Marine Sanctuaries Conservation Series ONMS-15-10

Long-term Monitoring of Surfgrass Meadows in the Monterey Bay National Marine Sanctuary: Recovery followed by Stability after the Termination of a Domestic Sewage Discharge.

U.S. Department of Commerce
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John S. Pearse, William T. Doyle, Vicki B. Pearse, Marcia M. Gowing,
J. Timothy Pennington, Eric Danner, Ann Wasser

John S. Pearse, William T. Doyle, Vicki B. Pearse, and Marcia M. Gowing: Institute of Marine Science, University of California, Santa Cruz, CA 95064; J. Timothy Pennington, Monterey Bay Aquarium Research Institute, Moss Landing, CA 95039; Eric Danner, Southwest Fisheries Science Center, Santa Cruz, CA 95060; Ann Wasser, Pacific Grove Museum of Natural History, Pacific Grove, CA, 93950

U.S. Department of Commerce
Penny Pritzker, Acting Secretary

National Oceanic and Atmospheric Administration
Kathryn Sullivan, Ph.D.
Acting Under Secretary of Commerce for Oceans and Atmosphere

National Ocean Service
Russell Callender, Ph.D., Acting Assistant Administrator

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Cover

California Naturalists from the Pacific Grove Museum of Natural History sampling the plot monitored by LiMPETS at Opal Cliffs, California. June 16, 2014. Soquel Point where the second plot is monitored is on the horizon, ~1 km away.

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Contacts

John S. Pearse, pearsester@gmail.com
William T. Doyle, billdoyle@surfnetusa.com/
Vicki B. Pearse, vpearse@gmail.com
Marcia M. Gowing, marcia_gowing@hotmail.com/
J. Timothy Pennington, peti@mbari.org
Eric Danner, eric.danner@noaa.gov
Ann Wasser, wasser@pgmuseum.org

Abstract

Surfgrass meadows are major habitats along the coast of the North Pacific Ocean, providing complex biotic communities and nurseries for fishes and crustaceans. They have been little studied in most areas, including central California. We present here the results of monitoring two 450m^2 plots over a period of 42 years within the Monterey Bay National Marine Sanctuary by citizen scientists (trained students and naturalists). One, the Soquel Point plot, was near a small (~3 million gallons per day) domestic sewage outfall that was discontinued in 1976, and the other, the Opal Cliffs plot, was in a comparison site ~1 km away. Monitoring was done nearly annually between 1973 and 2003, then in 2006, 2012, 2014, and 2015. The abundance of common seaweeds and invertebrates was recorded each year from counts of individuals, or their presence in 25 10x10 cm squares, in randomly placed 50x50 cm quadrats (mean number of counts, 24.3; range 10-41).

Surfgrasses (*Phyllospadix* spp., mainly *P. torreyi*) were absent in the Soquel Point plot when the sewage was being discharged and were first seen in the plot in 1978, two years after the sewage discharge was terminated. Surfgrass abundance increased slowly and was comparable to that in the Opal Cliffs plot only in the late 1990s, over 20 years after the termination of the sewage discharge. In contrast, species in one genus of coralline algae (*Corallina*) were abundant when the sewage was being discharged and declined slowly for 30 years following discharge termination, never reaching levels comparable to those in the Opal Cliffs plot. Frilly red algae (*Cryptopleura* spp.) were nearly absent from the Soquel Point plot when the sewage was discharged and rose *just before* the discharge was terminated, reaching levels comparable to those of *Corallina* spp. Levels of *Cryptopleura* spp. and *Corallina* spp. slowly decreased in parallel while those of *Phyllospadix* spp. rose, suggesting both facilitation (*Corallina* spp. facilitating both *Cryptopleura* spp. and *Phyllospadix* spp.) and competition (*Phyllospadi*x spp. eventually dominating).

The abundance of species of a second genus of coralline algae, *Bossiella,* was low in the Soquel Point plot when the sewage was discharged, increased *just before* termination of the discharge, and remained similar to or slightly higher than that at Opal Cliffs during the rest of the monitoring period. Abundances of sea lettuces (*Ulva* spp.), turban snails (*Tegula* spp.), and hermit crabs (*Pagurus* spp.), which were low when the sewage was discharged, also increased *just before* the discharge was terminated. The increase in the abundance of these taxa corresponded to a steady decrease in grease content in the sewage. Within a few years after the sewage discharge was terminated, the abundances of all these taxa stabilized; they remained low and similar to those in the Opal Cliffs plot for the remainder of the monitoring period.

In the Opal Cliffs plot, ~1 km downstream from the discharge, the sewage discharge apparently enhanced the abundance of coralline algae (both *Corallina* and *Bossiella*), frilly red algae, sea lettuces, and honeycomb tube worms. Abundance of all these taxa decreased after the discharge was terminated, indicating that they had benefited from the nutrients in the sewage.

Sunburst anemones (*Anthopleura sola*) were more abundant in the Soquel Point plot than the Opal Cliffs plot throughout most of the monitoring period. They were likely established in the Soquel Point plot when the sewage had denuded the area, exposing bare rock suitable for attachment, then were able to persist for decades following the termination of the sewage discharge and the re-establishment of the surfgrass meadow.

Overall taxon richness of both seaweeds and invertebrates was lowest in the Soquel Point plot and highest in the Opal Cliffs plot when the sewage was discharged, converged to moderate levels in both plots within a few years after the discharge was terminated, and then remained steady and indistinguishable throughout the rest of the monitoring period. This overall stability in taxon richness was similar to the abundances seen for most specific taxa monitored. The surfgrasses, *Corallina* spp., and frilly red algae in the Soquel Point plot took longer to stabilize, 20 to 30 years after the termination of the sewage discharge.

This long-term monitoring program demonstrates that citizen science programs using trained students and naturalists can provide robust information about the condition of intertidal communities within National Marine Sanctuaries. It found that surfgrass communities are remarkably resilient, even after chronic disturbance (in this case by domestic sewage) removes the foundation species (surfgrasses). Although recovery of the surfgrasses took decades, most taxa in the community returned to abundances similar to those recorded in the comparison plot within a few years, and the overall community structure displayed persistent stability. Similar resilience can be expected with other disturbances such as major storms, chemical spills, or ship groundings that could damage surfgrass meadows. The consequences of disruption from global warming are uncertain, and these data provide a baseline for future evaluation.

Key Words

Monterey Bay National Marine Sanctuary, citizen science, LiMPETS, surfgrasses, *Phyllospadix,* coralline algae, *Cryptopleura*, domestic sewage impact and recovery, long-term monitoring

Acknowledgements

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Introduction

Seagrasses are flowering plants that form extensive, productive meadows in shallow marine habitats around the world (Green and Short 2003). They are particularly important on soft muddy or sandy substrates in bays and estuaries where they support diverse communities and serve as nurseries for fishes and invertebrates (Boström et al. 2008, Cullen-Unsworth et al. 2014), as well as important carbon sinks in a world of dangerously increasing CO_2 (Fourqurean et al. 2012). While most inhabit soft bottoms, species in the genus *Phyllospadix* W.J.Hooker live on rocky, surf-swept shores of the North Pacific (Short et al. 2007). Known as surfgrasses, they are indicators of the low zone in the rocky intertidal (Ricketts et al. 1985, Foster et al. 1988). They attach firmly to the bedrock, trapping sand among their rhizomes, and form a specialized habitat that supports a wide variety of species while excluding others (Stewart and Myers 1980, Turner 1985, Duncan et al. 2014). They are a "foundation" species (Dayton 1972, Shelton 2010, Moulton and Hacker 2011), effectively serving as an "ecosystem engineer" (Jones et al. 1994).

Three species of surfgrasses, *Phyllospadix serrulatus* Ruprecht ex Ascherson, *P. scouleri* W.J.Hooker, and *P. torreyi* S.Watson, co-occur on the west coast of North America from Alaska to Mexico (den Hartog and Kuo 2006), and the latter two are prominent shoreline features in California. The largest surfgrass meadow in the Monterey Bay National Marine Sanctuary occurs on the northern shores of Monterey Bay between Soquel Point and the mouth of Soquel Creek. In 1952, Santa Cruz County began discharging primary-treated, domestic sewage off Soquel Point into the southern portion of this surfgrass meadow. By the early 1970s surfgrass was all but gone in a large area down current from the discharge and replaced by a stunted cover of upright coralline algae and diatom-coated mudstone.

Undergraduate students in classes at the University of California, Santa Cruz began documenting the impact of the sewage discharge in the fall of 1971. They determined the extent of the area affected and the number and abundance of species present in comparison with other areas away from the discharge (Doyle and Pearse 1972). In 1973 two 450 m^2 plots were established, one within the affected area and a second within an apparently unaffected area ~1 km away. These were monitoring annually until 2003, then again in 2006, 2012, 2014, and 2015. A preliminary note reported the apparent recovery of the surfgrass meadow in the Soquel Point plot in the mid 1990s, ~20 years after the sewage discharge was terminated in 1976 (Pearse et al. 1998).

We now more fully document changes in the Soquel Point plot after the sewage discharge was terminated, as well as the near-stability of the surfgrass community in the Opal Cliffs plot over the same 42-year period. Documentation of the impact of domestic sewage on surfgrass communities is scanty, as is documentation of their recovery once discharge is terminated. In addition, other major disruptions − including those following ongoing shifts in global climate (increases in sea temperature, decreases in pH, sea level rise, disease) − are likely to impact surfgrass communities and other major intertidal ecosystems around the world (Duncan et al. 2014). Our findings provide insight into the various ways taxa within this complex intertidal community respond over a long time period.

Study Site

Cliffs on the northern shore of Monterey Bay overlook the wave-cut, nearly flat but channeled intertidal platform of fine-grained Purisima mudstone. The intertidal platform extends from the base of the cliffs at a near zero tide level out 40 to 50 m to a depth of about -1.5’ MLLW, and supports a large surfgrass meadow (Cover photo, Figs. 1, 2, 3). Santa Cruz County’s East Cliff-Capitola sewage treatment plant, designed to handle 4 million gallons of primary-treated domestic sewage, went into operation in 1952. It discharged liquid waste into the intertidal of Monterey Bay off Soquel Point on the outer edge of the surfgrass meadow. Incoming waves swept in from the southwest carrying the sewage northeast back across the intertidal platform (Figs. 1, 2, 3, 4). In the fall of 1971, surfgrass was all but absent in an area of ~5,000 m^2 extending ~120 m northeast of the sewer outfall.

A 15x30 m plot was established on the outer edge of the platform in the center of the affected area (36.9550333, -121.972). This plot was designated the Soquel Point plot. A second 15x30 m plot, the Opal Cliffs plot, was established ~1 km to the northeast of the outfall on what appeared to be an unaffected surfgrass meadow (36.959917, -121.963817) (Figs. 1, 2, 3).

Figure 1. Photos showing the intertidal platform from the cliff top: (left) Soquel Point, 1977, with arrows pointing to the sewer block (right arrow) and the Soquel Point plot (left arrow); (right) Opal Cliffs, 1974, with arrow pointing to the Opal Cliffs plot.

Between 1968 and 1971, dry-weather flow of the sewage discharge increased from slightly less than 2 million gallons per day to 2.9 million gallons per day (U.S. Environmental Protection Agency, 1973), and it was between 2.5 and 3.5 mgd from 1971 to 1976 (Fig. 4), after which the discharge was terminated. Cases of hepatitis among local surfers prompted an increase in chlorination in the early 1970s (Talley 1973) with average levels of 10 to 14 ppm of chlorine gas (Cl_2). While the daily load of suspended solids decreased from about 110 ppm to 80 ppm during that time, the level of grease in the sewage dropped from about 85mg/l to about 20mg/l in 1976, just before discharge was terminated on June 9, 1976.

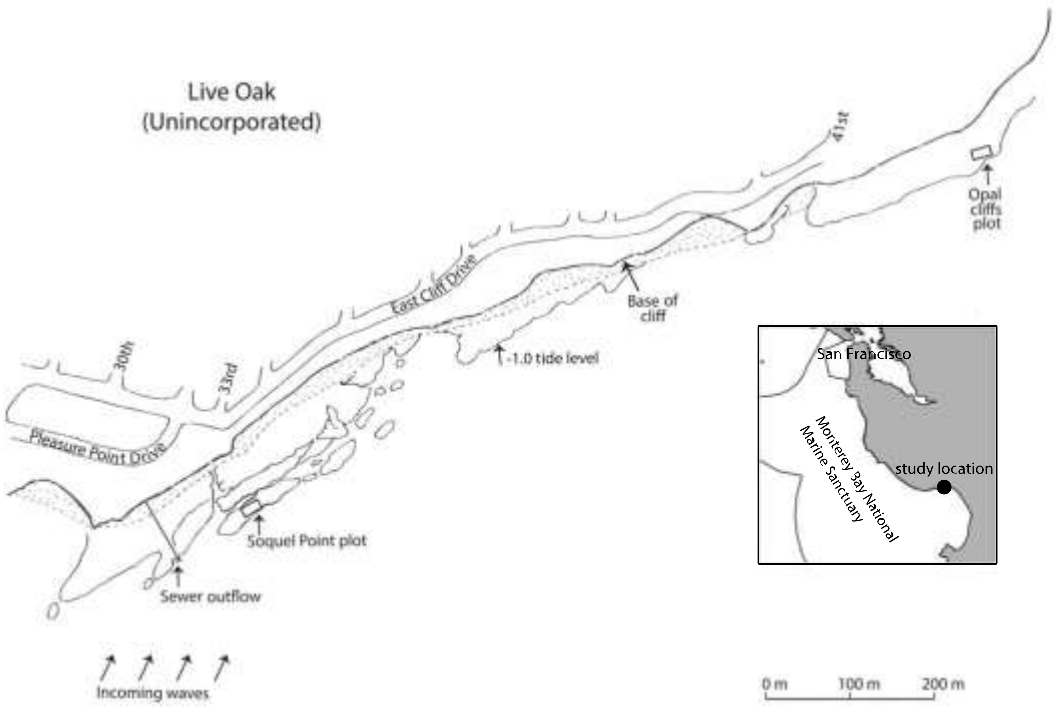


Figure 2. Map of study area in northern Monterey Bay showing the location of the sewer outfall and the two $450m^2$ plots that were monitored from 1973 to 2015.

Figure 3. Google views of the Soquel Point plot (left) and Opal Cliffs plot (right). White arrows point to locations of the plots; yellow arrow points to sewer outflow.

Figure 4. Photo of the block at the end of the sewage discharge pipe in 1974. The Soquel Point plot is in the background directly behind the person on the right (arrow). Note the surfgrass in the foreground on the seaward side of the pipe. Waves swept across the pipe carrying the sewage landward across the intertidal platform in the background.

