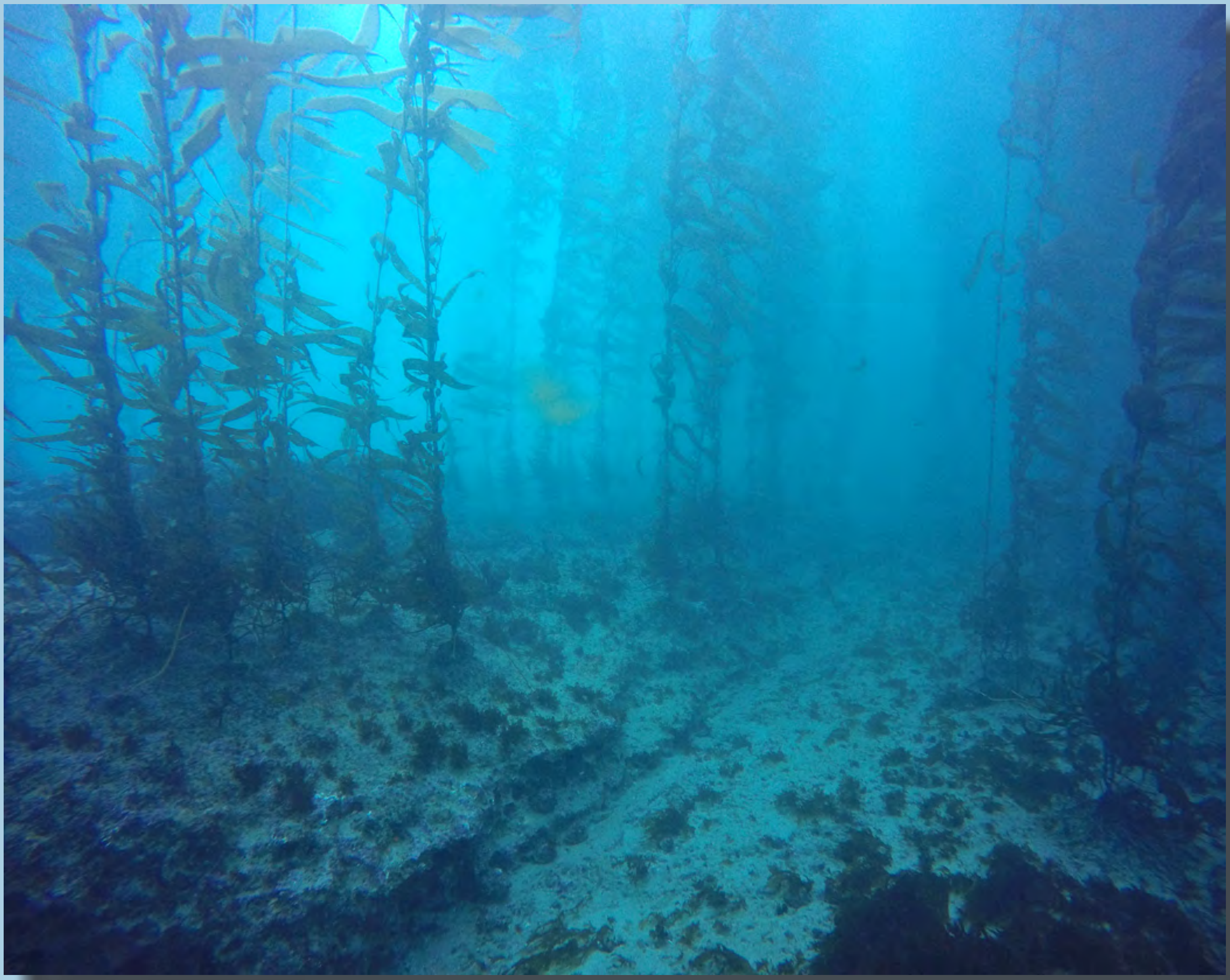
Prepared in cooperation with the U.S. Navy

Kelp Forest Monitoring at Naval Base Ventura County, San Nicolas Island, California: Fall 2018 and Spring 2019, Fifth Annual Report



Open-File Report 2020–1091

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

Cover Photo: Giant kelp forest at Nav Fac 100 supersite, San Nicolas Island, California, April 2, 2017. Photograph courtesy of Zach Randell, Oregon State University, used with permission.

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By Michael C. Kenner and Joseph A. Tomoleoni

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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)
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

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
WS	withering syndrome

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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 sinks (Wilmers and others, 2012) and are an important source of nearshore 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), outermost of the California Channel Islands, is home to a diverse group of terrestrial and marine organisms and includes 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 they 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 about 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 increased and is currently greater than 120 individuals (Hatfield and others, 2019). 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, that occurred at a site at the west end of the island in the early 2000s, though initiated by sea urchin disease, was likely facilitated to some degree by sea otter foraging (Kenner and Tinker, 2018).

These ecosystems also are the target of many fisheries, including urchin and lobster. Urchin fisheries, which target the larger red sea urchin, may release the smaller but more mobile purple sea urchin from competitive control (Dayton and others, 1998). Lobster fisheries may release purple sea urchins from predatory control (Lafferty, 2004). Owing to the distance from the mainland, however, SNI kelp forests and reefs have been somewhat protected from the degree of harvest and other anthropogenic impacts experienced by the southern California mainland. Invasive species are another issue, and there are a few invasive 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 at SNI and, so far, the invasive kelp *Undaria pinnatifida* and the green alga *Caulerpa taxifolia* have not been observed there. *Sargassum horneri*, in particular, has demonstrated a capability to outcompete native kelps at some of the other Channel Islands but it is unclear what indirect effects it may have on community structure (Marks and others, 2015).

Because the surrounding kelp forests fall within the management boundary of the SNI Integrated Natural Resources Management Plan (INRMP; U.S. Navy, 2015), USGS works with the Navy to provide surveys of this ecologically important ecosystem that inform natural resource managers of trends in the population abundance of particular species. In addition, long-term surveys allow for an understanding of potential changes in species diversity and community composition as a result of trophic or other interactions.

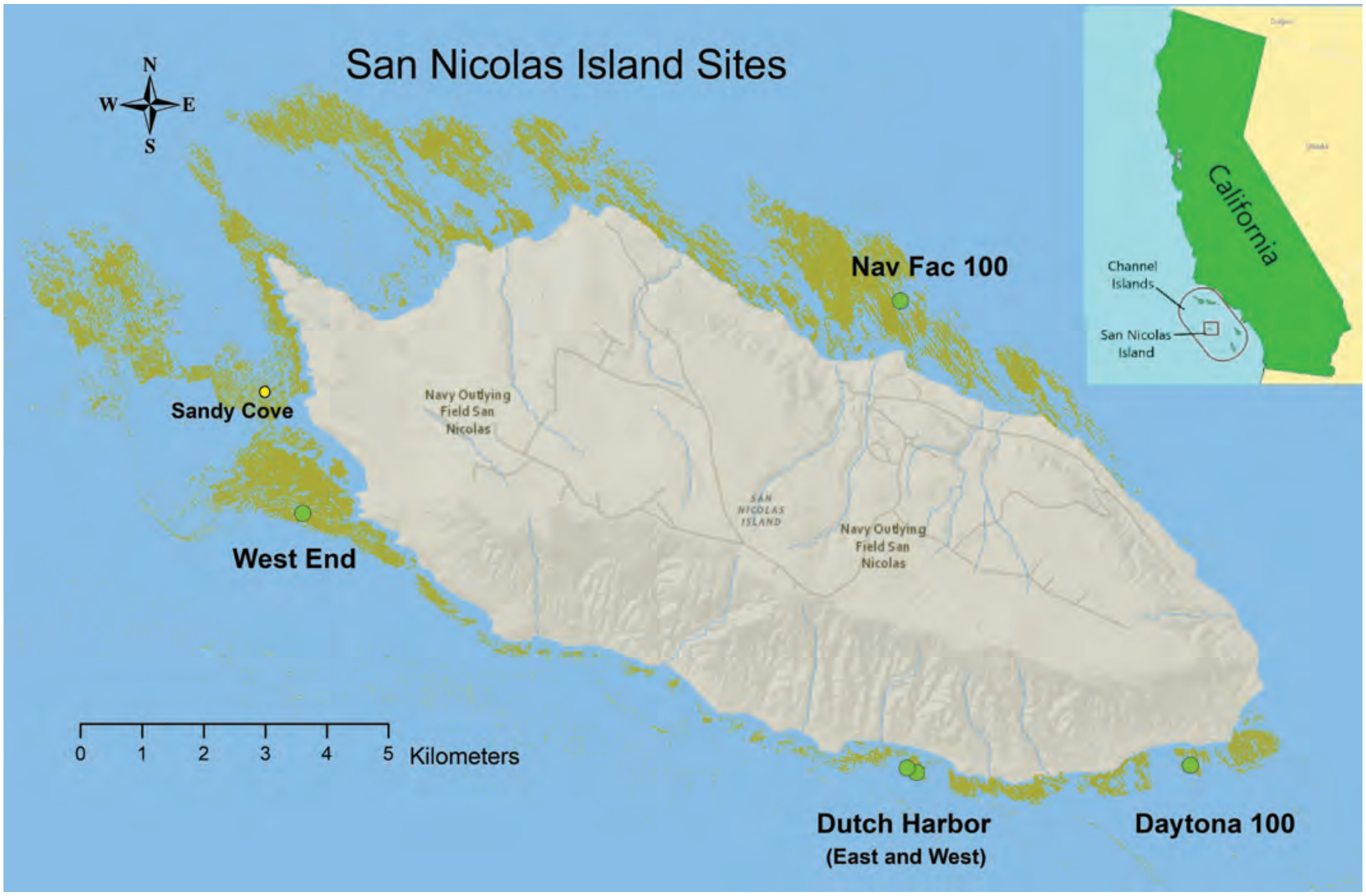

Figure 1. San Nicolas Island, California, study site locations and December 2018 kelp-canopy expanse.

The U.S. Geological Survey (USGS) 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 2018 (October 2–5) and spring 2019 (April 3–6). Together they will be herein referred to as year 5 because, although the trips were made in different calendar years, they were approximately 6 months apart and were conducted under the fifth year of this contract. The previous sampling year (fall 2017 and spring 2018) is referred to as year 4. The year 5 data are compared with data collected during eight trips from fall 2014 through spring 2018. Differences in counts between these expeditions can result from seasonal factors, stochastic variation, or sampling error, but temporal comparison can reveal population trends. Where appropriate, long-term data collected during the 33 years prior to the implementation of these slightly revised protocols will be presented in order to lend some context to the observations reported here.

Genus and species names used in this report are those currently recognized as valid in the Integrated Taxonomic Information System (ITIS.gov). Upon first use, the name recognized as valid by the World Register of Marine Species (WoRMS; marinespecies.org) is shown in brackets if different. The exception is *Sargassum horneri* which does not show up in any discernable form in ITIS.gov.

Methods

Site Design and Sampling Protocols

Four permanent "supersites" were sampled at the island, and each is composed of two subunit sites (figs. 1, 2). Most of these supersites 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 by 2-m benthic band transects (swaths) and ten 1-square-meter (m^2) random point contact (RPC) quadrats (see details in the following subsections). 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, except in the case of Dutch Harbor, where these segments are on adjacent reefs. 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 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 (10–12 m deep) 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 locations.

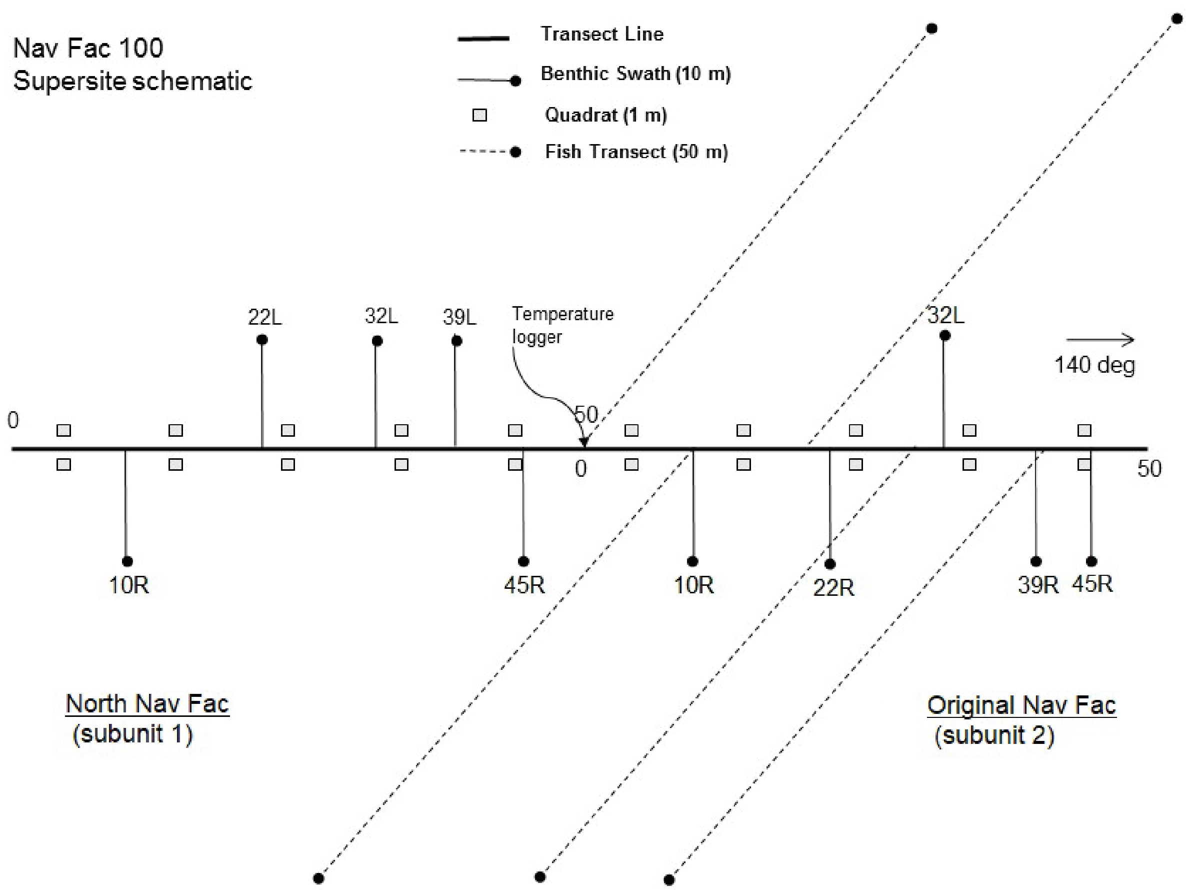

Figure 2. Typical supersite layout (Nav Fac 100). [Note that fish transects are on cardinal compass bearings and may not run perpendicular to main transect line]

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; S, south]

Marker name	Latitude	Longitude	Transect bearing
Nav Fac 100			
North Nav Fac 0 m	N33.27385˚	W119.48681˚	140˚
Nav Fac 0 m/N Nav Fac 50 m*	N33.27354˚	W119.48647˚	140˚
Nav Fac 50 m	N33.27310˚	W119.48626˚	
West End			
West End urchin 0 m	N33.24772˚	W119.57419˚	100˚
W End kelp 0 m/W End urchin 50 m*	N33.24762˚	W119.57367˚	110˚
West End kelp 50 m	N33.24742˚	W119.57318˚	
Dutch Harbor			
West Dutch Harbor 0 m	N33.21652˚	W119.48547˚	55˚
West Dutch Harbor 50 m	N33.21672˚	W119.48503˚	
East Dutch Harbor 0 m*	N33.21598˚	W119.48407˚	25˚
East Dutch Harbor 50 m	N33.21630˚	W119.48381˚	
Daytona 100			
South Daytona 0 m	N33.21643˚	W119.44420˚	0˚
Daytona 0 m/S Daytona 50 m*	N33.21687˚	W119.44412˚	0˚
Daytona 50 m	N33.21731˚	W119.44400˚	

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 by 2-m swaths, which run perpendicular to the main 100-m transect, were sampled by divers at each supersite. See table 2 for swath locations and orientations. Although nominally 20 m^2, the actual substrate sampled per swath was more, because of reefs, undercuts, boulders and other benthic features. First, researchers 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, using meter sticks as guides, then counted the target organisms (table 3) that occurred within 1 m on either side of the tape. Divers measured in situ sea star and mollusk size (millimeters [mm])—maximum arm length from center for sea stars (following the curve of the arm) and maximum shell length for mollusks. For giant kelp (*M. pyrifera*) greater than 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 alga. Stipe counts are more variable with age but give an indication of algal 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 tall stiff stipe) but 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*.

We measured the test diameter (millimeters) 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 they were encountered to avoid size selective bias.

Table 2. 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 m to 50 m. Note that the 45R swath at Daytona 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					
West End urchin	10L	22L	32R	39L	45L
West End kelp	10R	22R	32L	39R	45L
Dutch Harbor					
West Dutch	10R	22L	32L	39L	45L
East Dutch	10R	22R	32L	39R	45R
Daytona 100					
Daytona	10R	22R	22L	32L	39L
South Daytona	10R	22L	32R	39R	45R

Table 3. Species and measurements sampled on 10-m by 2-m swaths.

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

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)
Apostichopus 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
Tealia 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

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 at each supersite. Within each quadrat, 20 points were distributed in a fixed pattern, each representing an estimate of 5-percent cover. Divers identified all organisms that intersected with an imaginary line running vertically through each point up to 1 meter above the substratum. Each species was scored 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) also was 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 RPC sampling, also were used to sample densities of certain smaller species that are rare or difficult to count on swaths. Unlike the RPC sampling, which yields a measure of cover, these were actual counts of individuals. Within each quadrat, divers counted Norris's top snails (*Norrisia norrisii*), any *Tegula* species observed, red turban snails (*Lithopoma gibberosa* [*Pomaulax gibberosus*]), chestnut cowries (*Cypraea spadicea* [*Neobernaya spadicea*]), stalked tunicates (*Styela montereyensis*), Kellet's whelks (*Kelletia kelletii*), white-spotted rose anemones (*Tealia lofotensis* [*Urticina equis*]), orange puffball sponges (*Tethya aurantia* [*T. californiana*]) and the invasive brown alga (*Sargassum horneri*). These last four species also were counted on swaths.

Table 4. Point contact and 1-square meter 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					
West End urchin	R05	L05	R10	L10	R15	L15	R25	L25	R35	L35
West End kelp	R05	L05	R10	L10	R20	L20	L25	L40	R45	L45
					Dutch Harbor					
West Dutch	R10	R15	L15	L20	R25	L25	L30	R35	L35	R40
East 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

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. Except for those which follow the main transect line, these headings are north, south, east or west and may be as much as 40 degrees (°) off of perpendicular to the main transect line (fig. 2). 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. Juveniles also were recorded separately when morphologically distinct. Divers estimated total length (TL) of small fish (less than 20-centimeter [cm] TL) to the nearest 1 cm and larger fish (greater than 20 cm) to the nearest 5-cm interval. For schools of a species, a size range was recorded. As described earlier in the text, 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 high counts typically recorded there, fish only were 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 without size estimations 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—start point and bearing.

[* Fish not sized on these transects; ON means transect is on the main line. **Abbreviations**: m, meter; E, east; W, west; N, north; S, south]

Supersite and sites	Transects				
	1	2	3	4	5
Nav Fac 100					
Nav Fac	0-m E	10-m W	20-m E	30-m W	40-m W
West End					
West End urchin	0-m N	10-m N	20-m N	30-m N	ON
West End kelp	0-m S	10-m N	20-m S	30-m N	ON
Dutch Harbor					
West Dutch	0-m W	10-m W	30-m W*	45-m W*	ON*
East Dutch	0-m E	10-m W	20-m E*	30-m W*	40-m E*
Daytona 100					
Daytona	0-m E	0-m W	10-m E	20-m W	30-m E

Supersite Descriptions

See table 1 for subunit site coordinates and transect orientations and figure 1 for supersite 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 fall 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* [*Thylocodes sqamigerus*]. Kelps were common, including understory kelps *Laminaria* spp. and *Pterygophora californica* and canopy-forming giant kelp, *M. pyrifera*. 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 generally have been low throughout the site, although the more rugose eastern portion of the site appears to support more fish than the flat western side of the main transect line. The new part of the supersite (North Nav Fac), which was established in fall 2014, included some kelp dominated and some 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, however, has been slow, but *C. osmundacea* and various annual brown algae have covered large areas (fig. 3). The invasive brown alga *S. horneri*, which had not been observed at SNI before, first appeared at the site in fall 2015.

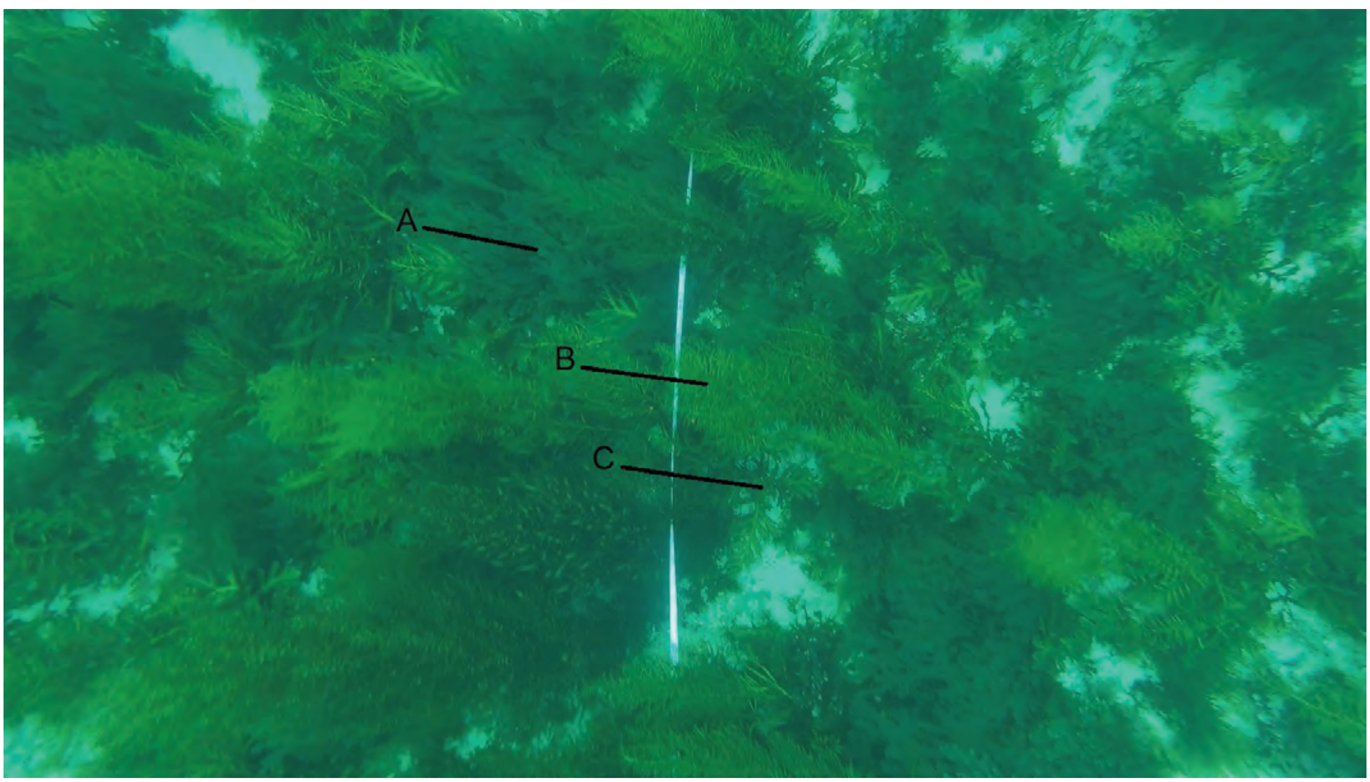

Figure 3. Nav Fac 100 supersite showing typical brown algae mix of *A*, *Dictyota binghamiae*; *B*, *Sargassum horneri*; and *C*, *Cystoseira osmundacea,* April 2019 (captured from video by Shannon Myers). Area shown is approximately 1 by 2 meters.

West End

The West End supersite is located off the southwest shore of the island. The bottom there generally is flat with scattered about 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 northwest 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 sampling began there 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 2001, the high density of *M. pyrifera* that recruited early on has largely given way to high densities of understory kelps and high bottom cover of fleshy red algae (fig. 4). 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.

Figure 4. West End supersite showing erect coralline and fleshy red algal bottom cover with understory kelp (center and left) and *Macrocystis pyrifera* (upper left and right), April 2019 (captured from video by Shannon Myers).

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 subunit site. The swaths traverse high-relief reefs up to 4 m in height with abundant cracks and ledges. 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 (fig. 5), 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. Rich invertebrate bottom cover at Dutch Harbor supersite, October 2018 (photograph by Zach Randell).

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 generally is flat with some 1–2 m ledges and boulders. The South Daytona subunit site, established in fall 2014, has somewhat higher relief and greater depth than the original Daytona site (northern 50 m). The area is exposed to occasional south swell. The prevailing wind blows offshore, so wind waves are usually small. The original Daytona site 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. 6). 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 since completion of the pier in 2005.

Figure 6. Daytona 100 supersite showing urchin and kelp dominated areas, April 2019 (captured from video by Shannon Myers).

Trip Conditions and Accomplishments

The fall 2018 trip took place October 2–5. A moderate long-period south swell and winds ranging up to 25 knots resulted in mostly fair to good diving conditions, moderate surge, and 5–8 m visibility. The Daytona 100 supersite was sampled under less favorable conditions with strong surge and poor visibility (ranging from 3 to 5 m). Water temperatures for the trip were about 16–17 degrees Celsius (°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 very sparse at all sites.

The spring 2019 sampling was conducted April 3–6. Winds generally were calm and the swell was moderate. Visibility was average, ranging from about 8–10 m. Water temperature was about 14 °C. We were again able to complete all sampling at the four supersites and download and redeploy the temperature loggers. Surface kelp canopies were absent at Nav Fac 100 and light at West End, Daytona 100, and Dutch Harbor.

Results

Island Wide

In 2018, mean sea temperatures were similar to the previous 2 years but about 1 °C cooler than in 2015. The maximum temperature recorded was slightly higher than in the previous 2 years though, and the range was again greater than was recorded in most previous years (fig. 7). Boxplots of bottom temperatures recorded at Nav Fac since 2006 and Dutch Harbor since 2012 are shown in figure 8. Each box represents a complete calendar year, so no plot is shown where there were missing months of data. Though the maximum is often higher than at Nav Fac, the mean, median, and other metrics are lower at Dutch Harbor in every year there is comparable data. Although temperatures at these two sites have declined since the 2014–15 El Niño, they are still higher than pre-El Niño conditions. In fact, the average annual mean temperature was approximately 1.1 °C higher in 2016–18 (15.45 °C at Nav Fac and 15.08 °C at Dutch Harbor) than for the years preceding the El Niño (14.44 °C during 2006–13 at Nav Fac and 14.03 °C during 2012–13 at Dutch Harbor). Temperature data recorded at three of the supersites from fall 2014 until spring 2019 and at Nav Fac 100 from fall 2015 until spring 2019 are shown in figure 9 (the temperature logger at Nav Fac 100 was lost after placement in fall 2014 and not replaced until fall 2015). Like in past years, late spring and early summer temperatures fluctuated on the order of 5 °C during an hour or two, possibly as a result of cold-water upwelling.

Counts of the large gastropod *Megastraea undosa* (fig. 10) have increased by an order of magnitude at all the supersites during the last 5 years. They have become particularly numerous at Nav Fac 100 where mean counts now exceed 50 per 20-m^2 swath. The density of the fucoid *C. osmundacea* also has increased at Nav Fac 100 and recently at Daytona 100 as well. The trend observed in year 4 (spring 2018) of increasing purple urchin densities leveled off at Nav Fac 100 and Dutch Harbor but continued in year 5 at West End and Daytona 100. *Strongylocentrotus purpuratus* densities at the latter supersite exceeded 1,000 per 20-m^2 swath, and large patches were dominated by the herbivores. As mentioned earlier, kelp surface canopies were sparse at all sites, but at Nav Fac 100 and Dutch Harbor, the counts of *Macrocystis* on transects were very low as well. The cover of fleshy red algae has declined recently at all sites except at Nav Fac 100, where it was already rare.

The invasive brown alga *S. horneri* was first observed in California at Long Beach Harbor 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. Typically, relatively low numbers are recorded in fall when plants are small (fig. 11); by spring, counts increase several-fold and because this annual alga produces copious reproductive fronds, cover increases dramatically. In spring 2019, however, densities of reproductive plants were considerably lower than the previous two spring seasons. It is not clear why this change occurred. *Sargassum horneri* has not been observed at any of the other SNI subtidal monitoring sites but has been seen attached at intertidal sites near Cosign Cove on the west end of SNI (S. Graham, unpub. data, 2020).

No abalone (*Haliotis* spp.) were counted at any of the sites in year 5 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. The timing of their decline corresponded with the decimation of the intertidal black abalone population on SNI by withering syndrome (WS; VanBlaricom and others, 1993), and the disease is known to have affected other abalone species. Because WS was not observed in subtidal habitats at SNI, however, it is possible fishing pressure or other factors may have contributed to the decline. Although sea otters could have played a part in reducing *H. rufescens* and *H. corrugate* density, sea otter numbers and distribution at the time make that unlikely.

