here again, only the original five swaths are used for this long-term view. Several abrupt but brief declines in purple urchin density are apparent in figure 33 for these sites, and some of these evoked an algal recruitment response. Beginning in the mid-2000s, both sites supported persistent understory kelp numbers, but these had a very patchy distribution because urchin numbers were still quite high. Daytona continues to be a patchwork of kelp and urchin dominated areas. Despite the precipitous loss of urchins at Nav Fac 100 in 2015 and their continued low densities there, the supersite did not experience the kind of exuberant kelp recruitment seen at West End in the early 2000s after sea urchin populations crashed there (fig. 36). *Macrocystis pyrifera* has thus far had only modest success at returning to Nav Fac 100, and *C. osmundacea* has been the main perennial to take hold, although understory kelps have recently reestablished. Annuals including various Dictyotales and the invasive alga *S. horneri* have been more prevalent there.

At Dutch Harbor, recruitment pulses of *M. pyrifera*, followed by attrition, senescence, and new recruitment, occurred in cyclic patterns of 2- to 3-year duration for two and a half decades. These appear as repeating peaks in figure 36. After 2007, however, there was an interruption to this pattern. In 2016, the first large recruitment in several years was observed in the fall following the El Niño storms of the previous winter. This cohort has now undergone attrition and the previous pattern may continue. The unusually high cover of fleshy red algae observed over the last decade might have contributed to the pattern interruption.

Following the loss of urchins at West End in 2001, *M. pyrifera* and understory kelps recruited heavily, and at this site, giant kelp also demonstrated a pattern of recruitment and attrition similar to that seen at Dutch Harbor. The magnitude of successive recruitments at West End, however, waned as understory kelp numbers and fleshy red algal benthic cover increased (fig. 37). This site is the most exposed to swell and perhaps, since these lower growing forms are better able to survive winter storms, they may have been able to outcompete *M. pyrifera* there. Since 2010, West End *M. pyrifera* densities have remained low, but the understory kelp and red algae revealed their own oscillating patterns. In 2016, *M. pyrifera* underwent a modest recruitment similar to Dutch Harbor. Although considerably smaller than previous recruitment pulses at this site, it was the largest in several years and corresponded with a decline in red algal cover. Although large numbers of small juvenile *M. pyrifera* were counted in spring 2017, there has not been another recruitment into the adult population.