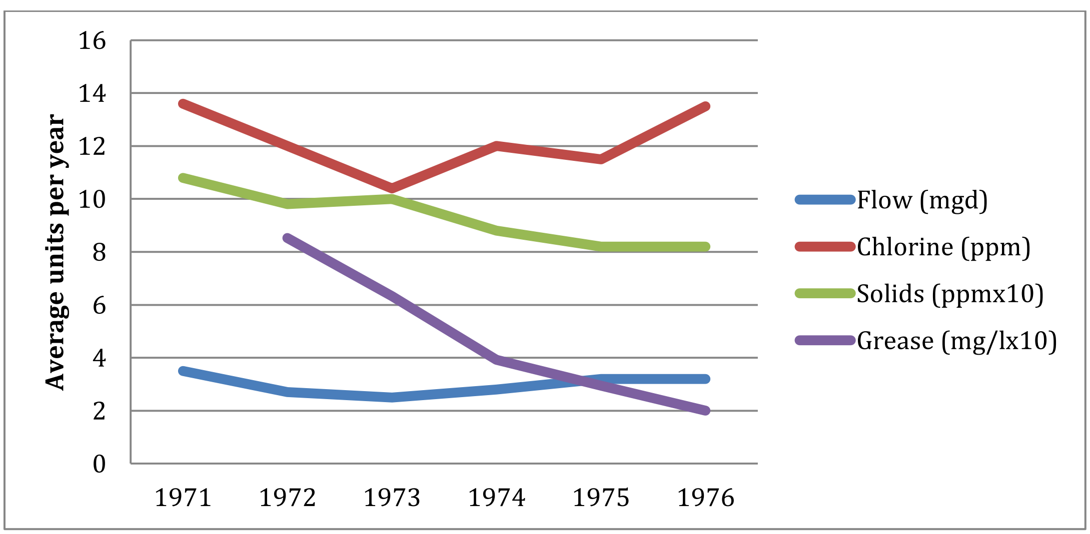


Figure 5. Characteristics of the sewage discharged at Soquel Point from 1971 until it was terminated in June 1976. (Data from the Santa Cruz County Sanitation District obtained in 1976.)

Monitoring Protocols

Classes of undergraduate students in quarter-long field courses were trained in field identification and monitoring protocols, beginning in 1972. In the spring of 1973 the classes established two 450m^2 plots, one in the affected area at Soquel Point ("Pleasure Point") and one in a comparison site ~1 km away off Opal Cliffs ("The Hook"). Both plots were located along single transect lines that were perpendicular to the shore and marked with stainless steel rods cemented into the substrate. The rods in the soft mudstone remained in place for various lengths of time before they needed to be replaced; by 2003 they were abandoned and the position of the plots was determined by cracks in the platform (see: limpets.org) and GPS. The GPS locations of the 0 and 15m ends of the transect tape are, respectively, N36° 57.302' W121° 58.260', N36° 57.299' W121° 58.254', and N36° 57.294' W121° 58.253' for the Soquel Point plot and N36° 57.595' W121° 57.829' and N36° 57.612' W121° 57.808' for the Opal Cliffs plot.

The abundances of the common organisms were estimated in both plots with a random sampling protocol (Murray et al. 2006). These two plots were monitored at the end of successive undergraduate classes nearly annually until 1998. This schedule provided time to train the students and also meant that monitoring could be done in late spring or early summer when there are suitable low tides. Some of the students remaining in the Santa Cruz area volunteered to continue the annual late spring to early summer monitoring to 2003, then again in 2006. Beginning in 2012, adults trained in the California Naturalists program of the Pacific Grove Museum of Natural History began monitoring the two sites.

The two 450 m^2 plots, each 15x30 m, were monitored using 50x50 cm quadrats divided into 25 10x10 cm squares. A random number table that provided positions for X-Y coordinates along and perpendicular to the transect line, respectively, was used to place the quadrats in the plots. Abundance was estimated using protocols adopted by LiMPETS (Long-term Monitoring Program and Experiential Training for Students, see: limpets.org). To quantify abundance, we used either total number of individuals within the quadrat (discrete organisms) or number of squares within which an organism was attached (cloning or aggregated organisms such as algae and surfgrasses) (Foster et al. 1988).

Teams of two to four people estimated the abundance of selected organisms within the quadrats, each team usually doing counts for 2-5 randomly placed quadrats. With 3 to 10 teams, we were able to obtain 10 or more replicate counts to obtain estimates of the mean abundance (mean and range of number of counts for each date: Soquel Point, 24.0, 10-41; Opal Cliffs, 24.5, 11-40; see Appendix).

In addition to the 50x50 cm quadrats used to estimate the abundance of organisms, 1x1 m quadrats were placed over stainless steel rods embedded in the rock as reference points. These were photographed to record changes in fixed quadrats over time (see Fig. 8).

Taxa Monitored

During the first several years of monitoring, an attempt was made to identify and monitor most macrophytes (=macroalgae and plants) and macroinvertebrates that were present in the quadrats. Specimens of species found in the area around Soquel Point, both within and outside the surfgrass-free area, also were collected, identified, and maintained as vouchers. Representative vouchers of invertebrates were deposited with the California Academy of Sciences, while algal vouchers were maintained in the collections of the University of California, Santa Cruz. Comprehensive lists were compiled, archived, and combined with species lists generated in similar surveys in the mid-1990s to compare intertidal biota in central California and Hawaii (Zabin et al. 2012; the number of invertebrate species recorded at Soquel Point more than doubled between 1972-3 and 1996-7).

However, it soon became evident that most species were too sparse to sample adequately with 50x50 cm quadrats. Moreover, many very similar species were difficult to distinguish in the field. Consequently, similar species were grouped and the list reduced mainly to genera that could both be reliably recognized and expected to be present in most quadrats. Recent analyses found very little difference for evaluating ecological conditions in littoral marine environments when genera are used rather than species (Díez et al. 2010, Xu et al. 2013). Nine of these taxa are treated in this report. Following Zabin et al. (2012), updated from the Worldwide Register of Marine Species, the common and scientific names of these taxa are:

1. Surfgrasses: *Phyllospadix* spp. (*P. scouleri* and *P. torreyi;* almost all *P. torreyi*). The epiphytic alga *Smithora naiadum* (C.L.Anderson) Hollenberg was usually very abundant on the blades of *Phyllospadix* spp. but was not quantified.

2. Coralline algae (part): *Bossiella* spp. (*B. californica* (Decaisne) P.C. Silva, *B. chiloensis* (Decaisne) H.W.Johansen, *B. dichotoma* (Manza) P.C. Silva, and *B. plumosa* (Manza) P.C.Silva).

3. Coralline algae (part): *Corallina* spp. (C. *chilensis* Decaisne, and *C. vancouveriensis* Yendo).
[For the 2006, 2012, and 2014 counts, *Bossiella* spp. and *Corallina* spp. were combined as "upright coralline algae"; these counts are not considered in this report.]

4. Frilly red algae: *Cryptopleura* spp. (*C. lobulifera* (J.Agardh) Kylin, *C. ruprechtiana* (J.Agardh) Kylin, and *C. violacea* (J.Agardh) Kylin).

5. Sea lettuces: *Ulva* spp. (including species in the formerly recognized genus *Enteromorpha* Link, which are notoriously difficult to distinguish from those in *Ulva* L.).

6. Sunburst sea anemones: *Anthopleura sola* Pearse and Francis, 2000 (before 2000 counted as the solitary form of *Anthopleura elegantissima* (Brandt, 1835), which was the only form found in these plots).

7. Honeycomb tubeworms: *Phragmatopoma californica* (Fewkes, 1889).

8. Turban snails: *Tegula* spp. (*T. brunnea* (Philippi, 1848) and *T. funebralis* (A.Adams, 1855)).

9. Hermit crabs: *Pagurus* spp. (*P. granosimanus* (Stimpson, 1859), *P. hirsutiusculus* (Dana, 1851) and/or *P. venturensis* Coffin, 1957).

In addition to enumerating the abundance of the above-named taxa, from 1973 to 1993 teams were asked to list other taxa found in the quadrats to estimate species richness. In most cases, species were not identified and only listed as distinct items, often with descriptive common names (e.g., filamentous alga, red sponge, colonial hydroid, small snail, channeled whelk, kelp crab, isopod, white tunicate.) Although underestimating the species richness, the lists can be used to compare the two plots and how the sewage discharge affected species richness.

Monitoring Schedule

Monitoring was possible only on extreme low tides, near or below -1.0' MLLW. Such low tides occur only in the early mornings of April to July and late afternoons of October to January. In 1976 monitoring was done in May, before the sewage discharge was terminated on June 9, and again in October. Otherwise, monitoring was in spring-summer every year until 2003, except for 1982 for the Opal Cliffs plot and 1989 for both plots. After 2003 both plots were monitored in 2006, 2012, 2014, and 2015. Monitoring required two days, one day at each site. Dates for the monitoring are given in the Appendix.

Data Analysis and Archive

John Pearse retained the collected data, including notes of the conditions during the monitoring and photographs. Summaries (means, standard deviations, sample sizes) were tabulated and graphed to track changes. Over the years, some of the original data sheets were lost. However, the means, sample sizes, and standard deviations remained available in tables and graphs, and they could be plotted with the more complete data to reveal major trends over the 42 years of monitoring. The numerical data used in this report are listed in the Appendix and posted on the LiMPETS website (limpets.org), and they can be used to compare with data collected in the future.

General observations

When the study began in 1971, the area around the Soquel Point plot was devoid of surfgrass and instead consisted of mostly sand-free bare mudstone covered with low-growing clumps of coralline algae (mainly *C. chilensis*) and diatoms, with a scattering of *Cryptopleura lobulifera* and stunted and deformed specimens of *Egregia menziesii* (var. *laevigata*)*, Laminaria setchellii, Stephanocystis osmundacea, Chondracanthus corymbiferus, Mazzaella volans, M. flaccida,* and *M. splendens* (Doyle and Pearse 1972). Sponges and tunicates were conspicuously absent, as were their nudibranch predators, and decapod crustaceans and sculpins were scarce (Zabin et al. 2012). The general aspect of the Soquel Point plot was in stark contrast with the Opal Cliffs plot, which was dominated by surfgrass that held a thick layer of sand over the mudstone. Over the following five years, the affected area landward of the Soquel Point plot expanded as the long blades of the surfgrass died back, leaving twisted rhizomes attached to the bedrock (Fig. 6).

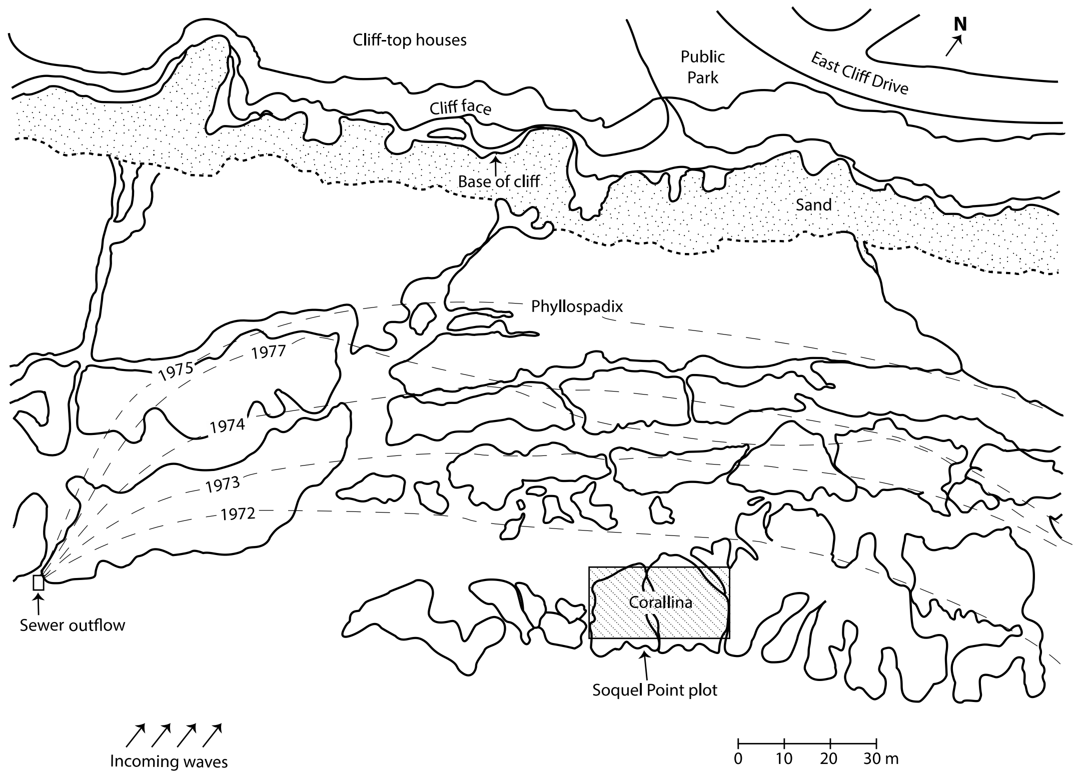


Figure 6. Map showing expansion of area without surfgrass blades between 1972 and 1975, and recovery in June 1977. Each surfgrass boundary was determined by walking along the edge and sketching it in on the original map drawn in 1972.

Within a month after the 9 June 1976 termination of the sewage discharge, the affected Soquel Point area was covered with a carpet of broad-bladed sea lettuces (*Ulva* spp.). Small areas manually scraped clean on 15 May 1976 were filled mainly with long, narrow-bladed *U. taeniata*, while similar scraped areas at Opal Cliffs were still bare, perhaps because of scour from surrounding surfgrass. Moreover, the branches of *Corallina* spp. had conspicuous, growing tips; the small, stunted vegetative clumps of *Stephanocystis osmundacea* were covered with new fronds; and there were many small recruits of the kelps *Egregia menziesii* and *Laminaria* sp. Small hermit crabs (*Pagurus* spp.) were conspicuously abundant within the first year of the termination, but after two years they declined as the lush new cover of coralline algae trapped sand, covering the previously near-bare mudstone.

The rhizomes of *Phyllospadix* (all, or nearly all, *P. torreyi)* remaining attached to rock around the edge of the affected area, beyond the study plot, sprouted new blades; an expanding surfgrass meadow was apparent within a year (Fig. 6). However, the area within the study plot remained nearly free of surfgrass for the following four years. The first appearance of a few seedlings was in 1978, and only small patches of surfgrass were present in 1980 (Fig. 7). Establishment of a dense cover of surfgrass proceeded very slowly, with large areas still lacking surfgrass in 1988 and not visually matching the Opal Cliffs area until about 20 years after the sewage discharge was terminated (Fig. 8, 9).