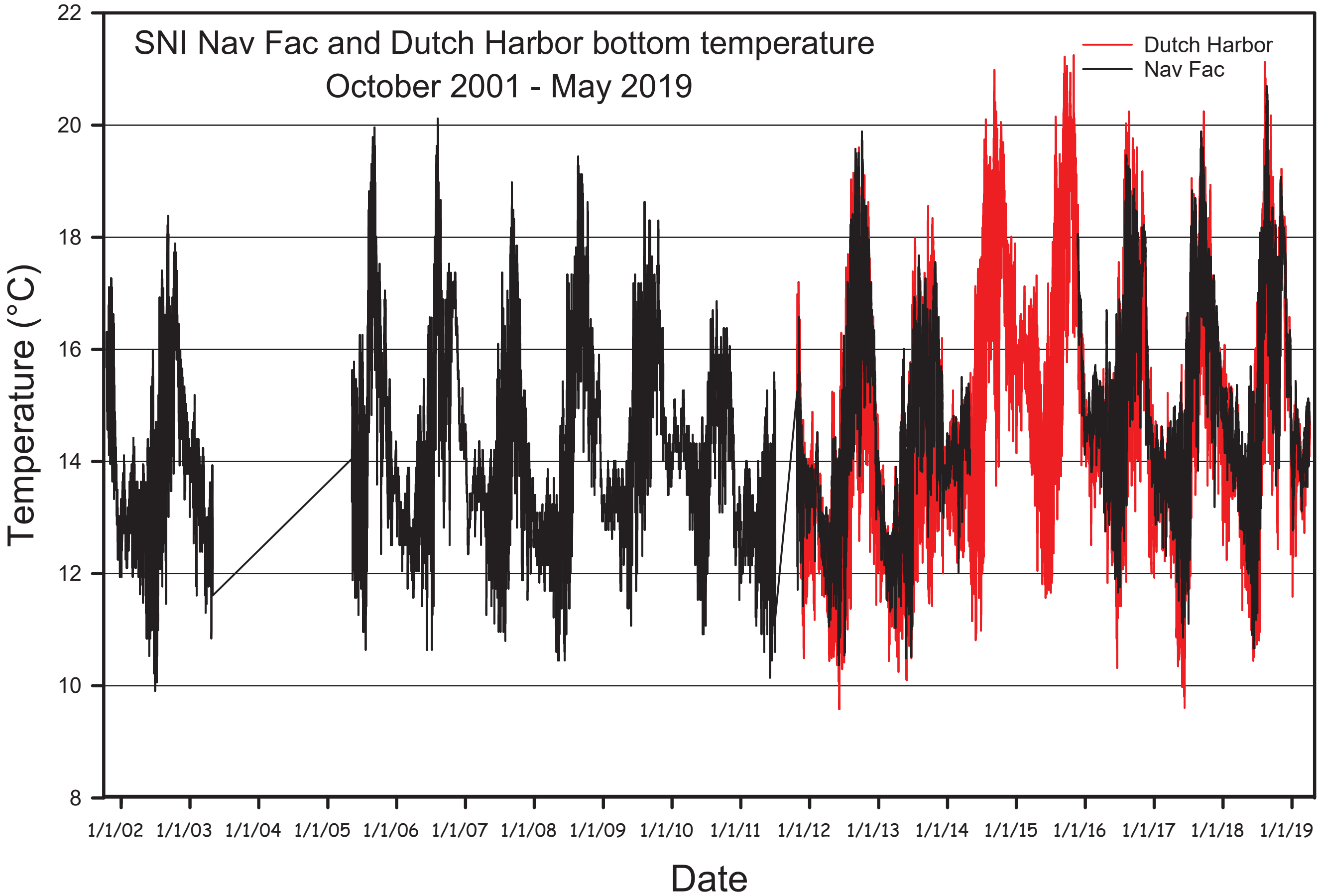

Figure 7. Eighteen-year temperature record from subtidal readings at San Nicolas Island subtidal sites. [Hourly temperature data from Nav Fac at 12-m depth from October 2001 to April 2019 (in black)—but note periods of missing data—and Dutch Harbor (in red) at 11-m depth from October 2011–April 2019]

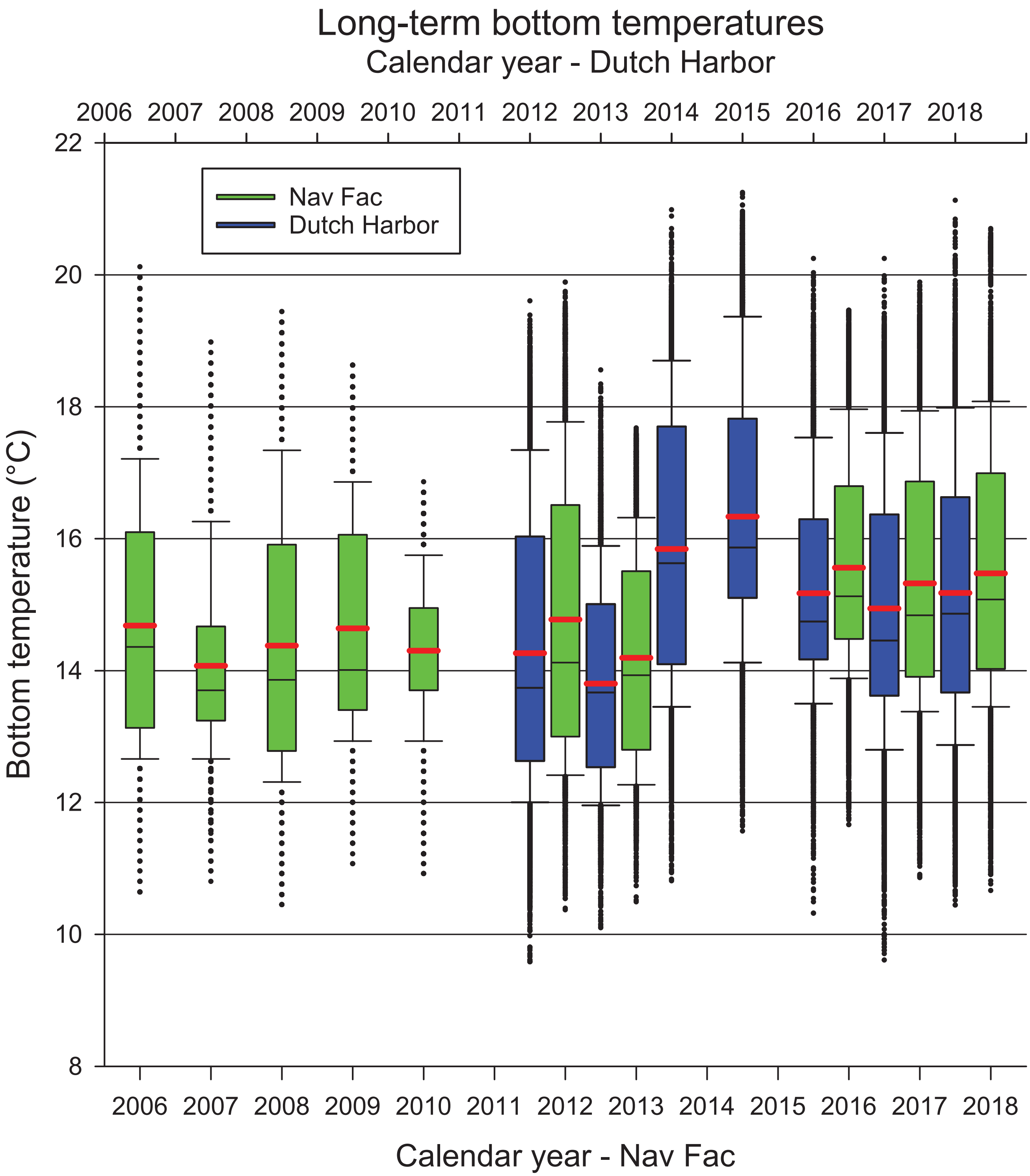

Figure 8. Annual bottom temperature at Nav Fac and Dutch Harbor. [The red line is the mean, the black line is the median, the box boundaries designate the 25th and 75th percentiles, and the caps on the whiskers are the 10th and 90th percentile. Outlying points are plotted beyond whisker caps and prior to 2012 have a dotted appearance because earlier data is only to nearest 0.1 degree Celsius (°C)]

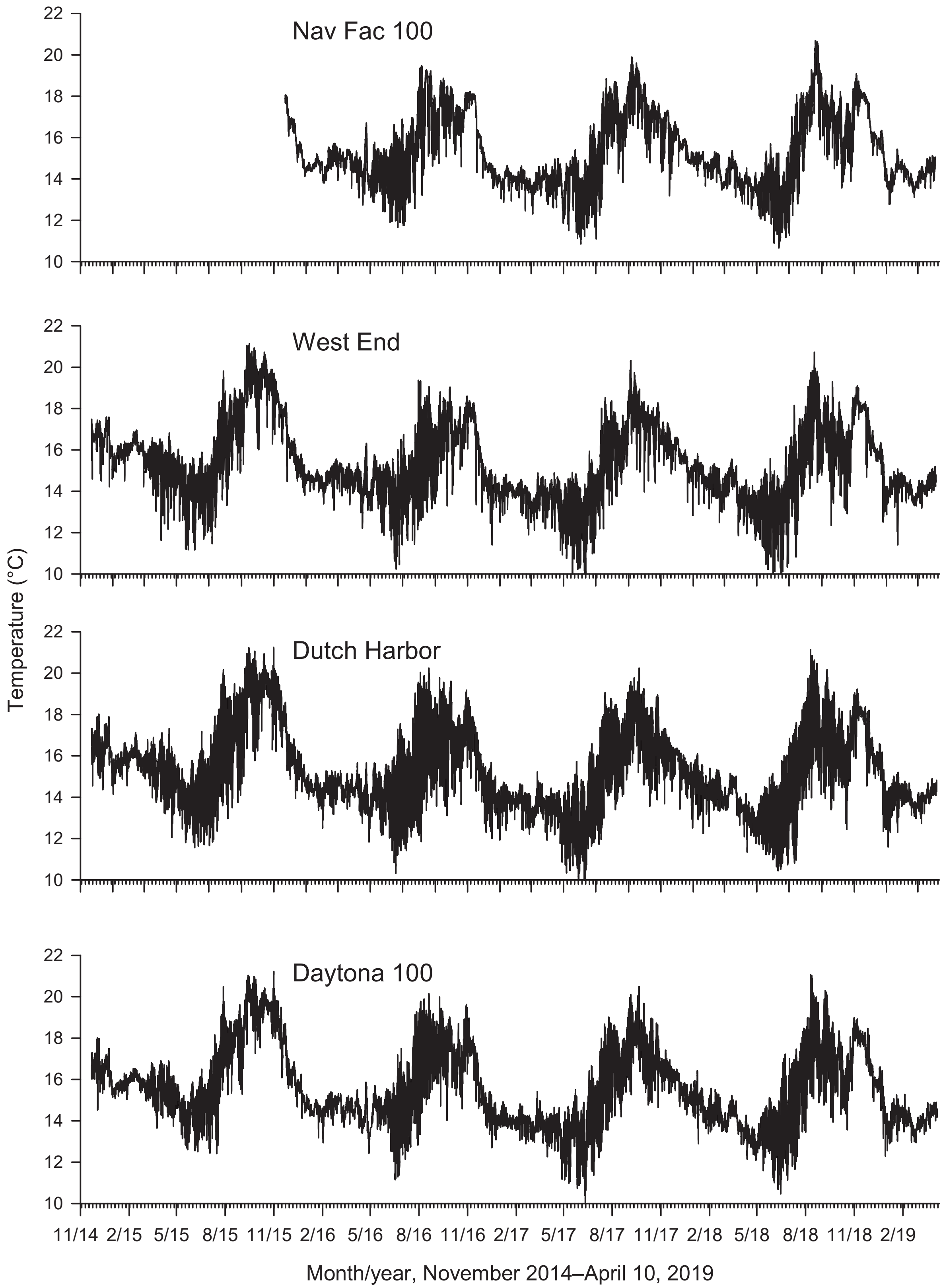

Figure 9. Hourly bottom temperature data for Nav Fac 100 from November 22, 2015, to April 10, 2019, and the other three supersites from November 22, 2014, to April 10, 2019.

Figure 10. The wavy turban snail (*Megastraea undosa*) with typical shell fouling of erect and encrusting coralline algae, October 2018 (photograph by Zach Randell). Basal diameter is approximately 10 centimeters.

Sea star numbers were still very low, apparently as a result of sea star wasting syndrome (SSWS). Bat star (*Patiria miniata*) densities again increased very slightly, but the mean of the counts at the four supersites (1.6 per 20-m^2 swath) remained less than half the long-term mean since 1980 (3.5 per 20-m^2 swath). The giant sea star (*Pisaster giganteus*) was the only other asteroid counted again. Only 3 were counted on each of the trips in year 5, which was down from 10 counted in spring 2018. No sign of SSWS or sea star recruitment was observed.

During the two trips in year 5, divers estimated the sizes of 5,903 fish and counted 9,026. Both trips yielded higher total fish counts than those from year 4 but considerably less than in the previous few years. The fall 2018 total of 3,475 was less than the long-term average of 4,410, but the spring 2019 count of 5,551 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 2018, and table 7 shows these data for spring 2019. As usual, the schooling species, blacksmith (*Chromis punctipinnis*) and señorita (*Oxyjulius californica*), comprised most of these counts.

Figure 11. Juvenile form of the invasive alga *Sargassum horneri*, typical of plants seen in fall, at Nav Fac 100 supersite, October 2018 (photograph by Zach Randell). Branch length is approximately 10–15 centimeters.

There was no recruitment of sheephead (*Semicossyphus pulcher*) observed at the sites in year 5. 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 5-year period are plotted by sex in figure 12. This figure shows recruitment during the first few surveys when warm water (averaging 16.5 °C and ranging above 21.0 °C) was prevalent. In fall 2018 and spring 2019, there were no individuals less than 14 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 relatively stable throughout the last several sample years. In year 5, there did appear to be more individuals in the larger size classes.

Table 6. Summary of fall 2018 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 names	Minimum size	Maximum size	Mean size	Number sized
Artedius spp.	unidentified sculpin	6	6	6.0	1
Atherinops affinis	topsmelt	17.5	17.5	17.5	8
Brachyistius frenatus	kelp perch	10	16	13.8	12
Caulolatilus princeps	ocean whitefish	40	45	42.5	4
Chromis punctipinnis	blacksmith	7.5	17.5	12.5	717
Rhinogobiops nicholsii	blackeye goby	8	11	9.7	5
Embiotoca jacksoni	black perch	10	35	19.4	54
Embiotoca lateralis	striped seaperch	10	25	16.3	13
Gibbonsia spp.	kelpfish	40	40	40.0	1
Girella nigricans	opaleye	20	56	37.0	44
Heterostichus rostratus	giant kelpfish	50	50	50.0	1
Hypsypops rubicundus	garibaldi	12	35	23.1	16
Medialuna californiensis	halfmoon	25	41	34.4	12
Myliobatis californica	bat ray	100	100	100.0	1
Oxyjulis californica	senorita	2.5	17.5	10.0	731
Oxylebius pictus	painted greenling	9	25	13.6	26
Paralabrax clathratus	kelp bass	10	52	33.7	71
Rhacochilus vacca	pile perch	25	35	30.0	13
Sebastes atrovirens	kelp rockfish	15	45	30.1	10
Sebastes caurinus	copper rockfish	42	42	42.0	1
Sebastes mystinus	blue rockfish	10	34	19.5	42
Sebastes serranoides	olive rockfish	10	40	26.7	17
Semicossyphus pulcher (f)	California sheephead (f)	15	67	38.0	98
Semicossyphus pulcher (m)	California sheephead (m)	15	100	63.0	24
Total sized	—	—	—	—	1,922

Table 7. Summary of spring 2019 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 names	Minimum size	Maximum size	Mean size	Number sized
Brachyistius frenatus	kelp perch	10	15	12.3	6
Caulolatilus princeps	ocean whitefish	34	60	45.2	7
Chromis punctipinnis	blacksmith	7.5	17.5	12.5	2,258
Rhinogobiops nicholsii	blackeye goby	6	12	9.3	8
Embiotoca jacksoni	black perch	12	35	20.1	53
Embiotoca lateralis	striped seaperch	11	25	17.4	15
Girella nigricans	opaleye	25	53	42.0	13
Halichoeres semicinctus	rock wrasse	15	15	15.0	1
Hypsurus caryi	rainbow seaperch	14	20	16.8	4
Hypsypops rubicundus	garibaldi	15	35	22.8	26
Medialuna californiensis	halfmoon	19	38	27.7	12
Oxyjulis californica	senorita	2.5	17.5	10.0	1,152
Oxylebius pictus	painted greenling	9	25	13.6	20
Paralabrax clathratus	kelp bass	7	70	33.0	85
Rhacochilus vacca	pile perch	29	38	34.0	3
Sebastes atrovirens	kelp rockfish	8	45	23.8	23
Sebastes chrysomelas	black and yellow rockfish	21	35	28.0	2
Sebastes mystinus	blue rockfish	10	37	21.8	95
Sebastes rastrelliger	grass rockfish	35	35	35.0	1
Sebastes serranoides	olive rockfish	16	52	35.8	23
Sebastes serriceps	treefish	25	31	28.0	2
Semicossyphus pulcher (f)	California sheephead (f)	14	60	33.2	141
Semicossyphus pulcher (m)	California sheephead (m)	20	90	66.0	31
Total sized	—	—	—	—	3,981

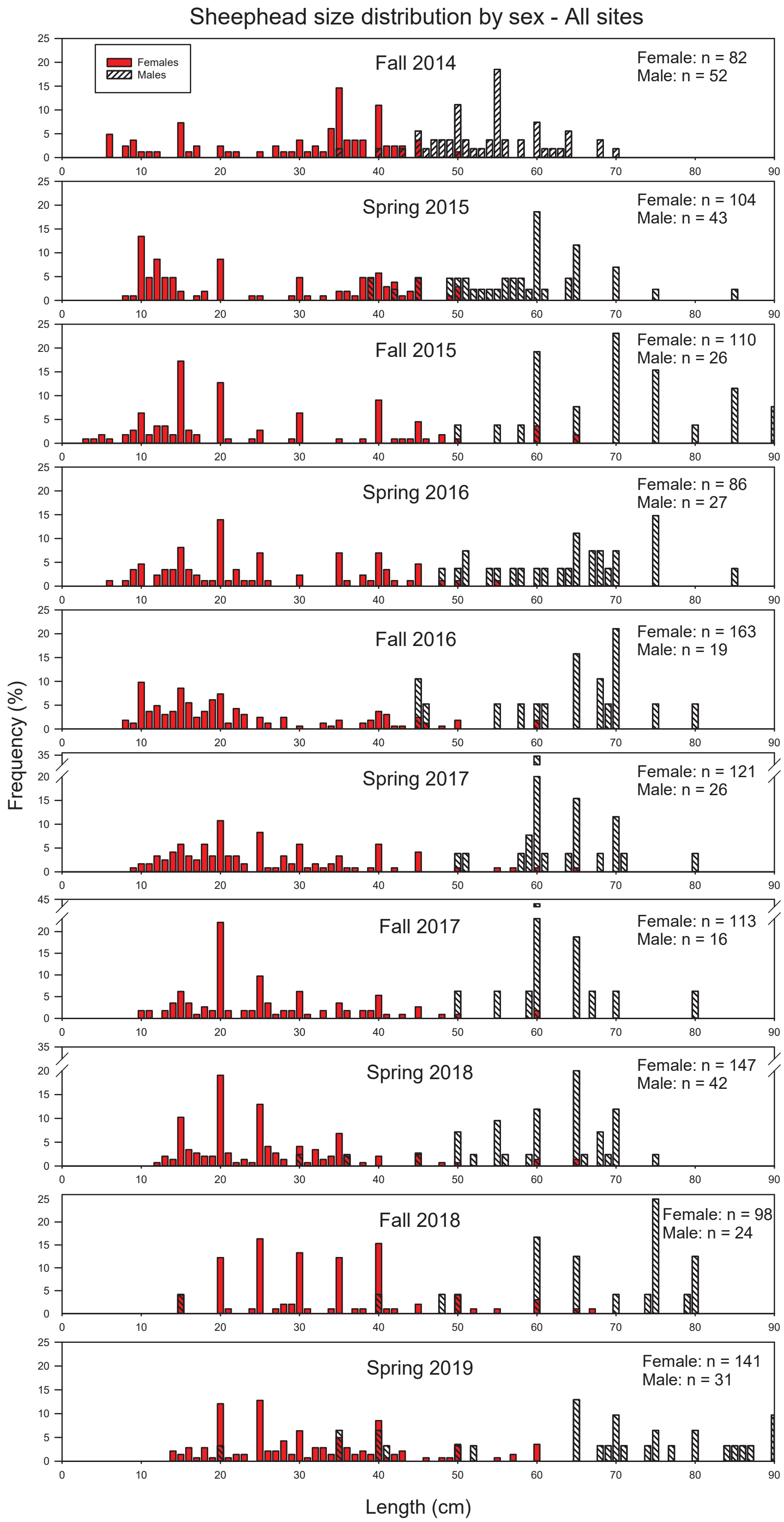

Figure 12. Size distribution by sex of sheephead (*Semicossyphus pulcher*) in fall 2014–spring 2019. [n = number of individuals]

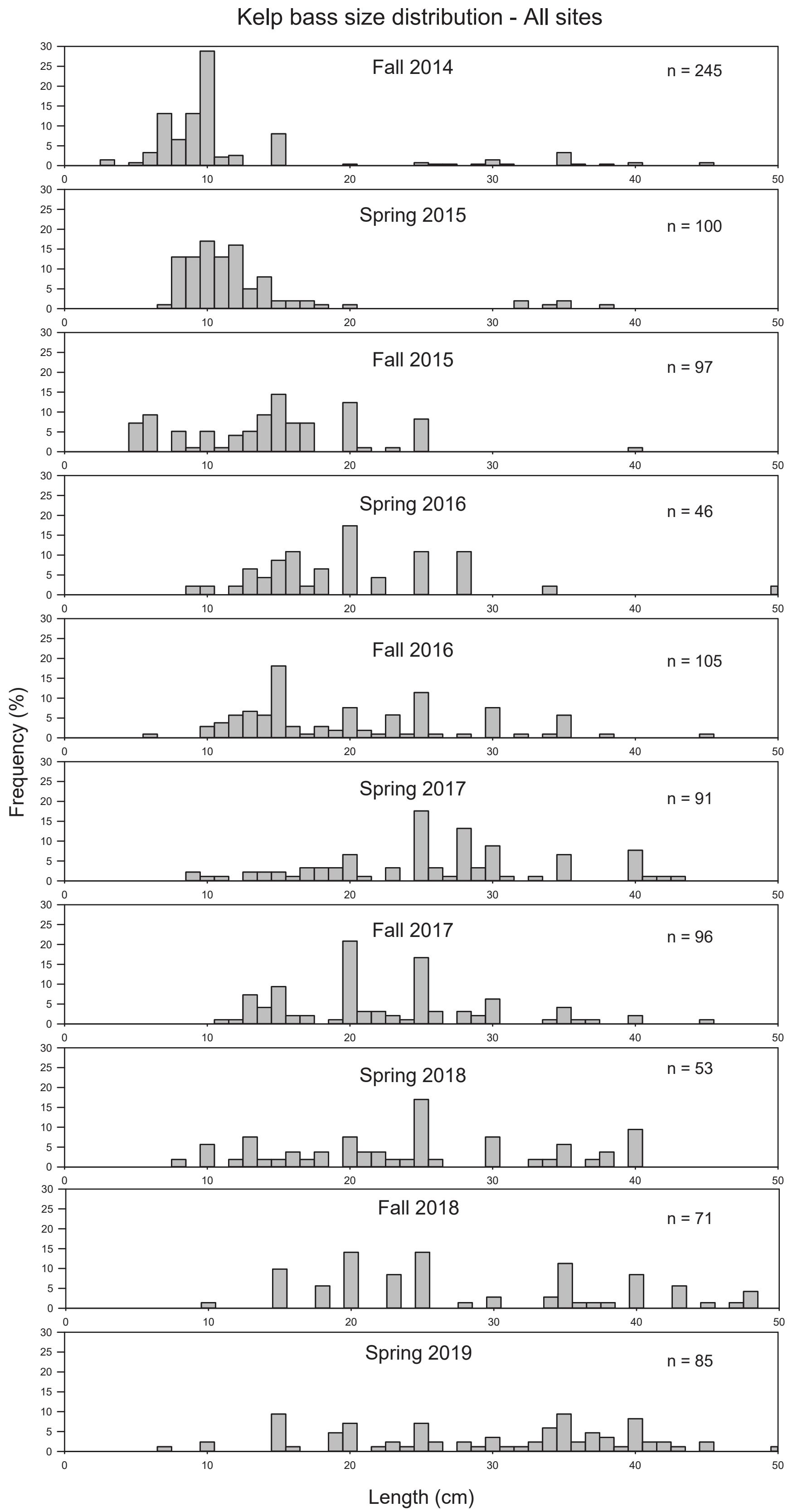

Figure 13. Size distribution of kelp bass (*Paralabrax clathratus*) in fall 2014–spring 2019. [n = number of individuals]

Nav Fac 100

After nearly 25 years of urchin overgrazing, Nav Fac 100 continued to change following its release from an urchin dominated state. Figure 14 shows counts during the last 5 years of some of the most dynamic species recorded on the swaths. Purple urchin (*S. purpuratus*) numbers declined substantially in 2015 but increased somewhat in 2018. Counts were lower in year 5 than in spring 2018 but were still two to three times higher than in 2016 and 2017, and they remained the second most common swath-counted organism. Nav Fac 100 has been supporting more macroalgae in recent years. The most abundant species counted on swaths (for the seventh time in a row) was *C. osmundacea*, whose numbers reached all-time highs. *Pterygophora californica* counts also increased in year 5. Spring counts of the invasive algae, *S. horneri*, were similarly high in 2017 and 2018 but were much lower in 2019. The cause of this reduction is unclear. Fall counts of the alga in 2018 were similar to the previous two fall seasons. Counts of the wavy turban snail (*M. undosa*) were again markedly higher this year making it the third most common of the swath-counted organisms. Table 8 shows the mean and standard deviation of swath counted organisms for this supersite in fall 2014 through spring 2019.

Macrocystis pyrifera densities were low on the supersite in year 5. Figures 15 and 16 show the number of stipes and the holdfast diameters of each *M. pyrifera* counted on the Nav Fac 100 permanent swaths for the last 10 sampling periods. Both metrics indicated there was poor survival and very little recruitment apparent between fall 2017 and spring 2018 and very little the following year so that by spring 2019 there were only 3 *M. pyrifera* greater than 1 m tall on the 10 supersite swaths.

A summary of the invertebrate sizes measured on swaths during the last 10 sampling trips is presented in table 9. Most of these species were not common enough to result in useful numbers of measurements. Two of the species, Kellet's whelk (*Kelletia kelletii*) and the wavy turban snail (*M. undosa*), were sufficiently numerous for analysis, however. There were only three *Kelletia* counted on the site in fall 2014, but then the number increased to 41 in fall 2015 before falling back to low levels again the next spring. Counts remained low until the last three sampling periods, when numbers again rose. An examination of their size structure revealed that these were likely recruitment events (fig. 17). Mobility and relatively low numbers contribute to our uncertainty concerning the fate of the 2015 recruits. Slow growth rates in this species (Cumberland, 1995) suggest that the size mode centered around 40 millimeters (mm) in the spring 2019 sample likely represents the same cohort which appeared in the spring 2018 sample.

Densities of *M. undosa*, which have continued to increase at Nav Fac 100 since urchins declined there, more than doubled between spring and fall 2017. Counts of *M. undosa* were down somewhat in spring 2018 but were substantially higher in year 5. The size structure of these snails (fig. 18) indicated that most of the recent increase was likely a result of movement rather than recruitment of young. The majority of the population (96 percent) was between 25 and 80 mm in shell length. Based on growth rates from tagging studies conducted in Baja California, (Martone and Micheli, 2012), these snails were likely between 1 and 5 years of age—but perhaps somewhat older, owing to slower growth as a result of colder water temperatures at SNI.

Most of the sea urchin size data we have collected does not resolve into easily identifiable cohorts, perhaps because of variation in growth rates or mortality. In order to more easily identify changes in the size structure over time or differences among sites, we have summarized these data for purple and red sea urchins by calculating the percent of each sample in three size bins: one representing recruits up to 1 year of age, one representing the largest individuals, and one size bin in between. Sea urchin growth is variable depending on food quality and availability as well as physical factors such as spine damage (Ebert, 1968; Kenner, 1992), but a reasonable approximation of first year's growth potential in southern California is 25 mm for *S. purpuratus* (Ebert, 1977; Russell, 1987) and 35 mm for *S. franciscanus* (Tegner and Dayton, 1991; Ebert and Russell, 1992). The largest size bin was chosen to represent the oldest urchins and consists, arbitrarily, of the largest 15 percent of each species from the pooled data from all sites and 5 years of collections. The middle size bin may represent several cohorts depending on growth. For purple urchins, these size bins are less than or equal to 25 mm, 26–40 mm, and greater than 40 mm (table 10), and for red urchins, they are less than or equal to 35 mm, 36–75 mm, and greater than 75 mm (table 11).

Purple sea urchin size distribution at Nav Fac 100 showed little change in the last 2 years. The size distribution has not shown any sign of a large recruitment event since 2014 (fig. 19). There were, however, a few individuals less than or equal to 10 mm in diameter, which indicated some recruitment in all sampling periods. Although an effort was made to include small individuals in size samples at the rate they were encountered, this size class was likely under sampled. Small urchins often take refuge in holdfasts and under rocks, algae, or other invertebrates making any non-destructive sampling methodology biased against them. Although the portion of purple urchins in the smallest size bin had declined from the time of the 2014 recruitment, it was close to 50 percent in the most recent three samples (table 10). The high proportion of urchins in the smallest size bin, combined with the low proportion in the largest size bin, made the size distribution most similar to Daytona 100.

Strongylocentrotus franciscanus declined slightly from year 4 levels, returning to densities similar to those recorded in 2016 and 2017. Their size distribution continued a trend of losing smaller and larger individuals until in spring 2019; 98 percent of the sample was between 35 and 100 mm in test diameter (fig. 20). In year 5, this supersite had the fewest red urchins in the smallest size bin but retained the most in the largest size bin (table 11).

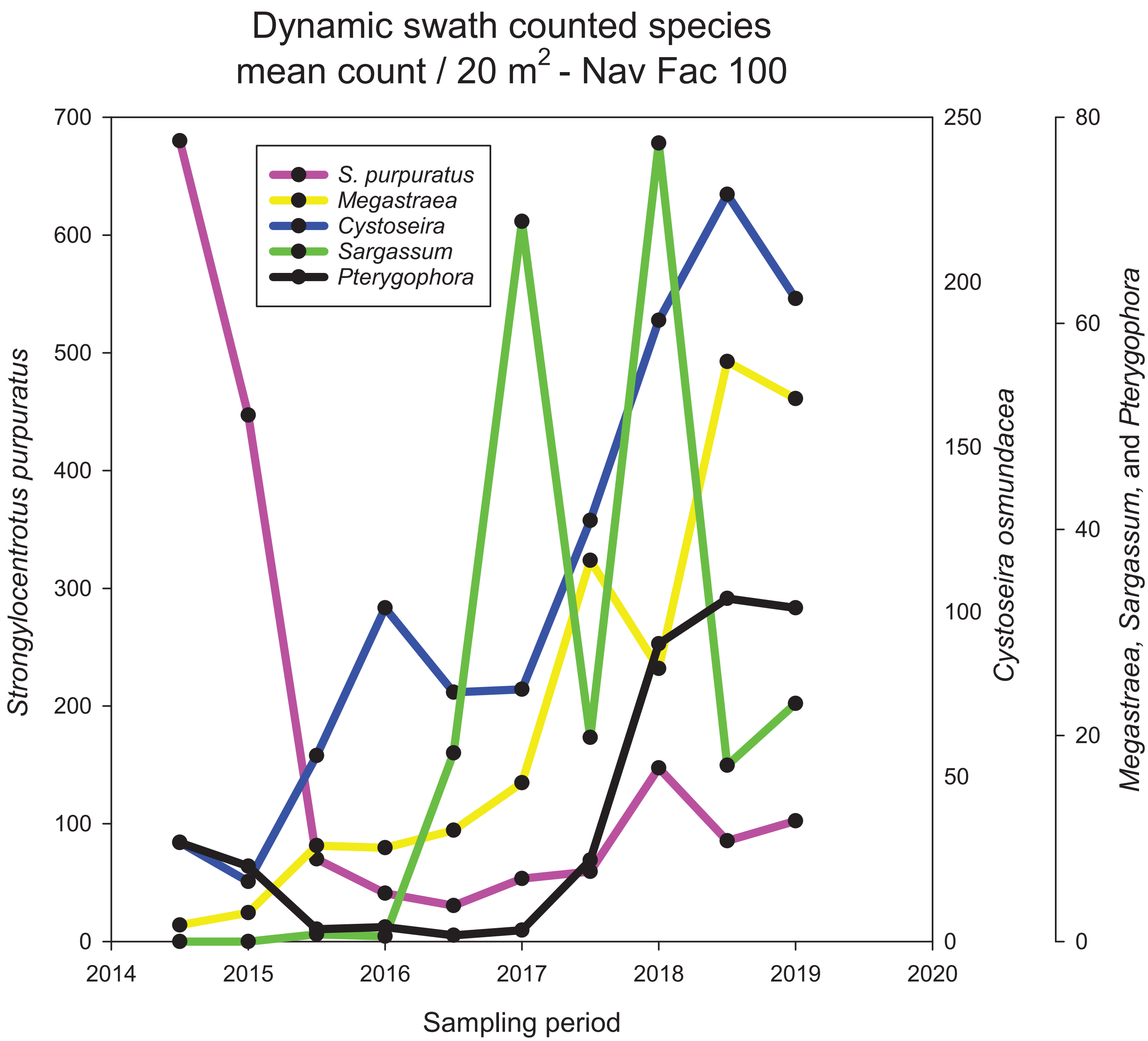

Figure 14. Mean densities of some swath-counted species that have demonstrated changing abundance at Nav Fac 100 during the last 5 years. [Note three vertical axes for densities of different species groups]

Table 8. Nav Fac 100 mean (standard deviation) swath counts for fall 2014 through spring 2019 expressed as individuals per 20-square meter transect.

