

Biodiversity of the Rocky Intertidal Zone in the Monterey Bay National Marine Sanctuary: A 24-Year Comparison

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Ten rocky intertidal platforms along the coast of San Mateo and Santa Cruz counties were surveyed for biotic richness in 1971–1973 by students of the University of California, Santa Cruz, with support from California Sea Grant and the Association of Monterey Bay Area Governments. The data gathered provided a baseline that could be used for evaluating future changes. In 1996–1997, students from the university resurveyed these 10 sites, with support from California Sea Grant and the Monterey Bay National Marine Sanctuary. The data collected were compared with earlier data to assess how the biota on this coast had changed over the past 24 years, after experiencing droughts, floods, a major El Niño, a severe earthquake, and increasing disturbance by humans.

Sites were chosen to range from areas heavily affected by humans within Monterey Bay to more remote areas on the open coast of southern San Mateo County (Figure 1). A small domestic sewer outfall occurred intertidally at Soquel Point until 1976, and another just offshore at Almar Street until 1988. Clamming continues to be popular at Point Santa Cruz, and Natural Bridges is used extensively for tide-pooling excursions. In contrast, access to Pigeon Point and the Año Nuevo sites is difficult; the Año Nuevo area is also protected from human activities, because of the growing elephant seal population.

Each site was surveyed at low tide by teams of 20–30 students on 2 days during the spring quarters of 1996 and 1997 and on 1 day during the fall quarter of 1996. This regimen was more focused than that of 1971–1973, when smaller groups of students visited the sites for seven successive quarters (fall 1971–spring 1973). Extensive surveys were made of most groups of

macroscopic algae and invertebrates that could be found without destroying the habitat; fishes were also sampled in 1996–1997, but not in the 1970s. Specimens that could not be identified in the field were identified in the laboratory, and preserved for documentation. Vouchers of most invertebrate species found in the 1970s were deposited in the collections of the California Academy of Sciences to be used for verification of identification in comparison with species collected in the 1990s. Professional consultants helped with particularly difficult taxa: algae (Kathy Ann Miller), sponges (Welton Lee), and bryozoans (Judith Winston).

In addition to the surveys of species richness, quantitative surveys were done at 5 of the 10 sites beginning in the early 1970s and continued intermittently to the present (Figure 1). Relatively flat uniform areas covered with characteristic visually dominant species (mussels, anemones, algae, surf grasses) were selected and served as large permanent plots that could be randomly sampled by using 50 x 50-cm² quadrats.

Species richness was similar for 1971–1973 and 1996–1997 for both algae and invertebrates (Figure 2). Nearly the same numbers of species of algae were found at all sites, reflecting the thorough surveys done by experienced workers in both surveys. However, an average of 30% more species of invertebrates was found at each site in the 1990s than in the 1970s, probably because of experience gained by the principal investigator during the intervening years. The Año Nuevo sites were particularly rich in number of invertebrate species in the 1970s, which was attributed to enrichment by the growing seal rookeries there (Pearse, 1981). On the other hand, the increase in species numbers at the Año Nuevo sites in the 1990s was less than expected, possibly because the number of pinnipeds in the rookeries had reached detrimental levels. Higher than expected numbers of invertebrate species were notable at the relatively remote and exposed sites at Pigeon Point and the heavily used, more protected sites at Point Santa Cruz and Soquel Point within Monterey Bay. The increase at Soquel Point, at

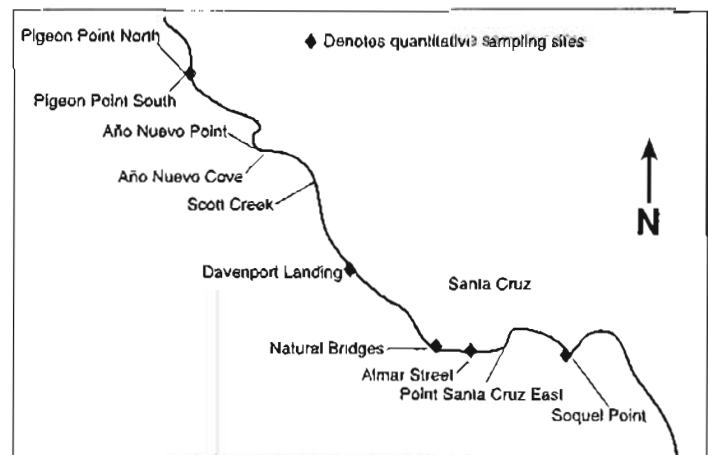


Figure 1. Locations of the 10 rocky intertidal sites on the coast of Santa Cruz and southern San Mateo counties that were intensively surveyed for species composition in 1971–1973 and 1996–1997. The 5 sites where permanent plots were established for quantitative sampling (see Figure 4) are designated with diamonds.