Figure 7. Photos of surfgrass (*Phyllospadix* torreyi) returning to the Soquel Point plot; Seedling found attached to coralline algae in 1978 among lush cover of *Corallina* spp., *Cryptopleura* spp., and *Ulva* spp. (left), and small patches of surfgrass (arrows) among the dense cover of *Corallina* spp. in 1980 (right).

Figure 8. Photos of people sampling the Soquel Point plot in 1975 (upper left), 1980 (upper right), 1993 (middle left), and 2015 (middle right); and the Opal Cliffs plot in 1974 (lower left) and 2015 (lower right).

The most noticeable macroinvertebrates in the affected area were large, solitary sea anemones, later determined to be *Anthopleura sola* (considered at the time to be the "solitary form" of *Anthopleura elegantissima*). These are shown in a 1-m^2 quadrat photographed over time (Fig. 9). Three were in the same location within the quadrat in 1975 and 1980, then at least 2 in 1988, and 1 in 1993, although it was difficult to be sure if the others were not buried in the sand. The one noted in 1993 was present in subsequent years until 1997 when the stainless steel pin marking the position of the quadrat was lost.

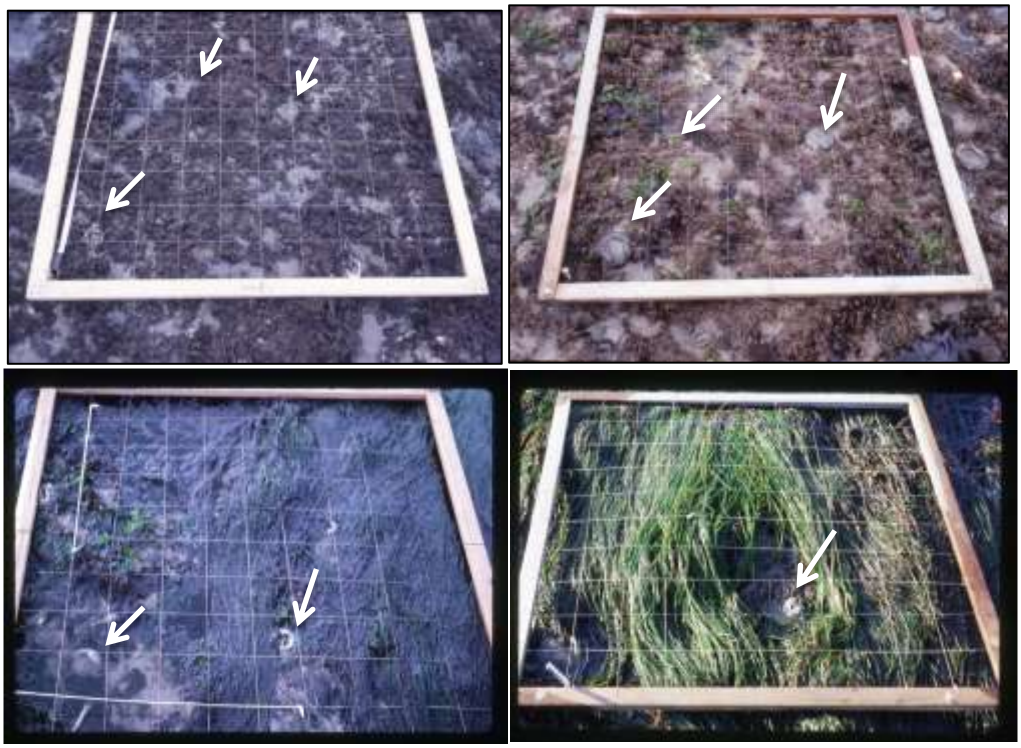


Figure 9. Photos of the same 1-m^2 quadrat within the Soquel Point plot. Upper left: 1975, no surfgrass. Upper right: 1980, no surfgrass. Lower left: 1988, partially filled with surfgrass. Lower right: 1993, surfgrass abundant. Note the specimens of sunburst anemones, *Anthopleura sola,* located in the same positions (arrows). The stainless steel rod in the lower, left-hand corner of the quadrat was used to locate and position the quadrat.

One other conspicuous macroinvertebrate at Soquel Point, the honeycomb tube polychaete *Phragmatopoma californica,* was present in low abundance in the monitored plot. However, it formed aggregations of sandy mounds shoreward of where the surfgrass cover was reduced when the sewage was discharged (Fig. 10). The mounds all but disappeared after the sewage discharge ceased.

Figure 10. Photo of honeycomb tubeworm (*Phragmatopoma californica*) mounds shoreward of the Soquel Point plot in 1975 when sewage was discharged. Students in the center of the photograph were monitoring quadrats shoreward of the Soquel Point plot; their data are not included in this paper. Arrow points to area of the Soquel Point plot.

Monitoring Results

Surfgrasses (*Phyllospadix* spp., nearly all *P. torreyi*)

As noted in the general observations above, surfgrass appeared as scattered clumps in the Soquel Point plot about four years after the sewage discharge was terminated: its abundance increased slowly after that (Fig. 11). In contrast, surfgrass abundance remained nearly constant throughout the 42-year monitoring period in the Opal Cliffs plot. The abundance of surfgrass in the Soquel Point plot did not reach that in the Opal Cliffs plot until the late 1990s, more than 20 years after the sewage discharge was terminated. The relatively low abundance of surfgrass in the 2015 count corresponded to an unusually low amount of sand cover, exposing bare rock covered with a bloom of opportunistic sea lettuces (*Ulva* spp.)(see Fig. 14).

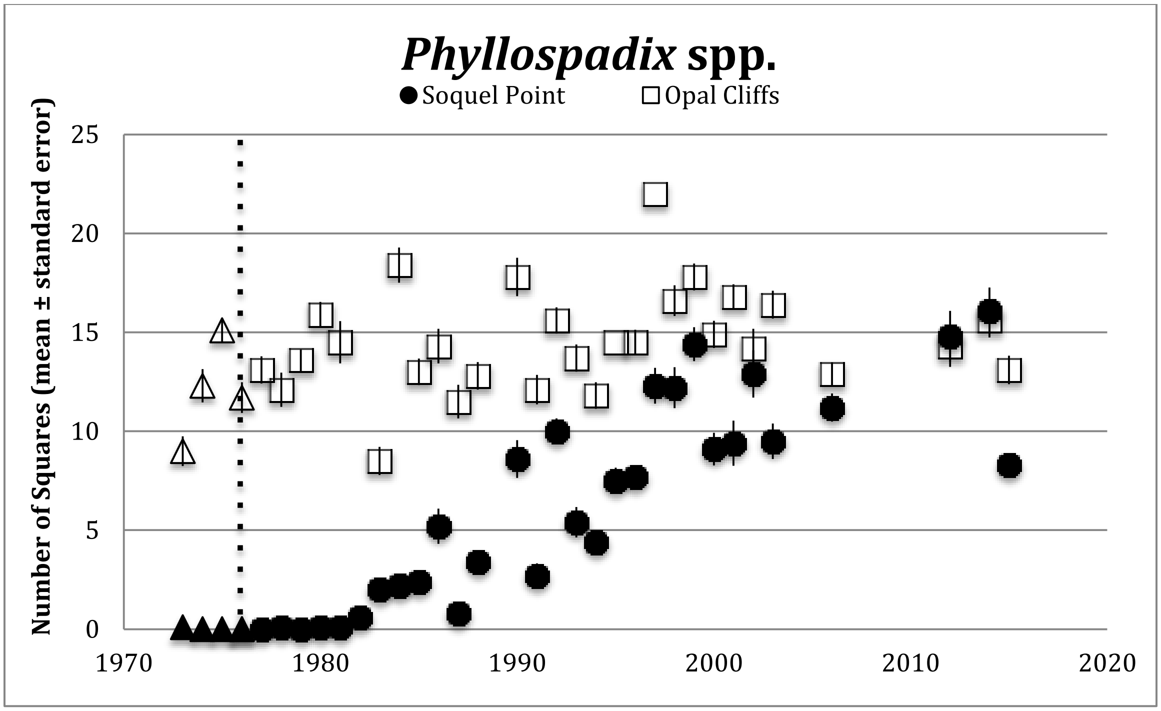


Figure 11. Changes in the abundance of surfgrasses (*Phyllospadix* spp., nearly all *P. torreyi*) within 50x50 cm quadrats in the Soquel Point and Opal Cliffs plots. Triangle symbols are for the years when the sewage was discharged. Dotted vertical line indicates when sewage discharge terminated.

<u>Upright coralline algae (*Bossiella* spp. and *Corallina* spp.)</u>
The two main genera of upright coralline algae revealed very different patterns in response to the sewage discharge and its termination.

Although stunted in appearance, *Corallina* spp. were found in nearly every 10x10 cm square of the quadrats before sewage discharge ended. Despite showing vigorous growing tips after the sewage discharge stopped, they started to decrease in abundance starting about three years after termination of the sewage discharge (Fig. 12). They had not reached the low level of abundance found in the Opal Cliffs plot by 2015, nearly 40 years later. At Opal Cliffs the abundance of *Corallina* spp. increased to relatively moderate levels over the four years prior to the termination of the discharge, then fell to low levels throughout the remainder of the monitoring period.

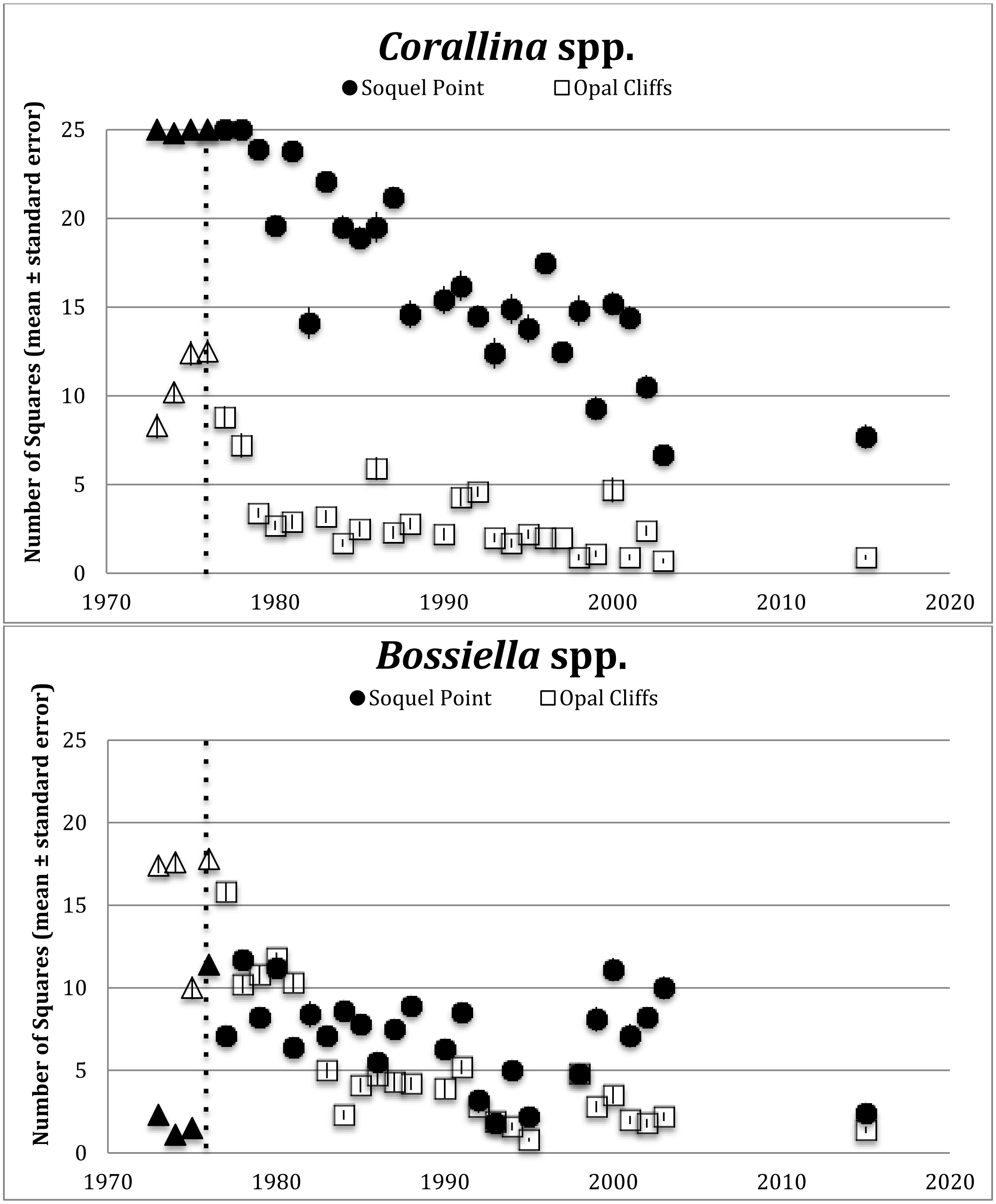


Figure 12. Changes in the abundance of upright coralline algae *Corallina* spp. (above) and *Bossiella* spp. (below) within 50x50 cm quadrats in the Soquel Point and Opal Cliffs plots. Triangle symbols are for the years when the sewage was discharged. Dotted vertical line indicates when sewage discharge terminated.

In contrast to *Corallina* spp., the abundance of *Bossiella* spp. was very low at Soquel Point when the sewage was discharged; it rose immediately to moderate levels just *before* the discharge's termination, and then decreased very slowly over the following monitoring period (Fig. 12). In the Opal Cliffs plot the abundance of *Bossiella* spp. was relatively high during the sewage discharge and immediately after its termination, then slowly declined. Three years after the discharge ended, the abundance of *Bossiella* spp. was similar between the two sites, although mean values were always higher in the Soquel Point plot.

<u>Frilly red algae (*Cryptopleura* spp.)</u>
The abundance of frilly red algae was near zero in the Soquel Point plot when the sewage was discharged, but increased in the year *before* the sewage discharge was terminated. These species were present in nearly every 10x10 cm square of the quadrats for several years afterwards (Fig. 13 above). In the Opal Cliffs plot, abundance was moderately high when the sewage was discharged and increased after the discharge ended. At both sites the abundance of frilly red algae generally declined over the succeeding years, stabilizing at relatively low levels, but was consistently higher in the Soquel Point than in the Opal Cliffs plot.