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

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
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)	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)	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)	0.3 (0.48)	0.3 (0.67)

Table 8. Nav Fac 100 mean (standard deviation) swath counts for fall 2014 through spring 2019 expressed as individuals per 20-square meter transect.—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	Fall 2018	Spring 2019
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)	226.6 (184.77)	195 (141.01)
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)	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)	2 (2.31)	1.6 (1.65)
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)	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)	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)	2.9 (3.28)	6.8 (4.71)
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)	1.6 (1.35)	0.9 (0.74)
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)	0.1 (0.32)	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)	0.8 (1.03)	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)	1.4 (1.35)	0.3 (0.48)
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)	56.3 (10.45)	52.7 (25.28)
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)	0.1 (0.32)	0 (0.00)
Apostichopus 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)	0.1 (0.32)	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)	0.2 (0.42)	0.2 (0.42)
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)	0 (0.00)	0.1 (0.32)
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)	33.3 (26.75)	32.4 (26.53)
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)	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)	17.1 (29.98)	23.1 (32.83)
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)	6 (16.36)	6.4 (17.31)
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)	85.5 (59.55)	102.4 (80.45)
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)	3.2 (1.99)	2.3 (2.11)
Tealia 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)	0 (0.00)	0.2 (0.42)
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)	0.5 (0.85)	0.8 (1.03)

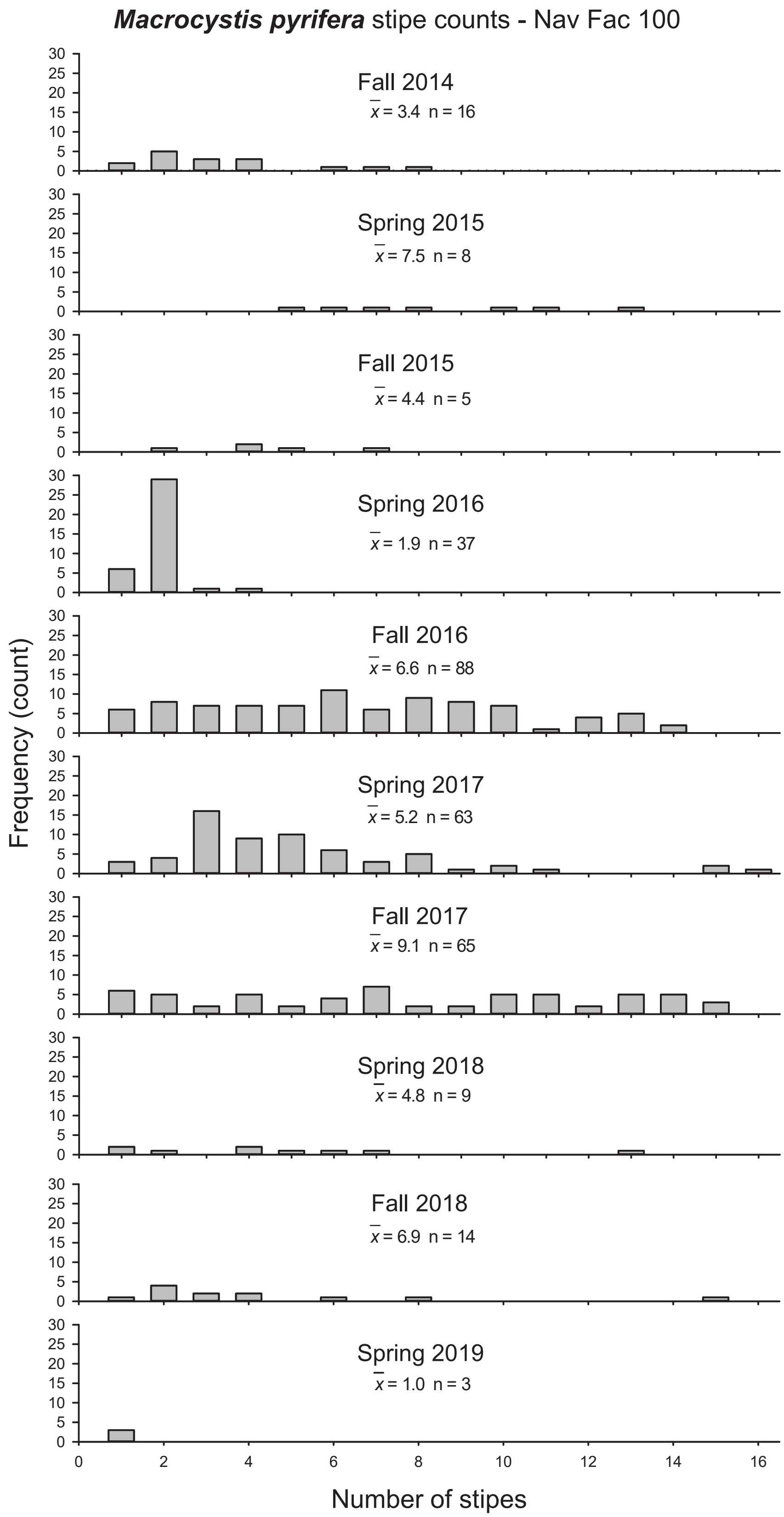

Figure 15. Nav Fac 100 *Macrocystis pyrifera* greater than 1-meter (m) tall stipe counts by season (fall 2014–spring 2019). [$\bar{x}$ is mean count, n is number of individuals]

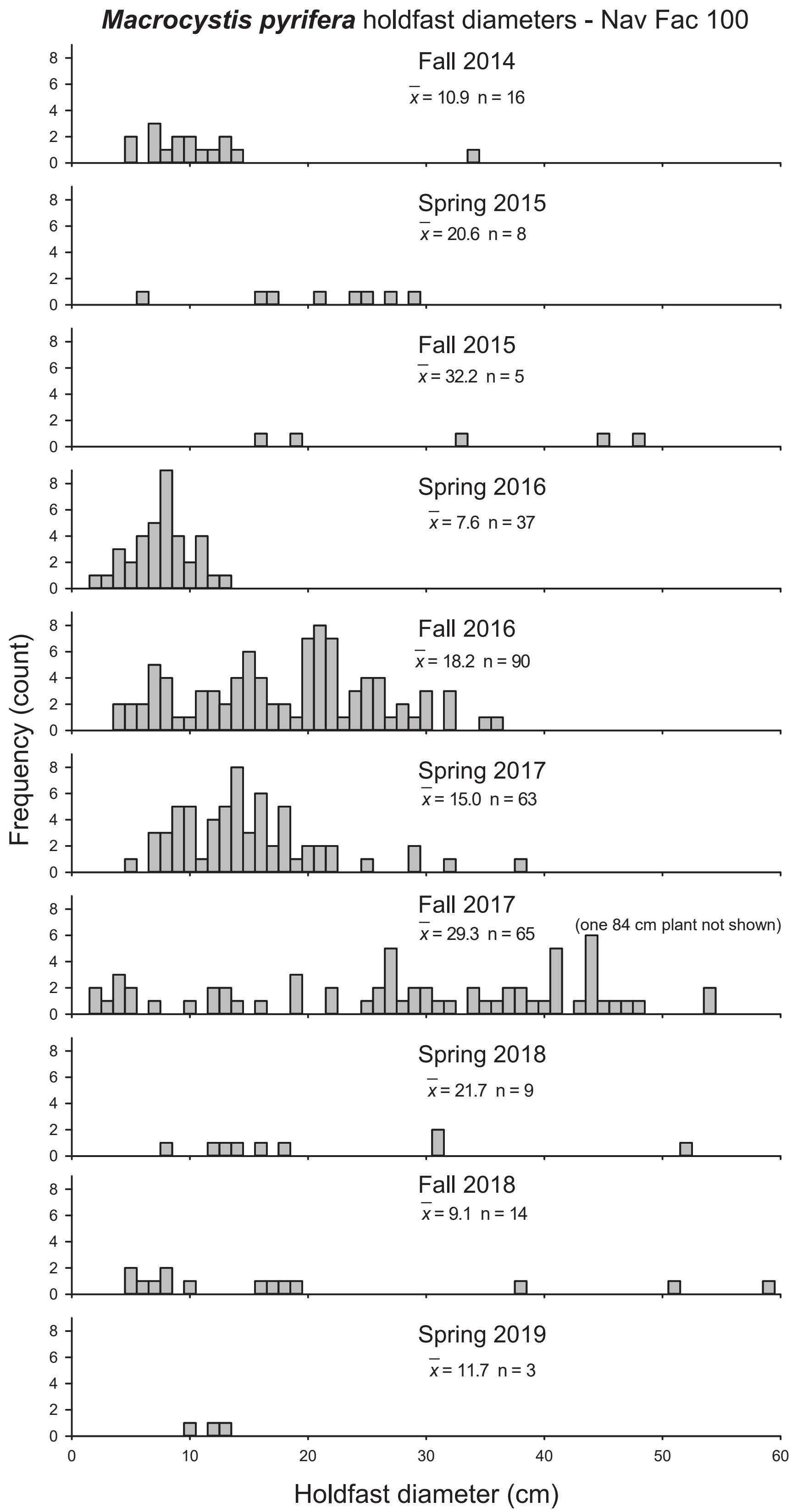

Figure 16. Nav Fac 100 *Macrocystis pyrifera* greater than 1-meter (m) tall holdfast diameters by season (fall 2014–spring 2019). [$\bar{x}$ is mean count, n is number of individuals]

Table 9. Sizes of invertebrates measured on swaths at Nav Fac 100, fall 2014 through spring 2019.

[*Strongylocentrotus* spp. excluded. See figures 19 and 20 for purple and red urchin size data. **Abbreviations:** N, sample size; Min, minimum; —, no data; Max, maximum]

Size	Species name							
	Crassadoma gigantea	***Dermasterias imbricata***	***Kelletia kelletii***	***Lytechinus anamesus***	***Megastraea undosa***	***Megathura crenulata***	***Patiria miniata***	***Pisaster giganteus***
Year 1: 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	—
Year 1: 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
Year 2: 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	—
Year 2: 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	—
Year 3: 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	—
Year 3: Spring 2017								
N	4	0	12	0	155	0	1	0
Min	55	—	11	—	15	—	27	—
Max	60	—	130	—	101	—	27	—
Mean	58.3	—	57.9	—	50.1	—	27.0	—
Year 4: 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	—
Year 4: 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

Table 9. Sizes of invertebrates measured on swaths at Nav Fac 100, fall 2014 through spring 2019.—Continued

[*Strongylocentrotus* spp. excluded. See figures 19 and 20 for purple and red urchin size data. **Abbreviations:** N, sample size; Min, minimum; —, no data; Max, maximum]

Size	Species name							
	Crassadoma gigantea	***Dermasterias imbricata***	***Kelletia kelletii***	***Lytechinus anamesus***	***Megastraea undosa***	***Megathura crenulata***	***Patiria miniata***	***Pisaster giganteus***
Year 5: Fall 2018								
N	3	0	29	0	563	1	2	0
Min	43	—	32	—	19	110	64	—
Max	84	—	112	—	97	110	75	—
Mean	61.7	—	70.7	—	53.2	110.0	69.5	—
Year 5: Spring 2019								
N	3	0	64	0	528	0	2	1
Min	48	—	24	—	19	—	61	104
Max	71	—	153	—	121	—	81	104
Mean	57.0	—	59.2	—	51.6	—	71.0	104.0

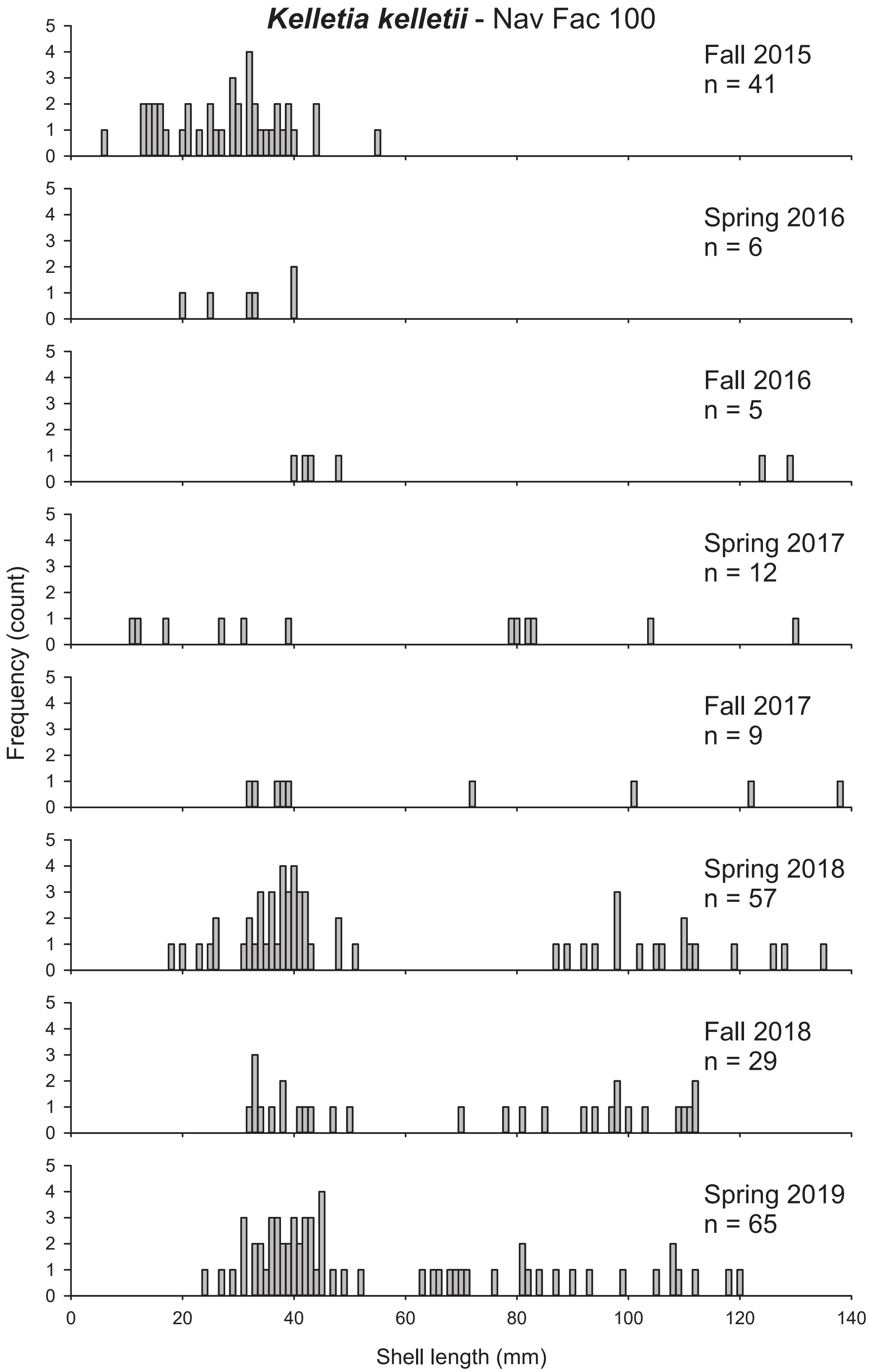

Figure 17. Size structure of Kellet's whelk (*Kelletia kelletii*) at Nav Fac 100 in fall 2014–spring 2019. [n = number of individuals]

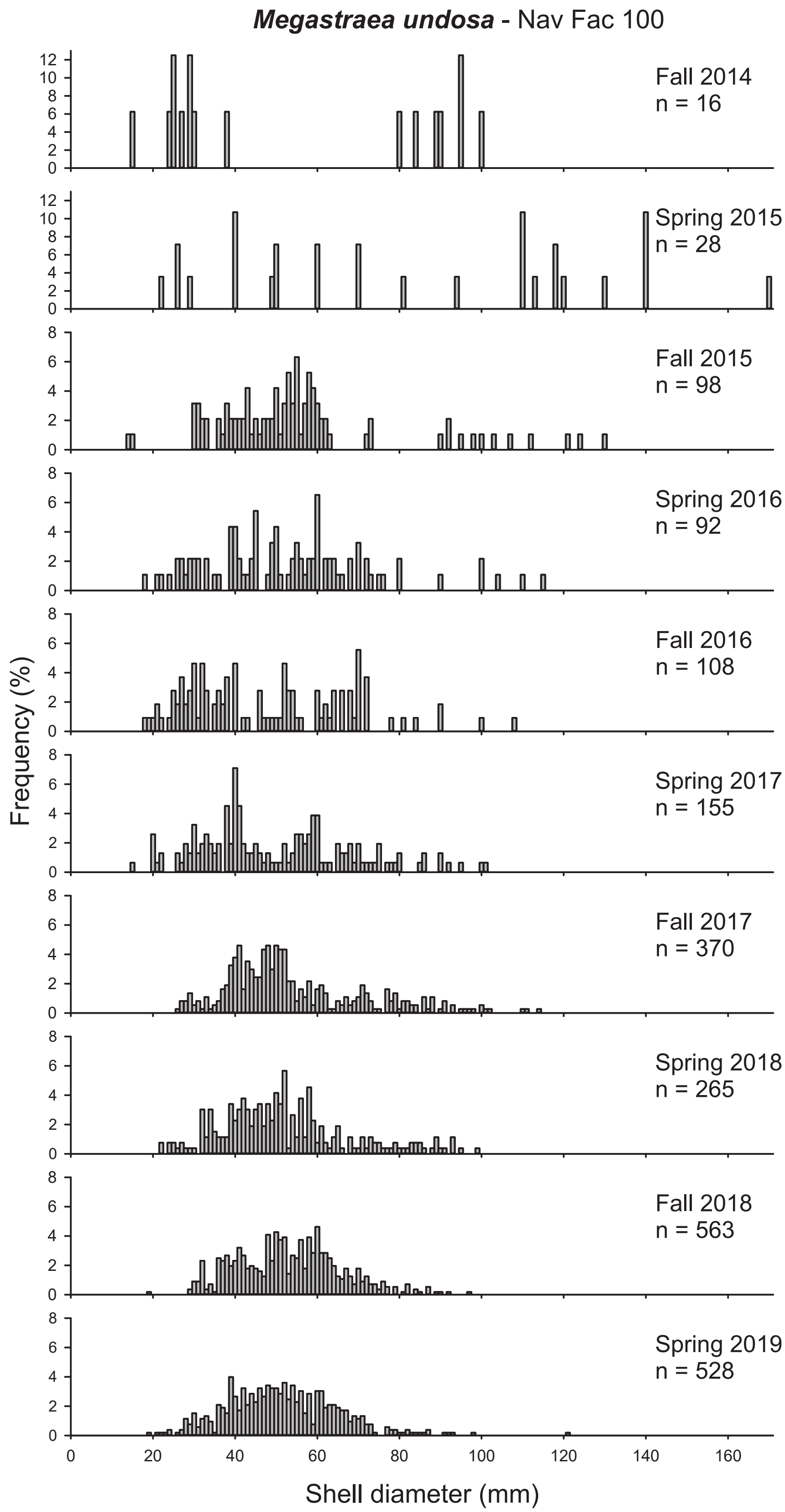

Figure 18. Nav Fac 100 size structure of wavy turban snails (*Megastraea undosa*) in fall 2014–spring 2019. [Note different frequency scales, n = number of individuals]

Table 10. Percentage of *Strongylocentrotus purpuratus* in three size bins at each supersite in fall 2014–spring 2019.

[≤, less than or equal to; >, greater than]

	Sample									
Size class	**Fall 2014**	**Spring 2015**	**Fall 2015**	**Spring 2016**	**Fall 2016**	**Spring 2017**	**Fall 2017**	**Spring 2018**	**Fall 2018**	**Spring 2019**
Nav Fac 100										
≤25	85.7	91.0	65.9	30.1	24.8	52.7	34.0	50.4	48.5	47.5
26–40	13.8	9.0	28.3	65.7	63.1	44.1	52.4	37.7	44.1	41.5
>40	0.5	0.0	5.8	4.2	12.1	3.2	13.7	11.9	7.4	11.0
West End										
≤25	29.3	10.8	25.0	28.8	33.3	35.6	21.7	32.6	41.7	32.4
26–40	38.9	47.5	53.2	49.8	57.7	53.2	56.7	52.7	47.6	48.5
>40	31.7	41.7	21.8	21.5	9.0	11.2	21.7	14.7	10.7	19.1
Dutch Harbor										
≤25	34.3	18.5	25.5	16.0	14.0	30.6	25.5	32.9	27.2	26.6
26–40	35.9	52.7	47.7	42.3	52.4	55.3	48.9	45.9	53.0	49.8
>40	29.8	28.8	26.8	41.8	33.6	14.2	25.5	21.2	19.8	23.7
Daytona 100										
≤25	65.3	39.5	55.1	31.1	39.7	42.9	45.0	40.1	49.5	46.5
26–40	34.7	56.0	42.4	65.8	57.4	52.2	52.0	57.2	47.1	43.3
>40	0.0	4.5	2.4	3.2	2.9	4.9	3.0	2.8	3.3	10.1

Table 11. Percentage of *Strongylocentrotus franciscanus* in three size bins at each supersite in fall 2014–spring 2019.

[≤, less than or equal to; >, greater than]

Size class	**Fall 2014**	**Spring 2015**	**Fall 2015**	**Spring 2016**	**Fall 2016**	**Spring 2017**	**Fall 2017**	**Spring 2018**	**Fall 2018**	**Spring 2019**
Nav Fac 100										
≤35	21.5	23.7	36.3	3.4	3.8	7.7	5.4	7.4	4.4	2.9
35–75	49.3	41.4	37.2	33.9	42.7	63.6	57.4	60.7	81.5	78.5
>75	29.2	34.8	26.5	62.6	53.5	28.7	37.3	31.9	14.1	18.5
West End										
≤35	20.7	3.0	22.9	15.3	17.6	17.9	13.4	21.1	14.1	18.8
35–75	63.7	84.7	73.5	84.3	79.6	80.9	85.9	77.9	84.8	80.7
>75	15.6	12.4	3.6	0.4	2.8	1.2	0.7	1.0	1.2	0.5
Dutch Harbor										
≤35	34.4	19.5	16.9	9.9	8.7	8.3	13.8	24.5	8.4	8.4
35–75	59.6	77.1	75.8	82.3	88.3	89.4	79.5	73.4	85.4	85.7
>75	5.9	3.4	7.2	7.7	3.0	2.3	6.7	2.1	6.2	5.9
Daytona 100										
≤35	30.1	10.5	12.4	3.4	2.7	12.2	6.6	4.9	6.0	4.8
35–75	53.7	48.0	56.5	70.3	68.0	69.4	73.5	83.3	88.4	86.1
>75	16.2	41.5	31.1	26.3	29.3	18.3	19.9	11.8	5.6	9.1

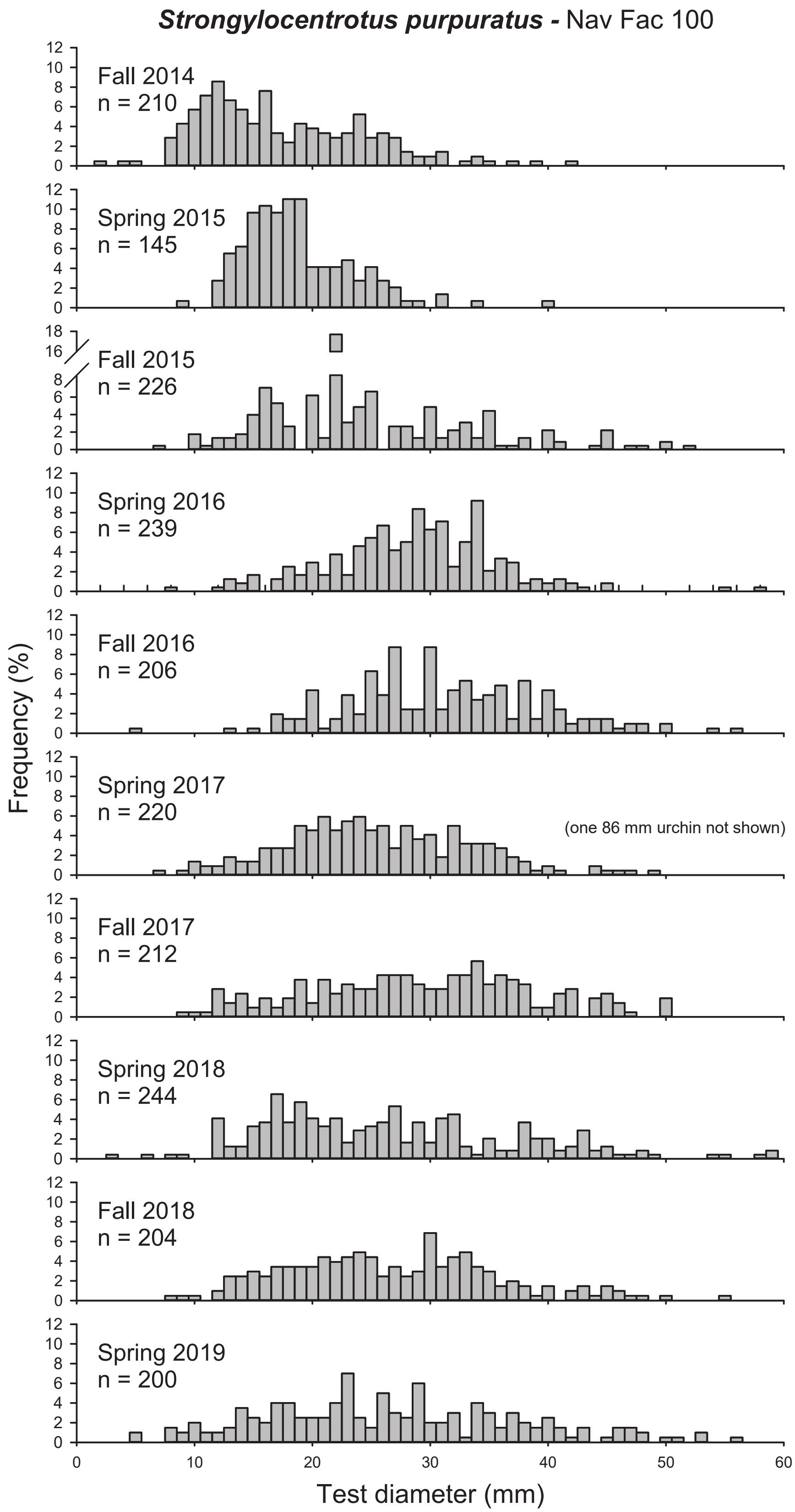

Figure 19. Nav Fac 100 size structure of purple urchins (*Strongylocentrotus purpuratus*) in fall 2014–spring 2019. [n = number of individuals]

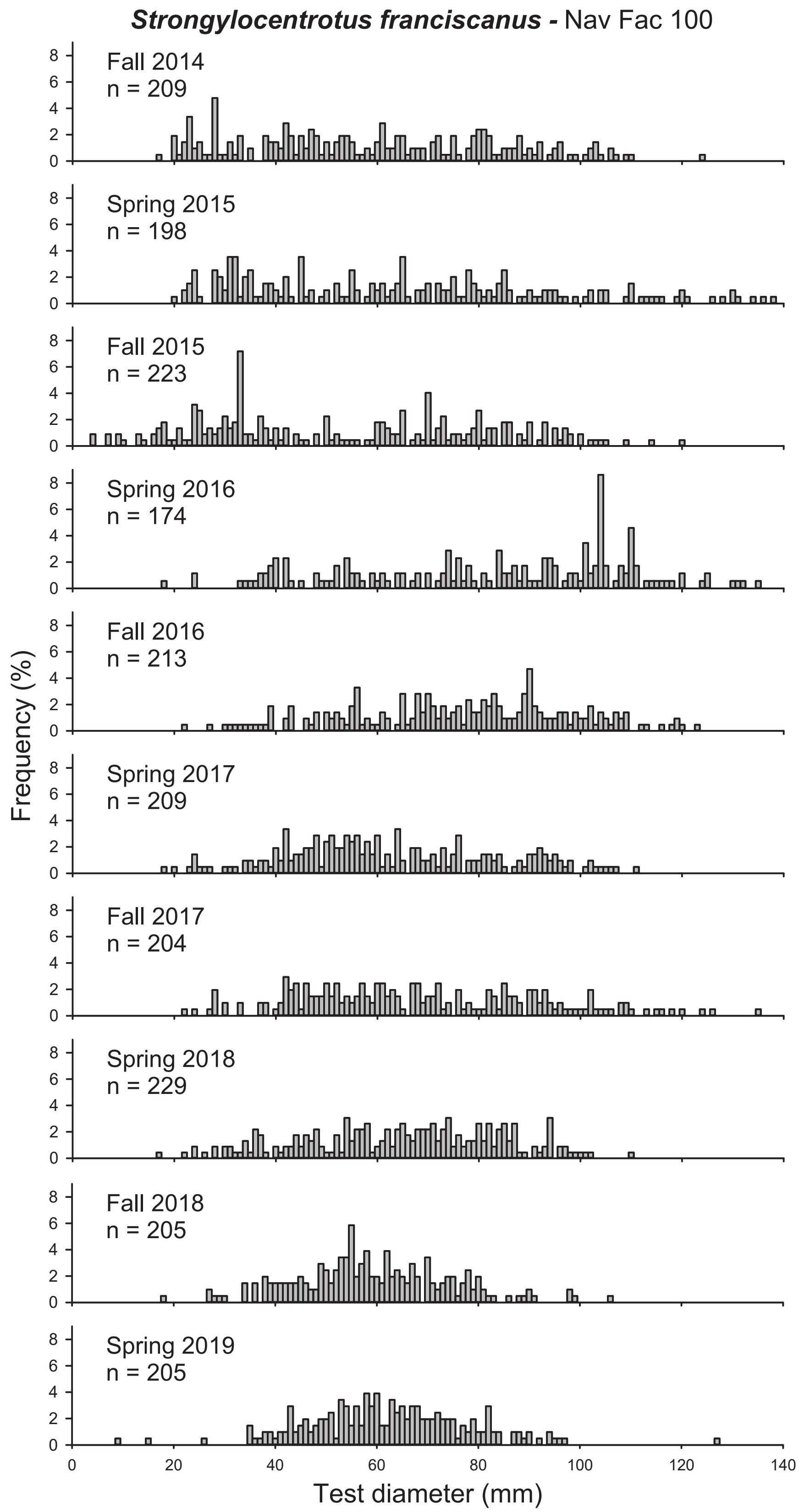

Figure 20. Nav Fac 100 size structure of red urchins (*Strongylocentrotus franciscanus*) in fall 2014–spring 2019. [n = number of individuals]

The mean numbers of organisms counted in 1-m^2 quadrats is shown in table 12. The orange puffball sponge (*Tethya aurantia*) continued to be present at low densities but declined slightly in year 5. The invasive alga *S. horneri* declined also (like it did in the swath counts). Total counts of this species in quadrats declined from 130 in spring 2017 to 83 in spring 2018, and then to 31 in spring 2019. The number of cover points scored however, was almost identical for these first 2 periods (93 and 95 respectively) but dropped to 20 in spring 2019.

Cover data collected from RPC quadrats are summarized in figure 21 as categories of cover at the different supersites over time. The amount of exposed bare rock gradually declined at Nav Fac 100 after the 2015 decline in purple urchin density. Conversely, brown algae (here a mix of *Dictyota binghamiae*, *Dictyopteris undulata*, *C. osmundacea*, *Taonia lennabackerae,* and *S. horneri*) has become one of the dominant cover categories since 2015. There is a marked seasonal component to the brown algae cover, with spring cover nearly twice as high. Although the spring cover of this category remained constant, the portion contributed by *S. horneri* dropped considerably. *Sargassum horneri*, which had been the species with the third highest cover in spring 2017 and spring 2018, dropped to eighth ranking in spring 2019 (table 13). Encrusting coralline algae, *D. binghamiae* and *C. osmundacea* were the top ranked cover species. The sand castle worm (*Phragmatopoma californica*) gradually declined from the peak cover it achieved in fall 2017 (14.25 percent); by spring 2019, it had dropped to 1.75 percent cover but ranked second after 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, though lowest of all the supersites in fall 2018, exceeded those measured at West End in spring 2019 (table 14). The schooling species señorita (*O. californica*) and blacksmith (*C. punctipinnis*) made up most of the count, but kelp bass (*Paralabrax clathratus*) and sheephead (*S. pulcher*) were regular members of the fish assemblage at the site (table 15). Three fish transects run west from the main line, over a flat uniform benthos that was mostly devoid of refuge and kelp, whereas the remaining two fish transects run east of the main line, over an area with more habitat heterogeneity, including rocky ridges, boulders, and ledges. Greater fish abundance and diversity was routinely observed on the two easterly transects compared to the three transects that traverse flat bottom to the west.

Table 12. Mean (and standard deviation) numbers of rare species counted on twenty 1-square meter quadrats from Nav Fac 100, fall 2014 through spring 2019.

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Lithopoma 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)	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)	0 (0.00)	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)	0.2 (0.49)	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)	0.1 (0.31)	0.3 (0.57)
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)	2.1 (4.68)	1.6 (2.39)
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)	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)	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)	0.1 (0.31)	0.1 (0.22)
Tealia 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)	0 (0.00)	0 (0.00)

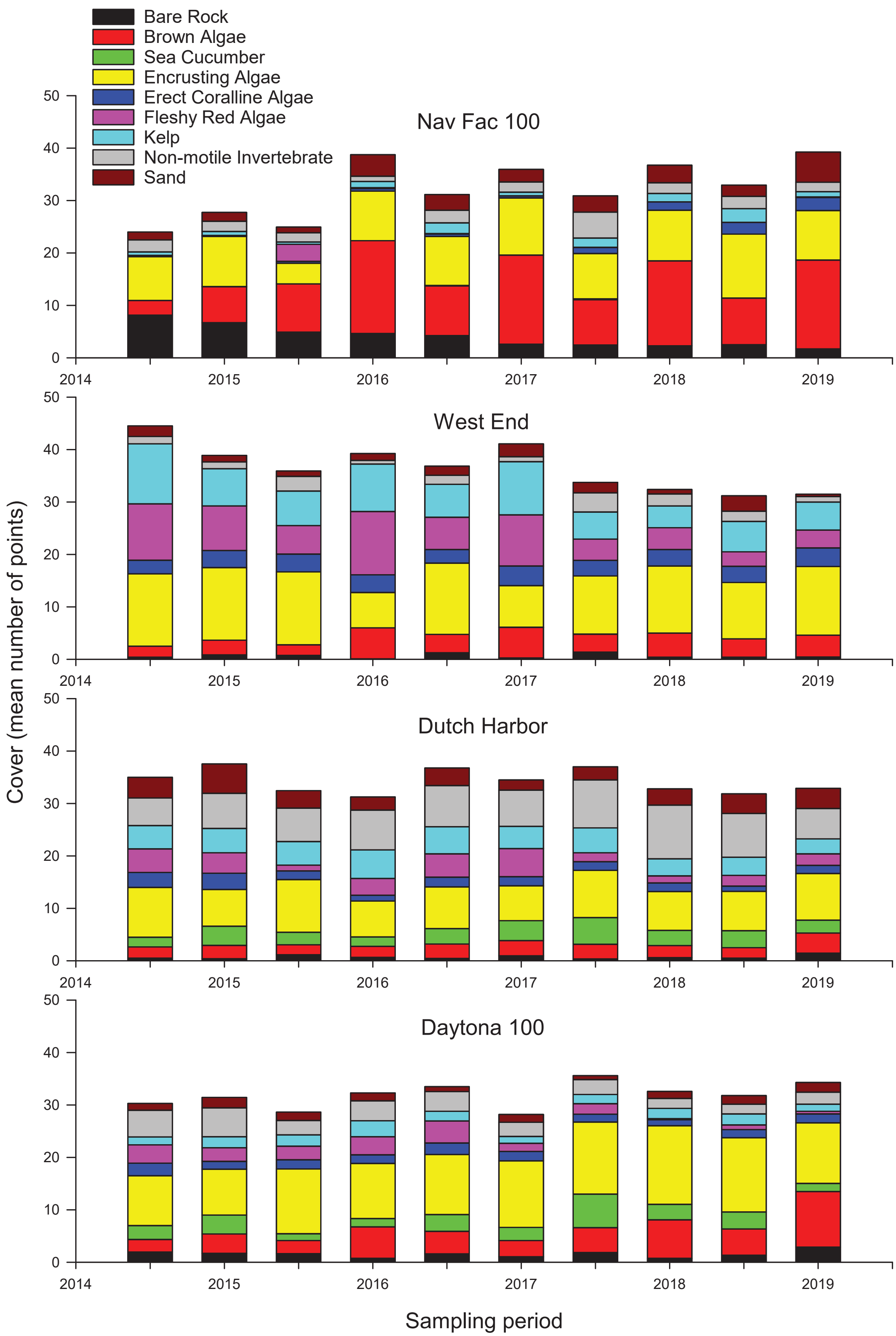

Figure 21. Mean percent cover categories by supersite in fall 2014 through spring 2019. [Categories are bare rock (black), brown algae (non-kelp; red), sea cucumbers (green), encrusting algae (yellow), erect coralline algae (blue), fleshy red algae (pink), kelp (turquoise), non-motile invertebrates (gray) and sand (brown)]

Table 13. Nav Fac 100 point contact “species” ranked by the sum of points for fall 2014 through spring 2019.