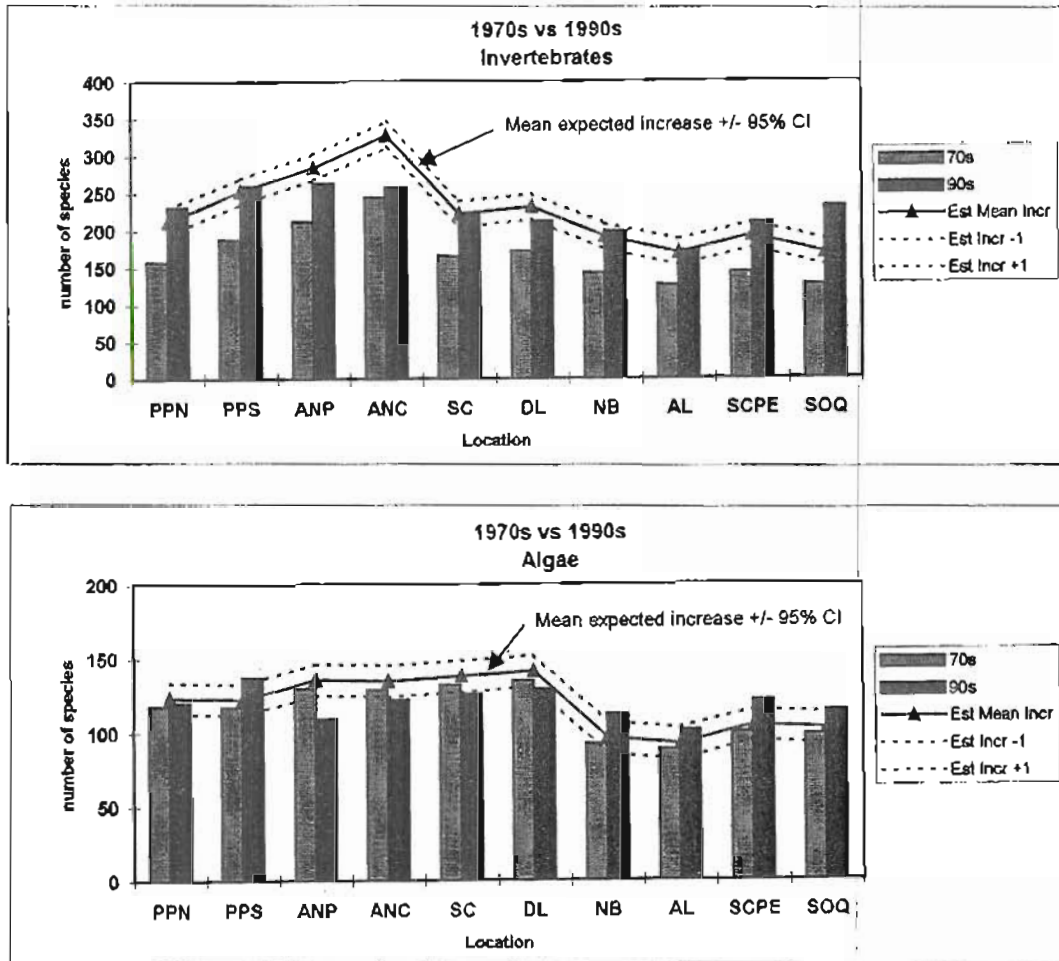


Figure 2. Number of species found at each site in 1971–1973 and 1996–1997. The average change \pm 95% confidence interval (CI) is added to the 1970s values to indicate the expected values for the 1990s. PPN, Pigeon Point north; PPS, Pigeon Point south; ANP, Año Nuevo Point; ANC, Año Nuevo Cove; SC, Scott Creek; DL, Davenport Landing; NB, Natural Bridges; AL, Almar Street; SCPE, Santa Cruz Point east; SOQ, Soquel Point; Est, estimated; Incr, increase.

least, almost certainly reflects a response to the termination of the sewer outfall there in 1976.