<u>Sea lettuces (*Ulva* spp.)</u>
Although relatively high in 1973, sea lettuce abundance dropped to near zero in the Soquel Point plot in 1974 and 1975, when the sewage was being discharged. Abundance rose in 1976 *before* the sewage discharge was terminated, and reached high levels in 1977 and 1978 followed by a drop to near zero in 1979 (Fig. 13 below). In contrast, in the Opal Cliffs plot, sea lettuce abundance dropped steadily from moderately high in 1973 to near zero in 1979. After 1979, mean abundance of sea lettuce in both plots fluctuated from very low to moderate levels with no apparent pattern. The relatively high abundance in the Soquel Point plot in 2015 corresponded to an unusually low cover of sand on the rocks and a drop in the abundance of surfgrass.

<u>Honeycomb tubeworms (*Phragmatopoma californica*)</u>
As noted above, large mounds of honeycomb tubeworms occurred shoreward of the Soquel Point plot when the sewage was discharged (see Fig. 10). These animals were always relatively scarce in both the Soquel Point and Opal Cliffs plots (Fig. 14). However, they were more abundant in the Opal Cliffs plot when the sewage was discharged and just after; then they fluctuated at low levels with no apparent pattern.

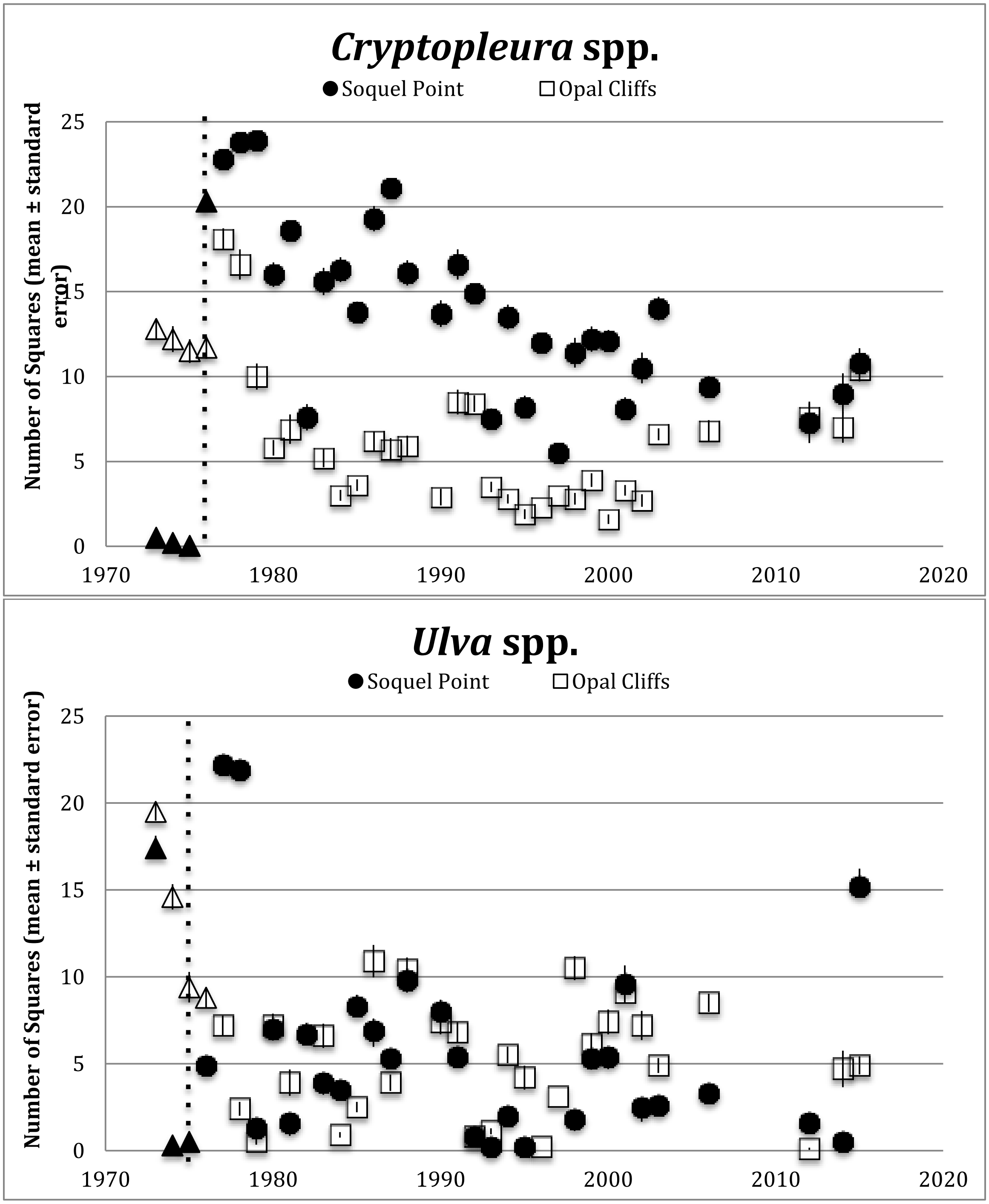


Figure 13. Changes in the abundance of frilly red algae (*Cryptopleura* spp.) and sea lettuces (*Ulva* spp.) within the Soquel Point and Opal Cliffs plots. Triangle symbols are for the years when the sewage was discharged. Dotted vertical line indicates when sewage discharge terminated.

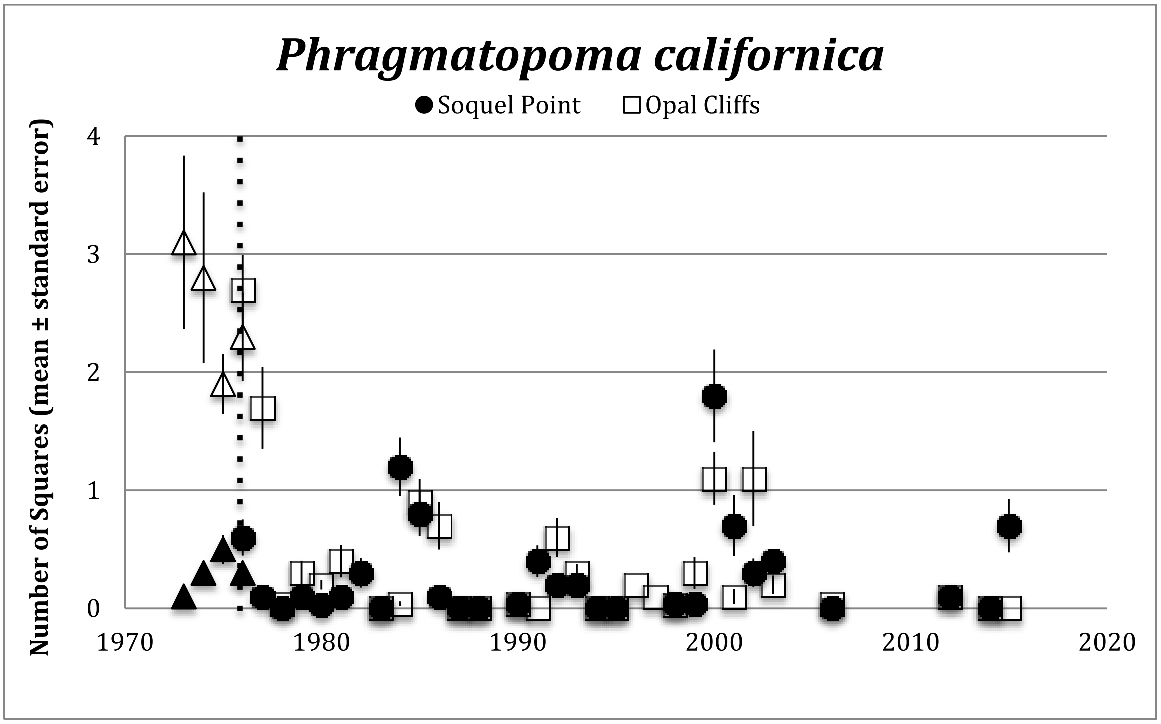


Figure 14. Changes in the abundance of honeycomb tubeworms (*Phragmatopoma californica*) within 50x50 cm quadrats in the Soquel Point and Opal Cliffs plots. Triangle symbols are for the period when the sewage was discharged. Dotted vertical line indicates when sewage discharge terminated. Two symbols each are given for 1976, a triangle for before (May) and a circle or square for after (October) the discharge was terminated in June. Note that the Y-axis only goes to 4 squares and the "high" value in 1973 is actually relatively low.

Sunburst anemones (*Anthopleura sola*)

Large specimens of sunburst anemones were conspicuous on the sand-free rocks at Soquel Point before the termination of the sewage outfall (see Fig. 9), and they continued to be present in similar numbers through the following monitoring period (Fig. 15). While their numbers varied considerably among the years, probably due to variation in sand burial, the mean number was always higher in the Soquel Point plot than the Opal Cliffs plot until 2002, after which mean numbers were nearly identical in both plots. In 2014 for the first time the mean number of sunburst anemones was substantially higher in the Opal Cliffs plot than in the Soquel Point plot.

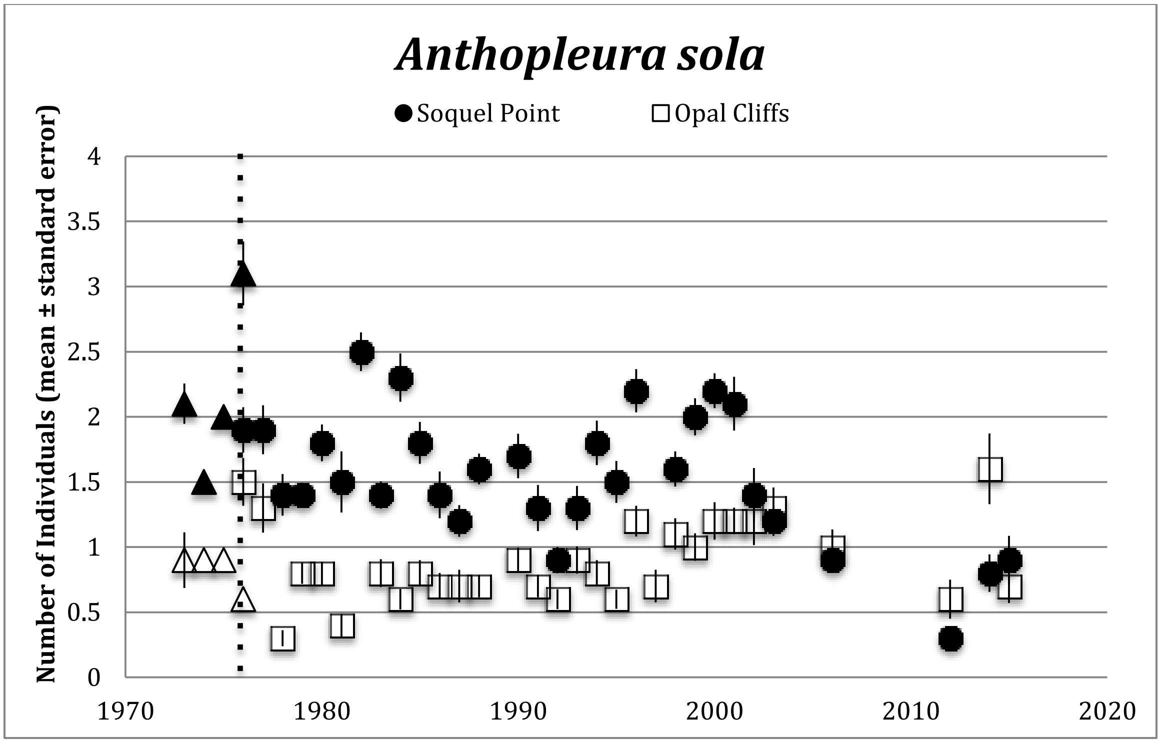


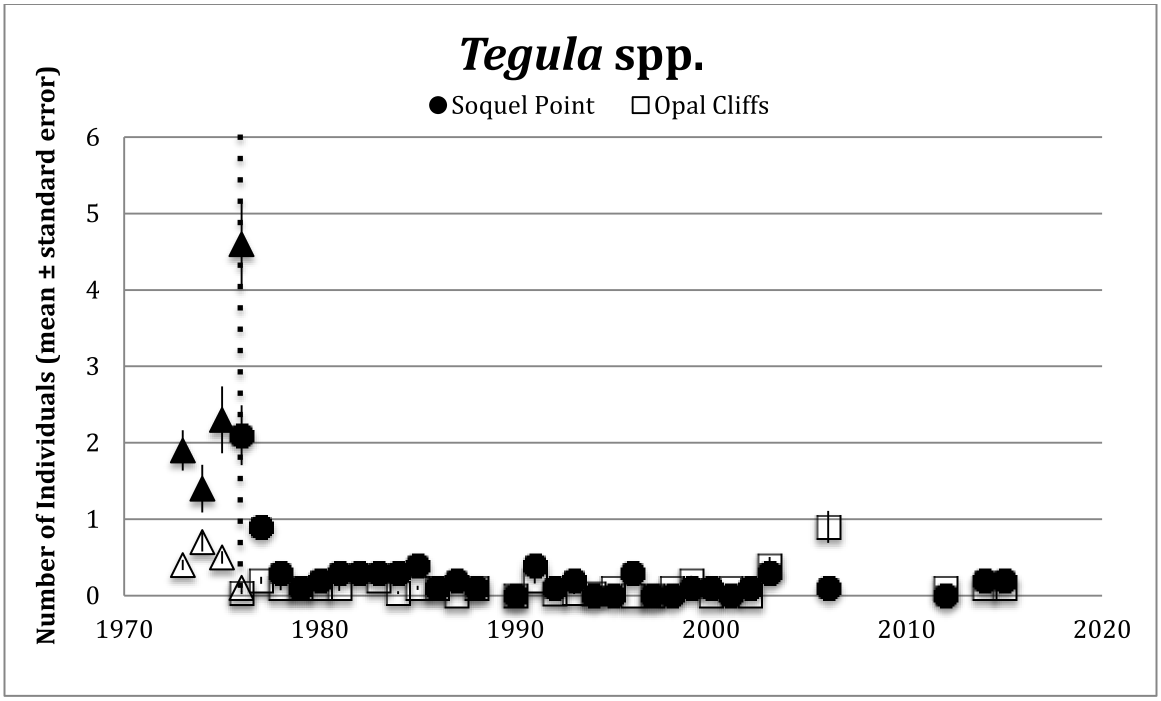
Figure 15. Changes in the abundance of sunburst anemones (*Anthopleura* sola) within 50x50 cm quadrats in the Soquel Point and Opal Cliffs plots. Triangle symbols are for the period when the sewage was discharged. Dotted vertical line indicates when sewage discharge terminated. Two symbols each are given for 1976, a triangle for before (May) and a circle or square for after (October) the discharge was terminated in June.

Turban snails (*Tegula* spp.)