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

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Encrusting coralline algae	164	191	79	186	182	218	172	193	237	188
Dictyota binghamiae	36	33	7	135	70	126	99	111	47	157
Bare substratum	163	134	98	93	85	52	49	46	50	34
Cystoseira osmundacea	11	18	39	77	57	68	67	88	107	131
Sand	30	34	22	82	60	48	62	67	43	115
Dictyopteris undulata	9	84	50	93	45	29	1	22	20	30
Sargassum horneri	0	0	1	0	8	93	3	95	0	20
Corallina officinalis	4	2	7	6	7	7	16	23	34	32
Phragmatopoma californica	0	0	0	0	11	21	57	20	19	7
Pterygophora californica	7	9	5	17	9	5	9	12	28	15
Serpulorbis squamiger	12	10	9	6	13	8	11	7	15	16
Unidentified brown algae	0	0	77	0	0	0	0	0	0	0
Filamentous red algae	0	1	63	0	0	0	0	0	0	0
Taonia lennebackerae	0	2	0	33	0	23	1	1	0	0
Barnacle	23	15	2	0	0	0	0	0	0	0
Kelp holdfast	0	0	1	0	10	2	14	6	3	1
Eisenia arborea	5	4	0	2	4	4	1	6	8	2
Calliarthron spp.	1	0	0	3	2	1	2	7	6	13
Mucus tube polychaete	0	2	20	0	9	0	0	0	0	0
Macrocystis pyrifera >1 m	0	0	0	0	14	1	7	2	6	0
Pink encrusting bryozoan	0	0	0	0	2	2	18	3	2	3
Laminaria spp.	1	1	1	3	2	1	4	2	7	2
Astrangia lajollaensis [*haimei*]	4	3	0	0	1	3	4	2	1	5
Encrusting red algae	3	0	0	3	5	0	1	0	7	1
Sargassum muticum	0	0	7	4	8	0	0	1	0	0
Bossiella spp.	0	1	0	1	0	0	5	2	5	5
Zonaria farlowii	0	0	3	0	1	1	2	6	4	1
Diopatra ornate	1	1	0	0	3	0	3	3	2	1
Orange encrusting sponge	2	2	1	3	1	0	1	0	4	0
Filamentous brown algae	0	0	0	11	0	0	0	0	0	0
Balanus spp.	0	0	0	7	1	0	0	0	2	0
Tethya aurantia	2	1	2	3	0	0	0	1	0	0
Diatom film	8	0	0	0	0	0	0	0	0	0
Macrocystis pyrifera <1 m	0	1	2	2	1	1	0	1	0	0
Codium fragile	0	2	0	0	0	5	0	0	0	0
Metandrocarpa dura	0	0	0	0	0	0	2	4	1	0
Balanophyllia elegans	2	1	1	0	1	0	0	0	1	0
Pholad clam	0	3	0	0	2	1	0	0	0	0
Spirobranchus spinosus	0	1	0	0	0	2	0	0	0	3
Cryptopleura spp.	0	0	1	3	1	0	0	0	0	0
Young Laminariales	0	0	0	0	1	0	0	3	0	0
Laurencia pacifica	0	0	0	0	0	0	1	0	0	2

Table 13. Nav Fac 100 point contact "species" ranked by the sum of points for fall 2014 through spring 2019.—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	Fall 2018	Spring 2019
Archidistoma [*Eudistoma*] *psammion*	0	0	0	0	0	1	1	0	0	0
Cucumaria salma	0	1	0	0	0	0	1	0	0	0
Cystodytes lobatus	0	0	0	0	1	1	0	0	0	0
Lissothuria nutriens	0	0	0	0	0	0	2	0	0	0
Unidentified sponge	0	0	0	0	1	0	0	1	0	0
Anthopleura sola	0	0	0	0	1	0	0	0	0	0
Boltenia villosa	0	0	0	0	0	0	1	0	0	0
Corynactis californica	0	0	0	0	0	0	0	0	0	1
Cucumaria piperata	0	0	0	0	1	0	0	0	0	0
Desmarestia ligulate	0	0	0	1	0	0	0	0	0	0
Eupentacta quinquesemita	0	0	0	0	1	0	0	0	0	0
Halichondria spp.	0	0	0	1	0	0	0	0	0	0
Lagenocella spp.	0	0	0	0	1	0	0	0	0	0
Nienburgia andersoniana	0	0	0	0	1	0	0	0	0	0
Pterosiphonia spp.	0	0	1	0	0	0	0	0	0	0
Strongylocentrotus franciscanus	0	0	0	1	0	0	0	0	0	0
Stylantheca porphyra [*papillosa*]	0	0	0	0	0	0	1	0	0	0

Table 14. 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 2019.

[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: Overall /m^2	Density: Benthic /m^2	Density: Midwater /m^2	Number sized
Year 1: 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	19	3,592	2.05	1.70	2.19	3,592
Year 1: 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	19	990	0.57	0.89	0.44	990
Year 2: 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

Table 14. 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 2019.—Continued

[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	
Dutch Harbor	27	4,256	1.22	1.64	1.05	1,673
Daytona 100	16	738	0.42	0.81	0.27	738
Year 2: 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	14	336	0.19	0.31	0.15	336
Year 3: 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
Year 3: 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
Year 4: Fall 2017						
Nav Fac 100	11	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
Year 4: 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	14	936	0.53	1.33	0.22	936
Year 5: Fall 2018						
Nav Fac 100	11	149	0.09	0.12	0.07	149
West End	15	523	0.15	0.18	0.14	523
Dutch Harbor	24	2,201	0.63	0.63	0.63	648
Daytona 100	16	602	0.34	0.45	0.30	602
Year 5: Spring 2019						
Nav Fac 100	10	420	0.24	0.43	0.16	420
West End	15	339	0.10	0.20	0.05	339
Dutch Harbor	24	3,494	1.00	0.77	1.09	1,924
Daytona 100	15	1,298	0.74	0.59	0.80	1,298

Table 15. Nav Fac 100 fish counts—adult (juvenile)—in fall 2014 through spring 2019 by species.

[f, female; m, male]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Artedius spp.	0	1	0	0	0	0	0	0	0	0
Brachyistius frenatus	1	0	0	0	1	0	0	0	0	3
Caulolatilus princeps	3	0	2	0	0	0	0	0	0	0
Chromis punctipinnis	370	40	117 (53)	129	245	345	113	149	55	142
Rhinogobiops nicholsii	57	1	5	0	4	1	3	9	1	5
Embiotoca jacksoni	12	7	4	7	3	11	9	0	15	7
Embiotoca lateralis	2	0	0	0	0	0	0	0	0	0
Galeorhinus galeus	0	0	0	1	0	0	0	0	0	0
Girella nigricans	3	1	2	1	25	1	2	0	2	0
Halichoeres semicinctus	0	0 (1)	0	0	1	0	0	1	0	0
Heterodontus francisci	0	0	0	0	0	1	0	0	0	0
Hypsurus caryi	5	0	0	0	6	0	0	0	0	2
Hypsypops rubicundus	1	1	2	1	8	6	4	1	4	5
Medialuna californiensis	0	0	35	16	3	1	37	1	0	1
Neoclinus spp.	0	0	0	0	1	0	0	0	0	0
Oxyjulis californica	119	68	45	864	57	721	116	484	37	203
Oxylebius pictus	8	2	0	1	0	0	1	0	0	0
Paralabrax clathratus	114	7	26 (16)	22	9	21	18	14	11	17 (1)
Rhacochilus vacca	4	0	5	0	1	0	0	1	2	0
Sebastes atrovirens	4	0	2	1	2	0	2	0	1	0
Sebastes chrysomelas	3	0	0	1	0	0	0	0	0	0
Sebastes mystinus	4	0	0	1	2	2	0	0	1	0
Sebastes rastrelliger	0	0	0	1	0	0	0	0	0	0
Sebastes serranoides	0	3	0	0	1	0	0	0	0	0
Sebastes serriceps	1	0	0	0	0	1	0	0	0	0
Semicossyphus pulcher (f)	17	2 (1)	23 (3)	15 (2)	32 (6)	21	20	35	19	27
Semicossyphus pulcher (m)	3	1	4	4	1	1	0	6	1	7
Stereolepis gigas	0	0	0	0	0	2	0	1	0	0
Torpedo californica	1	0	0	0	0	0	0	0	0	0

West End

West End continued to be algal-dominated, and the brown alga, *C. osmundacea*, and the understory kelps, *Laminaria* spp. and *P. californica*, remained abundant with little change during the last 5 years (table 16). Figure 22 shows counts of some of the most dynamic species that were counted on the swaths at this supersite. The purple urchin was consistently the most common invertebrate counted on swaths, and their numbers have increased during the last few years. In year 5, their densities were the highest recorded at West End since urchin numbers plummeted there in 2001. Red urchins have followed a very similar trend and also are at their highest level since 2001. Although their densities were about 17 percent of purple urchins in the last sampling periods, they were the second most common invertebrate on swaths. *Megastraea undosa* densities were near zero 3 years ago but have steadily increased since then. Though still far below the urchin species, they now rank as the third most common invertebrate in the swath counts at this supersite. Like at Nav Fac 100, the increase at West End seemed not to result from recruitment of young individuals; shell diameters less than 40 mm accounted for only 4–16 percent of the last three samples. It appears that three waves of *M. pyrifera* recruitment have occurred during the last 5 years, but only two peaks in the density of “adult” *M. pyrifera* (those greater than 1 m tall) were apparent during this period (seen in fall 2016 and spring 2019).

Table 16. West End mean (standard deviation) swath counts for fall 2014 through spring 2019 expressed as individuals per 20-square meter transect.

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

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
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)	0.2 (0.63)	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)	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)	0 (0.00)	0.9 (1.60)
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)	46.2 (22.70)	62 (29.27)
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)	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)	1.6 (1.58)	2.4 (2.22)
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)	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)	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)	0.9 (1.20)	2.6 (5.85)
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)	46.2 (48.98)	64.5 (57.32)
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)	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)	9.8 (12.10)	113.5 (258.29)
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)	4.4 (1.84)	9.1 (10.98)
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)	9.9 (6.64)	11.6 (4.70)
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)	0.5 (0.71)	0.2 (0.42)
Apostichopus 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)	0 (0.00)	0.4 (0.52)
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)	1.1 (1.20)	1.1 (1.20)
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)	0.2 (0.42)	0 (0.00)
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)	25 (23.33)	32.5 (30.82)
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)	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)	0 (0.00)	0 (0.00)
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)	31.5 (42.25)	45.5 (60.75)
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)	185.2 (123.17)	266.2 (179.42)

Table 16. West End mean (standard deviation) swath counts for fall 2014 through spring 2019 expressed as individuals per 20-square meter transect.—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	Fall 2018	Spring 2019
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)	2.2 (2.49)	2.5 (2.88)
Tealia 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)	0.7 (1.57)	0.7 (1.57)
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)	23.1 (22.94)	56.4 (126.14)

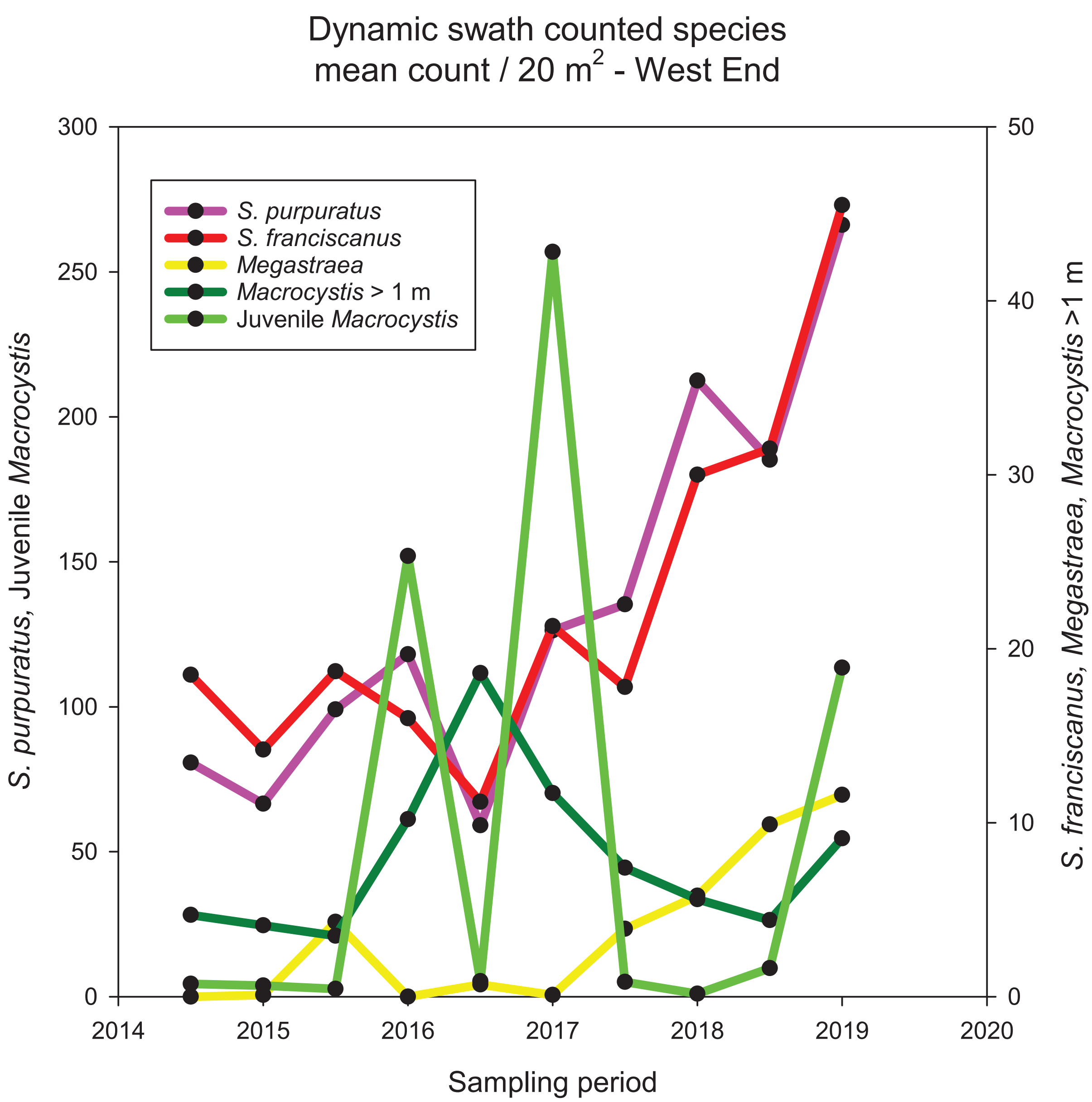

Figure 22. Mean densities of some swath-counted species that have demonstrated changing abundance at West End during the last 5 years. [Note two vertical axes for densities of different species groups]

West End stipe counts and holdfast diameters of *M. pyrifera* plants greater than 1 m tall are plotted in figures 23 and 24. Echoing the earlier-mentioned recruitment pulses, the distributions revealed distinct modes of younger plants apparent in spring 2016–spring 2017 and then again in spring 2019. During the spring 2019 sampling trip, most of the kelps were young and had less than five stipes and holdfasts less than 15 cm. Many of these young plants did not yet reach the surface, which contributed to the sparse canopy observed on the site.

Table 17 provides a summary of the sizes of invertebrates measured on swaths at West End for all seasons. Only Kellet's whelk (*K. kelletii*) were observed in all sampling periods at West End. However, the rock scallop (*Crassadoma gigantea*), bat star (*P. miniata*), and *M. undosa* were present in most samples. As mentioned earlier in the text, the latter increased in abundance during the last 2 years.

There is a suggestion of recruitment in *S. purpuratus* in the fall 2018 size data, but it did not appear as a distinct mode (fig. 25). Recruitment also is reflected in the increase in the proportion of the smallest size bin (table 10). The density of this species, as counted on swaths, has more than tripled in 5 years (without any obvious recruitment pulses). The proportions of purple urchin size bins at West End most closely resembled those from Dutch Harbor. Similarly, red urchins (*S. franciscanus*), although increasing in density in recent sampling periods, showed no distinct recruitment events. There was little change in size distribution apparent in recent periods (fig. 26). This supersite had the lowest proportion of large red urchins of all the sites (table 11), and it is likely that predation by sea otters, which have been concentrating near West End for many years, was responsible for this pattern (Kenner and Tinker, 2018). The low densities of these red urchins, which on this site mostly occurred in crevices and under boulders, made it unlikely that commercial harvest would be a factor.

Of the invertebrate species counted in 1-m^2 quadrats at West End, only the stalked tunicate (*Styela montereyensis*) and the orange puffball sponge (*T. aurantia*) were observed on all sampling trips (table 18). The gastropods, *L. gibberosa*, *C. spadicea*, *K. kelletii*, and *N. norrisii*, occurred at the site, but were not present in quadrats in more than a few sampling periods.

The West End has the most cover from fleshy red algae of any of the supersites (fig. 21), but that category of cover has declined by about half in the last 2 years there. Encrusting algae, brown algae, erect coralline algae, and kelp were the categories that provided the most bottom cover at West End. The species accounting for most of the remaining cover after encrusting corallines, were the erect coralline *Calliarthron* spp., encrusting red algae, the brown algae *D. binghamiae* and *C. osmundacea*, and several species of fleshy red algae (table 19). The understory kelp, *Laminaria* spp., increased in percent cover but did not reach levels measured prior to fall 2017.

The number of fish species observed at West End declined slightly to 15 on both year 5 sampling trips from the 17 or 18 found there during the previous 6 trips (table 14). The total number of fish counted was similar to the totals there for year 4 but was considerably lower than previous trips. Though overall fish density at West End exceeded what was measured at Nav Fac 100 in fall 2018, that was not the case in spring 2019. The most common fish were the schooling species señorita (*O. californica*) and blacksmith (*C. punctipinnis*). Blue rockfish (*Sebastes mystinus*), black perch (*Embiotoca jacksoni*), and sheephead (*S. pulcher*) were among the other common species there (table 20).

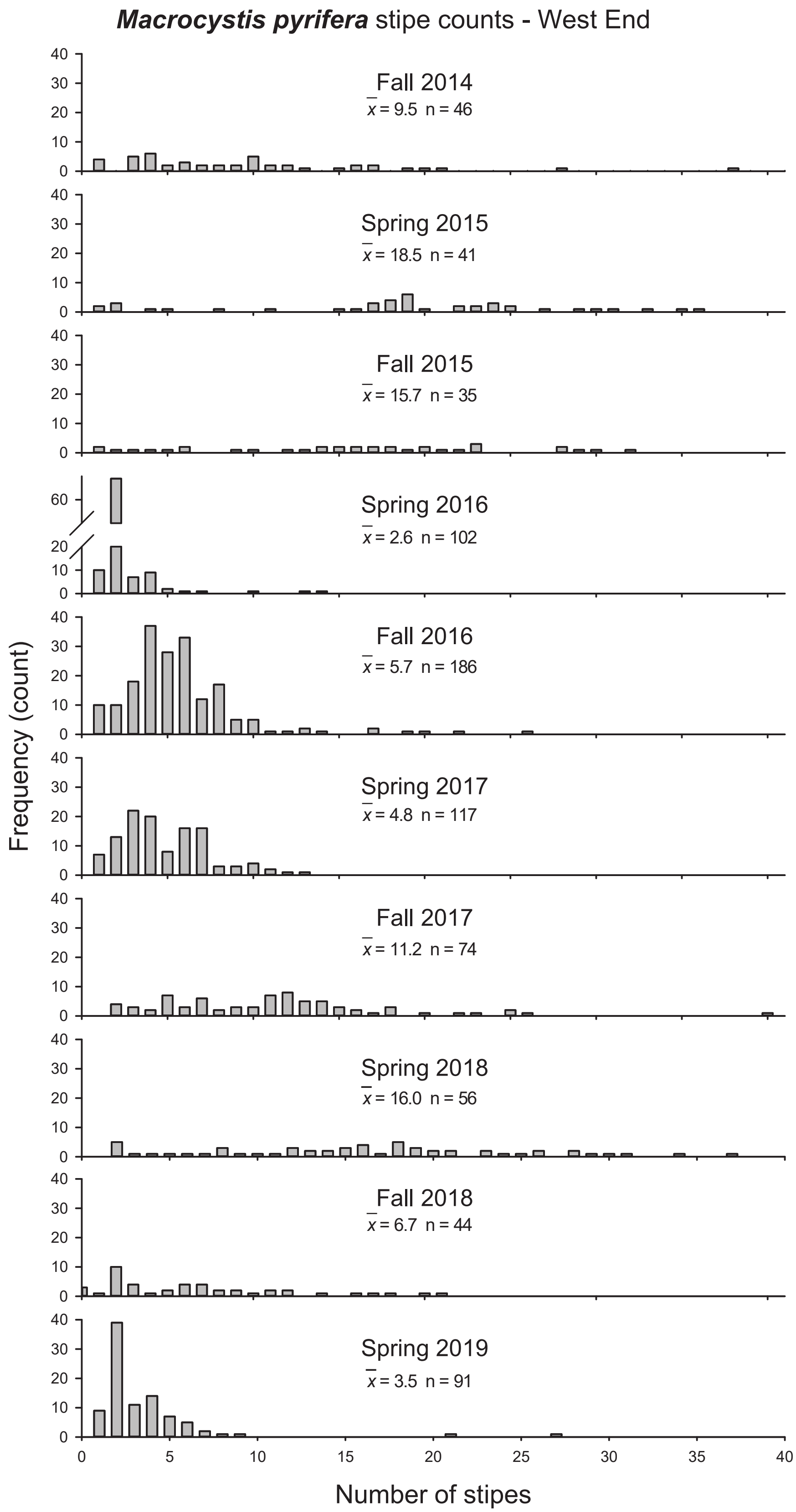

Figure 23. West End *Macrocystis pyrifera* greater than 1-meter (m) tall stipe counts by season in fall 2014–spring 2019. [$\bar{x}$ is mean count, n is number of individuals]

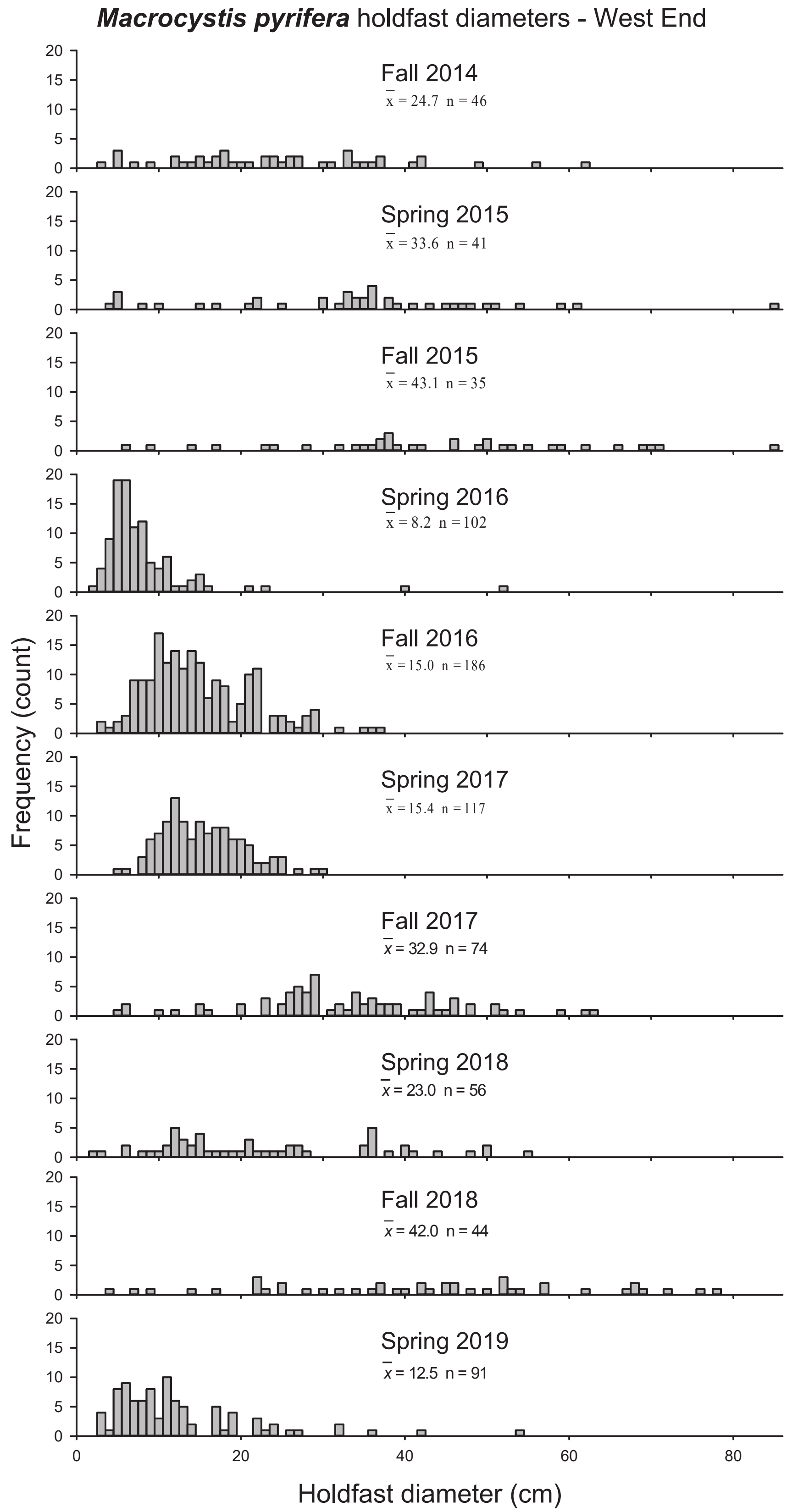

Figure 24. West End *Macrocystis pyrifera* greater than 1-meter (m) tall holdfast diameters by season in fall 2014–spring 2019. [$\bar{x}$ is mean diameter, n is number of individuals]

Table 17. Sizes of invertebrates measured on swaths at West End in fall 2014 through spring 2019.

[*Strongylocentrotus* spp. excluded. See figures 25 and 26 for purple and red urchin size data. **Abbreviations**: N, sample size; Min, minimum; —, no data; Max, maximum]

Size	Species name						
	Crassadoma gigantea	*Haliotis rufescens*	*Kelletia kelletii*	*Megastraea undosa*	*Megathura crenulata*	*Patiria miniata*	*Pisaster giganteus*
Year 1: 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	—
Year 1: 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	—
Year 2: 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	—	—
Year 2: 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	—
Year 3: 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
Year 3: 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
Year 4: 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	—
Year 4: 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

Table 17. Sizes of invertebrates measured on swaths at West End in fall 2014 through spring 2019.—Continued

[*Strongylocentrotus* spp. excluded. See figures 25 and 26 for purple and red urchin size data. **Abbreviations**: N, sample size; Min, minimum; —, no data; Max, maximum]

Size	Species name						
	Crassadoma gigantea	*Haliotis rufescens*	*Kelletia kelletii*	*Megastraea undosa*	*Megathura crenulata*	*Patiria miniata*	*Pisaster giganteus*
	Year 5: Fall 2018						
N	0	0	9	99	5	11	2
Min	—	—	42	30	100	30	111
Max	—	—	60	90	140	65	130
Mean	—	—	51.1	57.0	118.4	49.8	120.5
	Year 5: Spring 2019						
N	9	0	26	116	2	8	0
Min	40	—	27	21	72	40	—
Max	71	—	53	93	106	55	—
Mean	50.6	—	39.5	55.2	89.0	49.4	—

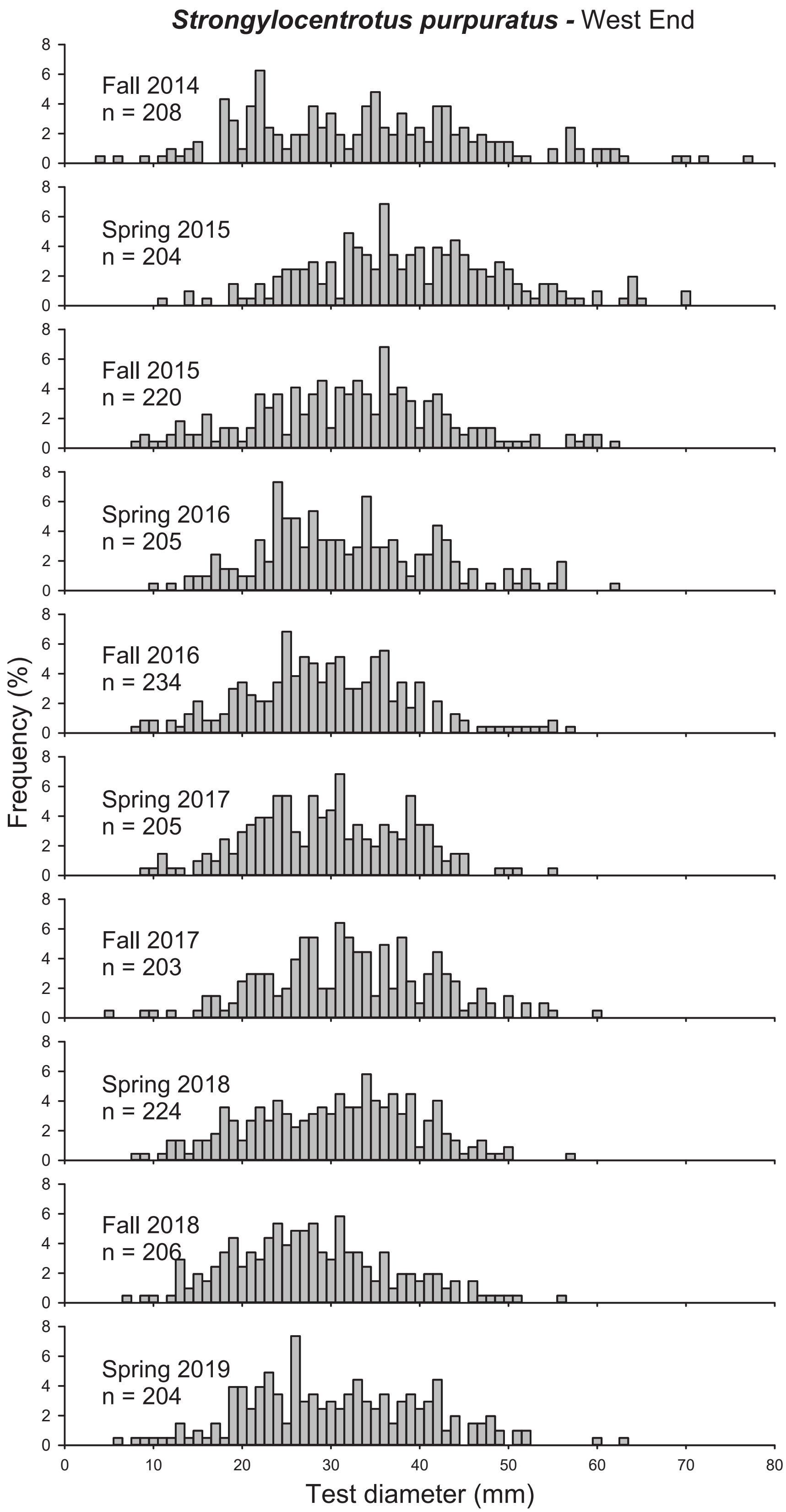

Figure 25. West End size structure of purple urchins (*Strongylocentrotus purpuratus*) in fall 2014–spring 2019. [n = number of individuals]

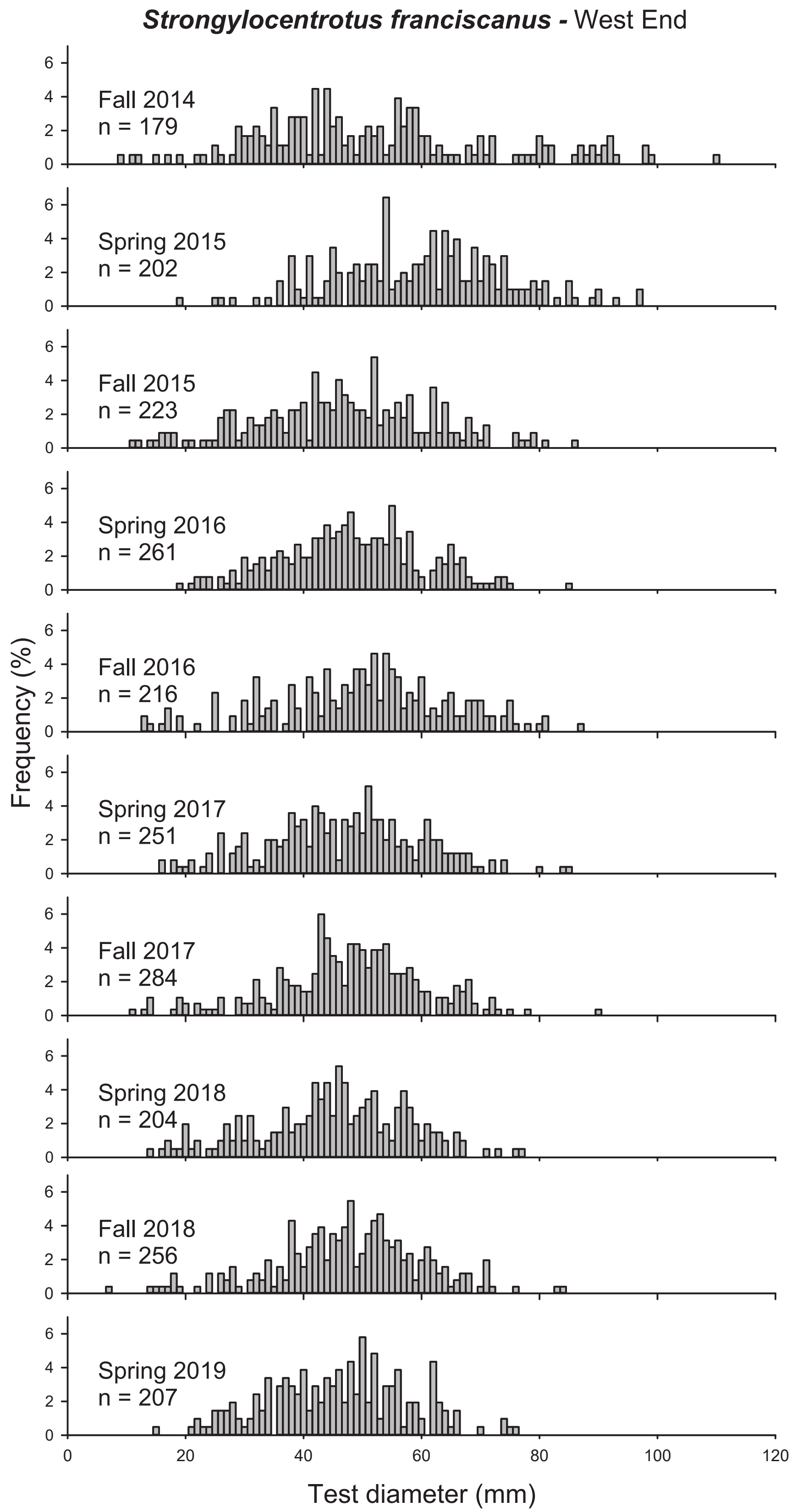

Figure 26. West End size structure of red urchins (*Strongylocentrotus franciscanus*) in fall 2014–spring 2019. [n = number of individuals]

Table 18. Mean (and standard deviation) numbers of rare species counted on twenty 1-square meter quadrats from West End, fall 2014 through spring 2019.