The visually dominant species also remained stable at each of the sites, as shown by both photographic and quantitative sampling data (except Soquel Point, where surf grasses eventually returned after the sewer discharge was terminated in 1976). Mussel beds continue to dominate the platforms at Almar Street, Natural Bridges, and Davenport Landing (Figure 3); anemone beds dominate another large part of the Davenport Landing site; and mixed red algal cover predominates at Año Nuevo, Pigeon Point, and Point Santa Cruz. The Scott Creek site is unusual; it has an extremely mixed cover of visual dominants, with beds of mussels, anemones,

and red algae, but the mosaic pattern also has remained unchanged over the past 24 years.

Similarity among the sites with respect to shared species showed a similar pattern between 1972–1973 and 1996–1997 (Figure 4). The San Mateo sites at Pigeon Point and Año Nuevo remained distinct and separate from sites on the Santa Cruz coastline. Such similarity suggests long-term, site-specific stability within these different assemblages. However, the Soquel Point site, which placed outside all the other sites in the 1970s, clustered with Point Santa Cruz, the other site within Monterey Bay, in the 1990s; as noted with the species richness data, this change almost certainly reflects the recovery from the sewage discharge at Soquel Point.

Despite the apparent stability of these rocky intertidal platforms, species composition at all the sites showed considerable flux. About two thirds of the algal species and half of the invertebrate species found at each site were present in both the early 1970s and the mid-1990s (Figure 5). Many of the species were relatively rare and were found only at one or two sites during the entire surveys and at different sites during the two periods. Others were so rare that they were found only once or twice anywhere. The Año Nuevo sites contained an exceptionally high proportion of rare species of invertebrates, a finding that partially accounts for the high species richness of the sites. These results indicate that thorough, repeated surveys of a site are needed before

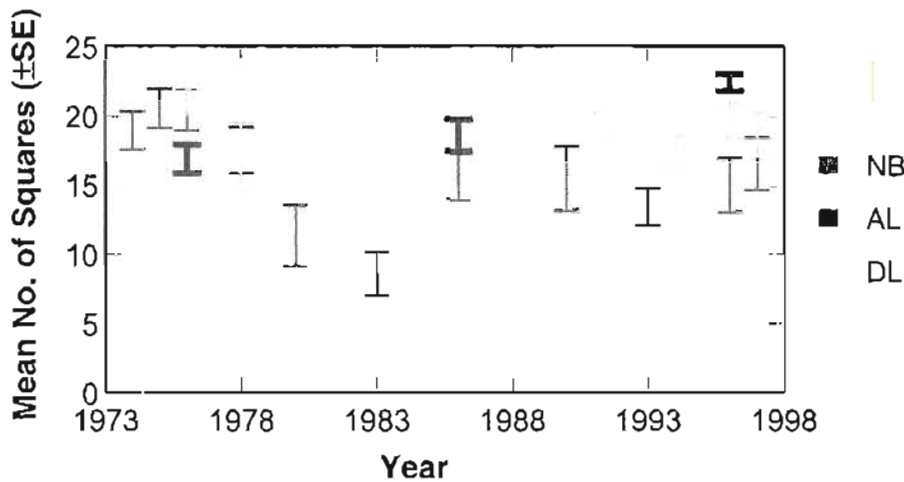


Figure 3. Abundance of the sea mussel *Mytilus californianus* from 1973 to 1997 in plots at three sites with large mussel beds. The mean number of 10 × 10-cm squares with mussels within 10–30 randomly placed 0.25-m² quadrats is plotted. AL, Almar Street; DL, Davenport Landing, NB, Natural Bridges; SE, standard error.