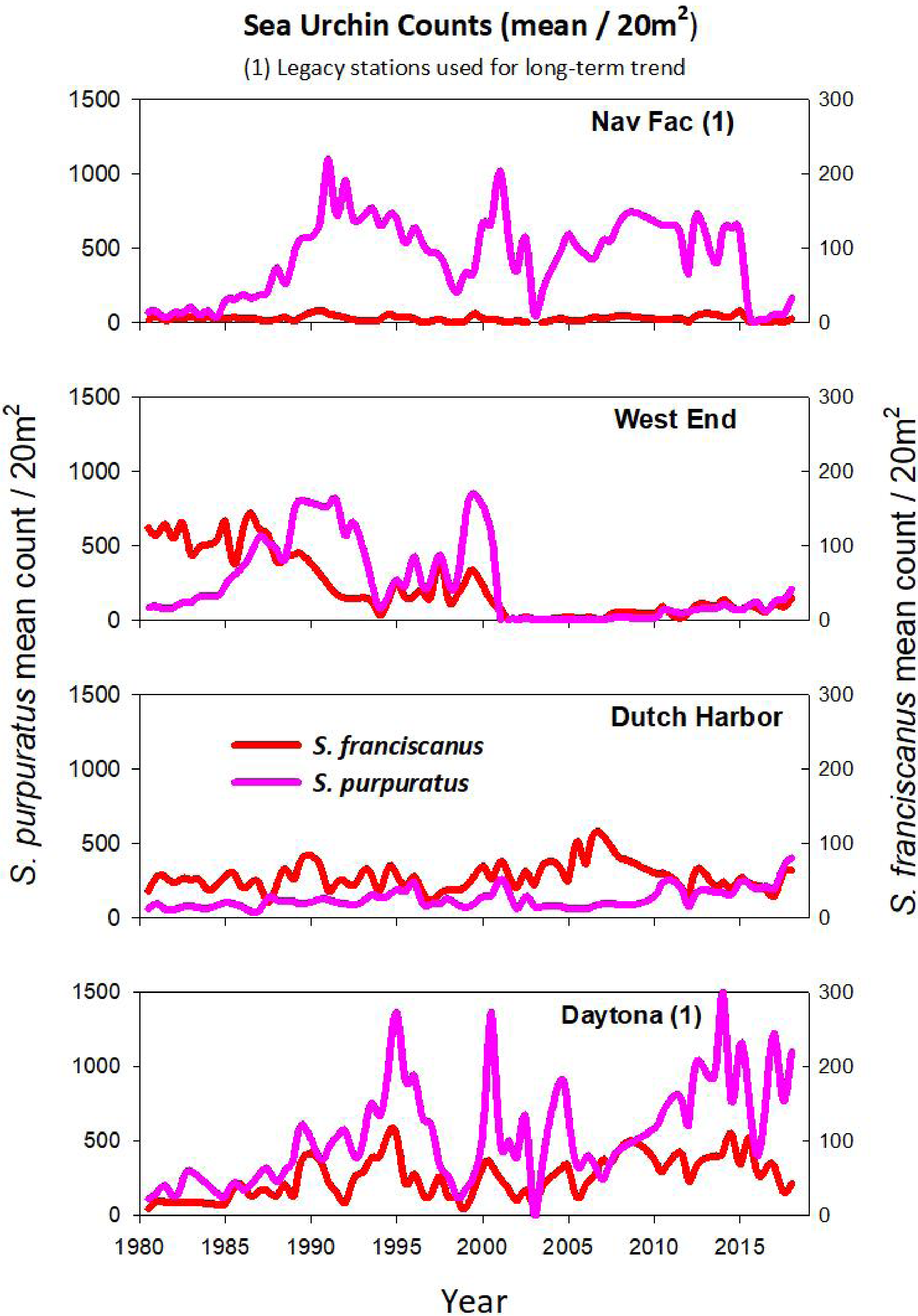

Figure 33. Long-term trends in urchin abundance. Note that Nav Fac and Daytona are the legacy sites (half the size of the supersites) presented to show history. *Strongylocentrotus purpuratus* and *S. franciscanus* are shown on different scales.

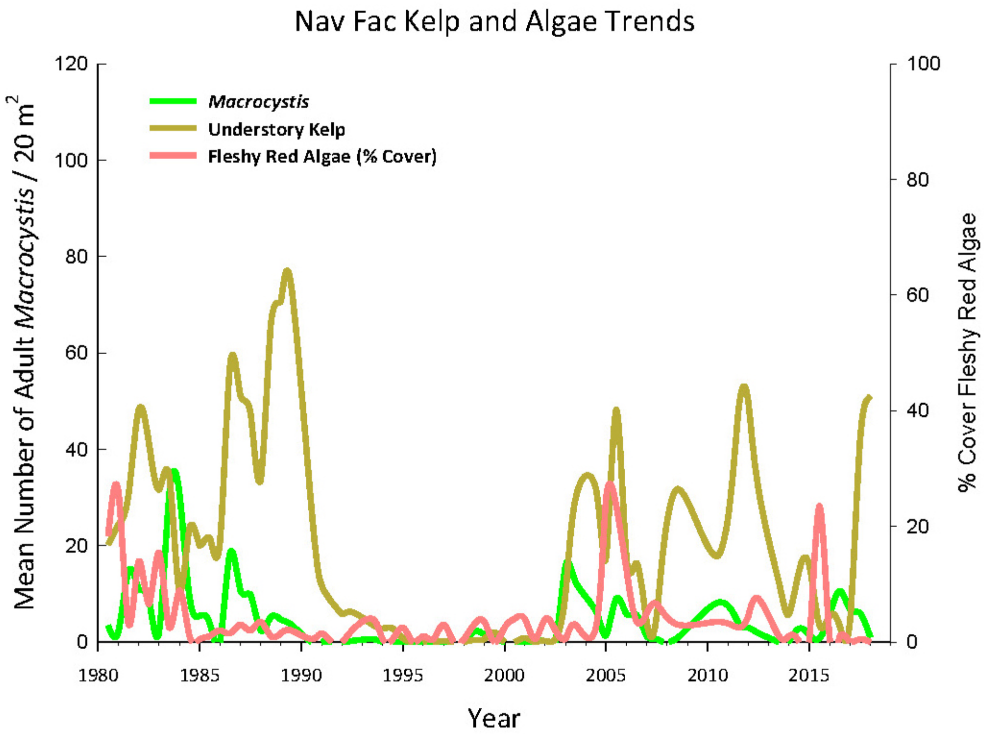

Figure 34. Kelp (*Macrocystis pyrifera* and understory species) and fleshy red algae cover trends over time at Nav Fac. Original transects only used for long-term trends.