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Lithopoma 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)	0.1 (0.22)	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)	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)	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)	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)	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)	0.1 (0.22)	0.2 (0.49)
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)	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)	0.1 (0.31)	0.1 (0.31)
Tealia 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)	0.0 (0.00)	0.0 (0.00)

Table 19. West End point contact “species” ranked by the sum of points for fall 2014 through spring 2019.

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

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Encrusting coralline algae	267	257	249	125	257	140	196	203	168	221
Calliarthron spp.	48	59	67	65	49	69	58	57	55	58
Laminaria spp.	102	67	60	57	56	88	28	20	25	48
Rhodymenia californica	83	47	41	67	73	68	30	31	15	5
Cystoseira osmundacea	38	52	39	51	46	58	32	43	22	38
Pterygophora californica	89	51	45	25	26	29	21	28	23	30
Dictyota binghamiae	4	4	2	67	21	58	36	49	45	44
Sand	41	25	21	26	35	49	40	17	59	9
Encrusting red algae	9	20	29	10	15	18	25	53	47	41
Cryptopleura spp.	43	10	21	69	4	40	9	25	4	19
Kelp holdfast	21	8	15	10	15	19	27	20	28	10
Macrocystis pyrifera <1 m	3	5	5	71	2	31	2	1	23	11
Gigartina [*Chondracanthus*] *exasperate*	32	24	13	17	17	14	8	3	1	1
Bare substratum	8	17	15	1	25	5	28	8	8	9
Pink encrusting bryozoan	13	10	28	4	19	10	14	12	12	0
Macrocystis pyrifera >1 m	12	3	6	8	16	15	20	11	10	4
Nienburgia andersoniana	3	27	5	43	0	23	0	1	1	0
Prionitis lanceolata	7	16	9	13	11	6	16	4	13	8
Gelidium robustum	15	20	10	7	5	6	7	7	7	9
Phragmatopoma californica	0	0	2	1	3	1	31	11	11	12
Young Laminariales	0	0	0	6	4	21	1	3	2	4
Botryocladia pseudodichotoma	2	0	1	2	2	11	5	5	6	5
Cryptopleura ruprechtiana	16	12	0	6	0	3	0	0	0	0
Serpulorbis squamiger	2	0	3	1	1	1	5	8	8	6
Bossiella spp.	3	4	1	0	0	6	1	5	4	8
Eisenia arborea	2	8	1	4	7	0	4	0	5	0
Pterosiphonia spp.	0	2	3	0	0	7	0	4	0	14
Metandrocarpa dura	2	2	0	3	5	0	9	0	5	2
Neoptilota [*Ptilota*] *densa*	6	2	1	7	1	1	2	0	0	0
Corallina officinalis	1	2	0	3	3	0	1	1	3	5
Plocamium pacificum	2	2	1	2	1	2	0	1	2	5
Callophyllis flabellulata	0	0	0	0	7	8	0	0	0	0
Kallymenia pacifica	3	0	2	1	1	1	0	2	3	1
Orange encrusting sponge	4	2	1	0	2	0	3	0	1	0
Didemnum carnulentum	1	2	1	0	2	0	4	1	0	0
Unidentified sponge	1	5	2	0	0	0	1	1	0	0
Acanthacora cyanocrypta	1	0	7	0	0	0	0	1	0	0
Anthopleura sola	1	2	0	1	0	2	1	1	0	0
Synoicum spp.	0	0	0	0	0	0	0	8	0	0
Aglaophenia spp.	0	0	0	2	0	5	0	0	0	0
Barnacle	0	0	7	0	0	0	0	0	0	0
Dictyopteris undulata	0	0	0	0	3	0	0	0	3	1

Table 19. West End point contact "species" ranked by the sum of points for fall 2014 through spring 2019.—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	Fall 2018	Spring 2019
Filamentous red algae	3	2	0	0	0	0	1	0	1	0
Laurencia pacifica	0	2	0	1	0	2	1	0	0	1
Opuntiella californica	0	2	0	0	1	0	2	0	2	0
Epiactis prolifera	0	0	2	0	0	0	2	0	1	0
Balanophyllia elegans	0	1	0	1	0	0	0	1	0	1
Bryopsis corticulans	0	0	0	0	0	0	0	2	0	2
Polyneura spp.	0	1	0	3	0	0	0	0	0	0
Tethya aurantia	1	0	0	1	0	0	0	1	0	0
Crisia spp.	0	0	1	0	0	0	0	1	0	0
Desmarestia ligulata	0	0	0	1	0	1	0	0	0	0
Diopatra ornata	0	1	0	0	0	0	1	0	0	0
Dodecaceria spp.	0	0	1	0	0	0	1	0	0	0
Pikea spp.	0	1	1	0	0	0	0	0	0	0
Red algae	0	0	0	2	0	0	0	0	0	0
Styela montereyensis	1	1	0	0	0	0	0	0	0	0
Archidistoma psammion	0	0	0	0	1	0	0	0	0	0
Corynactis californica	1	0	0	0	0	0	0	0	0	0
Eupentacta quinquesemita	0	0	0	0	0	1	0	0	0	0
Fauchea [*Gloiocladia*] *laciniata*	0	0	0	0	0	1	0	0	0	0
Laurencia spp.	0	0	0	0	0	1	0	0	0	0
Leucosolenia eleanor	0	0	0	0	0	0	1	0	0	0
Pachythyone rubra	0	0	0	0	0	0	1	0	0	0
Pholad clam	0	0	0	0	0	0	0	0	1	0
Polyclinum planum	0	0	1	0	0	0	0	0	0	0
Prionitis spp.	0	0	0	0	0	1	0	0	0	0
Red algal turf	0	0	0	1	0	0	0	0	0	0
Stylantheca porphyra	0	0	0	0	1	0	0	0	0	0

Table 20. West End fish counts—adult (juvenile)—in fall 2014 through spring 2019 (by species).

[f, female; m, male]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Artedius spp.	0	0	1	1	0	0	0	0	0	0
Brachyistius frenatus	40	6	1	0	29	1	1	1	6	3
Chromis punctipinnis	1,030	305 (27)	788	214	385	232	26	168	98	47
Rhinogobiops nicholsii	2	0	1	0	0	0	0	0	0	0
Embiotoca jacksoni	43	6	17	10	36	17	33	37	21	26
Embiotoca lateralis	61	7	7	1	10	5	4	7	8	5
Gibbonsia spp.	3	0	0	0	0	0	0	0	0	0
Girella nigricans	7	1	3	5	7	9	6	1	34	2
Gymnothorax mordax	0	0	0	1	0	0	0	0	0	0
Halichoeres semicinctus	0	0	0	0	0	0	0	1	0	0
Heterostichus rostratus	1	0	0	0	0	0	0	0	0	0
Hypsurus caryi	6	0	2	3	8	0	7	3	0	0
Hypsypops rubicundus	1	0	0	0	3	3	1	5	1	4
Medialuna californiensis	0	0	1	2	0	0	0	3	2	1
Myliobatis californica	0	0	0	0	0	0	0	0	1	0
Neoclinus spp.	0	0	0	0	0	0	1	0	0	0
Ophiodon elongatus	0	0	0	0	0	1	0	0	0	0
Oxyjulis californica	2,613	286	1,751	1,146	529	792	159	305	277	171
Oxylebius pictus	8	8	10	7	1	5	1	2	4	2
Paralabrax clathratus	11	2 (2)	22 (3)	5	15	18	3	5	14	11
Rhacochilus toxotes	0	0	0	0	2	0	0	0	0	0
Rhacochilus vacca	4	1	0	1	1	0	1	0	0	0
Scorpaenichthys marmoratus	0	1	0	0	0	0	0	0	0	0
Sebastes atrovirens	16	1	7	0	3	3	4	1	1	2
Sebastes auriculatus	0	0	0	1	0	0	1	0	0	0
Sebastes carnatus	0	0	0	0	0	2	0	0	0	0
Sebastes caurinus	0	0	0	0	0	0 (1)	0	0	0	0
Sebastes chrysomelas	12	0	9	4	1	1	1	0	0	0
Sebastes mystinus	126	278 (12)	14	21	123	59	33	60	17	24
Sebastes rastrelliger	2	0	0	0	1	0	0	2	0	1
Sebastes serranoides	0	0	4	10	48 (25)	4	2	6	1	7
Sebastes serriceps	1	0	0	0	0	0	0	0	0	0
Sebastes spp.	0	0	0	0	0	0 (1)	0	0	0	0
Semicossyphus pulcher (f)	20	10 (2)	32	15	20	28	16	31	28	29
Semicossyphus pulcher (m)	13	3	4	0	6	11	3	15	10	4
Stereolepis gigas	1	0	0	0	0	0	0	0	0	0
Torpedo californica	1	0	0	0	0	0	0	0	0	0

Dutch Harbor

Figure 27 shows mean counts of some of the most dynamic species that were counted on the swaths at the Dutch Harbor supersite during the last 5 years. Both purple and red sea urchins, which had doubled in density between 2017 and 2018, leveled off with the latter species reaching 14.5 percent of the former. The rock scallop (*C. gigantea*) followed a similar trend in recent years, increasing substantially in 2017 and then leveling off. Like at West End, the wavy turban snail (*M. undosa*) increased from near zero in the last 2 years and, at Dutch Harbor, its density has approximately doubled in each of the last four sampling trips. Juvenile *M. pyrifera* showed two sizeable recruitments in the last 5 years with peaks in fall 2016 and spring 2019. Only the earlier peak corresponded to a jump in the density of plants greater than 1 m, however.

Purple urchins, followed by red urchins, remained the most common swath-counted organism at Dutch Harbor (table 21). The spotted rose anemone, *T. lofotensis*, was third. *Laminaria* spp. was the most common kelp except in the last period when juvenile *M. pyrifera* recruited.

Figures 28 and 29 show the stipe counts and holdfast diameters of *M. pyrifera* throughout the last 10 sampling periods at Dutch Harbor. In contrast to West End, Dutch Harbor showed no recruitment pulse in the "adult" population in year 5. There were only 2 plants with less than 10-cm holdfast diameter, and the total count of 12 plants in the "adult" *Macrocystis* population in spring 2019 was the lowest recorded since counts began in 1980. There were, however, a total of 248 juvenile *Macrocystis* counted on the supersite in spring 2019; this was the second highest recorded in more than 10 years.

Sizes of invertebrates measured on the swaths at Dutch Harbor are summarized in table 22. As mentioned earlier, counts of the rock scallop (*C. gigantea*) leveled off during the last two sample years, and in year 5, their mean size was only slightly higher than previous sample years. Counts of the wavy turban snail (*M. undosa*) increased considerably in fall 2018 and again in spring 2019, but their sizes showed little change. Counts of Kellet's whelk (*K. kelletii*), the giant keyhole limpet (*Megathura crenulata*), and the sea star, *P. miniata*, were too low or variable to draw conclusions from the size data.

The size distribution of *S. purpuratus* showed little substantive change in recent years, but there were fewer individuals greater than 60 mm than in most previous samples (fig. 30). Despite this, Dutch Harbor continued to have the most purple urchins in the largest size bin of all the supersites (table 10). In fall 2017 and spring 2018, red urchins showed an increase in the smaller sizes (fig. 31). By year 5, the increased proportion had been passed on to the middle and large size bins (table 11), and the resulting size frequency plot in spring 2019 looked remarkably similar to that from 2-years earlier.

Tealia lofotensis continued to be relatively stable in density and remained the most common species in the 1-m^2 quadrat counts (table 23). The orange puffball sponge (*T. aurantia*) and the stalked tunicate (*S. montereyensis*) remained present at lower numbers.

Excluding the bare substrate category, Dutch Harbor RPC quadrats continued to have a relatively even mix of categories of species with encrusting algae and non-motile invertebrates as the most common (fig. 21). This is the only supersite where invertebrates rival encrusting algae as the dominant cover category. There has been a slight decrease in the cover of fleshy red algae during the last 2 years. Of the cover taxa recorded, encrusting coralline algae dominated, followed by *C. osmundacea*, *Laminaria* spp., and the tube-building polychaete, *Diopatra ornata.* The small sea cucumbers, *Pachythyone rubra* and *Cucumaria piperata*, and pink encrusting bryozoans also were quite common (table 24). More than at any of the other sites, cover here was 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 14). 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 25). No juvenile *S. pulcher* were observed in year 5 because warm-water associated recruitment (Cowen, 1985) came to an end with the switch to cooler ocean conditions in 2016. Many of the fish transects at Dutch Harbor traverse a high relief reef with a multitude of cracks, crevices, and ledges that serve as refuge for a variety of fishes. On most of the west-heading transects, a sharp drop-off and near vertical wall from 6 m at the reef crest down to 15 m at the bottom is encountered. The water column above the drop-off is often teeming with high numbers of fish of more than a dozen species; however, the final 10–30 m at the distal end of these western transects traverse a sand channel that is mostly devoid of fish. The fact that nearly all of the fish recorded are seen on only about one half the lengths of these western transects underscores the incredible productivity of Dutch Harbor's rocky reefs.

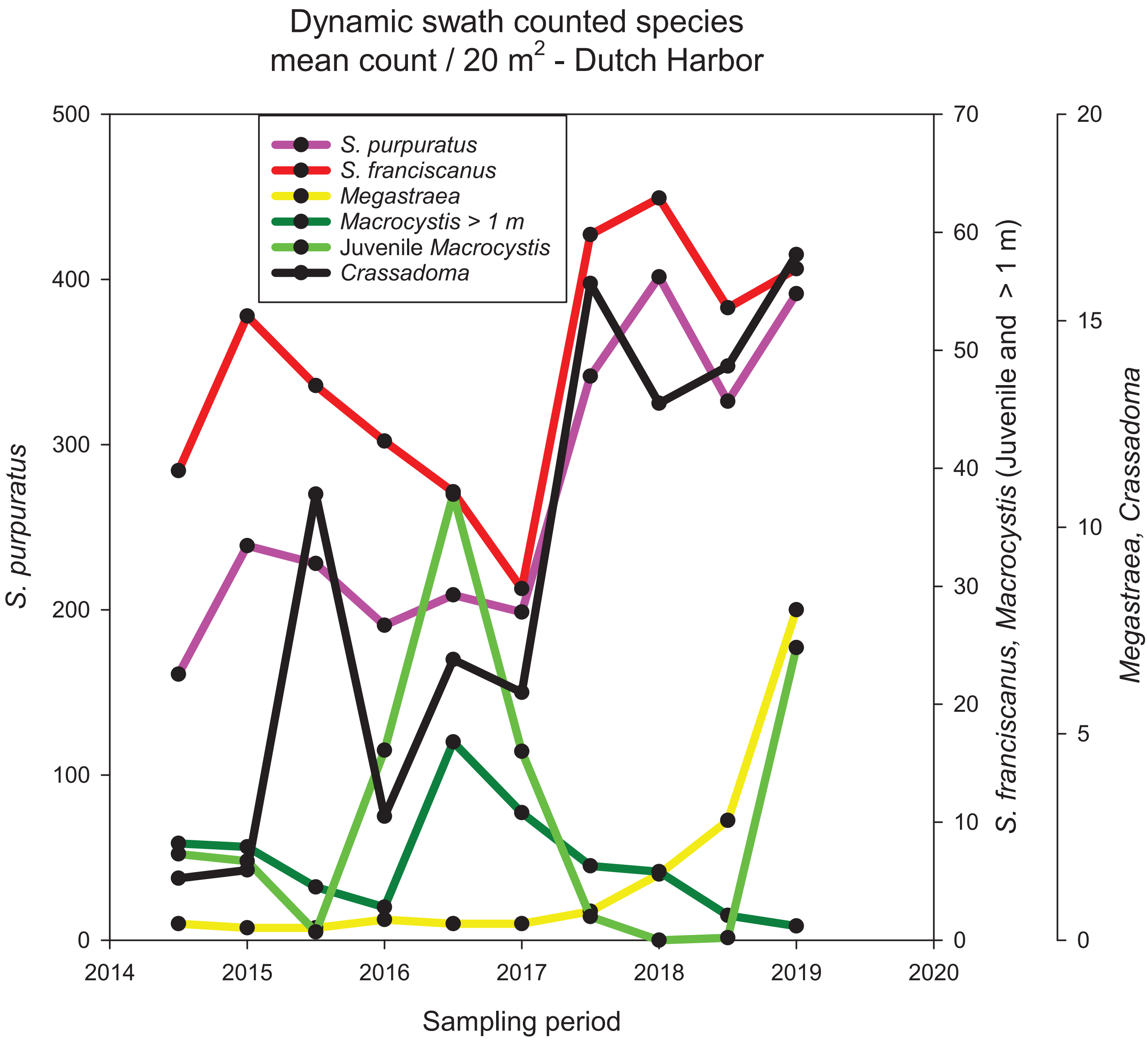

Figure 27. Mean densities of some swath-counted species that have demonstrated changing abundance at Dutch Harbor during the last 5 years. [Note three vertical axes for densities of different species groups]

Table 21. Dutch Harbor mean (standard deviation) swath counts for fall 2014 through spring 2019 expressed as individuals per 20-square meter transect.

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

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
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)	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)	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)	13.90 (10.14)	16.60 (8.30)

Table 21. Dutch Harbor mean (standard deviation) swath counts for fall 2014 through spring 2019 expressed as individuals per 20-square meter transect.—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	Fall 2018	Spring 2019
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)	5.90 (8.10)	10.30 (12.74)
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)	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)	5.40 (6.52)	5.10 (5.76)
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)	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)	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)	0.50 (1.08)	2.60 (3.27)
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)	7.20 (7.33)	12.00 (15.94)
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)	0.10 (0.32)	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)	0.20 (0.42)	24.80 (41.13)
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)	2.10 (1.52)	1.20 (1.55)
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)	2.90 (2.23)	8.00 (5.54)
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)	0.80 (1.03)	0.50 (0.53)
Apostichopus 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)	0.30 (0.67)	3.50 (5.68)
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)	1.80 (1.81)	3.00 (2.11)
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)	0 (0.00)	0.10 (0.32)
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)	0.40 (0.84)	0.40 (0.70)
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)	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)	0 (0.00)	0 (0.00)
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)	53.60 (28.91)	56.90 (26.58)
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)	326.20 (136.24)	391.30 (184.02)
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)	5.70 (2.98)	7.40 (5.72)
Tealia 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)	37.50 (21.45)	38.60 (22.23)
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)	1.20 (2.57)	7.10 (12.27)

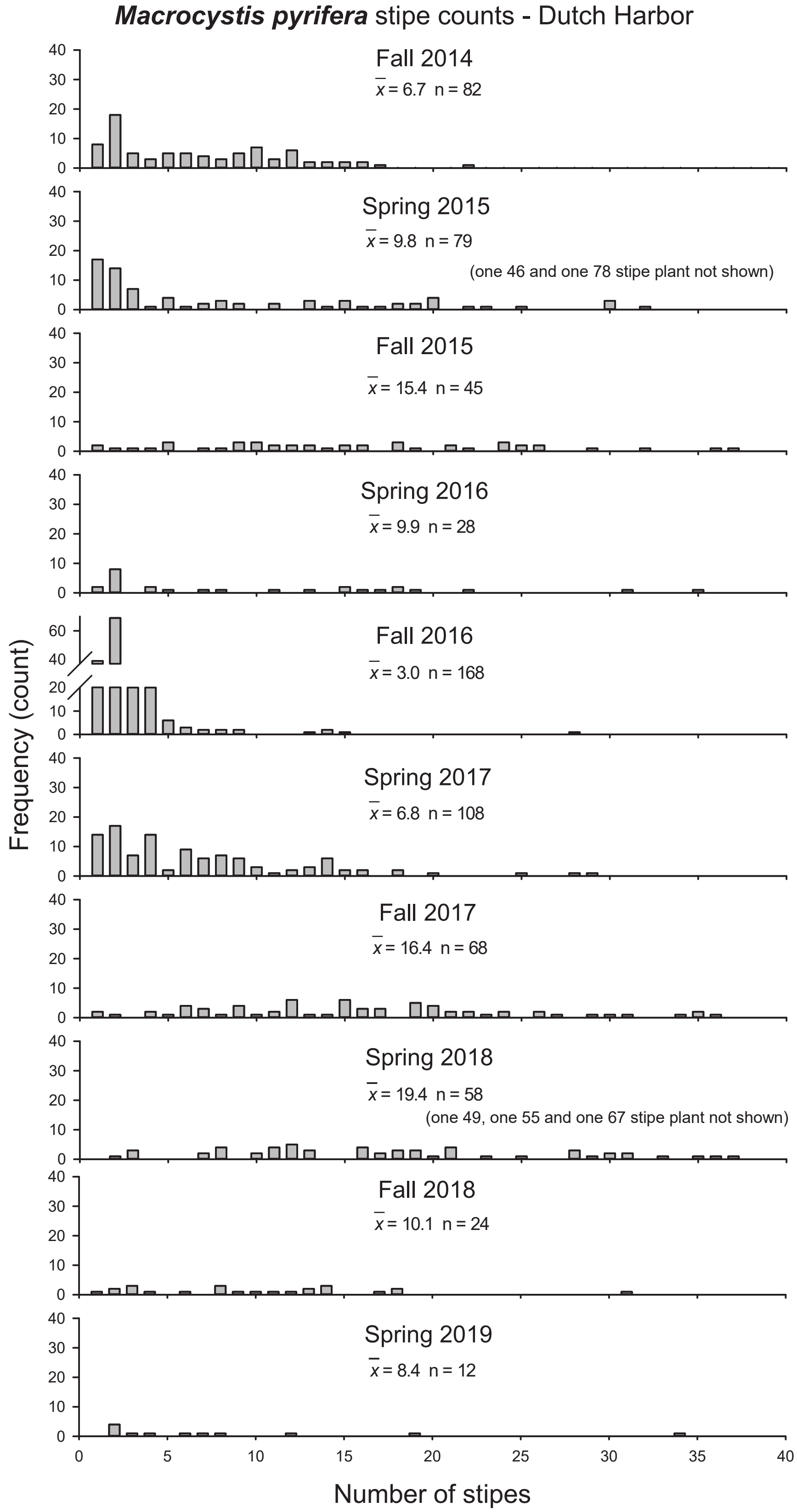

Figure 28. Dutch Harbor *Macrocystis pyrifera* greater than 1-meter (m) tall stipe counts by season in fall 2014–spring 2019. [$\bar{x}$ is mean count, n is number of individuals]

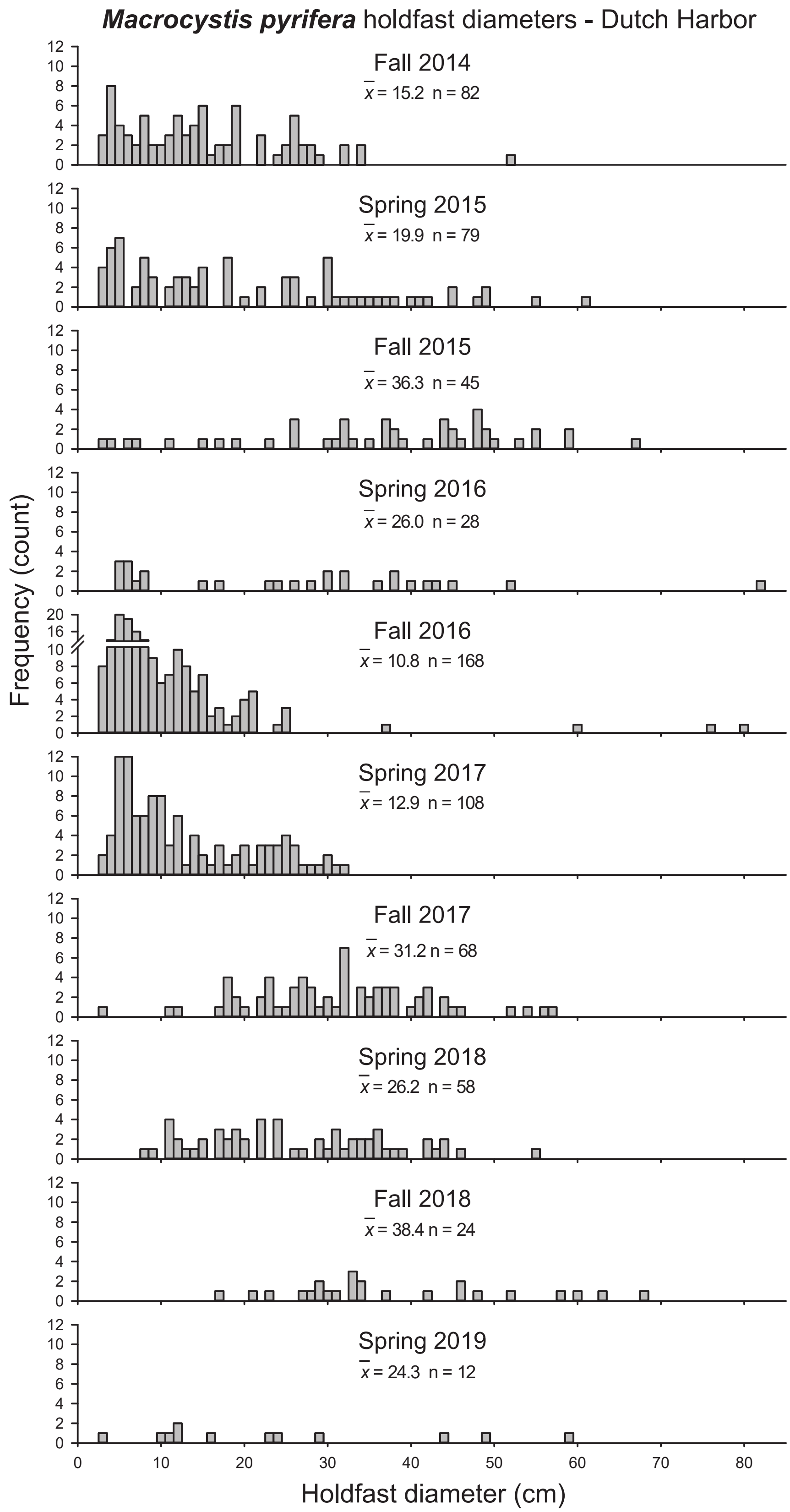

Figure 29. Dutch Harbor *Macrocystis pyrifera* greater than 1-meter (m) tall holdfast diameters by season in fall 2014–spring 2019. [$\bar{x}$ is mean diameter, n is number of individuals]

Table 22. Sizes of invertebrates measured on swaths at Dutch Harbor in fall 2014 through spring 2019.

[*Strongylocentrotus* spp. excluded. See figures 30 and 31 for purple and red urchin size data. **Abbreviations**: N, sample size; Min, minimum; —, no data; Max, maximum]

Size	Species name						
	Crassadoma gigantea	*Dermasterias imbricata*	*Kelletia kelletii*	*Megastraea undosa*	*Megathura crenulata*	*Patiria miniata*	*Pisaster giganteus*
Year 1: 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	—
Year 1: 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	—
Year 2: 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	102.2	56.8	—
Year 2: 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	80.5	56.7	77.0	111.3	55.5	—
Year 3: 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	—
Year 3: 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	—
Year 4: Fall 2017							
N	158	0	1	8	11	20	0
Min	26	—	47	37	28	20	—
Max	113	—	47	81	125	91	—
Mean	65.0	—	47.0	52.0	95.8	61.3	—
Year 4: 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

Table 22. Sizes of invertebrates measured on swaths at Dutch Harbor in fall 2014 through spring 2019.—Continued

[*Strongylocentrotus* spp. excluded. See figures 30 and 31 for purple and red urchin size data. **Abbreviations**: N, sample size; Min, minimum; —, no data; Max, maximum]

Size	Species name						
	Crassadoma gigantea	*Dermasterias imbricata*	*Kelletia kelletii*	*Megastraea undosa*	*Megathura crenulata*	*Patiria miniata*	*Pisaster giganteus*
Year 5: Fall 2018							
N	188	0	5	46	9	18	0
Min	24	—	38	35	102	40	—
Max	150	—	47	80	130	87	—
Mean	73.4	—	41.8	58.0	116.6	64.2	—
Year 5: Spring 2019							
N	166	0	26	84	5	27	1
Min	24	—	29	28	67	26	45
Max	125	—	84	92	114	101	45
Mean	68.2	—	55.1	59.0	96.6	59.4	45.0

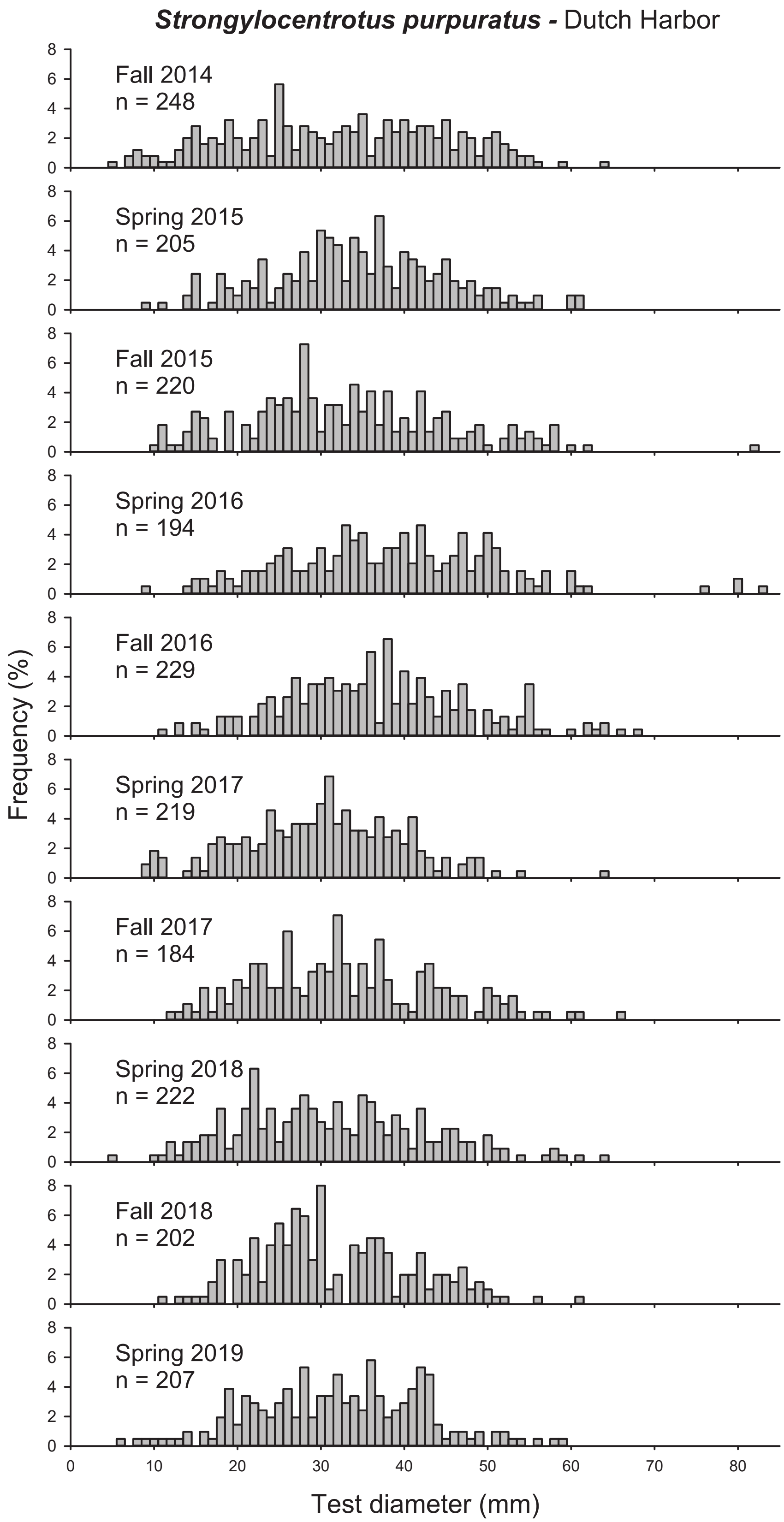

Figure 30. Dutch Harbor size structure of purple urchins (*Strongylocentrotus purpuratus*) in fall 2014–spring 2019. [n = number of individuals]

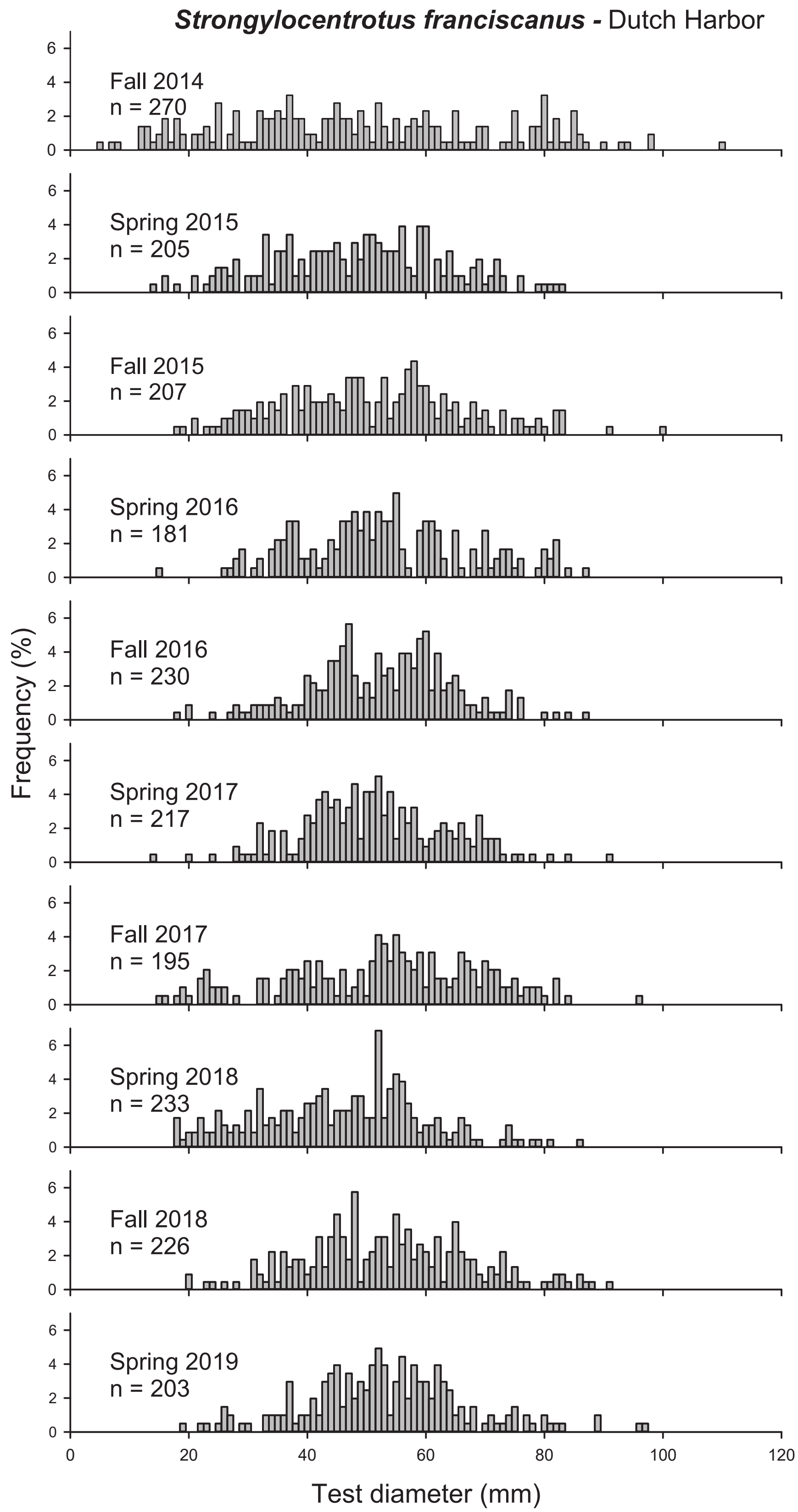

Figure 31. Dutch Harbor size structure of red urchins (*Strongylocentrotus franciscanus*) in fall 2014–spring 2019. [n = number of individuals]

Table 23. Mean (and standard deviation) numbers of rare species counted on twenty 1-square meter quadrats from Dutch Harbor in fall 2014 through spring 2019.