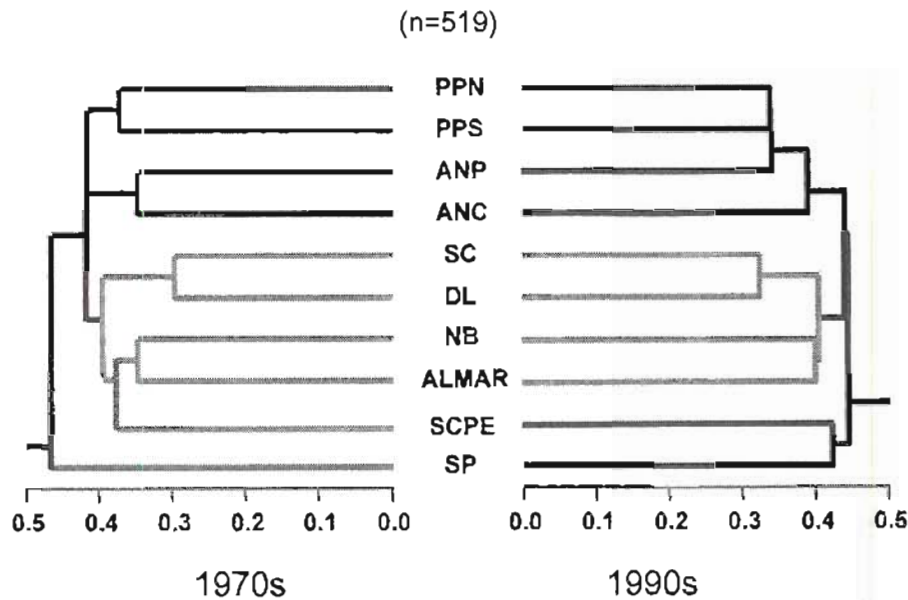


Figure 4. Similarities among the 10 different sites in species composition of invertebrates in the 1971–1973 and 1996–1997 surveys. Similarity index is the number of species in common. Note little change in pattern, except for Soquel Point (SP) where the Santa Cruz County sewage outfall existed until it was shut down in 1976. Site designations same as in Figure 2.

the full species richness of the site can be reliably determined or used for comparison with other times or sites.

Species turnover between the two study periods was chaotic, without much evident pattern. Increases in the numbers of invertebrate species occurred mainly at Pigeon Point, Point Santa Cruz, and Soquel Point (see Figure 2); the change at the

Soquel Point site reflected recovery from the termination of the intertidal sewage outfall there in 1976. We have not been able to detect an underlying pattern of particular classes of species that have changed. Among the invertebrates, approximately 28% of the species have the center of their distribution south of Monterey Bay, 15% have the center of their distribution north

of Monterey Bay, and 57% appear to have broad coastwide distributions. This pattern held for both times studied, even for sites that increased in species richness. We found little evidence of a shift in species composition during the past 24 years that might reflect global warming, as indicated by a 70-year comparison of a site in southern Monterey Bay (Barry et al., 1995).

These surveys show that there is considerable flux in species composition, both spatially and temporally, in the rocky intertidal biota of southern San Mateo and Santa Cruz counties. Nevertheless, a remarkable stability has existed during the past two-plus decades, and we found no evidence of degradation or deterioration despite increasingly heavy use by people.

The data collected in these surveys are still being analyzed. Moreover, they are being transferred to an electronic database to be maintained by the California Academy of Sciences for accessibility for future workers.

Accomplishments

Although considerable flux occurred in species composition of algae and invertebrates at each site during the past 24 years, little change has occurred overall within or among the sites. Nearly the same numbers of species of algae were found at all sites in 1996–1997 as in 1971–1973, regardless of the degree of disturbance by humans. More species of invertebrates were recorded at every site in the mid-1990s than in the early 1970s, but this increase mainly reflected increased experience by the project leader. We found no evidence of ecologic degradation, even at the sites most heavily used by humans. One site, Soquel Point, showed marked improvement between the two study periods. This site is adjacent to the County of Santa Cruz's sewage outfall that was discontinued in 1976; the site is now nearly indistinguishable from surrounding areas after a protracted recovery during the past 20 years.