Turban snails were more numerous in the Soquel Point plot than in the Opal Cliffs plot when the sewage was discharged and for a few years afterwards (Fig. 16, above). Particularly striking was the increase in mean number three weeks *before* the sewage discharge was terminated in June 1976. These were mostly very small snails. By 1979 turban snail abundance was very low and, except for 2006, nearly identical between the two sites.

Hermit crabs (*Pagurus* spp.)

Hermit crabs were rare in the Soquel Point plot when the sewage was discharged in 1973-74, but a few were counted in the 1975-76 samples *before* the sewage discharge was terminated (Fig. 16, below). Abundance increased by October 1976 only four months after the discharge was stopped, peaked in 1978, exceeding the abundance in the Opal Cliffs plot, then dropped to levels that were consistently lower than in the Opal Cliffs plot. The high number of hermit crabs in 1976-78, with many very small animals, probably reflected new recruits from the plankton and an abundance of empty snail shells.



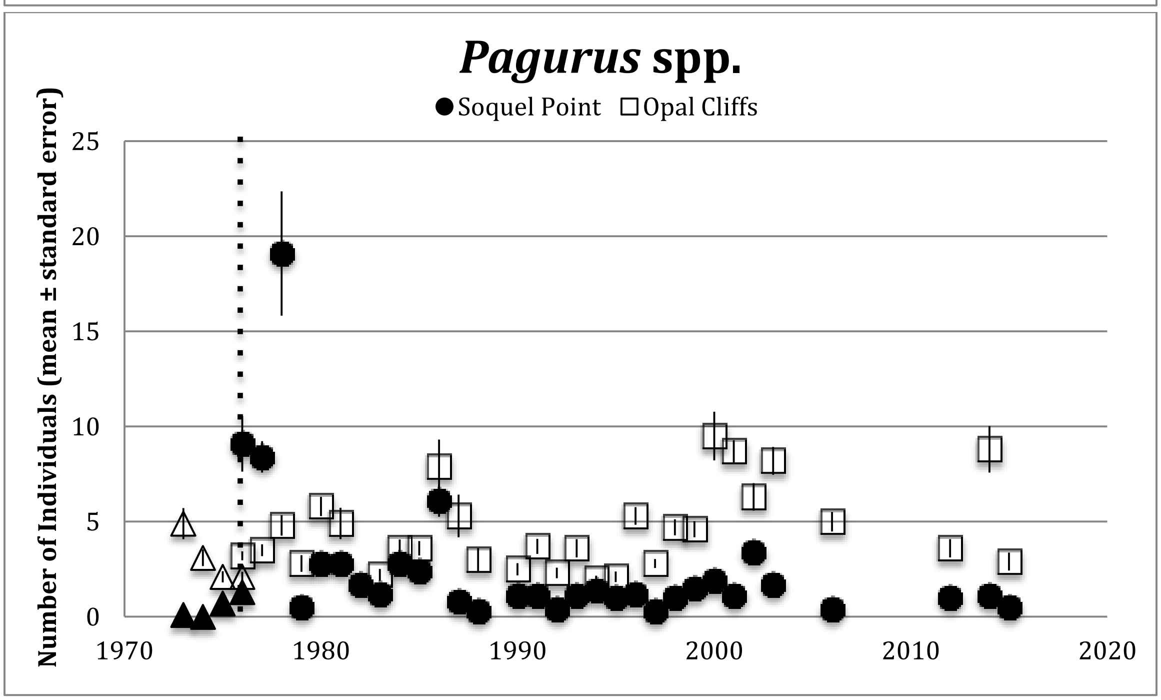


Figure 16. Changes in the abundance of turban snails (*Tegula* spp.) (above) and hermit crabs (*Pagurus* spp.) (below) within 50x50 cm quadrats in the Soquel Point and Opal Cliffs plots. Triangle symbols are for the period when the sewage was discharged. Dotted vertical line indicates when sewage discharge terminated. Two symbols each are given for 1976, a triangle for before (May) and a circle or square for after (October) the discharge was terminated in June.

Taxon richness

When monitoring began in 1973, about one-third as many taxa of both macrophytes and macroinvertebrates were noted in the quadrats in the Soquel Point plot as in the Opal Cliffs plot (Fig. 17). These proportions narrowed before the sewage discharge was terminated, both because of increased numbers in the Soquel Point plot and in the case of macroinvertebrates, decreased numbers in the Opal Cliffs plot. From 1978 to 1992 the number of taxa in the two plots was indistinguishable, and collection of these data was discontinued.

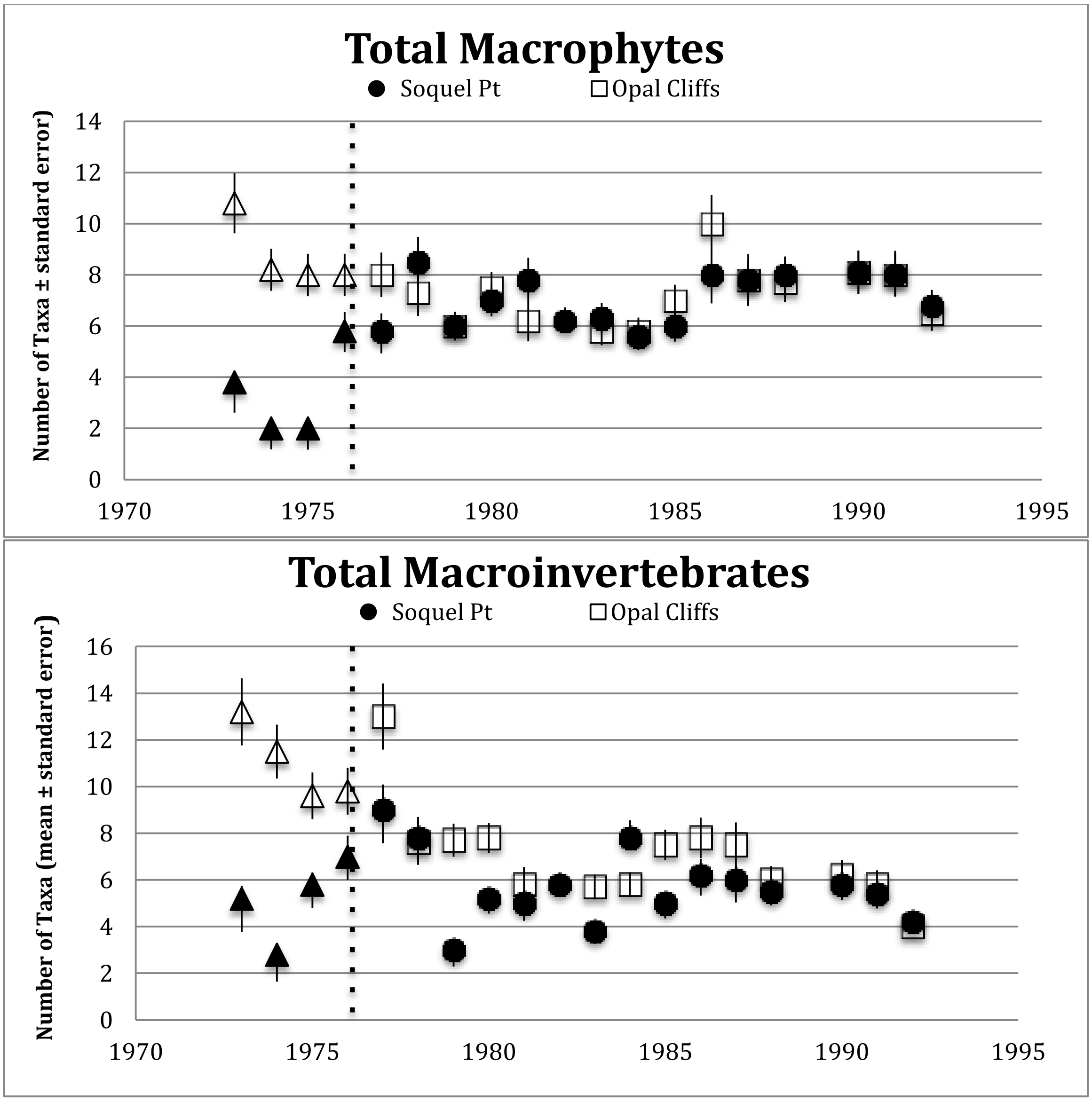


Figure 17. Changes in the abundance of macrophyte and macroinvertebrate taxa within 50x50 cm quadrats in the Soquel Point and Opal Cliffs plots. Triangle symbols are for the years when the sewage was discharged. Dotted vertical line indicates when sewage discharge terminated.

Discussion

Seagrass meadows are known to be sensitive to a wide variety of natural and anthropogenic disturbances (Short and Wyllie-Echeverria 1996, Orth et al. 2006, Hughes et al. 2009, Waycott et al. 2009, Hogarth 2015). However, little documentation has been published on the impacts of domestic sewage pollution on seagrass meadows in the intertidal (reviewed for California by Foster et al. 1988) and even less for surfgrass meadows (e.g., North 1964, Littler and Murray 1975, Pearse et al. 1998). As sewage treatment has improved on the west coast of North America and sewage disposal has moved offshore, documentation of the impact of sewage on surfgrass meadows in the future is unlikely (but see, for e.g., Archambault et al. 2001, Cabral-Oliveira et al. 2014 for recent studies on the impact of sewage disposal in the rocky intertidal on other assemblages.) Nevertheless, the present monitoring program demonstrates how a large disturbed area within a surfgrass meadow recovered after the termination of long-term stress from domestic sewage. Moreover, although the comparison area, ~1 km distant, was also affected by the sewage discharge, it showed remarkable stability in the abundance of the species monitored over the entire 42-year period. Of course, as Underwood (1994) points out, replicate sites, if such had been available, are needed to conclusively show the impact of sewage on this seagrass meadow, but the available data in this study, including the photographs, are compelling.

How the domestic sewage negatively impacted the surfgrass community near the sewage discharge outfall is unknown. Between 1972, when our observations began, and 1976, when the discharge was stopped, the area that was devoid of surfgrass cover more than doubled, suggesting that whatever was impacting the surfgrass was an ongoing and perhaps increasing stress. Chlorine, used as a disinfectant, is a known toxin, and it produces a large variety of organo-halogenated by-products known to be toxic when mixed with organic material (Abarnou and Miossec 1992). Between 1973 and 1976 the level of chlorine in the sewage remained nearly unchanged (see Fig. 5). However, with increasing concern about health issues, the level of chlorination had increased in the early 1970s (Talley 1973), which may have led to the expanded die-off of surfgrass recorded between 1972 and 1975 (see Fig. 6).

After the sewage discharge was stopped, surfgrass foliage (mainly or all, *P. torreyi)* appeared relatively quickly *shoreward* of the monitored plot at Soquel Point. This rapid recovery was almost certainly due to regrowth of blades from surviving rhizomes that were defoliated during the previous few years. Similar rapid recovery was observed after a fuel spill from a grounded ship on the Monterey Peninsula; the blades of *Phyllospadix scouleri* were bleached and lost while the rhizomes remained intact (Walder and Foster 2000). However, there were no rhizomes surviving *within* the monitored Soquel Point plot, and new plants were established there only from seedlings that recruited into the plot. No recruitment of seedlings was noted until 1978, two years after the sewage discharge was terminated. Moreover, accumulation of seedlings and their subsequent growth by rhizome expansion was very slow. Substantial increase did not begin until 1982, and it took over 20 years for surfgrass abundance to reach that recorded in the comparison plot at Opal Cliffs. Similarly, Dethier (1984), Turner and Lucas (1985), McConnico and Foster (2005), and Shelton (2010) followed the recovery of *P. scouleri* populations after storm or artificial removal, and they likewise found that when the plants were completely removed, re-establishment and recovery were very slow, in part because of barriers to seed attachment and seedling mortality.

Seeds of *Phyllospadix* attach to branching, low-growing algae, including upright coralline algae such as *Bossiella* and *Corallina* (Gibbs 1902, Turner 1983, Dethier 1984, Turner and Lucas 1985, Blanchette et al. 1999, Menge et al. 2005, Shelton 2010). Reed et al. (2009) found that seedling recruitment into meadows of *P. torreyi* depended on both seed production and dispersal. Although a large surfgrass meadow that could have provided numerous seeds surrounded our Soquel Point plot, we have no measure of seed production. If seed production was moderate to high in the surrounding meadow, seed availability should not have been limiting. Blanchette et al. (1999) found that species of *Bossiella* and *Corallina* were only moderately effective at snaring seeds of *P. torreyi,* and this may be a factor in the slow expansion of the surfgrass meadow in the Soquel Point plot. Nevertheless, seedlings with only a few blades were noted in 1978 attached to coralline algae, without being attached to underlying rock (see Fig. 7). It seems likely that as the blades grew, they produced drag on the seedling and the host coralline alga, and wave surge broke most seedlings free, washing them away before they had a chance to become securely attached to the underlying rocks. The seedlings that became successfully attached to the rocks were the ones that spread by rhizome growth to eventually re-establish the meadow. Such rhizome growth would likely be very slow as found by Turner (1983) and Turner and Lucas (1985) for rhizome growth of *P. scouleri* in Oregon.

Turning to coralline algae, Dawson (1959: p. 182, 1965: p. 225) noted that "… several species of *Bossiella* and *Corallina* are markedly tolerant of high levels of foreign substances in intertidal waters of southern California, and … their abundance in some areas is the result of their ability to compete more favorably in such an environment than a majority of other algal species." His examples were in areas around three domestic sewage outfalls and, with respect to *Corallina* spp., are similar to our observations at Soquel Point, as well as two other intertidal sites in the Monterey Bay area that had small outfalls of domestic sewage disinfected with chlorine in the mid-20th century (Point Pinos and Carmel Bay, JSP, pers. obs.). Species of *Corallina* also have been found to be more abundant in the intertidal around other sewage outfalls around the world (e.g., Littler and Murray 1975, Archambault et al. 2001, Cabral-Oliveira et al. 2014), although not always (e.g., Bellgrove et al. 1997, Díez et al. 2009). On the other hand, we documented a striking difference between the abundance of *Corallina* and *Bossiella* in the Soquel Point plot when sewage was discharged; *Corallina* was abundant and dominated in the plot while *Bossiella* was nearly absent (Fig. 12). Clearly, different genera and probably species of coralline algae respond differently to various forms of chemical toxins.