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Lithopoma 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)	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)	0.0 (0.00)	0.0 (0.00)
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)	0.0 (0.00)	0.1 (0.22)
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)	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)	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)	0.1 (0.31)	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)	0.1 (0.22)	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)	0.3 (0.44)	0.2 (0.37)
Tealia 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)	0.3 (0.55)	0.6 (0.89)

Table 24. Dutch Harbor point contact "species" ranked by the sum of points for fall 2014 through spring 2019.

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

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Encrusting coralline algae	182	129	187	128	151	122	167	139	137	167
Sand	79	112	67	50	67	39	50	62	75	77
Laminaria spp.	45	57	46	47	43	40	58	50	43	38
Cystoseira osmundacea	38	27	38	27	33	43	56	45	32	55
Diopatra ornata	33	43	19	26	42	22	18	41	40	44
Pink encrusting bryozoan	5	16	23	40	33	33	58	66	35	17
Pachythyone rubra	13	29	25	19	35	44	69	36	28	11
Cucumaria piperata	24	39	23	17	19	30	31	22	33	31
Rhodymenia californica	64	42	14	24	29	44	19	5	9	16
Calliarthron spp.	27	34	18	19	18	16	15	9	9	12
Cryptopleura spp.	13	16	2	27	42	34	9	1	18	14
Corallina officinalis	27	20	12	2	16	19	15	24	10	16
Bare substratum	10	8	23	13	9	19	7	12	10	29
Eisenia arborea	16	15	9	14	23	19	17	4	10	10
Encrusting red algae	8	11	14	9	8	11	13	9	13	11
Dictyota binghamiae	5	24	0	14	21	14	0	1	8	19
Crisia spp.	6	11	5	16	3	13	15	18	5	11
Aglaophenia spp.	6	1	6	3	14	16	16	10	24	5
Kelp holdfast	5	2	18	21	13	10	8	6	8	3
Corynactis californica	12	9	7	6	13	9	7	4	1	4

Table 24. Dutch Harbor point contact "species" ranked by the sum of points for fall 2014 through spring 2019.—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	Fall 2018	Spring 2019
Astrangia lajollaensis	4	8	3	5	7	6	6	9	10	8
Macrocystis pyrifera >1 m	8	0	9	16	5	7	8	5	6	2
Plocamium pacificum	2	13	3	10	4	8	3	10	8	4
Cellaria spp.	0	5	10	5	7	0	13	12	7	3
Balanophyllia elegans	4	6	7	12	6	3	4	7	0	3
Barnacle	12	6	29	0	0	0	0	0	0	0
Pterygophora californica	8	15	8	3	4	4	2	0	2	0
Acarnus erithacus	9	3	3	4	2	3	3	4	6	2
Macrocystis pyrifera <1 m	6	1	0	7	14	5	2	0	0	4
Nienburgia andersoniana	1	4	1	2	4	9	1	4	0	3
Diatom film	0	0	0	0	0	0	0	0	0	28
Hippodiplosia [*Primavelans*] *insculpta*	1	1	1	5	0	4	9	3	4	0
Bossiella spp.	3	8	3	1	3	0	3	0	1	3
Serpulorbis squamiger	2	2	2	1	0	4	2	5	4	2
Eupentacta quinquesemita	0	5	0	0	5	2	2	0	3	6
Lagenocella spp.	1	1	2	6	4	0	3	2	3	0
Orange encrusting sponge	0	4	1	2	6	1	4	3	1	0
Abietinaria spp.	0	1	2	0	3	5	3	2	3	2
Acanthacora cyanocrypta	1	2	0	0	0	1	2	6	6	0
Anthopleura sola	2	4	0	3	4	2	0	1	0	2
Bugula spp.	2	3	3	4	1	0	2	0	1	1
Filamentous red algae	6	1	1	1	1	4	0	0	0	2
Phragmatopoma californica	0	1	1	0	3	0	4	1	5	1
Urticina /*Tealia* spp.	3	1	0	7	2	2	0	0	1	0
Phidolopora pacifica	0	3	1	3	2	1	2	1	1	0
Gigartina exasperata	4	0	0	0	3	2	1	0	0	1
Botryocladia pseudodichotoma	0	0	0	0	2	2	1	3	0	1
Unidentified sponge	0	1	0	2	1	0	2	1	0	2
Kallymenia pacifica	0	0	0	0	2	1	0	3	1	1
Plumularia spp.	0	0	0	0	0	0	0	4	1	3
Stylantheca porphyra	0	0	0	1	0	3	2	1	0	1
Archidistoma psammion	0	0	0	0	0	0	4	0	3	0
Tethya aurantia	1	1	0	0	0	0	1	1	3	0
Didemnum carnulentum	0	0	0	0	0	3	2	1	0	0
Strongylocentrotus purpuratus	1	1	2	0	0	0	0	0	2	0
Young Laminariales	1	3	0	1	1	0	0	0	0	0
Bryopsis corticulans	0	0	0	0	0	1	0	0	2	1
Epiactis prolifera	0	0	1	0	0	3	0	0	0	0
Red algal turf	0	0	0	0	0	0	0	0	4	0
Cystodytes lobatus	0	0	0	0	0	0	0	0	0	3
Dictyopteris undulata	0	0	0	1	0	1	0	0	0	1
Gelidium robustum	0	0	0	0	2	0	0	1	0	0

Table 24. Dutch Harbor point contact "species" ranked by the sum of points for fall 2014 through spring 2019.—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	Fall 2018	Spring 2019
Laurencia pacifica	0	2	0	0	0	0	0	0	0	1
Pterosiphonia spp.	0	0	0	0	0	2	0	0	1	0
Spheciospongia confoederata	1	0	0	1	0	0	0	0	0	1
Synoicum spp.	0	0	0	0	3	0	0	0	0	0
Anthopleura spp.	0	0	1	0	0	1	0	0	0	0
Lissothuria nutriens	0	0	0	0	0	0	0	0	1	1
Mucus tube polychaete	0	0	0	0	0	0	0	0	2	0
Styela montereyensis	0	0	0	0	0	0	1	0	0	1
Unidentified bryozoan	0	0	0	0	0	0	0	0	0	2
Balanus spp.	0	0	0	0	1	0	0	0	0	0
Boltenia villosa	0	0	0	0	0	1	0	0	0	0
Callophyllis flabellulata	0	0	0	0	0	1	0	0	0	0
Clavelina huntsmani	0	0	0	0	0	1	0	0	0	0
Codium fragile	1	0	0	0	0	0	0	0	0	0
Codium setchellii/hubbsii	0	0	0	0	1	0	0	0	0	0
Colpomenia spp.	0	0	0	0	0	0	0	0	0	1
Crassadoma gigantea	0	0	0	0	0	0	0	1	0	0
Desmarestia ligulata	0	0	0	0	1	0	0	0	0	0
Filamentous green algae	0	0	0	0	1	0	0	0	0	0
Leucetta [*Leucandra*] *losangelensis*	0	1	0	0	0	0	0	0	0	0
Opuntiella californica	0	0	0	0	0	0	0	0	0	1
Pholad clam	0	0	0	0	0	1	0	0	0	0
Pista elongata	0	0	0	0	0	0	0	0	1	0
Prionitis lanceolata	0	0	1	0	0	0	0	0	0	0
Strongylocentrotus franciscanus	0	1	0	0	0	0	0	0	0	0
Unidentified brown algae	0	0	0	0	0	0	0	0	0	1
Tealia lofotensis	0	0	0	0	0	0	0	1	0	0

Table 25. Dutch Harbor fish counts—adult (juvenile)—in fall 2014 through spring 2019 (by species).

[f, female; m, male]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Artedius spp.	0	0	0	0	0	0	0	0	2	0
Atherinops affinis	0	0	0	0	185	0	145	0	8	110
Brachyistius frenatus	52	5	18	2	31	0	3	10	5	4
Caulolatilus princeps	0	0	0	1	0	0	4	0	0	4
Cephaloscyllium ventriosum	0	0	0	4	0	0	0	0	0	0
Chromis punctipinnis	4,044	1,435 (405)	1,581	1,461	1,711 (70)	1,110	976	1,193	1,427	2,647
Rhinogobiops nicholsii	36	12	11	1	8	10	8	2	6	14
Embiotoca jacksoni	40	22 (2)	62	25	43	27	67	64	45	27
Embiotoca lateralis	43	21 (3)	27	15	19	12	24	26	17	14
Gibbonsia spp.	1	0	0	0	0	0	0	0	1	0
Girella nigricans	53	27	39	18	28	48	105	23	45	26
Halichoeres semicinctus	0	0	4	2	0	0	2	0	0	2
Hypsurus caryi	0	0	3	2	8	3	33	10	2	2
Hypsypops rubicundus	17 (4)	14	23 (1)	18	26 (1)	17	28	18	33	26
Medialuna californiensis	43	55	70	13	14	31	9	8	10	8
Mycterperca xenarcha	0	0	0	0	0	0	1	0	0	0
Neoclinus spp.	0	0	0	0	1	0	0	0	0	0
Ophiodon elongatus	3	0	1	2	0	0	0	0	0	0
Oxyjulis californica	3,742	1,816 (57)	1,068	237	622 (125)	548	239	683	130	137
Oxylebius pictus	74	50 (1)	46	13	25	11	46	12	34	37
Paralabrax clathratus	111	41 (29)	69	3	40	48	38	26	48	26
Rhacochilus toxotes	7	0	1	1	1	0	7	1	1	1
Rhacochilus vacca	17	6	27	8	17	10	13	13	14	5
Sardinops sagax	0	0	170	0	0	0	0	0	0	0
Scomber japonicus	40	0	0	5	0	0	0	0	0	0
Scorpaenichthys marmoratus	6	2	6	1	1	1	0	1	0	1
Sebastes atrovirens	49	73 (27)	108	17	64	24	38	23	35	41
Sebastes auriculatus	0	1	0	0	0	0	0	0	0	0
Sebastes carnatus	0	3 (2)	1	0	1	0	0	2	0	0
Sebastes caurinus	2	1	3	2	3	1	1	0	1	0
Sebastes chrysomelas	25	16	22	8	10	5	6	2	2	11
Sebastes melanops	0	0	0	2	0	0	0	0	0	0
Sebastes mystinus	195	101 (3)	392	144	183	279	177 (120)	190	81	133
Sebastes rastrelliger	2	7	2	2	2	0	0	1	0	0
Sebastes serranoides	144	100 (28)	272	38	77 (9)	47	96 (95)	115	89	74
Sebastes serriceps	6	1	5	4	2 (2)	1	4	0 (1)	1	2
Semicossyphus pulcher (f)	57 (6)	51 (49)	177 (17)	87 (3)	138 (2)	110 (1)	141	162	141	118
Semicossyphus pulcher (m)	22	37	30	14	13	7	15	28	23	24

Daytona 100

Mean counts of some of the most dynamic swath-counted species at Daytona 100 are shown for the last 5-year period in figure 32. At this site, the two common sea urchin species have opposite trajectories in year 5. *Strongylocentrotus purpuratus* has reached mean densities of greater than 1,000 per 20-m^2 swath, which is the highest in the 5 years that the combined supersite has been sampled, whereas *S. franciscanus* has declined to its lowest density, at less than 50 per swath. The supersite still maintains patches of urchin dominated and kelp dominated areas. Purple urchins remained the most common swath-counted organism at Daytona 100, whereas red urchins were replaced as second most abundant by the fucoid, *C. osmundacea*, in spring 2019 (table 26). *Cystoseira osmundacea* has more than doubled in density during the last 2 years, whereas the understory kelp *Eisenia arborea* has fallen to less than 25 percent of densities it had in 2014–17. Of the other understory kelps, *P. californica* declined by about half in year 5, but the density of *Laminaria* spp. remained about the same. Finally, the wavy turban snail, *M. undosa*, similar to its trend at West End and Dutch Harbor, has been gradually increasing during the last couple of years.

In spring 2019, the density of *M. pyrifera* fell to its lowest level in the 5-year sampling history of Daytona 100. Based on the stipe counts and holdfast diameters recorded there (figs. 33, 34), the remaining population was composed primarily of medium aged plants. Unlike in some previous sampling periods, there were no holdfast diameters less than 10 cm or greater than 50 cm.

A summary of the density and sizes of non-echinoid invertebrate species observed at Daytona 100 is shown in table 27. Kellet's whelk (*K. kelletii*) followed a recruitment pattern similar to that seen at Nav Fac 100 (compare fig. 35 to fig. 17). At Daytona 100, however, the apparent recruitment was in spring 2016 rather than in fall 2015. At both locations, there appeared to be another recruitment in spring 2018, but at Daytona 100, subsequent size distributions looked more like possible growth, whereas Nav Fac 100 may have had another recruitment pulse in spring 2019.

As mentioned earlier, wavy turban snail (*M. undosa*) densities continued to increase to record levels. No recruitment class is evident in the size frequency plots, however (fig. 36). The distribution from this supersite is skewed more toward larger individuals than that from Nav Fac 100.

The orange puffball sponge (*T. aurantia*) continued to be the only species consistently counted in 1-m^2 quadrats (table 28). The gastropod *K. kelletii,* though not observed in quadrats the previous year, was the only other invertebrate counted in quadrats in year 5.

There appear to be several modes in the Daytona 100 purple urchin size data (fig. 37). Like Nav Fac 100, this supersite had high proportions of small size classes and consistently low numbers of larger urchins (table 10). The size distribution of red urchins, whose density declined, has changed considerably in the last few years. It has followed a pattern seen at several of the sites of condensing the distribution into the middle sizes, with few small or large individuals (fig. 38). This pattern also is apparent in the decreased proportions in the largest and smallest size bins in table 11.

Encrusting coralline algae was again the most common cover species in year 5, with the brown alga *D. binghamiae* remaining the second most common (table 29). In fall 2018, the small holothurian *P. rubra* was the third most common, but in spring 2019, it was surpassed by increasing cover of *C. osmundacea* and bare substrate. Cover categories throughout time, as shown in figure 21, indicated a continuation of the trend observed in year 4 of increasing cover of brown algae (primarily *D. binghamiae* and *C. osmundacea*) and decreasing cover of fleshy red algae.

Daytona 100 was similar to West End in number of fish species but ranked second (after Dutch Harbor) for benthic, midwater, and overall fish density (table 14). Most of the fish counted there were of the schooling species blacksmith (*C. punctipinnis*) and señorita (*O. californica*), but kelp bass (*P. clathratus*) and sheephead (*S. pulcher*) continued to be fairly common (table 30). The east-heading transects at this site begin in an urchin barren but continue through an area of flat bottom but kelp-rich habitat, which typically features few fish. The final 10 m of these transects incorporate a high relief reef, where the majority of fish are observed.

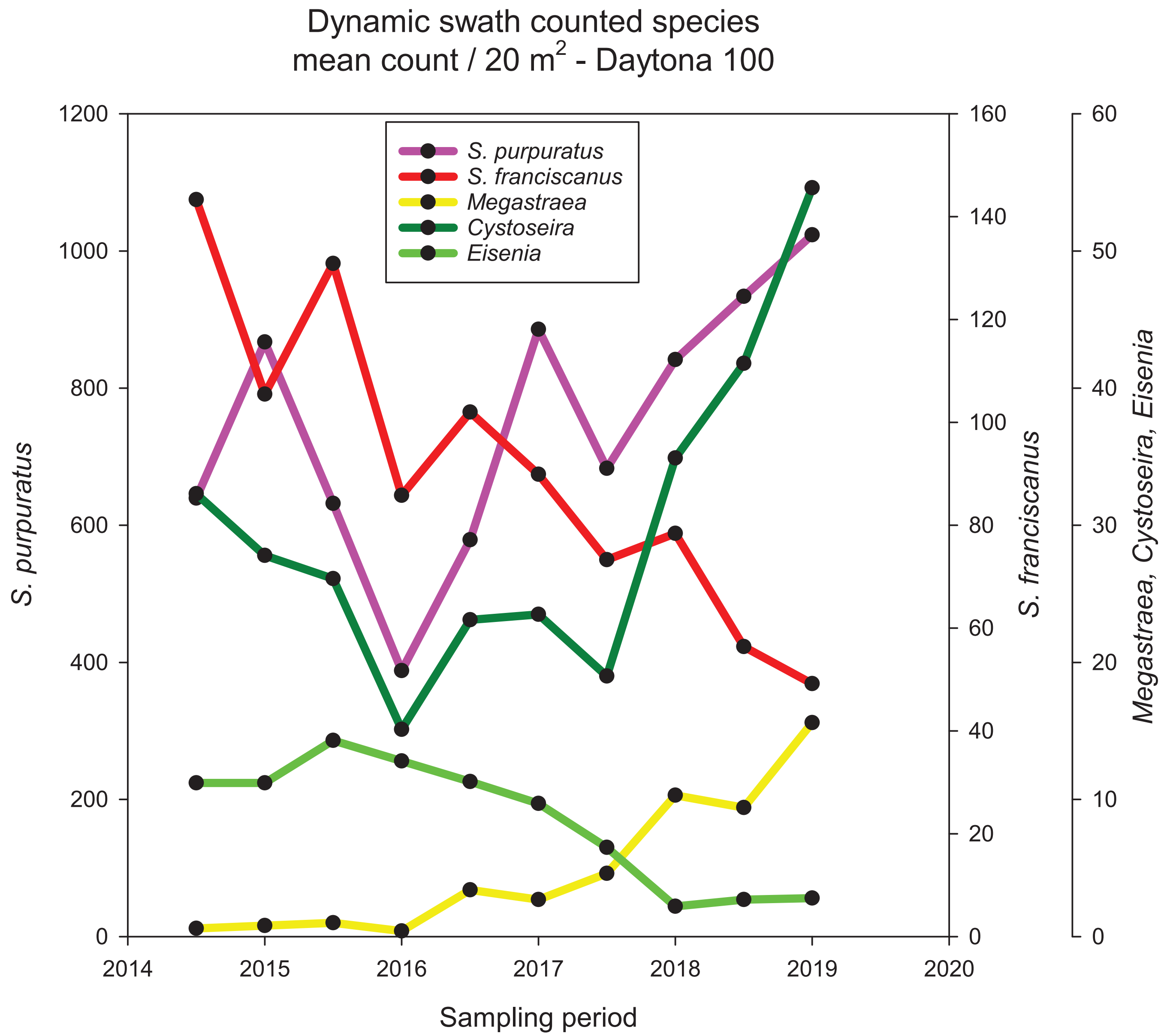

Figure 32. Mean densities of some swath-counted species that have demonstrated changing abundance at Daytona 100 during the last 5 years. [Note three vertical axes for densities of different species groups]

Table 26. Daytona 100 mean (standard deviation) swath counts for fall 2014 through spring 2019 expressed as individuals per 20-square meter transect.

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

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
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)	0.30 (0.95)	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)	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)	2.70 (4.30)	3.30 (3.95)

Table 26. Daytona 100 mean (standard deviation) swath counts for fall 2014 through spring 2019 expressed as individuals per 20-square meter transect.—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	Fall 2018	Spring 2019
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)	41.80 (56.19)	54.60 (50.59)
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)	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)	2.70 (2.83)	2.80 (2.62)
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)	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)	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)	2.30 (2.16)	2.70 (2.41)
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)	13.90 (20.44)	10.90 (15.49)
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)	0.30 (0.48)	0 (0.00)
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)	1.60 (1.43)	0.90 (0.57)
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)	1.50 (1.35)	0.70 (0.82)
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)	9.40 (9.52)	15.60 (11.35)
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)	0.60 (0.70)	0.20 (0.42)
Apostichopus 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)	0.20 (0.63)	0.60 (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)	1.70 (1.25)	2.10 (1.91)
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)	0.10 (0.32)	0.10 (0.32)
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)	0.70 (1.25)	0.70 (1.25)
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)	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)	0 (0.00)	0.10 (0.00)
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)	56.40 (61.95)	49.20 (53.96)
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)	933.70 (554.59)	1,023.50 (551.40)
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)	4.80 (4.08)	5.10 (4.53)
Tealia 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)	0.20 (0.63)	0.70 (1.34)
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)	0.80 (1.48)	0.60 (0.84)

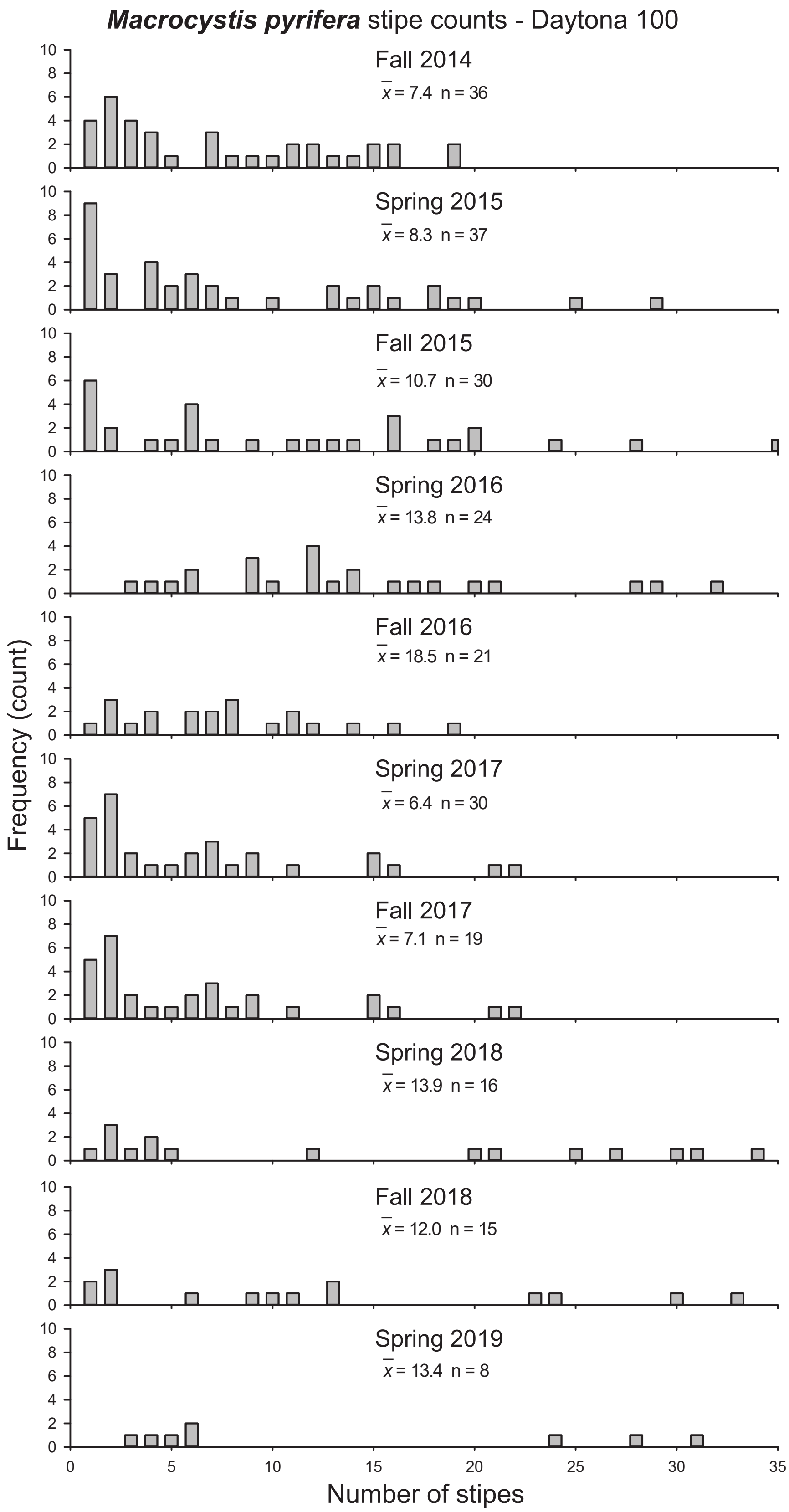

Figure 33. Daytona 100 *Macrocystis pyrifera* greater than 1-meter (m) tall stipe counts by season in fall 2014–spring 2019. [$\bar{x}$ is mean count, n is number of individuals.]

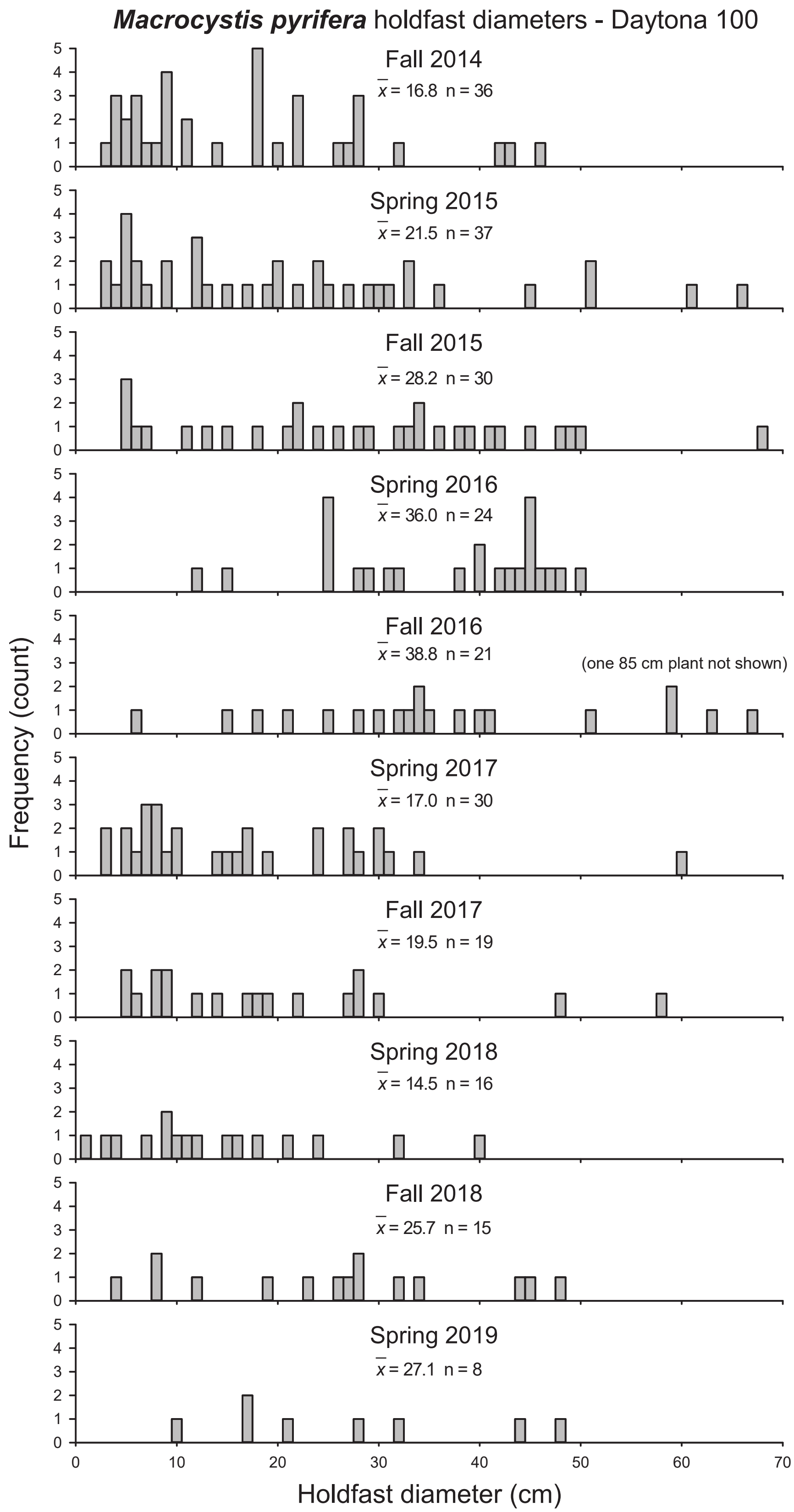

Figure 34. Daytona 100 *Macrocystis pyrifera* greater than 1-meter (m) tall holdfast diameters by season, fall 2014–spring 2019. [$\bar{x}$ is mean diameter, n is number of individuals]

Table 27. Sizes of invertebrates measured on swaths at Daytona 100 in fall 2014 through spring 2019.