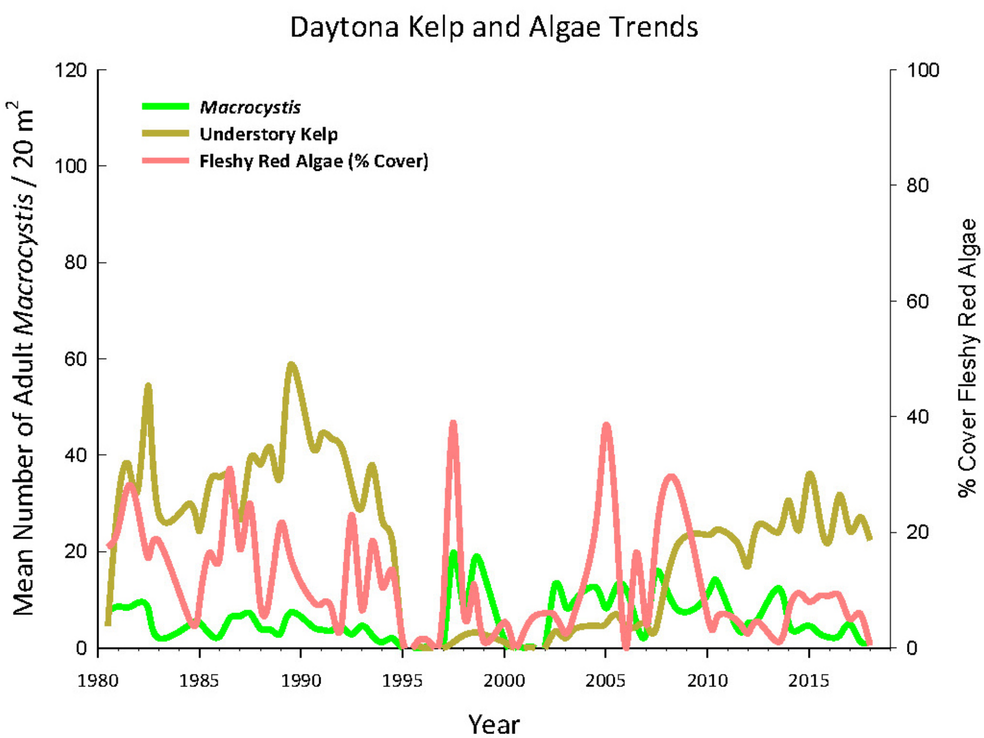

Figure 35. Kelp (*Macrocystis pyrifera* and understory species) and fleshy red algae cover trends over time at Daytona. Original transects only used for long-term trends.