The abundances of *Bossiella* spp., *Cryptopleura* spp., and *Ulva* spp. were higher in the Opal Cliffs plot than the Soquel Point plot when the sewage was discharged, and their abundances dropped over the years after the sewage discharge was terminated. In addition, the abundance of *Corallina* spp. in the Opal Cliffs plot was highest just before the sewage discharge was terminated, after which it slowly dropped to lower levels. All of these algae probably benefited from the nutrient enrichment due to the sewage as reported for *Ulva* spp. and other algae by North et al. (1970) in southern California, as well as in Australia (Bellgrove et al. 1997, Archambault et al. 2001, Bishop et al. 2002, Bellgrove et al. 2010). In addition, the suspension feeding, sabellariid tubeworms *Phragmatopoma californica* formed large mounds at Soquel Point near the Soquel Point plot, but not within it, when the sewage was discharged. This tubeworm was more abundant in the Opal Cliffs plot when the sewage was discharged than at any time afterwards. Another species of sabellariid, *Sabellaria alveolata* L., was also reported to be much more abundant near a sewage outfall than at two reference sites on the coast of Portugal (Cabral-Oliveira et al. 2014). Whether these animals benefited from increased food particles (e.g., bacteria) or dissolved organic material in the water remains unresolved. Regardless, at least some of the species in the healthy-appearing surfgrass community in the Opal Cliffs plots, more than one kilometer distant from the sewage discharge pipe, appeared to be enhanced by the nutrients in the sewage. On the other hand, surfgrass itself at Opal Cliffs showed little difference between when the sewage was discharged and afterwards, indicating that it was not nutrient limited.

Cryptopleura, in particular, increased from near absence in the Soquel Point plot in 1973-75 to very high abundance *just before* and immediately after the sewage discharge was terminated in 1976. This increase corresponded to a decrease in suspended solids and grease content in the sewage. Subsequently, its abundance decreased very slowly over about 20 years before reaching levels seen in the Opal Cliffs plot. The slow decrease in the abundance of *Cryptopleura* spp. closely followed that of *Corallina* spp., both in contrast to the increase in abundance of *Phyllospadix* spp. (Fig. 18). These correlations in abundance suggest both facilitation and competition among the three taxa (Connell and Slayter 1977).

The abrupt increase in *Cryptopleura* in the Soquel Point plot had no effect on the abundance of *Corallina*, and there is no evidence that the two taxa compete for space, with one displacing the other. Indeed, it seems more likely that *Corallina* facilitates *Cryptopleura* by providing substrate for attachment when sand held by the luxuriant growth of *Corallina* and *Phyllospadix* covers the rocks. On the other hand, the slow increase in *Phyllospadix* corresponds to a slow decrease in both *Cryptopleura* and *Corallina* (Fig. 20), suggesting competitive interactions. McConnico and Foster (2005) suggested that *Cryptopleura* and upright coralline algae that recruited in a low intertidal area cleared by a ship grounding inhibited the re-establishment of *Phyllospadix.* Similarly, Bellgrove et al. (2010) found that turfs of *Corallina officinalis* became established after sewage disposal in the intertidal in Australia removed a canopy-forming fucoid alga, and such turfs could prevent the fucoid's re-establishment. They proposed that alternative stable states might occur between those dominated by fucoids and those dominated by coralline turf. However, with respect to surfgrass meadows, our findings support the conclusion of Menge et al. (2005) that surfgrass is the competitive dominant, and although *Corallina* might inhibit the recruitment of surfgrass by snaring seeds then breaking off*,* it does snare seeds and given enough time after a major disturbance, surfgrass will eventually become established and displace other space holders by trapping sand that covers the rocky substrate needed by other species for attachment. But the time required for restoration is in the order of decades. Díez et al. (2014) were concerned that canopy-forming algae in northern Spain that were replaced by coralline algae after long-term exposure to sewage showed no evidence of recovery 11 years after sewage upgrade, and they suggested that global climate change was involved.

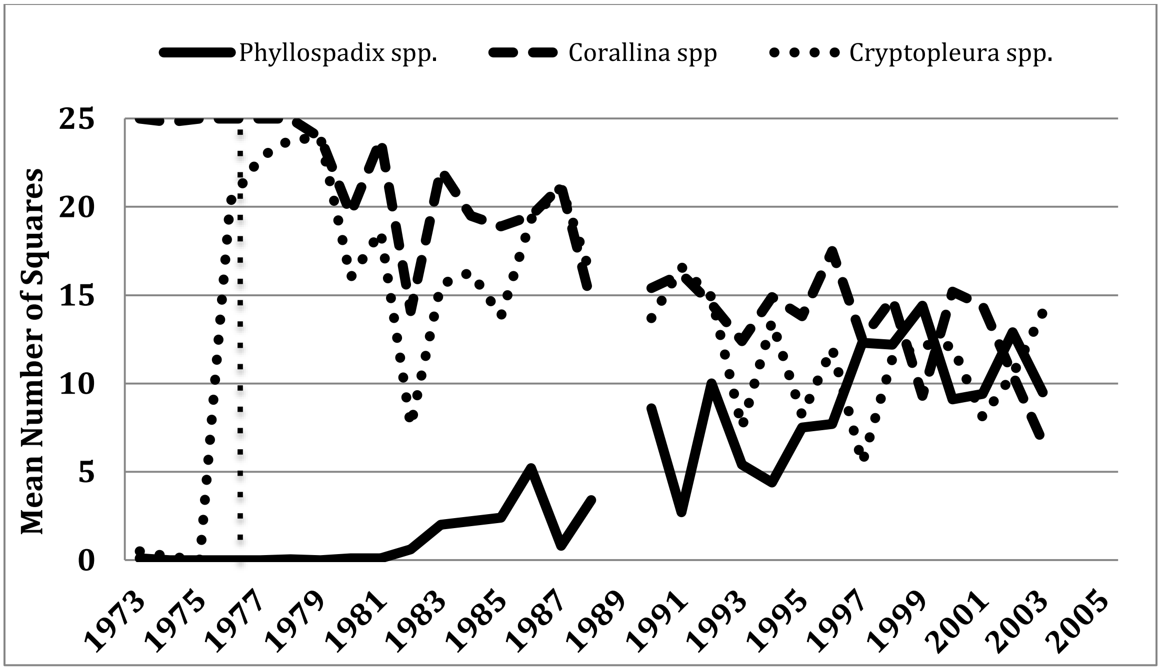


Figure 18. Abundances of surfgrasses (*Phyllospadix* spp.), coralline algae (*Corallina* spp.), and frilly red algae (*Cryptopleura* spp.) in the Soquel Point plot. Dotted vertical line indicates when sewage discharge was discontinued.

The increase in abundance of *Cryptopleura* spp. in the Soquel Point plot *just before* the sewage discharge was terminated in 1976 also was noted with *Bossiella* spp., *Ulva* spp., *Tegula* spp., *Pagurus* spp., and the richness of both macrophytes and macroinvertebrates. Indeed, turban snails (*Tegula* spp.) were more abundant in the Soquel Point plot when the sewage was still being discharged than at any other time during out monitoring. While the amount of suspended solids decreased somewhat between 1971 and 1976, the most notable change in the sewage treatment was the decrease in grease content (see Fig. 5). Among other effects, grease could inhibit algal (including diatom) attachment and growth on the rocks. Thus the decrease in grease could explain the increase in abundance of organisms when sewage was still being discharged into the intertidal. In addition, after the sewage discharge was stopped, the new luxuriant growth of coralline algae trapped sand that obliterated most of the rock surfaces on which turban snails graze. These observations indicate that the affected area at Soquel Point could have undergone considerable restoration if the treatment had been improved further, as has been found around sewage-affected areas in northern Spain (Bustamante et al. 2012, Díez et al. 2013).

The abundance of hermit crabs (*Pagurus* spp.) was lower in the Soquel Point plot than the Opal Cliffs plot throughout nearly the whole period of this survey, suggesting subtle differences between the two plots beyond their exposure to sewage. For example, Opal Cliffs is less exposed to incoming waves that Soquel Point. The exception was the first two years (1977-78) after the sewage discharge was terminated when many small hermit crabs were found in the Soquel Point plot. These small hermit crabs probably reflected the renewed occupation of empty snail shells that had accumulated earlier when the hermit crabs were absent.

The one species that was found to be unchanging in abundance throughout most of this 42-year monitoring period was the sunburst anemone, *Anthopleura sola*. These animals were consistently more abundant in the Soquel Point plot than the Opal Cliffs plot, both when the sewage was discharged and after until 2006. *Anthopleura sola* is a southern species that appears to have increased in the Monterey Bay area within the past several decades (Pearse and Francis 2000). With the decline in surfgrass cover, the relatively sand-free rocks in the sewage-affected area at Soquel Point may have been particularly favorable for recruitment of these anemones. Once established, they could survive attached to the rocks even after the sand accumulated among the luxuriant growth of coralline algae and later, surfgrass. The lifespan of anemones, including sunburst anemones, is unknown, but they apparently lack senescence (Shick 1991) so are potentially immortal. Our photographs of the same 1 m^2 plot between 1975 and 1993 showed individual sunburst anemones in nearly the same locations, and the one remaining in 1993 was seen until 1997, suggesting lifespans of at least 22 years.

Johnson and Roberts (2009) reviewed 216 studies on the effects of contaminants upon the diversity of marine communities and concluded that species richness tended to be the most sensitive index. Although our attempt at following species richness was not thorough (we did not specifically identify most species), it did show patterns seen in other studies (e.g., Bustamante et al. 2012, Díez et al. 2013), with the taxon richness values converging in the Soquel Point and Opal Cliffs plots two years after the sewage discharge was terminated. Afterwards, taxon richness remained remarkably stable and indistinguishable between the two plots. The same stability was seen in most of the other taxa monitored, the exceptions being *Phyllospadix* spp., *Corallina,* spp., and *Cryptopleura* spp., all of which took decades or more to reach comparable levels in the two plots. Such stability was seen despite considerable climatic and oceanographic variability that occurred during this time period (Pennington et al. 2007). There is little evidence, for example, of any impact from the major El Niño events of 1982 and 1997-98, except perhaps on the abundance of *Cryptopleura,* which was noticeably low in the Soquel Point plot in both 1982 and 1997 (see Fig. 20).

Our monitoring protocol is commonly used to monitor rocky intertidal shores (Murray et al. 2006); it averages multiple random samples taken within a defined area to detect changes in a relatively large area (in our case 450m^2 plots). It is what Menge et al. (2005) called the "mean field approach." However, it ignores changes that might be occurring *within patches* in the area. For example, many taxa were recorded in our surveys for the taxon richness data, most being different and in low abundance within the two plots and among years. Most of the species recorded for Soquel Point and other locations on the Santa Cruz-San Mateo coast in the early 1970s and mid 1990s were rare (Zabin et al. 2012). Consequently, even though taxon richness appeared to be very stable in our monitoring, we have little evidence that the same taxa were present year after year or in the two monitored plots. Consequently, our monitoring provides little information about the dynamic changes that may have gone on *within or among* patches in our plots.

Menge et al. (2005) examined community structure, disturbance by storms, and species interactions within a surfgrass meadow in Oregon using a "spatially explicit approach" that followed small individual quadrats over 15 years at 5 sites differing in wave exposure. They found, as we did, that average patterns of species abundance were relatively constant through time. In contrast, there was considerable change in the "mosaic elements" of their communities that were mainly related to wave exposure. As documented for other intertidal landscapes (Paine and Levin 1981, Sousa 1984), most changes noted by Menge et al. (2005) involved patches of competitive dominants (surfgrasses in their case) that were torn out by storms and then recovered, displacing other species that were more transitory. Our monitoring protocols would not detect such change within our plots if they occurred. Still, while documenting surfgrass slowly recolonizing space, the photos we took of the same 1m^2 quadrats showed considerable differences in species distribution and abundance within them (see Fig. 9). Clearly, interactions among species in our plots were likely very dynamic on a small scale, both spatially and temporally, even though our monitoring protocol, which addressed large scale disturbance and recovery, could not detect them

While surfgrass meadows appear to remain healthy in the northeastern Pacific, they can experience damage from human coastal activities, as has been seen in Korea where surfgrass meadows have been severely degraded by on-shore development (Park and Lee 2009). Pollution from oil spills, such as occurred when a tanker went aground on the Monterey Peninsula, also can destroy large areas of surfgrass (Walder and Foster 2000, McConnico and Foster 2005). In addition, surfgrass meadows will likely be susceptible to severe storms and rising sea level that are expected to result from global warming. And global warming could make surfgrass meadows susceptible to pathogens. For example, wasting diseases, caused by the heterokont *Labyrinthula,* which have devastated eelgrass (*Zostera marina* L.) meadows around the Northern Hemisphere, are now being found in other species of seagrasses (Sullivan et al. 2013).

The potential of large-scale losses of surfgrass meadows has led to several efforts to develop methods to restore them (Wyllie-Echeverria et al. 2007). Working with *Phyllospadix torreyi* in southern California, for example, Bull et al. (2004) found that transplanting short lengths of rhizomes was much more effective for establishing meadows than transplanting laboratory-reared seedlings. Park and Lee (2009) also used short pieces of shoots (with blades) to successfully establish meadows of *P. japonicus* in Korea. Success with pieces of transplanted surfgrasses rather than seeds or seedlings is in line with our finding of very slow recovery in the Soquel Point plot from field-recruited seedlings. Recently, attempts to establish surfgrass meadows using seeded artificial reefs have been promising (Park et al. 2014).

Our long-term monitoring program can be useful for resource managers of the National Marine Sanctuaries when they consider the status of surfgrass meadows in their areas of concern. Both natural and anthropogenic causes can lead to the degradation of surfgrass meadows that serve as carbon sinks and habitats for many other species, including those important for fisheries. Baselines such as those provided here can be used to detect and evaluate declines, as well as provide predictions about how these habitats might recover. As found by Turner (1983) and Turner and Lucas (1985) for *P. scouleri* in Oregon, we found that recovery of surfgrass meadows composed mainly of *P. torreyi* in central California takes decades. In contrast, many other species in the system recover much more quickly. How the whole system functions without the underlying foundation species remains unknown and should be better understood before efforts are made at restoration.

The Soquel Point and Opal Cliffs plots are now part of a citizen-science program, Long-term Monitoring Program and Experiential Training for Students (LiMPETS), which monitors the shores of California in an integrated effort to follow changes in habitat-forming organisms as recommended by Duncan et al. (2014). Data summarized here are on the LiMPETS website (limpets.org), and more data will be added as they are collected. These data can be used to assess the health of surfgrass meadows in northern Monterey Bay and provide a baseline in the event of future disturbance of this rich and diverse ecosystem.

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Appendix

Data used in this report: dates, means, standard deviations, and number of quadrats counted on each monitoring day in the Soquel Point and Opal Cliffs plots. Data compiled from the LiMPETS website, Access files archived by E.M. Danner, and summary tables and graphs archived by J.S. Pearse. Most of the original data taken before 2000 have been lost, and in some cases only means and sample sizes remain.