[*Strongylocentrotus* spp. excluded. See figures 37 and 38 for purple and red urchin size data. **Abbreviations:** N, sample size; Min, minimum; —, no data; Max, maximum]

Size	Species name							
	Crassadoma gigantea	*Haliotis refescens*	*Kelletia kelletii*	*Lytechinus anamesus*	*Megastraea undosa*	*Megathura crenulata*	*Patiria miniata*	*Pisaster giganteus*
Year 1: 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	—
Year 1: 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	—
Year 2: Fall 2015								
N	17	0	5	0	10	5	7	0
Min	24	—	38	—	44	50	37	—
Max	170	—	135	—	85	120	86	—
Mean	74.6	—	68.6	—	59.3	86.0	66.7	—
Year 2: 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	—	56.6	75.0	49.8	—
Year 3: 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	—	57.6	100.6	67.0	—
Year 3: 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	—	62.7	96.5	52.3	75.0
Year 4: 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	—	64.3	88.2	62.3	—
Year 4: 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	65.8	92.4	53.7	—

Table 27. Sizes of invertebrates measured on swaths at Daytona 100 in fall 2014 through spring 2019.—Continued

[*Strongylocentrotus* spp. excluded. See figures 37 and 38 for purple and red urchin size data. **Abbreviations:** N, sample size; Min, minimum; —, no data; Max, maximum]

Size	Species name							
	Crassadoma gigantea	***Haliotis refescens***	***Kelletia kelletii***	***Lytechinus anamesus***	***Megastraea undosa***	***Megathura crenulata***	***Patiria miniata***	***Pisaster giganteus***
Year 5: Fall 2018								
N	27	0	23	0	94	6	17	1
Min	20	—	31	—	32	88	34	78
Max	152	—	111	—	101	98	82	78
Mean	82.3	—	55.7	—	65.8	93.3	63.1	78.0
Year 5: Spring 2019								
N	33	0	27	0	156	2	15	1
Min	40	—	31	—	24	91	25	92
Max	180	—	91	—	101	121	84	92
Mean	83.3	—	63.9	—	??	106.0	57.3	92.0

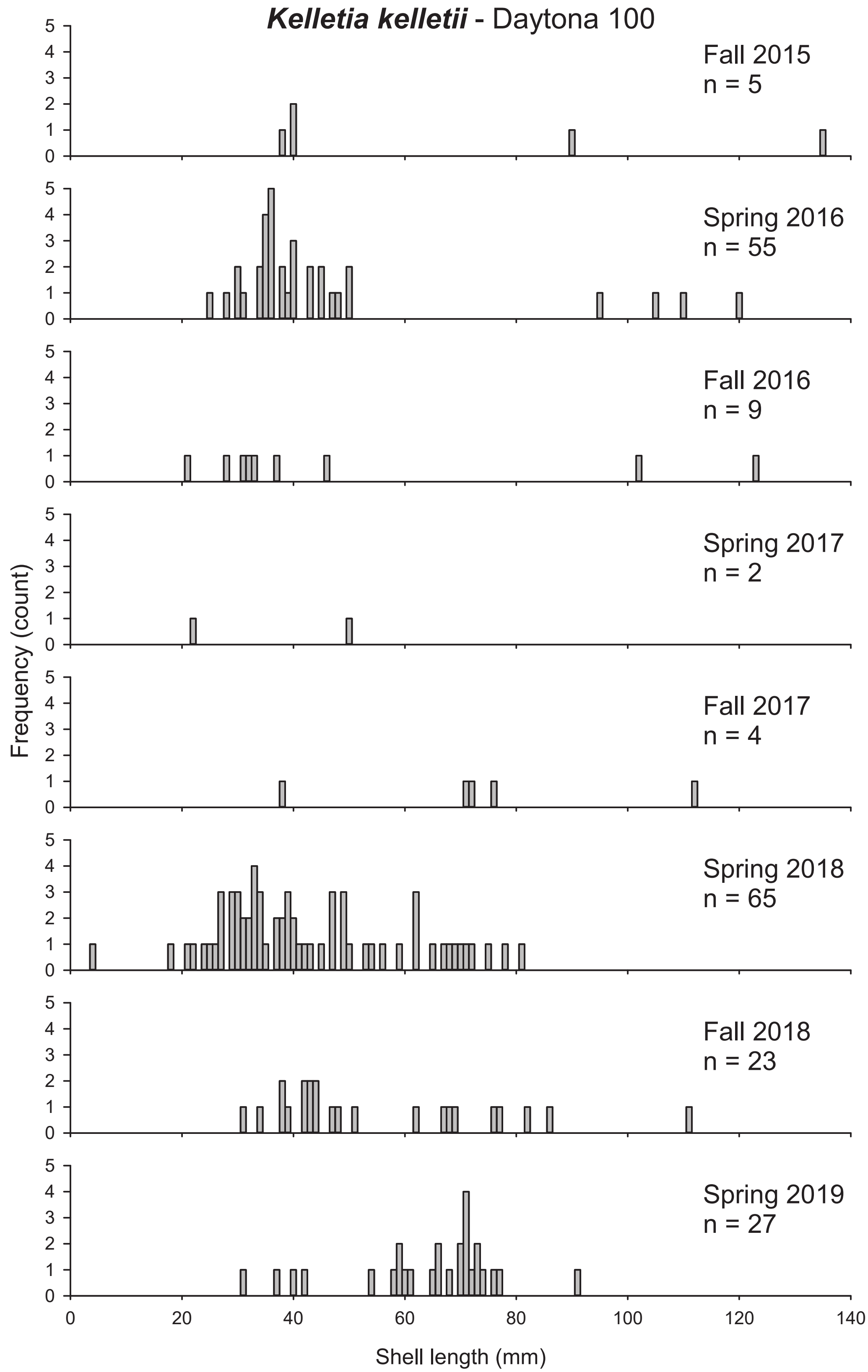

Figure 35. Size structure of Kellet's whelk (*Kelletia kelletii*) at Daytona 100 in fall 2014–spring 2019. [n = number of individuals]

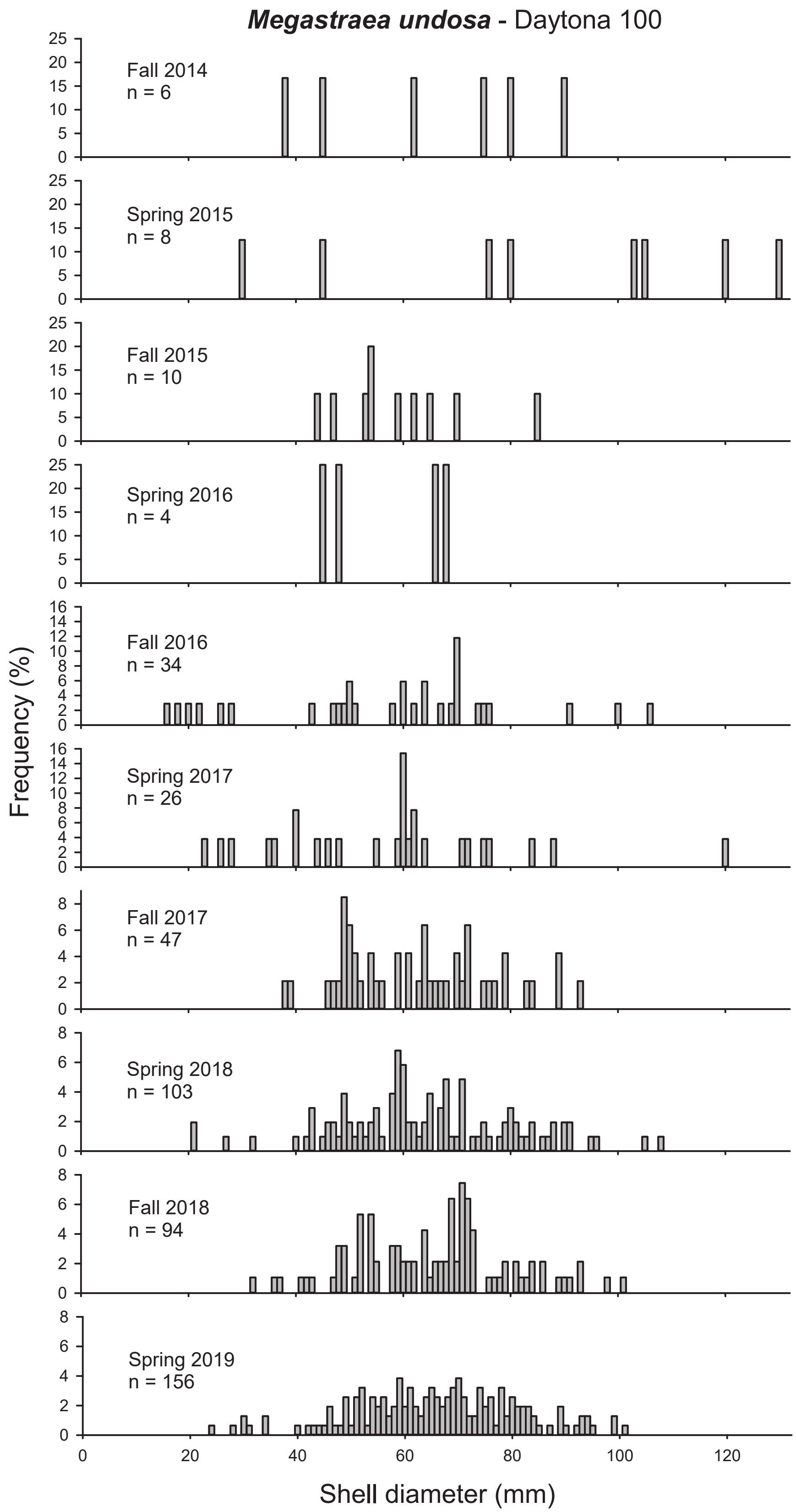

Figure 36. Daytona 100 size structure of wavy turban snails (*Megastraea undosa*) in fall 2014–spring 2019. [Note different frequency scales, n = number of individuals]

Table 28. Mean (and standard deviation) numbers of rare species counted on twenty 1-square meter quadrats from Daytona 100 in fall 2014 through spring 2019.

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Lithopoma 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)	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)	0.0 (0.00)	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)	0.0 (0.00)	0.1 (0.37)
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)	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)	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)	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)	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)	0.2 (0.57)	0.2 (0.37)
Tealia 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)	0.0 (0.00)	0.0 (0.00)

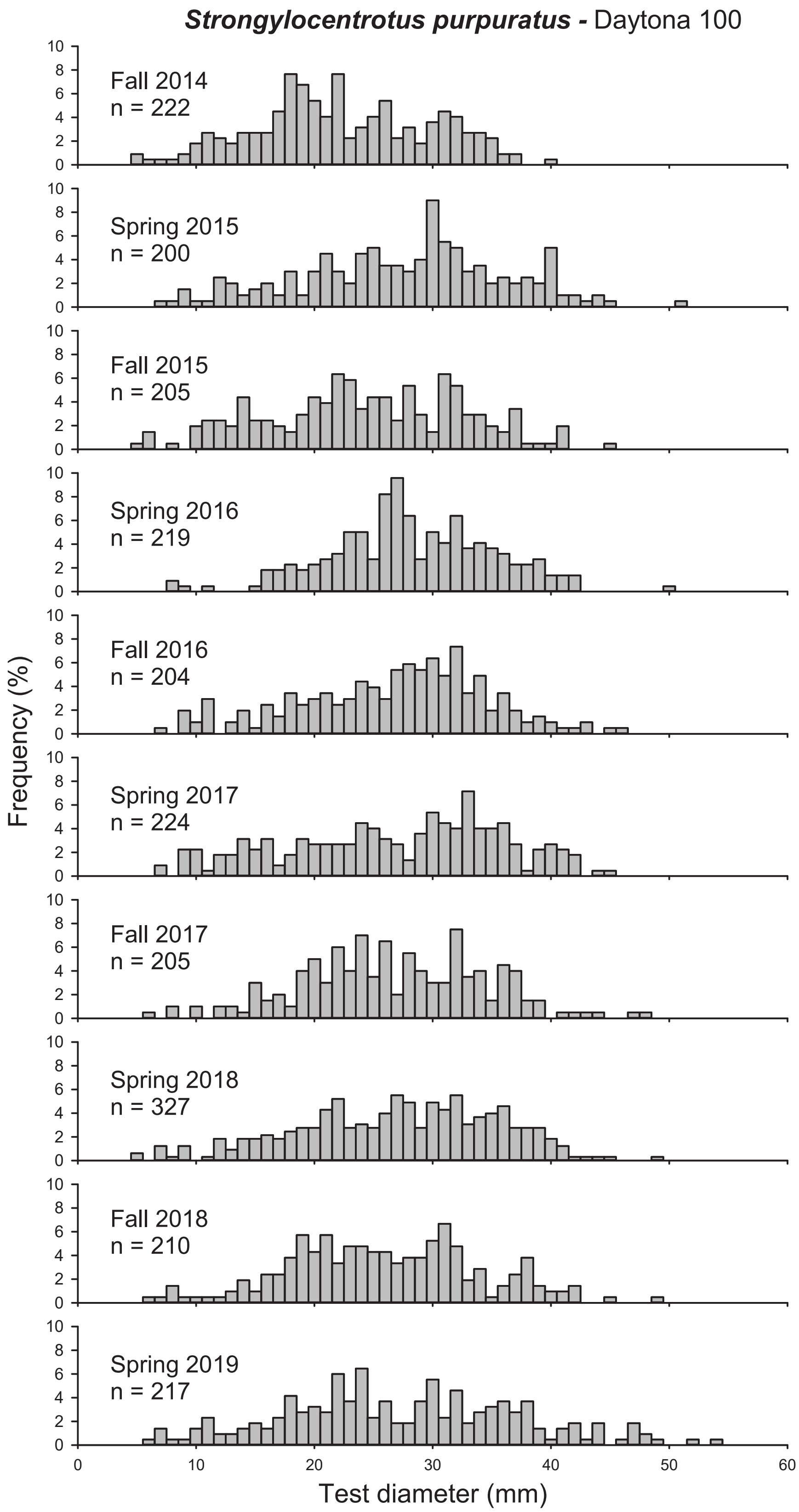

Figure 37. Daytona 100 size structure of purple urchins (*Strongylocentrotus purpuratus*) in fall 2014–spring 2019. [n = number of individuals]

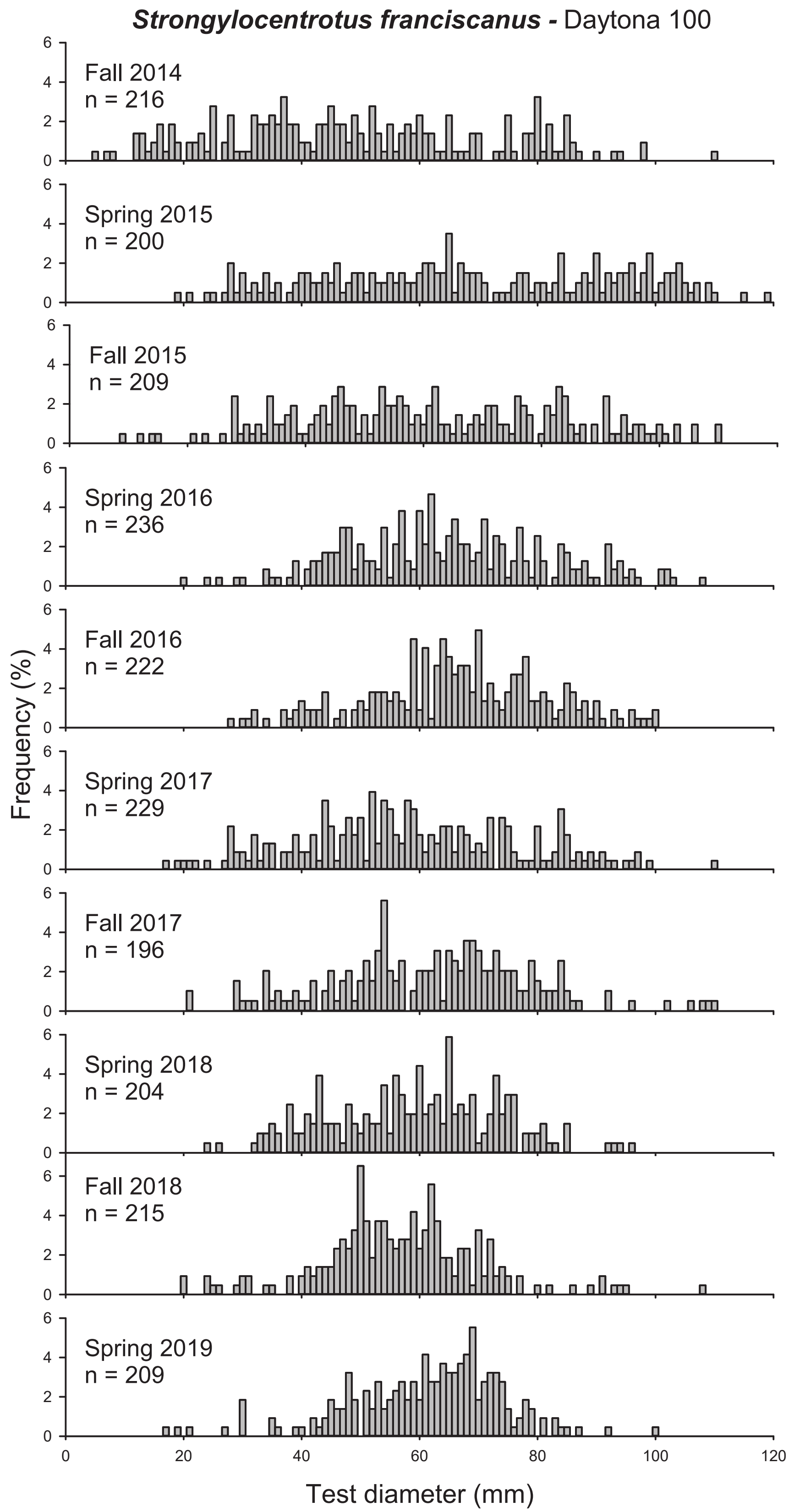

Figure 38. Daytona 100 size structure of red urchins (*Strongylocentrotus franciscanus*) in fall 2014–spring 2019. [n = number of individuals]

Table 29. Daytona 100 point contact "species" ranked by the sum of points for fall 2014 through spring 2019.

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

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Encrusting coralline algae	188	173	241	206	225	249	269	292	276	230
Dictyota binghamiae	26	42	27	90	59	38	75	115	52	136
Pachythyone rubra	23	41	13	16	23	37	113	35	39	10
Bare substratum	39	34	33	15	32	21	37	15	27	58
Sand	26	40	32	30	19	30	15	27	33	37
Cystoseira osmundacea	19	27	20	24	24	15	17	24	26	65
Cryptopleura spp.	27	25	31	46	66	25	18	0	5	0
Cucumaria piperata	29	28	12	15	40	12	13	24	24	16
Calliarthron spp.	29	12	23	26	30	16	21	17	17	19
Laminaria spp.	8	16	14	8	12	6	26	24	22	12
Pink encrusting bryozoan	1	5	12	22	34	21	15	12	9	15
Corallina officinalis	13	18	11	6	12	20	9	6	13	10
Rhodymenia californica	32	16	18	21	16	0	9	1	1	4
Barnacle	59	51	4	0	0	2	0	0	0	0
Eisenia arborea	13	14	15	17	15	5	4	5	8	7
Balanophyllia elegans	14	15	11	6	2	7	4	6	6	6
Kelp holdfast	3	3	8	19	5	12	3	6	10	2
Dictyopteris undulata	1	5	2	6	3	9	2	7	22	10
Serpulorbis squamiger	7	9	7	4	6	2	5	8	3	4
Encrusting red algae	2	2	6	4	4	5	6	8	7	1
Orange encrusting sponge	13	10	5	2	3	1	2	2	1	3
Macrocystis pyrifera >1 m	2	1	5	14	2	3	0	2	2	4
Astrangia lajollaensis	1	4	4	0	4	5	5	2	4	3
Filamentous red algae	7	0	3	0	0	0	8	0	9	3
Crisia spp.	0	0	5	15	6	0	1	1	0	0
Bugula spp.	2	3	0	8	4	0	8	0	1	0
Aglaophenia spp.	0	2	3	0	0	3	6	2	2	2
Macrocystis pyrifera <1 m	4	8	1	3	1	0	1	1	0	0
Strongylocentrotus purpuratus	6	2	2	1	0	5	0	1	1	0
Bossiella spp.	6	0	1	1	2	0	0	0	1	5
Lagenocella spp.	0	1	0	4	3	6	1	0	0	0
Laurencia pacifica	1	9	0	0	0	4	0	0	0	0
Eupentacta quinquesemita	1	2	1	1	1	1	2	0	0	3
Kallymenia pacifica	2	0	0	0	0	1	1	3	2	0
Tethya aurantia	0	1	1	1	0	1	0	2	0	3
Cellaria spp.	0	0	1	1	1	1	3	0	1	0
Mucus tube polychaete	0	0	0	0	7	1	0	0	0	0
Archidistoma psammion	0	0	0	0	0	1	3	0	3	0
Strongylocentrotus franciscanus	1	0	3	0	1	0	0	1	1	0
Dodecaceria spp.	1	2	1	1	0	0	1	0	0	0
Filamentous green algae	1	0	1	3	1	0	0	0	0	0
Plocamium pacificum	0	1	0	0	0	0	1	0	1	3

Table 29. Daytona 100 point contact "species" ranked by the sum of points for fall 2014 through spring 2019.—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	Fall 2018	Spring 2019
Pterygophora californica	0	0	0	0	2	0	1	1	0	2
Corynactis californica	0	3	0	1	0	0	0	0	0	1
Diopatra ornata	1	0	0	0	1	0	1	0	2	0
Metandrocarpa dura	0	0	0	4	0	0	0	0	1	0
Nienburgia andersoniana	0	1	0	2	1	0	1	0	0	0
Acarnus erithacus	0	1	0	0	2	0	0	0	1	0
Didemnum carnulentum	1	1	0	2	0	0	0	0	0	0
Hippodiplosia insculpta	0	0	0	3	0	1	0	0	0	0
Abietinaria spp.	0	0	1	0	0	0	0	1	1	0
Lissothuria nutriens	0	0	0	0	0	0	0	0	2	1
Pholad clam	0	0	0	0	1	1	0	0	0	1
Sargassum muticum	0	0	1	0	0	0	0	1	0	1
Spheciospongia confoederata	2	1	0	0	0	0	0	0	0	0
Synoicum spp.	0	0	0	0	0	0	0	0	0	3
Anthopleura sola	0	0	0	0	0	0	1	0	0	1
Balanus spp.	0	0	0	0	0	0	0	0	1	1
Bryopsis corticulans	0	0	0	0	0	2	0	0	0	0
Colpomenia spp.	1	0	0	0	0	0	1	0	0	0
Cucumaria salma	0	1	0	0	0	0	0	0	0	1
Cystodytes lobatus	0	0	0	1	0	0	0	1	0	0
Acanthacora cyanocrypta	0	0	0	0	0	1	0	0	0	0
Gigartina exasperata	1	0	0	0	0	0	0	0	0	0
Codium setchellii/hubbsii	0	1	0	0	0	0	0	0	0	0
Crassadoma gigantea	0	0	0	0	1	0	0	0	0	0
Dodecaceria fewkesi	0	0	0	0	0	0	0	0	0	1
Leucosolenia eleanor	0	0	0	0	0	0	0	0	1	0
Opuntiella californica	0	0	0	0	0	0	1	0	0	0
Phidolopora pacifica	0	1	0	0	0	0	0	0	0	0
Phragmatopoma californica	0	0	0	0	0	0	0	1	0	0
Plumularia spp.	0	0	0	0	0	0	0	0	0	1
Polysiphonia spp.	0	0	0	0	0	0	1	0	0	0
Pterosiphonia spp.	0	0	0	0	1	0	0	0	0	0
Red algal turf	0	0	0	0	0	1	0	0	0	0
Spirobranchus spinosus	0	0	0	0	0	0	1	0	0	0
Stylantheca porphyra	0	0	0	1	0	0	0	0	0	0
Taonia lennebackerae	1	0	0	0	0	0	0	0	0	0
Unidentified sponge	0	0	0	0	0	0	0	0	0	1

Table 30. Daytona 100 fish counts—Adult (Juvenile)—in fall 2014 through spring 2019 by species.

[f, female; m, male]

Species name	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Atherinops affinis	0	0	0	0	0	300	35	0	0	0
Brachyistius frenatus	3	5	5	0	10	0	4	0	4	0
Caulolatilus princeps	0	0	0	0	5	0	4	0	4	3
Chromis punctipinnis	1,611	331 (105)	322	120	333	440	168	177	136	450
Rhinogobiops nicholsii	43	10	2	2	6	3	2	3	0	1
Embiotoca jacksoni	9	26	11	7	18	4	7	0	10	13
Embiotoca lateralis	9	18	2	1	4	0	1	2	3	4
Girella nigricans	6	3	1	22	5	0	4	2	0	0
Halichoeres semicinctus	0	0	0	0	6	0	1	0	0	1
Heterostichus rostratus	0	0	0	0	0	0	0	0	1	0
Hypsurus caryi	0	0	0	0	2	0	0	0	0	0
Hypsypops rubicundus	9 (2)	13 (1)	7 (1)	4	15	2	11	6	1	7
Medialuna californiensis	2	6	10	0	7	12	4	1	5	8
Oxyjulis californica	1,448	216	225	92	164	707	240	643	354	689
Oxylebius pictus	35	21	7	2	5	4	2	1	2	5
Paralabrax clathratus	91	47	21	18	62	26	59	27	37	44
Rhacochilus vacca	4	7	1	0	0	1	3	1	11	2
Scorpaena guttata	0	1	0	0	0	0	0	0	0	0
Scorpaenichthys marmoratus	0	2	0	0	0	0	0	0	0	0
Sebastes atrovirens	36	59	7	4	13	2	10	7	3	1
Sebastes caurinus	1	0	0	0	0	0	0	0	0	0
Sebastes chrysomelas	9	1	0	1	0	1	3	0	0	0
Sebastes mystinus	203	22	59	14	17	8	8	9	2	19
Sebastes serranoides	25	33	24	5	18	4	13	11	2	0
Sebastes serriceps	2	0	0	0	0	0	1	0	0	0
Semicossyphus pulcher (f)	15 (2)	35 (3)	22 (2)	25 (1)	62	32	32	35	21	39
Semicossyphus pulcher (m)	27	25	9	18	7	10	6	11	6	12
Stereolepis gigas	0	0	0	0	0	0	1	0	0	0

Long-term Patterns

Though purple urchin densities crept up at all the supersites in the last 2 years, only Daytona 100 has shown any signs of active grazing. This supersite, which encompasses a patchwork of urchin and kelp dominated areas, exceeded a mean density of 1,000 purple urchins per swath in the last spring trip (2019). The next highest *S. purpuratus* density was at Dutch Harbor, where the mean density wavered a bit under 400 per swath—a record level at the supersite. The densities at West End, although well below those measured there in the 1980s and 1990s, were the highest since 2001. Red urchin densities have increased slightly at West End, flattened at Nav Fac 100 and Dutch Harbor, and declined gradually at Daytona 100. Figure 39 shows mean *S. purpuratus* and *S. franciscanus* densities since the original monitoring project was established in 1980 (appendix 1). In this figure, and the following figures showing long-term data, Daytona 100 and Nav Fac 100 are represented only by their long-established subsites (original five 20-m^2 swaths), and data from the additional 50-m transects that were added in 2014 are not included.

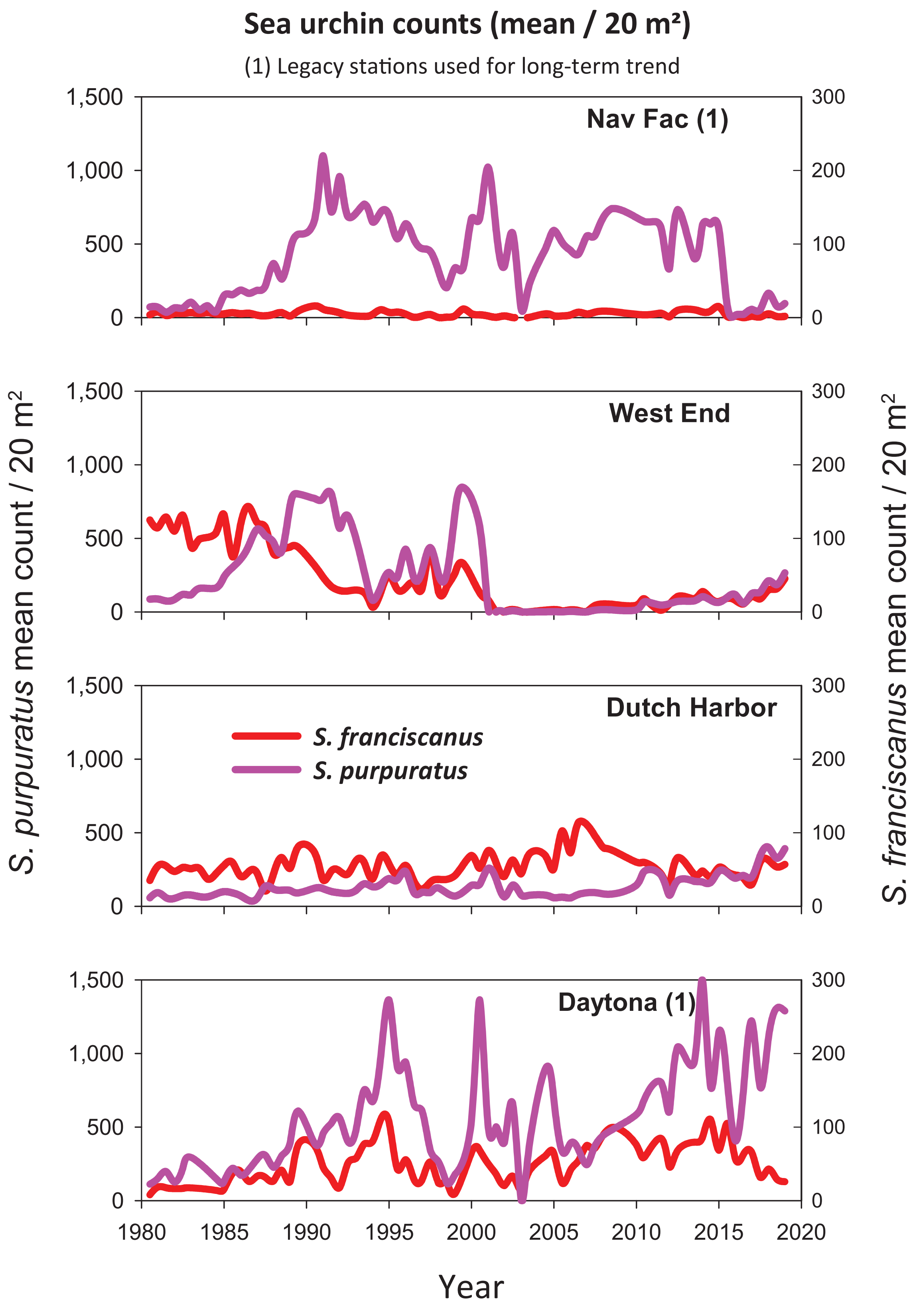

Figure 39. Long-term trends in urchin abundance. [Note that Nav Fac and Daytona are the legacy sites (half the size of the supersites) presented to show history. *Strongylocentrotus purpuratus* and *S. franciscanus* are shown on different scales]

Nav Fac first became heavily grazed by sea urchins in 1991. The corresponding rapid loss of kelps can be seen in figure 40. Several abrupt, but brief, declines in purple urchin density are apparent in figure 39. Between 2003 and 2015, the site consisted of distinct patches of algal dominated and urchin dominated areas. Finally, there was a precipitous loss of purple urchins there in 2015, which was followed by a pulse of fleshy red algae, a moderate *Macrocystis* recruitment, and recovery of understory kelps. In the most recent sampling periods, much of the site was dominated by the fucoid *C. osmundacea* and annual brown algae—including various dictyotales and the invasive alga *S. horneri*.

Daytona 100 followed a similar trajectory in that it first became urchin dominated in 1995, and dynamic swings in urchin abundance since then (fig. 39) were met with varying response from fleshy red algae, understory kelps, and *Macrocystis* (fig. 41). These algae, and *C. osmundacea*, persisted but had a very patchy distribution when urchin numbers rebounded. Daytona continued to be a patchwork of kelp and urchin dominated areas in 2019.

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 recruitments appear as repeating peaks in figure 42. 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 since undergone attrition and, in spring 2019, few adult *M. pyrifera* remained. There was, however, a fairly large recruitment of juvenile *Macrocystis* that could result in renewed numbers of mature plants in the fall.

Following the loss of urchins at West End in 2001 (fig. 39), *M. pyrifera* and understory kelps recruited heavily, and at this site, giant kelp also demonstrated a pattern of recruitment and attrition similar to—though more extreme than—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. 43). This site is the most exposed to swell and perhaps, because 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 understory kelp and red algae took on 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. In the most recent year, it appears that the decline in red algal cover may have been exploited by understory kelps rather than *M. pyrifera.*

In addition to the urchin and macroalgal dynamics, we have tracked for nearly four decades, long-term changes in the densities of the herbivorous gastropod, *M. undosa* show interesting trends. Densities of *M. undosa* have almost always been substantially higher at Nav Fac than at other sites. Though there were several unsynchronized peaks and falls in abundance among the sites prior to 2002, all sites had minimal numbers of this snail between 2002 and 2015. The decline and subsequent low levels of this species suggest a catastrophic event occurred in 2001–02 (fig. 44). Supporting this conclusion, one of us (Michael Kenner) recalls observing north facing beaches on SNI littered with *M. undosa* shells in the early 2000s. Recovery began at Nav Fac in fall 2015 and somewhat later at the other sites. One possible cause for the recent increase in *M. undosa* densities is that the species is reacting to release from predation by sea stars that have recently been reduced by SSWS.

As mentioned earlier, SSWS has devastated multiple species of sea stars along hundreds of miles of the Pacific coast of North America. Three asteroid species that were affected by the disease show very different histories of abundance over time at SNI. *Pisaster giganteus*, an important predator on snails, barnacles and bivalves, shows a complex pattern of abundance with a few brief synchronous declines among the sites until 2014 when densities at all sites dropped simultaneously (fig. 45). *Pycnopodia helianthoides*, a voracious predator on an assortment of invertebrate taxa, and the only sea star thought to have some potential for control of sea urchin populations in this system, was not observed at our sites at SNI until the early 1990s. It is not possible to say whether it is a periodic member of the SNI nearshore community because of infrequent recruitment success or whether it was eliminated by a prior disease outbreak before sampling began in 1980. After appearing in 1991, it was frequently seen at low densities at all sites, but most predictably at Dutch Harbor (fig. 46). In 2014, it disappeared from all sites and none have been observed since. Finally, *P. miniata*, which is a scavenger, experienced a major decline at all sites in the early 1980s apparently as a result of a disease event (fig. 47). This decline was not well synchronized among sites, however, lagging by 2 years or more between reductions observed at Nav Fac and other sites. Beginning in the early 1990s, it returned in moderate densities before eventually reaching higher numbers in the mid-2000s. It declined at all sites about 6 months later than the other two sea stars mentioned earlier and has since returned to moderate densities similar to those seen in the 1990s.