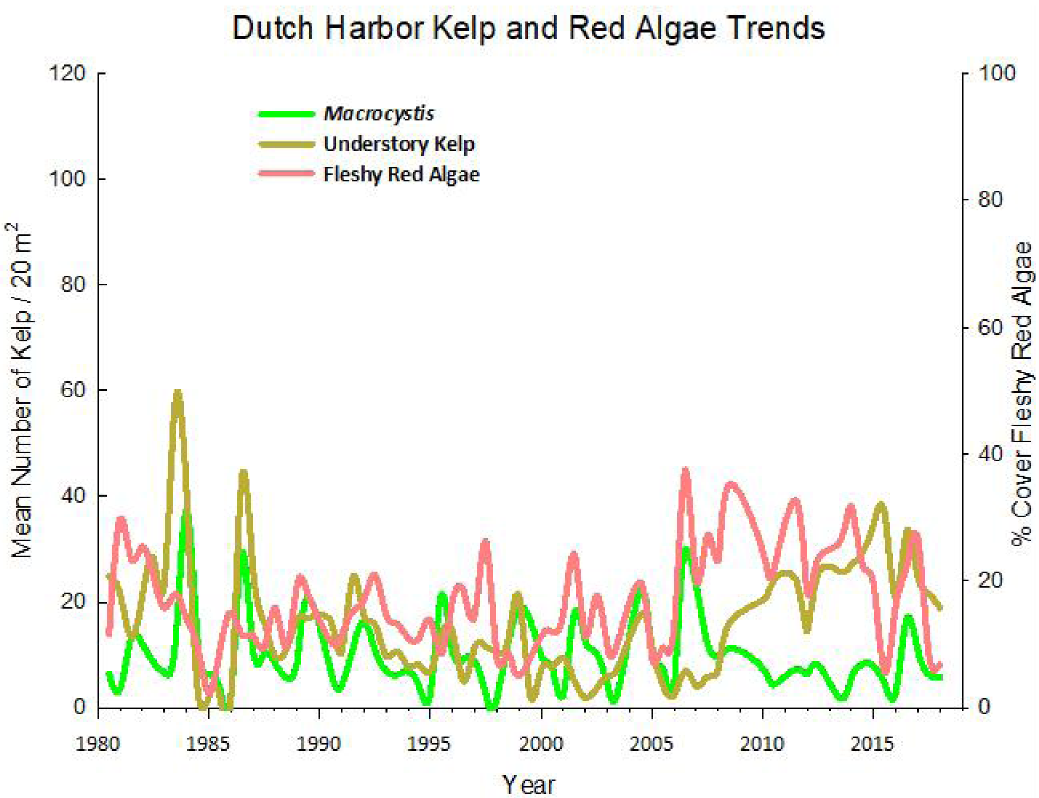

Figure 36. Kelp (*Macrocystis pyrifera* and understory species) and fleshy red algae cover trends over time at Dutch Harbor.

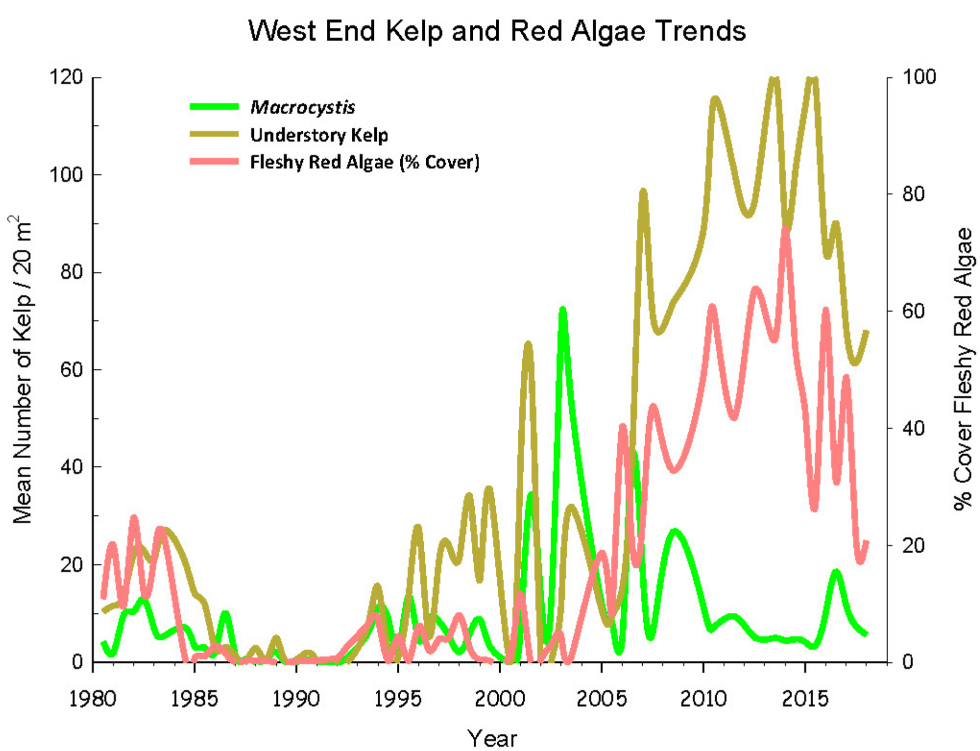

Figure 37. Kelp (*Macrocystis pyrifera* and understory species) and fleshy red algae cover trends over time at West End.

Conclusions and Management Considerations

The San Nicolas Island (SNI) subtidal monitoring project is one of the longest running programs of its type in the world. In addition to documenting the response of the rocky near-shore system to natural and anthropogenic perturbations for almost four decades, it has done so while the sea otter, arguably among the most influential organisms in the system, has returned and gradually increased at the island. Since the inception of the study, at least three major El Niño events, with associated severe storms, pummeled the island and bathed it with unusually warm water. Fisheries for red sea urchins and spiny lobster have exploited the area with unknown consequences. Invertebrate diseases have decimated abalone, sea stars, and sea urchin populations at different times and scales around the island, sometimes resulting in dramatic localized community shifts. Finally, *S. horneri*, an invasive brown alga with the potential to at least seasonally dominate the algal community, established at one of the sites. Several of these major disturbances have occurred since the expanded protocols were put in place in 2014.