These results are encouraging with respect to the ecologic health of

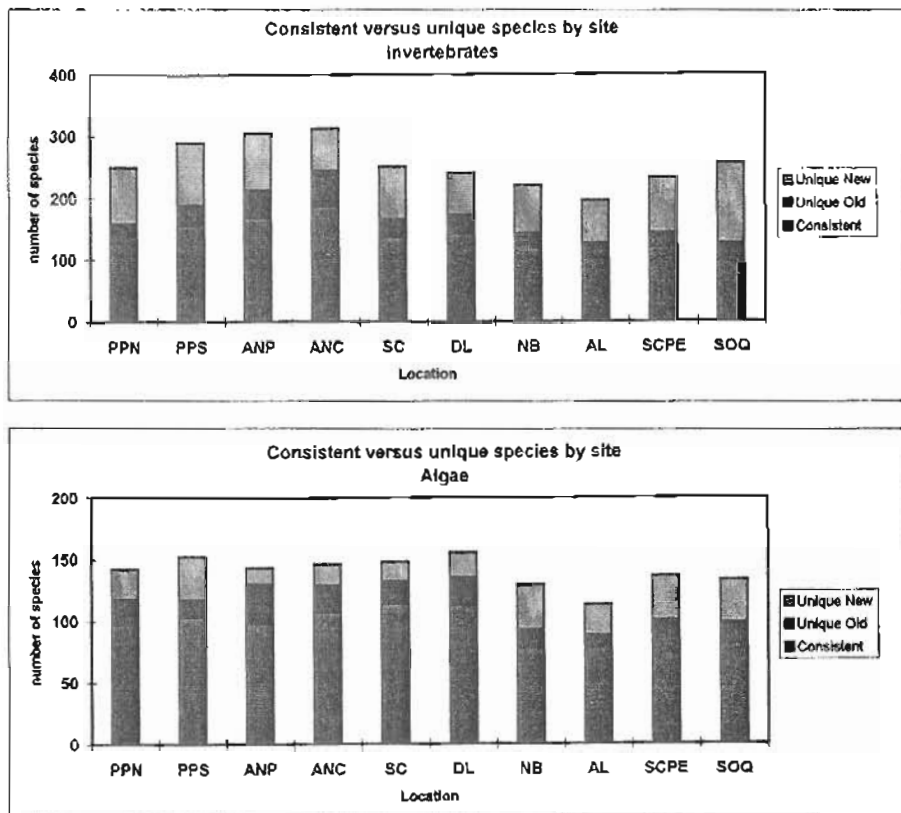


Figure 5. Number of species found at each site in both the 1971–1973 and 1996–1997 surveys (consistent species) and number of species found during only the survey periods (unique species). Site designations same as in Figure 2.

the intertidal biota of central California. Improved sewage treatment (consolidating and extending outfalls, upgrading treatment) probably has helped maintain this condition, and at one site, Soquel Point, has reversed a degraded condition. Moreover, increased public awareness and sensitivity during the past two decades probably has led to more careful use of popular intertidal platforms, particularly those adjacent to Natural Bridges State Beach, which now supports an active interpretive docent program for visitors to the rocky intertidal area who use our information.

Benefits

Our results have been welcomed by staff at the Monterey Bay National Marine Sanctuary, who intend to incorporate the data into descriptions of the sanctuary habitats and into management plans. The results have also been reassuring to the

Department of Parks and Recreation in their stewardship over the intertidal zone at Natural Bridges State Beach and Año Nuevo State Park. Incorporation of the results into the California Academy of Sciences databases assures that the data can be used for assessing changes in the intertidal biota in the future.

Cooperating Organizations

California Academy of Sciences, San Francisco, California
 Monterey Bay National Marine Sanctuary, Monterey, California
 University of California, Santa Cruz

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Presentations

- Watson, L., E. Danner, C. Zabin, and J. Pearse, J. 24-year comparison of the rocky intertidal of central California. Presented at the annual meeting of the Western Society of Naturalists, La Paz, Baja California Sur, Mexico, January 1997.
- Pearse, J., E. Danner, L. Watson, and C. Zabin. Stability and flux in the rocky intertidal (poster). Presented at the annual research symposium of the Monterey Bay National Marine Sanctuary, Santa Cruz, California, March 1997 (received symposium outstanding poster award).
- Danner, E., L. Watson, C. Zabin, and J. Pearse. Stability and flux in the rocky intertidal of central California: A 24-year comparison. Presented at the symposium for Marine Conservation Biology, Victoria, British Columbia, June 1997.
- Pearse, J. Stability and flux in the rocky intertidal. Presented to the Friends of the Moss Landing Marine Laboratories, Moss Landing, California, July 1997.
- Pearse, J. Stability and flux in the rocky intertidal of central California: A 24-year comparison. Presented at the Smithsonian Tropical Research Institute, Panama City, Panama, September 1997.
- Pearse, J. The rocky intertidal of central California: Good news. Presented at the University of California, Santa Cruz, October 1997, and at Monterey Bay Aquarium Research Institute, Moss Landing, California, November 1997.
- Pearse, J., E. Danner, L. Watson, and C. Zabin. Recovery of a rocky intertidal after closure of a sewage discharge. Presented at the annual meeting of the Western Society of Naturalists, Monterey, California, December 1997.