***Phyllospadix* spp.**

Soquel Point				Opal Cliffs			
Date	Mean	sd	#	Date	Mean	sd	#
1-Jun-73	0.1	0.4	22	4-Jun-73	9	6.9	21
25-Apr-74	0	0.0	19	26-Apr-74	12.3	8.4	25
27-Apr-75	0	0.0	30	29-Apr-75	15.1	5.8	23
15-May-76	0	0.0	35	16-May-76	11.7	7.6	24
25-Oct-76	0	0.0	15				
4-Jul-77	0	0.0	17	3-Jul-77	13.1	6.3	21
23-May-78	0.1	0.2	19	25-May-78	12.1	6.9	16
11-Jun-79	0	0.0	29	13-Jun-79	13.6	5.9	29
15-May-80	0.1	0.3	30	17-May-80	15.9	8.1	40
3-Jun-81	0.1	0.3	16	4-Jun-81	14.5	8.6	16
22-Jun-82	0.6	2.5	36				
12-Jun-83	2	5.2	28	13-Jun-83	8.5	8.1	32
15-Jun-84	2.2	6.2	32	16-Jun-84	18.4	9.4	28
4-Jun-85	2.4	6.2	36	5-Jun-85	13	7.6	32
23-Jun-86	5.2	8.7	24	24-Jun-86	14.3	7.8	20
13-Jun-87	0.8	2.0	24	14-Jun-87	11.5	6.8	16
4-Jun-88	3.4	6.4	32	5-Jun-88	12.8	7.3	28
23-Jun-90	8.6	10.1	28	24-Jun-90	17.8	10.2	28
13-Jun-91	2.7	5.6	20	14-Jun-91	12.1	7.3	24
5-May-92	10	7.2	30	1-May-92	15.6	7.9	35
21-Jun-93	5.4	7.5	24	22-Jun-93	13.7	7.2	28
24-Jun-94	4.4	6.0	36	25-Jun-94	11.8	7.6	32
13-Jul-95	7.5	6.7	26	14-Jul-95	14.5		24
4-Jun-96	7.7		26	5-Jun-96	14.5	6.2	24
21-Jun-97	12.3	11.5	40	22-Jun-97	22		24
26-Jun-98	12.2	9.9	23	25-Jun-98	16.6	8.6	31
15-Jun-99	14.4	8.4	24	16-Jun-99	17.8	7.1	27
3-Jul-00	9.1	9.0	30	2-Jul-00	14.9	7.1	27
26-May-01	9.4	8.8	15	27-May-01	16.8	6.7	29
27-May-02	12.9	9.9	17	26-May-02	14.2	8.9	21
18-May-03	9.5	8.6	23	17-May-03	16.4	7.2	26

12-Jun-06	11.2	7.6	29	13-Jun-06	12.9	5.6	23
4-Jul-12	14.8	8.1	10	8-May-12	14.3	8.3	16
14-Jun-14	16.1	8.1	12	16-Jun-14	15.6	5.7	11
17-Jun-15	8.3	4.3	14	2-Jul-15	13.1	5.6	15
Mean	5.5				14.3		

***Corallina* spp.**

Soquel Point				**Opal Cliffs**			
Date	Mean	sd	#	Date	Mean	sd	#
1-Jun-73	25	0.0	22	4-Jun-73	8.3	6.4	21
25-Apr-74	24.8	1.0	19	26-Apr-74	10.2	5.8	25
27-Apr-75	25	0.0	30	29-Apr-75	12.4	6.7	23
15-May-76	25	0.0	35	16-May-76	12.5	6.8	24
25-Oct-76	25	0.0	21				
4-Jul-77	25	0.0	17	3-Jul-77	8.8	5.8	21
23-May-78	25	0.0	19	25-May-78	7.2	5.5	16
11-Jun-79	23.9	3.0	29	13-Jun-79	3.4	3	29
15-May-80	19.6	6.6	30	17-May-80	2.7	3.2	37
3-Jun-81	23.8	1.9	16	4-Jun-81	2.9	3.3	16
22-Jun-82	14.1	10.7	36				
12-Jun-83	22.1	4.1	28	13-Jun-83	3.2	4.1	32
15-Jun-84	19.5	7.6	32	16-Jun-84	1.7	2.3	28
4-Jun-85	18.9	7.8	36	5-Jun-85	2.5	4.9	32
23-Jun-86	19.5	7.7	20	24-Jun-86	5.9	5.8	20
13-Jun-87	21.2	5.8	24	14-Jun-87	2.3	2.9	16
4-Jun-88	14.6	8.9	32	5-Jun-88	2.8	3.5	28
23-Jun-90	15.4	7.7	24	24-Jun-90	2.2	3.8	28
13-Jun-91	16.2	7.6	20	14-Jun-91	4.3	5.1	24
5-May-92	14.5	6.7	30	1-May-92	4.6	3.5	35
21-Jun-93	12.4	8.5	24	22-Jun-93	2	2.7	28
24-Jun-94	14.9	8.9	28	25-Jun-94	1.7	2.9	32
13-Jul-95	13.8	8.4	28	14-Jul-95	2.2	2.6	24
4-Jun-96	17.5		24	5-Jun-96	2		26
21-Jun-97	12.5		32	22-Jun-97	2		24
26-Jun-98	14.8	8.4	24	25-Jun-98	0.9	2	36
15-Jun-99	9.3	6.6	24	16-Jun-99	1.1	2	28
3-Jul-00	15.2	7.3	30	2-Jul-00	4.7	7.4	28
26-May-01	14.4	6.2	22	27-May-01	0.9	1.9	29
27-May-02	10.5	5.6	17	26-May-02	2.4	2.7	21
18-May-03	6.7	4.6	23	17-May-03	0.7	1.4	26
17-Jun-15	7.7	5.2	14	13-Jun-06	0.9	1.1	15
Mean	17.7				4.0		

Bossiella spp.

Soquel Point				Opal Cliffs			
Date	Mean	sd	#	Date	Mean	sd	#
1-Jun-73	2.3	3.5	22	4-Jun-73	17.4	4.2	21
25-Apr-74	1.1	2.3	19	26-Apr-74	17.6	5.9	25
27-Apr-75	1.5	1.8	30	29-Apr-75	10	6.6	23
15-May-76	11.4	5.7	35	16-May-76	17.8	6.5	24
4-Jul-77	7.1	4.8	17	3-Jul-77	15.8	5.1	21
23-May-78	11.7	4.1	19	25-May-78	10.2	4.3	16
11-Jun-79	8.2	6.6	29	13-Jun-79	10.8	5.9	29
15-May-80	11.2	6.6	30	17-May-80	11.8	4.2	37
3-Jun-81	6.4	4	16	4-Jun-81	10.3	4.4	15
22-Jun-82	8.4	9.6	36				
12-Jun-83	7.1	5	28	13-Jun-83	5	5.3	32
15-Jun-84	8.6	5	32	16-Jun-84	2.3	3.1	28
4-Jun-85	7.8	4.8	36	5-Jun-85	4.1	4.9	32
23-Jun-86	5.5	3.5	20	24-Jun-86	4.7	5.2	20
13-Jun-87	7.5	4.8	24	14-Jun-87	4.3	4.6	16
4-Jun-88	8.9	6.6	32	5-Jun-88	4.2	4.2	28
23-Jun-90	6.3	5	24	24-Jun-90	3.9	6.3	28
13-Jun-91	8.5	5.2	20	14-Jun-91	5.2	4.2	24
5-May-92	3.2	3.5	30	1-May-92	2.8	4.6	40
21-Jun-93	1.8	2.1	24	22-Jun-93	1.9	2.6	28
24-Jun-94	5	4.4	28	25-Jun-94	1.6	2.7	32
13-Jul-95	2.2	3.2	28	14-Jul-95	0.8	1.2	24
26-Jun-98	4.8	5.7	24	25-Jun-98	4.8	5.7	24
15-Jun-99	8.1	7.4	24	16-Jun-99	2.8	3.6	28
3-Jul-00	11.1	7.7	30	2-Jul-00	3.5	5.6	28
26-May-01	7.1	6.7	22	27-May-01	2	2.7	29
27-May-02	8.2	4.3	17	26-May-02	1.8	2.4	21
18-May-03	10	6.7	23	17-May-03	2.2	2.7	26
17-Jun-15	2.4	3.5	14	13-Jun-06	1.4	1.5	15
Mean	6.7				6.5		

***Cryptopleura* spp**

Soquel Point				Opal Cliffs			
Date	Mean	sd	#	Date	Mean	sd	#
1-Jun-73	0.5	0.9	22	4-Jun-73	12.8	5.5	21
25-Apr-74	0.2	0.4	19	26-Apr-74	12.2	7.6	25
27-Apr-75	0.03	0.2	30	29-Apr-75	11.5	6.7	23

15-May-76	20.3	3.4	35	16-May-76	11.7	6.4	24
4-Jul-77	22.8	2.7	17	3-Jul-77	18.1	5.8	21
23-May-78	23.8	2.8	19	25-May-78	16.6	7.1	16
11-Jun-79	23.9	1.4	29	13-Jun-79	10	8.3	29
15-May-80	16.0	8.2	32	17-May-80	5.8	5.7	38
3-Jun-81	18.6	4.9	16	4-Jun-81	6.9	6.9	16
22-Jun-82	7.6	9.0	34				
12-Jun-83	15.6	8.5	28	13-Jun-83	5.2	6.2	32
15-Jun-84	16.3	8.0	30	16-Jun-84	3	3.3	26
4-Jun-85	13.8	7.2	35	5-Jun-85	3.6	3.8	31
23-Jun-86	19.3	6.7	20	24-Jun-86	6.2	5	20
13-Jun-87	21.1	5.7	24	14-Jun-87	5.7	5.5	17
4-Jun-88	16.1	8.4	32	5-Jun-88	5.9	6.5	28
23-Jun-90	13.7	7.7	24	24-Jun-90	2.9	5.2	28
13-Jun-91	16.6	8	20	14-Jun-91	8.5	7.1	24
5-May-92	14.9	5.8	30	1-May-92	8.4	6.2	40
21-Jun-93	7.5	6.1	24	22-Jun-93	3.5	3.3	28
24-Jun-94	13.5	7.7	28	25-Jun-94	2.8	3.1	32
13-Jul-95	8.2	7.2	28	14-Jul-95	1.9	2.8	24
4-Jun-96	12		24	5-Jun-96	2.3		26
21-Jun-97	5.5		32	22-Jun-97	3		24
26-Jun-98	11.4	8.4	23	25-Jun-98	2.8	3.8	31
15-Jun-99	12.2	7.3	24	16-Jun-99	3.9	4.2	27
3-Jul-00	12.1	7.0	30	2-Jul-00	1.6	2.9	27
26-May-01	8.1	5.2	15	27-May-01	3.3	3.4	29
27-May-02	10.5	7.5	17	26-May-02	2.7	3.4	21
18-May-03	14	6.7	23	17-May-03	6.6	3.6	26
12-Jun-06	9.4	6.6	28	13-Jun-06	6.8	6.1	23
4-Jul-12	7.3	7.7	10	8-May-12	7.6	6.6	16
14-Jun-14	9	8.2	12	16-Jun-14	7	6	11
17-Jun-15	10.8	6.5	14	2-Jul-15	10.4	5.3	15
Mean	12.7				6.7		

***Ulva* spp.** **Soquel Point**

Date	Mean	sd	#
1-Jun-73	17.4	6.8	22
25-Apr-74	0.3	1.4	19
27-Apr-75	0.5	1	30
15-May-76	4.9	2.8	35
4-Jul-77	22.2	4.7	17
23-May-78	21.9	2.9	19

Ulva **Opal Cliffs**

Date	Mean	sd	#
4-Jun-73	19.5	4.7	21
26-Apr-74	14.6	7.3	25
29-Apr-75	9.4	8.4	23
16-May-76	8.8	5.9	24
3-Jul-77	7.2	5.3	21
25-May-78	2.4	3.2	16

11-Jun-79	1.3	1.6	29	13-Jun-79	0.5	1.8	29
15-May-80	7	5.6	30	17-May-80	7.2	8.2	37
3-Jun-81	1.6	1.5	16	4-Jun-81	3.9	5.9	15
22-Jun-82	6.7	7.6	36				
12-Jun-83	3.9	5	28	13-Jun-83	6.6	7.91	32
15-Jun-84	3.5	4.8	32	16-Jun-84	0.9	1.64	28
4-Jun-85	8.3	8	36	5-Jun-85	2.5	3.42	32
23-Jun-86	6.9	6.2	20	24-Jun-86	10.9	8.28	20
13-Jun-87	5.3	4.4	24	14-Jun-87	3.9	3.79	16
4-Jun-88	9.8	7.7	32	5-Jun-88	10.4	7.54	28
23-Jun-90	8	6.6	24	24-Jun-90	7.4	8.12	32
13-Jun-91	5.4	4.5	20	14-Jun-91	6.8	5.73	24
5-May-92	0.8	2.2	30	1-May-92	0.8	1.59	40
21-Jun-93	0.2	0.6	24	22-Jun-93	1.11	1.79	28
24-Jun-94	2	3	28	25-Jun-94	5.5	5.42	32
13-Jul-95	0.2	0.8	28	14-Jul-95	4.2	6.8	24
				5-Jun-96	0.2		26
				22-Jun-97	3.1		24
26-Jun-98	1.8	4.3	23	25-Jun-98	10.5	7.6	31
15-Jun-99	5.3	4	24	16-Jun-99	6.1	6.8	27
3-Jul-00	5.4	4.1	30	2-Jul-00	7.4	7.4	27
26-May-01	9.6	8.2	15	27-May-01	9.1	6.4	29
27-May-02	2.5	3.2	17	26-May-02	7.2	7.7	21
18-May-03	2.6	2.6	23	17-May-03	4.9	4.4	26
12-Jun-06	3.3	4.4	29	13-Jun-06	8.5	5	23
4-Jul-12	1.6	3.5	10	8-May-12	0.1	0.5	16
14-Jun-14	0.5	0.9	12	16-Jun-14	4.7	7	11
17-Jun-15	15.2	7.6	14	2-Jul-15	4.9	4	15
Mean	5.9				6.1		

Anthopleura sola

Soquel Point				**Opal Cliffs**			
Date	Mean	sd	#	Date	Mean	sd	#
1-Jun-73	2.1	1.2	15	4-Jun-73	0.9	1.6	14
25-Apr-74	1.5		17	26-Apr-74	0.9		14
27-Apr-75	2		24	29-Apr-75	0.9		23
15-May-76	3.1	1.9	15	16-May-76	0.6		15
25-Oct-76	1.9	1.6	21	23-Oct-76	1.5	1.8	24
4-Jul-77	1.9	1.8	23	3-Jul-77	1.3	1.7	20
23-May-78	1.4	1.5	22	25-May-78	0.3	0.6	24
11-Jun-79	1.4	1	28	13-Jun-79	0.8	0.8	24
15-May-80	1.8	1.7	36	17-May-80	0.8	1.1	39