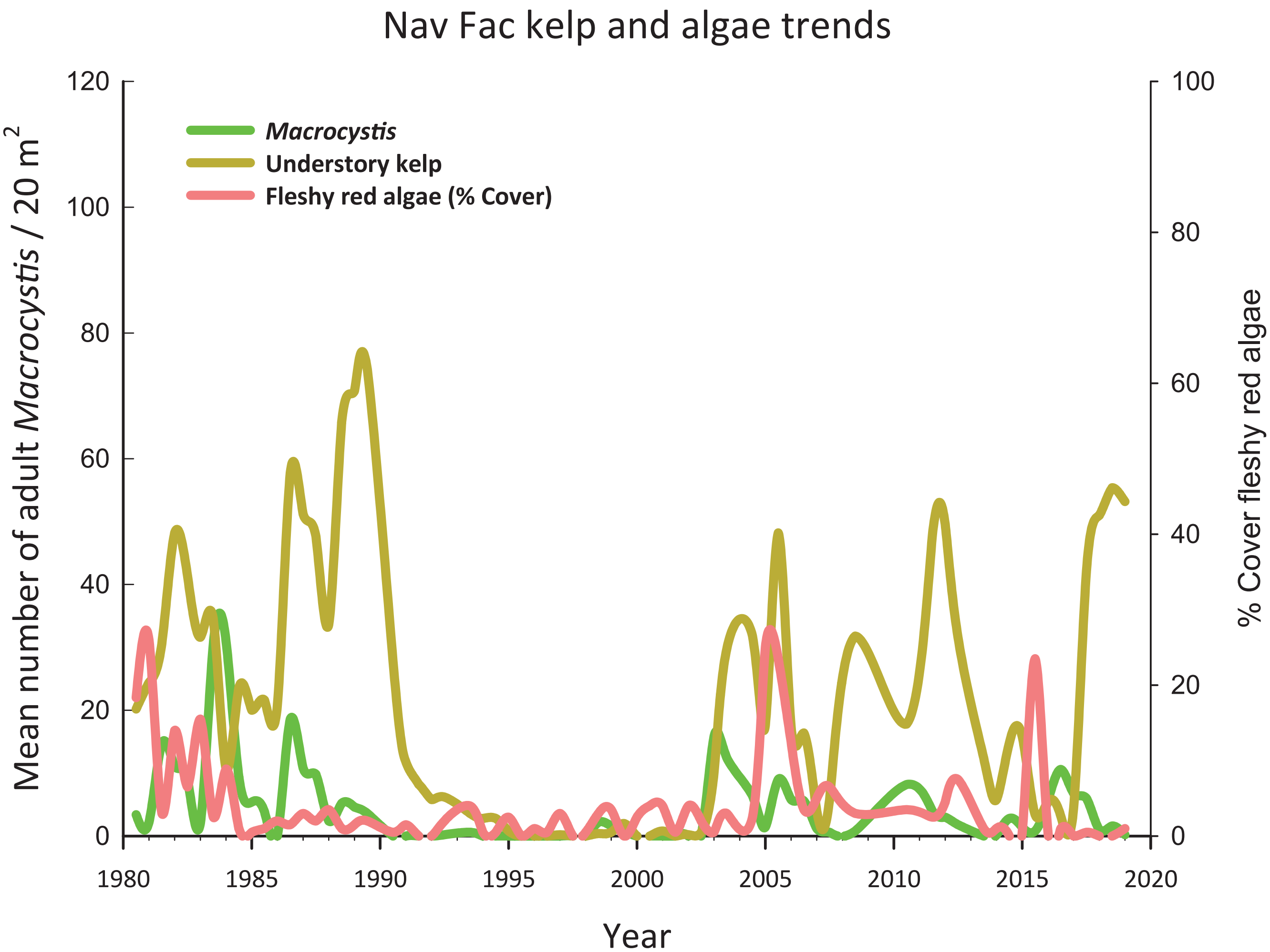

Figure 40. Kelp (*Macrocystis pyrifera* greater than 1 meter [m] tall and understory species) and fleshy red algae cover trends over time at Nav Fac. [Original transects only used for long-term trends]

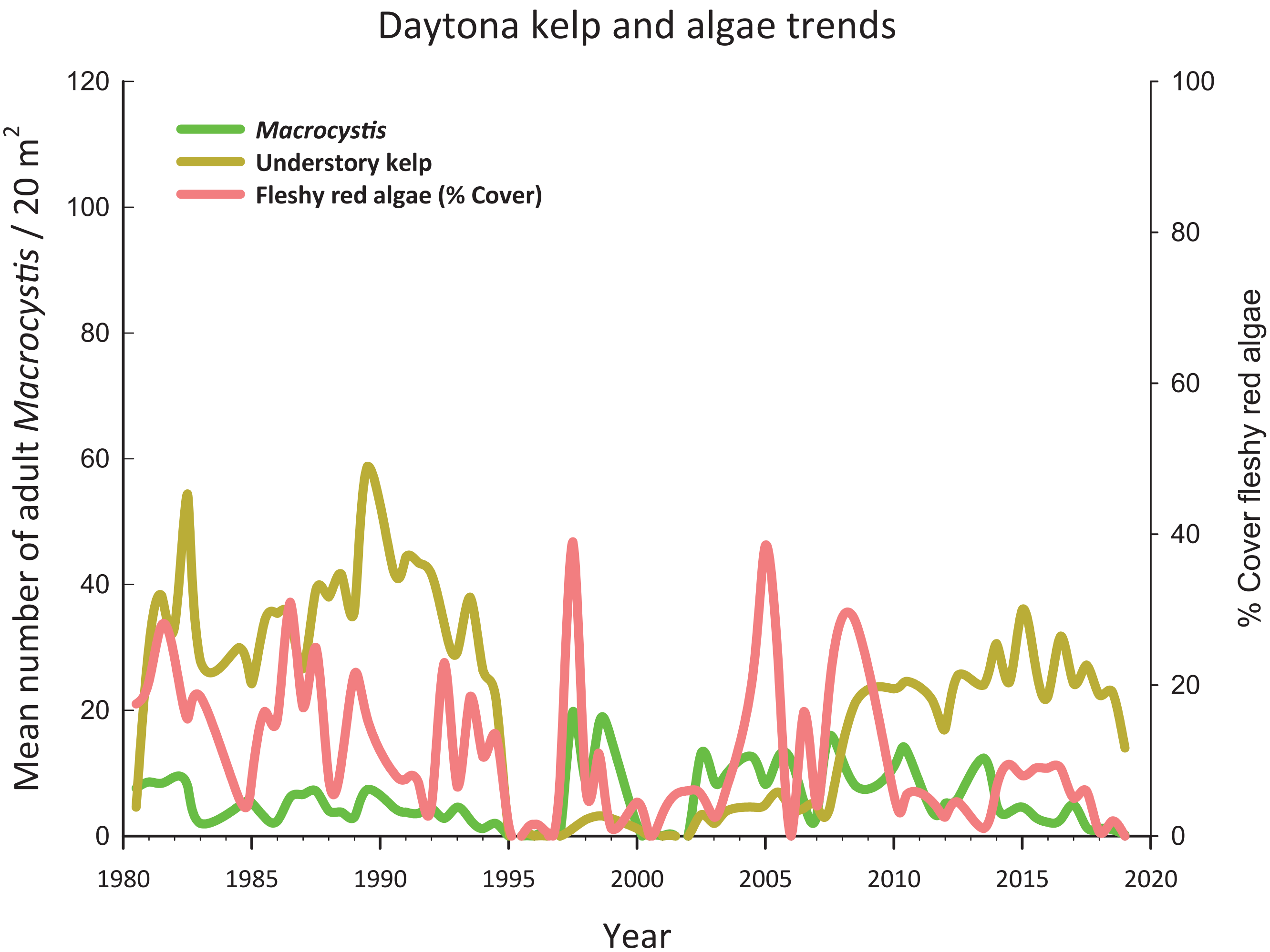

Figure 41. Kelp (*Macrocystis pyrifera* greater than 1 meter [m] tall and understory species) and fleshy red algae cover trends over time at Daytona. [Original transects only used for long-term trends]

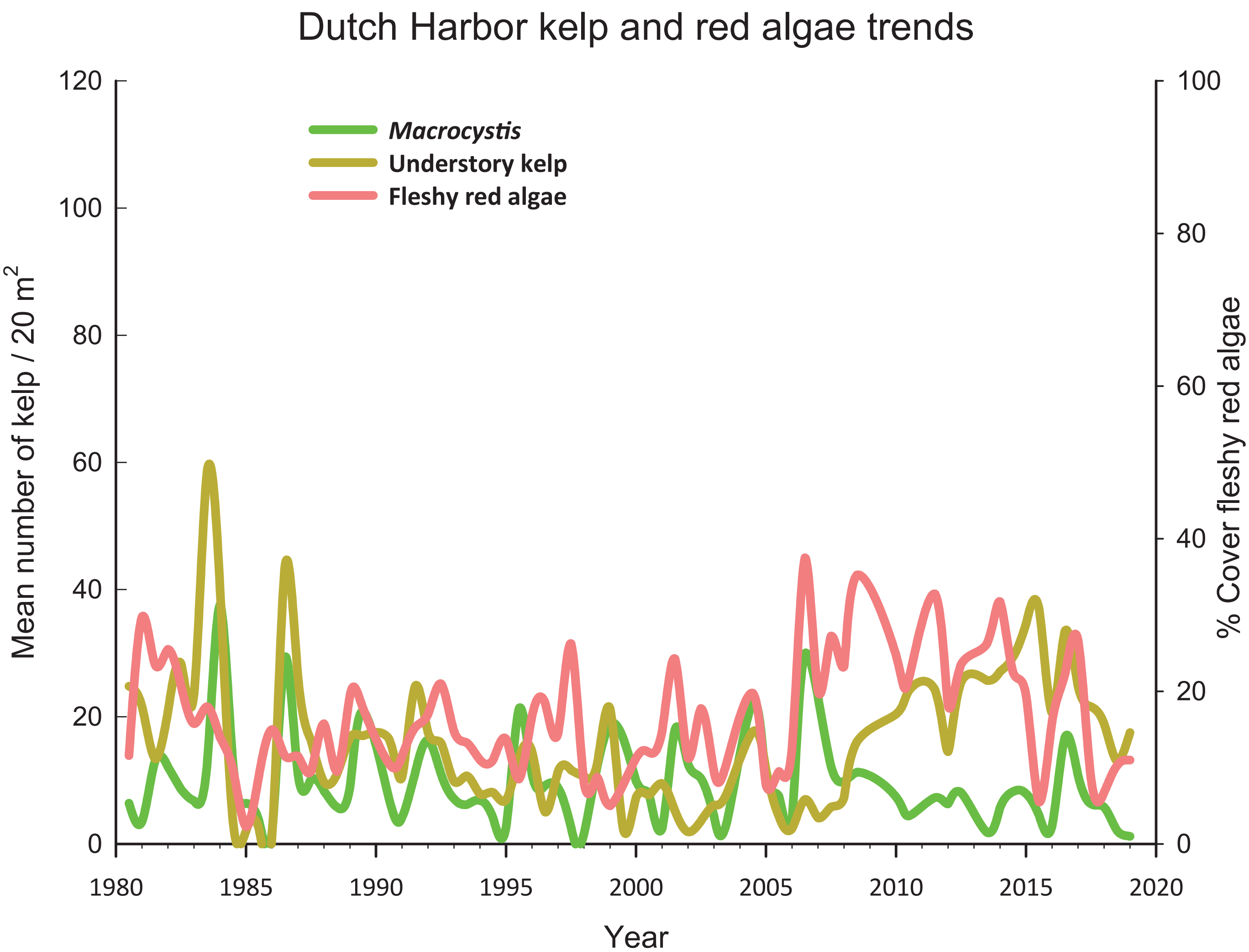

Figure 42. Kelp (*Macrocystis pyrifera* greater than 1 meter [m] tall and understory species) and fleshy red algae cover trends over time at Dutch Harbor.

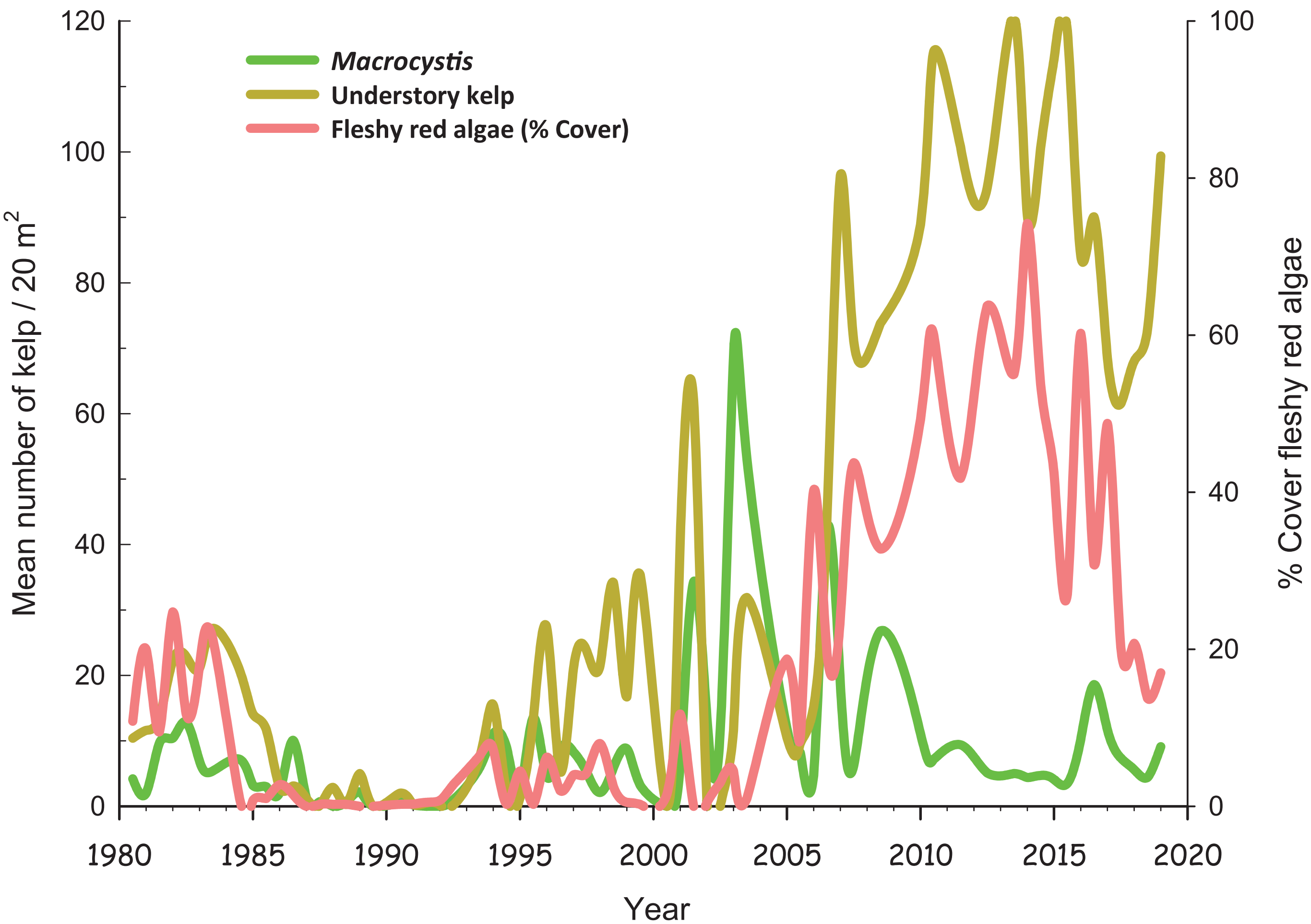

Figure 43. Kelp (*Macrocystis pyrifera* greater than 1 meter [m] tall and understory species) and fleshy red algae cover trends over time at West End.

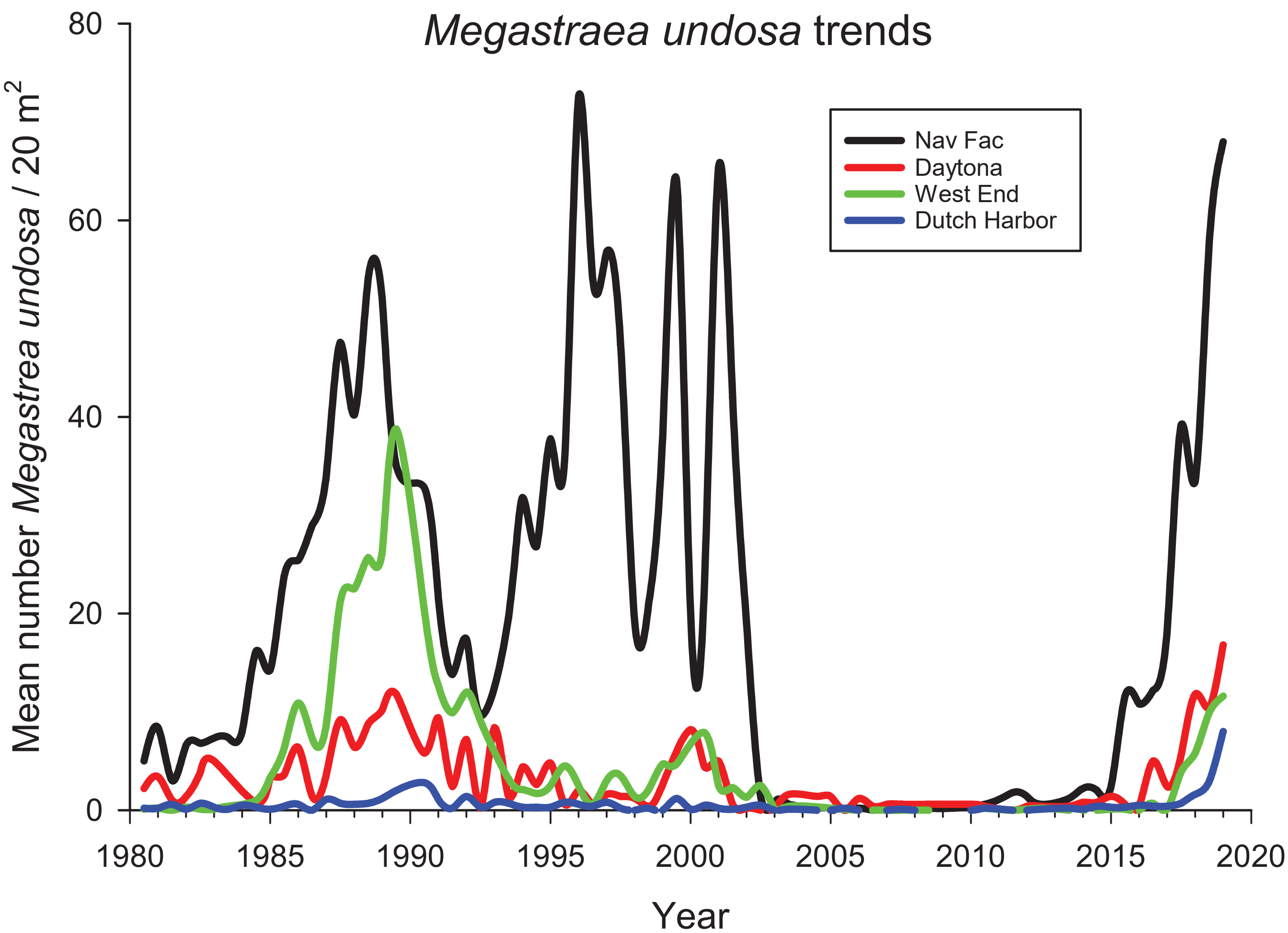

Figure 44. *Megastraea undosa* trends over time at West End, Dutch Harbor, and original five swaths of Nav Fac and Daytona from fall 1980 to spring 2019.

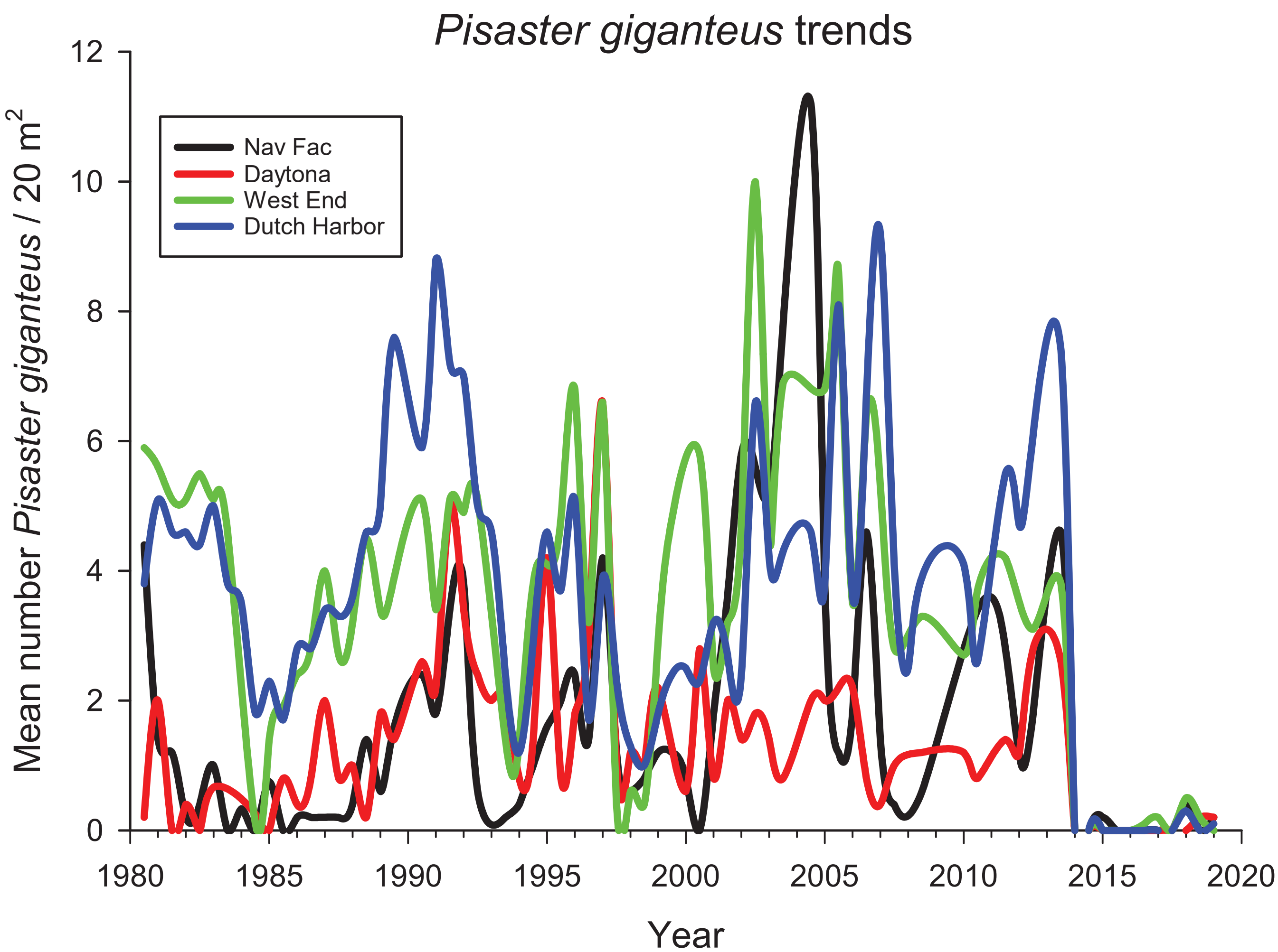

Figure 45. *Pisaster giganteus* trends over time at West End, Dutch Harbor, and original five swaths of Nav Fac and Daytona from fall 1980 to spring 2019.

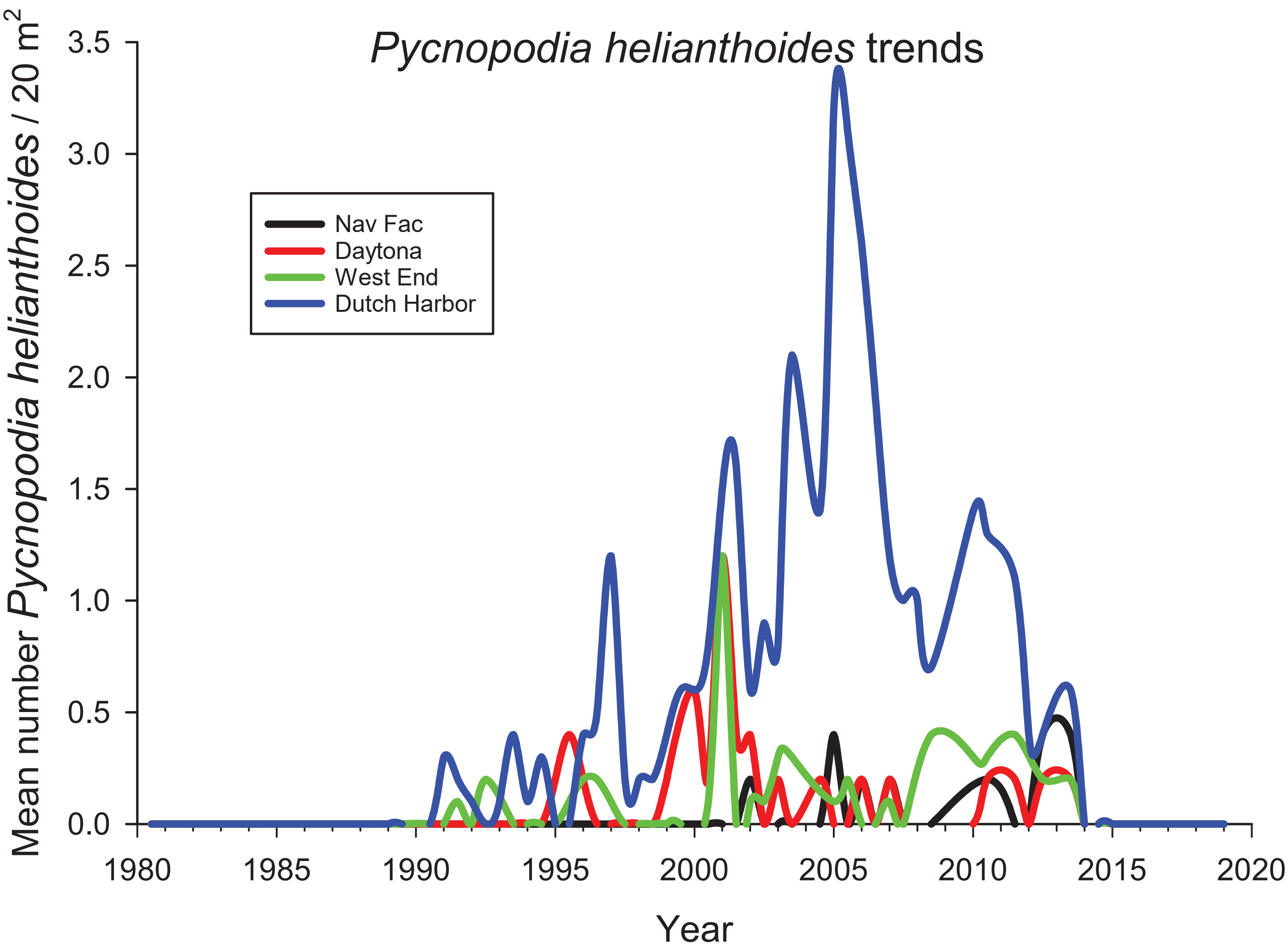

Figure 46. *Pycnopodia helianthoides* trends over time at West End, Dutch Harbor, and original five swaths of Nav Fac and Daytona from fall 1980 to spring 2019.

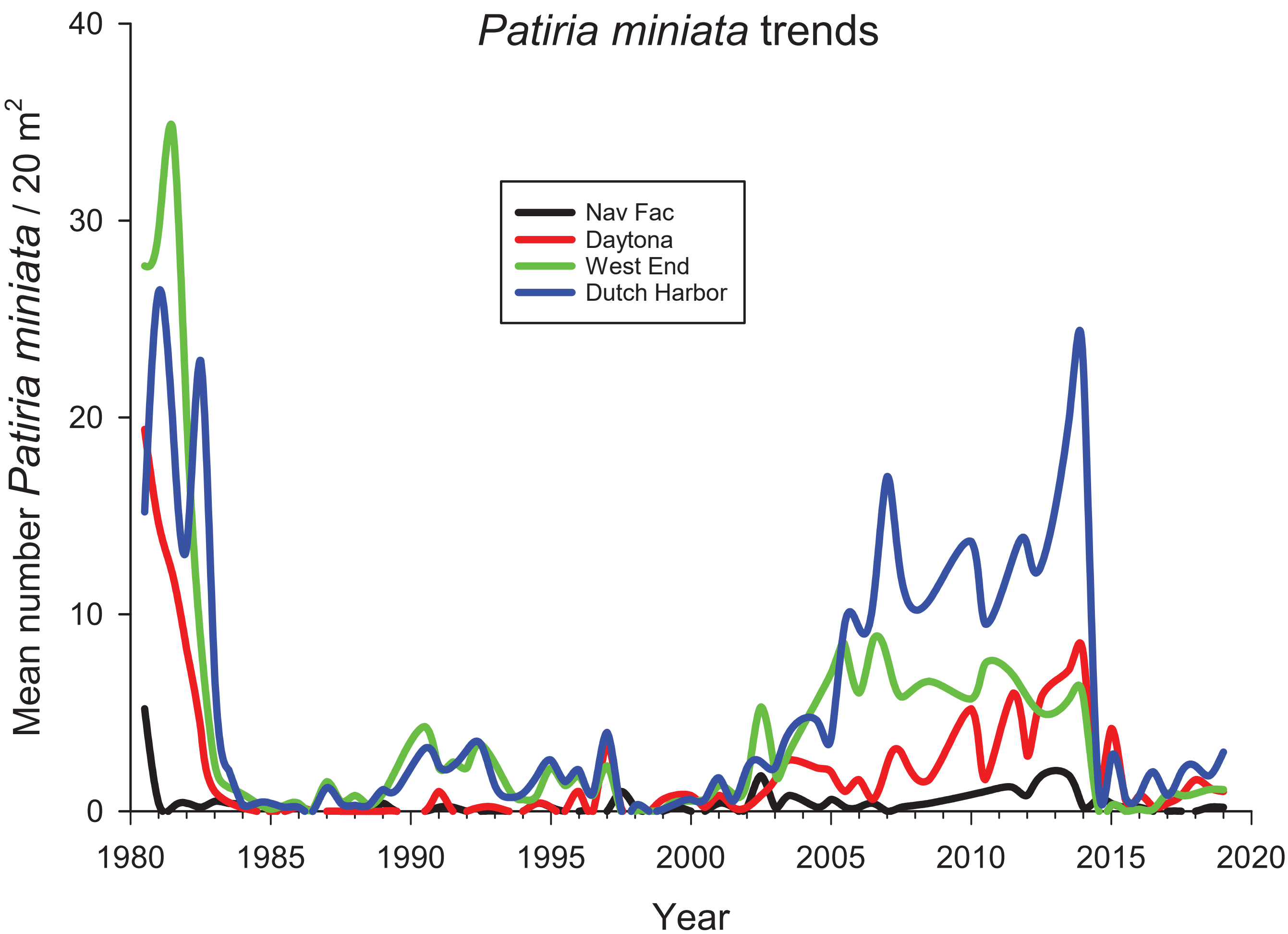

Figure 47. *Patiria miniata* trends over time at West End, Dutch Harbor, and original five swaths of Nav Fac and Daytona from fall 1980 to spring 2019.

Conclusions and Management Considerations

After nearly four decades of monitoring subtidal sites around San Nicolas Island (SNI), the U.S. Geological Survey (USGS) has amassed a wealth of data about how the nearshore community there responds to change. During this time, several El Niño events have arrived with sometimes violent storms and unusually warm water. Invertebrate diseases have decimated abalone, sea star, and sea urchin populations at different times and scales around the island, which sometimes resulted in dramatic localized community shifts. Fisheries for red sea urchins, spiny lobster, and some finfishes have exploited the area with unknown consequences. An invasive brown alga (*S. horneri*), with the potential to at least seasonally dominate the algal community, became established at one of the sites. These perturbations occurred while sea otters, an important species that had been extirpated from the ecosystem a century before, expanded from a fledgling re-introduced group to a population of more than 120 animals.

These types of perturbations are expected to continue to influence the nearshore ecosystem around SNI. *Sargassum horneri* will likely spread around the island, new disease outbreaks are likely to change the balance of species, and sea otters may eventually reach carrying capacity in the system and will have dramatic direct and indirect effects on community structure and composition. In addition, there could be new physical and biological challenges to the system. Warming seas, ocean acidification, rising sea level, and more violent storms have been predicted. New diseases and invasive species seem inevitable.

Each site we monitor has its own character that results 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 gather an appreciation for what is an expected response to disturbance and what changes can be cause for concern. Thus, continued monitoring of this system represents a unique opportunity to build a real 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 demonstrate the value of long-term ecosystem monitoring. Continuing the current monitoring program can be used 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 also could provide an opportunity to map the extent of the invasive alga *S. horneri* and remnant populations of abalone. Such an investigation could give resource managers further 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 the University of California Santa Cruz, 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, West End Urchin, West End Kelp, West Dutch Harbor, East Dutch Harbor and Daytona Beach. A seventh site, Sandy Cove, was added in 1986. 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 was passed on to the U.S. Geological Survey (USGS) 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. 1). 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 later, 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 also will help them 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 by 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 Channel Islands, four of the sites were expanded to twice their original size. With the goal to retain compatibility with more than 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, because 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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