We can expect that these types of perturbations will continue to influence the near-shore ecosystem around SNI: the distribution of *S. horneri* will spread to other areas, new disease episodes will alter community structure, and the expanding sea otter population will eventually spread its influence around the island. The system is also likely to face new issues in the future, including the effects of ocean acidification, warming sea temperatures and perhaps the increased frequency of destructive storms.

The sites we monitor each have their own character resulting from such physical factors as wave exposure, bottom relief, and substrate hardness, as well as site-specific stochastic ecological history. It is only through long-term studies such as this that we can predict what is an expected response to disturbance and what changes may be cause for concern. Thus, continued monitoring of this system represents a unique opportunity to build an understanding of the factors that drive ecosystem dynamics around SNI, to understand the role of top predators in ecosystem functionality, and to elucidate the ecosystem components that create resiliency to new and emerging threats.

Our results indicate that it may be valuable to continue the current monitoring program in order to apprise managers of the changing ecosystem and provide information to assist in decision making. The data also point to the potential value of an island-wide survey to help disentangle how forces such as predation, disease, and storms interact with stabilizers such as habitat and community complexity. An island-wide survey would also provide an opportunity to map the extent of the invasive alga *S. horneri* and remnant populations of abalone. Such an investigation would give resource managers insight into the workings of the ecosystem surrounding SNI.

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Appendix 1. Sampling History

In 1980, in anticipation of the translocation of sea otters to San Nicolas Island (SNI), U.S. Fish and Wildlife Service biologists, in cooperation with University of California, Santa Cruz (UCSC), established the SNI Subtidal Baseline project, a kelp forest monitoring program with the intention of documenting resulting ecosystem changes at the island (Kenner and others, 2013). Six permanent sites were initially installed: Nav Fac, Daytona, West End Urchin, West End Kelp, West Dutch Harbor, and East Dutch Harbor. A seventh site, Sandy Cove, was added in 1986. These locations are shown on figure 3 but Nav Fac, Daytona, and West End Urchin and Kelp are labeled by their supersite names (Nav Fac 100, Daytona 100 and West End). At these sites, kelps and a suite of motile macroinvertebrates were counted on fixed transects, the amount of exposed substrate and the cover of algae and sessile invertebrates were measured at fixed locations, and midwater and benthic fish were counted on transects. Responsibility for monitoring the sites passed on to the U.S. Geological Survey (USGS) in coopertation with UCSC in 1996. The sites have been monitored twice annually in spring and fall with a few exceptions since their inception.

In 2014, the U.S. Navy contracted with USGS to monitor the biota of four rocky reef sites around SNI (fig. 2). The purpose of this project was to continue to expand the 33-year dataset of subtidal monitoring at SNI but with modifications to the protocols so that these data were comparable with those from the other California Channel Islands. To achieve this, the six original USGS sites were expanded or combined as described below, and a few changes were made to data collection, including the addition of some invertebrates to the transect counts and the collection of size data on fish and some invertebrates. This project allows installation managers to characterize the long-term status and trends of communities and populations that occur within SNI's rocky reef and kelp forest habitat and their importance in the ecology of the Channel Islands. This perspective will also help installation managers to understand the potential effects of future perturbations such as disease events or changing environmental conditions.

The original sites consisted of a 50-meter (m) main transect with five 10 m x 2 m benthic band transects (swaths), ten 1-square-meter (m^2) random point contact (RPC) quadrats, and five 50-m fish transects. For better comparability to kelp forest monitoring conducted at other California Channel Islands, four of the sites were expanded to twice their original size. With the goal to retain compatibility with over three decades of previously collected data, the four new "supersites" were expanded to consist of a main transect with two 50-m subsections, each with the associated five swaths and ten RPC quadrats. The West End supersite was created by combining West End Urchin and West End Kelp sites which were already physically connected. The Dutch Harbor supersite was created by combining the East Dutch Harbor and West Dutch Harbor sites, which were about 140 m apart and roughly paralleled each other on two lobes of a reef separated by a sand channel. Nav Fac 100 and Daytona 100 were created by adding new segments to the existing Nav Fac and Daytona sites. Except in the case of Dutch Harbor, where these segments are on adjacent reefs, the 50-m main transects are connected in a linear fashion with the 50-m end of one connecting to the 0-m end of the other.