3-Jun-81	1.5	2.1	20	4-Jun-81	0.4	0.7	16
22-Jun-82	2.5	1.9	41				
12-Jun-83	1.4	1.1	28	13-Jun-83	0.8	1.2	32
15-Jun-84	2.3	2.1	32	16-Jun-84	0.6	0.8	26
4-Jun-85	1.8	1.9	35	5-Jun-85	0.8	1.1	31
23-Jun-86	1.4	1.6	20	24-Jun-86	0.7	0.9	20
13-Jun-87	1.2	1.2	24	14-Jun-87	0.7	1.0	16
4-Jun-88	1.6	1.3	30	5-Jun-88	0.7	0.9	27
23-Jun-90	1.7	1.6	22	24-Jun-90	0.9	1.0	27
13-Jun-91	1.3	1.5	18	14-Jun-91	0.7	0.8	22
5-May-92	0.9	1.1	30	1-May-92	0.6	0.9	35
21-Jun-93	1.3	1.4	17	22-Jun-93	0.9	1.1	28
24-Jun-94	1.8	1.7	25	25-Jun-94	0.8	1.1	30
13-Jul-95	1.5	1.6	25	14-Jul-95	0.6	0.7	23
4-Jun-96	2.2	1.7	26	5-Jun-96	1.2	1.2	26
				22-Jun-97	0.7	1.2	23
26-Jun-98	1.6	1.3	23	25-Jun-98	1.1	1.3	29
15-Jun-99	2	1.4	24	16-Jun-99	1.0	1.1	27
3-Jun-00	2.2	1.5	31	2-Jul-00	1.2	1.5	27
26-May-01	2.1	1.6	15	27-May-01	1.2	1.1	29
27-May-02	1.4	1.7	17	26-May-02	1.2	1.7	21
18-May-03	1.2	1.1	23	17-May-03	1.3	1.6	26
12-Jun-06	0.9	1	29	13-Jun-06	1	1.3	23
4-Jul-12	0.3	0.5	10	8-May-12	0.6	1.2	16
14-Jun-14	0.8	1	12	16-Jun-14	1.6	1.8	11
17-Jun-15	0.9	1.4	14	2-Jul-15	0.7	1	15
Mean	1.6				0.6		

Phragmatopoma californica

Soquel Point				**Opal Cliffs**			
Date	Mean	sd	#	Date	Mean	sd	#
1-Jun-73	0.1	0.3	16	4-Jun-73	3.1	5.5	14
25-Apr-74	0.3	0.6	20	26-Apr-74	2.8	5.8	16
27-Apr-75	0.5	1.2	24	29-Apr-75	1.9	2.5	24
15-May-76	0.3	0.8	15	16-May-76	2.3	2.9	15
25-Oct-76	0.6	1.4	21	23-Oct-76	2.7	2.9	24
4-Jul-77	0.1	0.3	23	3-Jul-77	1.7	3.1	20
23-May-78	0	0	22	25-May-78	0.04	0.2	24
11-Jun-79	0.1	0.4	28	13-Jun-79	0.3	1	24
15-May-80	0.03	0.2	36	17-May-80	0.2	0.5	39
3-Jun-81	0.1	0.5	20	4-Jun-81	0.4	1.1	16
22-Jun-82	0.3	1.6	41				

12-Jun-83	0	0	28	13-Jun-83	0	0	32
15-Jun-84	1.2	2.8	32	16-Jun-84	0.04	0.2	26
4-Jun-85	0.8	2.2	34	5-Jun-85	0.9	2.2	31
23-Jun-86	0.1	0.2	20	24-Jun-86	0.7	1.8	20
13-Jun-87	0	0	24	14-Jun-87	0	0	16
4-Jun-88	0	0	32	5-Jun-88	0	0	10
23-Jun-90	0.04	0.2	24	24-Jun-90	0.04	0.2	24
13-Jun-91	0.4	1.2	20	14-Jun-91	0	0	24
5-May-92	0.2		30	1-May-92	0.6	2.1	40
21-Jun-93	0.2	0.4	24	22-Jun-93	0.3	0.8	28
24-Jun-94	0	0	30	25-Jun-94	0	0	32
13-Jul-95	0	0	24	14-Jul-95	0	0	28
			23	5-Jun-96	0.2		24
			24	22-Jun-97	0.1		23
26-Jun-98	0.04	0.2	23	25-Jun-98	0.03	0.2	29
15-Jun-99	0.04	0.2	24	16-Jun-99	0.3	1.4	27
3-Jul-00	1.8	4.3	30	2-Jul-00	1.1	2.3	27
26-May-01	0.7	2	15	27-May-01	0.1	0.7	29
27-May-02	0.3	1	17	26-May-02	1.1	3.7	21
18-May-03	0.4	0.9	23	17-May-03	0.2	0.8	26
12-Jun-06	0	0	29	13-Jun-06	0.04	0.2	23
4-Jul-12	0.1	0.3	10	8-May-12	0.1	0.3	16
14-Jun-14	0	0	12	16-Jun-14	0	0	11
17-Jun-15	0.7	1.7	14	2-Jul-15	0	0	15
Mean	0.3				0.9		

***Tegula* spp.**

Soquel Point				**Opal Cliffs**			
Date	Mean	sd	#	Date	Mean	sd	#
1-Jun-73	1.9	2.1	16	4-Jun-73	0.4	0.5	14
25-Apr-74	1.4	2.8	20	26-Apr-74	0.7	1	16
27-Apr-75	2.3	4.3	24	29-Apr-75	0.5	0.8	24
15-May-76	4.6	4.2	15	16-May-76	0.1	0.4	15
25-Oct-76	2.1	3.6	21	23-Oct-76	0.04	0.2	24
4-Jul-77	0.9		17	3-Jul-77	0.2	0.4	20
23-May-78	0.3	0.5	12	25-May-78	0.1	0.3	24
11-Jun-79	0.1		25	13-Jun-79	0.1	0.3	24
15-May-80	0.2		30	17-May-80	0.1	0.6	39
3-Jun-81	0.3		15	4-Jun-81	0.1	0.3	16
22-Jun-82	0.3	0.5	24				
12-Jun-83	0.3		28	13-Jun-83	0.2	0.5	32

15-Jun-84	0.3	0.5	24	16-Jun-84	0.04	0.2	26
4-Jun-85	0.4	0.5	26	5-Jun-85	0.1	0.3	31
23-Jun-86	0.1		19	24-Jun-86	0.1	0.3	20
13-Jun-87	0.2		22	14-Jun-87	0	0	16
4-Jun-88	0.1		30	5-Jun-88	0.1	0.3	10
23-Jun-90	0		22	24-Jun-90	0.0	0.0	27
13-Jun-91	0.4	0.5	16	14-Jun-91	0.2	0.4	22
5-May-92	0.1		30	1-May-92	0.03	0.2	35
21-Jun-93	0.2		17	22-Jun-93	0.04	0.2	28
24-Jun-94	0		30	25-Jun-94	0.03	0.2	30
13-Jul-95	0		25	14-Jul-95	0.1	0.5	23
4-Jun-96	0.3		24	5-Jun-96	0.0	0.0	28
21-Jun-97	0	0	28	22-Jun-97	0.0	0.0	23
26-Jun-98	0	0	23	25-Jun-98	0.1	0.3	29
15-Jun-99	0.1	0.4	24	16-Jun-99	0.2	0.6	27
3-Jul-00	0.1	0.4	30	2-Jul-00	0	0	27
26-May-01	0	0	15	27-May-01	0.1	0.3	29
27-May-02	0.1	0.5	17	26-May-02	0	0	21
18-May-03	0.3	0.5	23	17-May-03	0.4	1.1	26
12-Jun-06	0.1	0.3	29	13-Jun-06	0.9	2	23
4-Jul-12	0	0	10	8-May-12	0.1	0.3	16
14-Jun-14	0.2	0.6	12	16-Jun-14	0.1	0.3	11
17-Jun-15	0.2	0.3	14	2-Jul-15	0.1	0.3	15
Mean	0.5				0.2		

***Pagurus* spp.**

Soquel Point				**Opal Cliffs**			
Date	Mean	sd	#	Date	Mean	sd	#
1-Jun-73	0.1	0.3	16	4-Jun-73	4.9	6.1	14
25-Apr-74	0	0	20	26-Apr-74	3.1	3.5	16
27-Apr-75	0.7	1.4	24	29-Apr-75	2.1	2.9	24
15-May-76	1.3	0.3	15	16-May-76	3.2	1.8	15
25-Oct-76	9.1	13.4	21	23-Oct-76	2.1	2.5	24
4-Jul-77	8.4	7.9	23	3-Jul-77	3.5	2.8	20
23-May-78	19.1	30.6	22	25-May-78	4.8	5.3	24
11-Jun-79	0.5	1.4	28	13-Jun-79	2.8	4.3	24
15-May-80	2.8	6.5	36	17-May-80	5.8	6.3	39
3-Jun-81	2.8	4.2	20	4-Jun-81	4.9	6.6	16
22-Jun-82	1.7	3.1	41				
12-Jun-83	1.2	2.9	28	13-Jun-83	2.2	3.5	32
15-Jun-84	2.8	3.7	32	16-Jun-84	3.6	4.8	26
4-Jun-85	2.4	4.2	34	5-Jun-85	3.6	4.2	31

23-Jun-86	6.1	7.5	20	24-Jun-86	7.9	12.6	20
13-Jun-87	0.8	0.9	24	14-Jun-87	5.3	8.9	16
4-Jun-88	0.3	0.5	30	5-Jun-88	3.0	6.4	27
23-Jun-90	1.1	1.3	22	24-Jun-90	2.5	3.3	27
13-Jun-91	1.1	1.4	18	14-Jun-91	3.7	3.7	22
5-May-92	0.4	0.9	30	1-May-92	2.3	3.3	35
21-Jun-93	1.1	1.8	17	22-Jun-93	3.6	5.1	28
24-Jun-94	1.4	1.7	25	25-Jun-94	2.0	1.8	30
13-Jul-95	1	1.2	25	14-Jul-95	2.1	2.6	23
4-Jun-96	1.2	1.3	26	5-Jun-96	5.3	4.9	28
21-Jun-97	0.3	0.7	28	22-Jun-97	2.8	3.0	40
26-Jun-98	1	1.8	23	25-Jun-98	4.7	4.5	29
15-Jun-99	1.5	1.8	24	16-Jun-99	4.6	4.4	27
3-Jul-00	1.9	1.8	30	2-Jul-00	9.5	13.3	27
26-May-01	1.1	1.2	15	27-May-01	8.7	6.3	29
27-May-02	3.4	5	17	26-May-02	6.3	6.6	21
18-May-03	1.7	3.1	23	17-May-03	8.2	7.5	26
12-Jun-06	0.4	0.7	28	13-Jun-06	5	4.9	23
4-Jul-12	1	1.5	10	8-May-12	3.6	3.8	16
14-Jun-14	1.1	2.9	12	16-Jun-14	8.8	8.1	11
17-Jun-15	0.5	1	14	2-Jul-15	2.9	3.6	15
Mean	2.3				4.4		

Total Macrophytes

Soquel Point				**Opal Cliffs**			
Date	Mean	sd	#	Date	Mean	sd	#
1-Jun-73	3.8	1.5	22	4-Jun-73	10.8	2.1	21
25-Apr-74	2	1.3	19	26-Apr-74	8.2	1.6	25
27-Apr-75	2	0.7	30	29-Apr-75	8	2.3	23
15-May-76	5.8	0.5	15	16-May-76	8	2.2	24
4-Jul-77	5.8	0.2	17	3-Jul-77	8	1.8	21
23-May-78	8.5	2	19	25-May-78	7.3	1.4	16
11-Jun-79	6	1	29	13-Jun-79	6	1.3	29
15-May-80	7	0.7	30	17-May-80	7.5	1.4	37
3-Jun-81	7.8	1.2	20	4-Jun-81	6.2	1.3	15
22-Jun-82	6.2	1.7	34				0
12-Jun-83	6.3	1.4	28	13-Jun-83	5.8	1.7	28
15-Jun-84	5.6	2	26	16-Jun-84	5.8	1.3	30
4-Jun-85	6	2	30	5-Jun-85	7	1.4	33
23-Jun-86	8	2.2	19	24-Jun-86	10	2.2	20
13-Jun-87	7.8	1.8	23	14-Jun-87	7.8	2	15
4-Jun-88	8	1.2	31	5-Jun-88	7.7	0.8	26

23-Jun-90	8.1	1.5	22	24-Jun-90	8.1	1.1	23
13-Jun-91	8	1.7	18	14-Jun-91	8	1.7	22
5-May-92	6.8	0.8	30	1-May-92	6.5	1.3	22

Total Macroinvertebrates

Soquel Point				**Opal Cliffs**			
Date	Mean	sd	#	Date	Mean	sd	#
1-Jun-73	5.2	1.1	22	4-Jun-73	13.2	3.3	21
25-Apr-74	2.8	0.8	19	26-Apr-74	11.5	4	25
27-Apr-75	5.8	2	30	29-Apr-75	9.6	2.3	23
15-May-76	7	1.3	15	16-May-76	9.8	2.1	24
4-Jul-77	9	1.6	17	3-Jul-77	13	4.6	21
23-May-78	7.8	1.8	19	25-May-78	7.6	1.7	16
11-Jun-79	3	1.2	29	13-Jun-79	7.7	3	29
15-May-80	5.2	1.7	30	17-May-80	7.8	2.3	37
3-Jun-81	5	3.7	20	4-Jun-81	5.8	2.3	15
22-Jun-82	5.8	1.8	34				0
12-Jun-83	3.8	1.3	28	13-Jun-83	5.7	2	28
15-Jun-84	7.8	1.6	26	16-Jun-84	5.8	2.3	30
4-Jun-85	5	2	30	5-Jun-85	7.5	2.4	33
23-Jun-86	6.2	2	19	24-Jun-86	7.8	2.3	20
13-Jun-87	6	2.3	23	14-Jun-87	7.5	2.6	15
4-Jun-88	5.5	1.1	31	5-Jun-88	6	1.8	26
23-Jun-90	5.8	2	22	24-Jun-90	6.2	2.2	23
13-Jun-91	5.4	2.2	18	14-Jun-91	5.8	2.1	22
5-May-92	4.2	1.8	30	1-May-92	4	2.1	22