The expansion of sites for this project did not include additional fish transects. Therefore, since the supersites at West End and Dutch Harbor were formed by combining existing sites, they each have 10 fish transects, whereas Nav Fac 100 and Daytona 100 each have only 5 fish transects.

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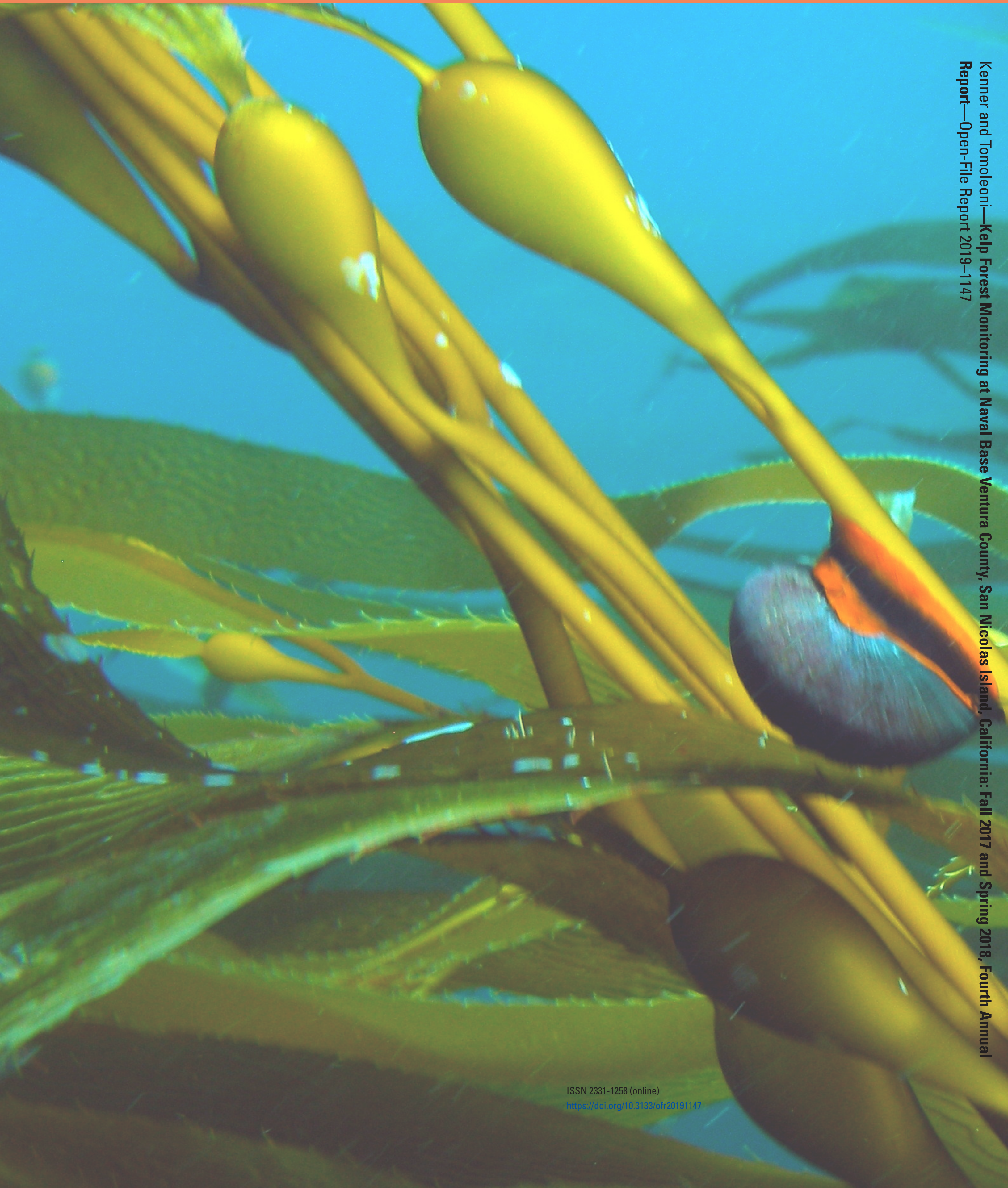

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