

INTERTIDAL ECOLOGY OF SAN NICOLAS ISLAND

R. I. Caplan¹ and R. A. Boolootian²

University of California, Los Angeles

INTRODUCTION

The islands are among the last native frontiers found in the southern California region. With growth and expansion of human activity it seems probable that these Southern California islands may soon lose their natural state. Some information on the flora and fauna of these islands has been obtained from San Nicolas Island. Brandegee (1890) described some of the plant species. Howell (1935) and Dunkle (1950) also described the terrestrial plants. The marine algae were investigated by Dawson (1949) and Paul C. Silva (personal communication). Grinnell (1897) documented both the marine and terrestrial avian fauna; Bartholomew (1951) studied the marine mammals and Cockerell (1939) the marine invertebrates.

At present San Nicolas Island is a military base under the administration of the United States Navy. Since fishermen and other unauthorized personnel are not allowed to visit the island, the intertidal areas are undisturbed and well preserved. This island represents the last undisturbed refuge for the typical marine biota which once characterized the California coast.

In June 1964, a study of the littoral ecology of two rocky areas at San Nicolas Island was initiated. The objective of this investigation was to characterize the patterns of zonation of the major flora and fauna. These patterns were compared to those on the Pacific Coast mainland, revealing the similarities and differences between the littoral zones and indicating the biogeographic position of the intertidal biota of San Nicolas Island.

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1. Present address: Department of Zoology, University of Washington, Seattle, Washington.
 2. Present address: Biological Sciences Curriculum Study, University of Colorado, Boulder, Colorado.

... and development of various schemes of classifying rocky intertidal zones is summarized by Lewis (1964). In his summary, he suggests a zonation design in which the intertidal region is divided into the Littoral Zone, a region subjected to tidal fluctuations, and the Sublittoral Zone, a region which lies below the influence of tidal fluctuations. Lewis further divides the Littoral Zone into the Littoral Fringe and the Eulittoral Zone. The Eulittoral Zone can be further subdivided into the Upper, Middle, and Lower Eulittoral zones. The biological elements which characterize these divisions are summarized below. The Littoral Fringe contains encrustations of lichens and blue-green algae, as well as littorinids. The next zone, the Upper Eulittoral Zone, is occupied by barnacles, hence the term "balanoid zone"; the Middle Eulittoral Zone contains furoid algae and limpets, while the Lower Eulittoral Zone consists of laminarians in the temperate regions, ascidians in the semitropics, and corals in the tropics. The Sublittoral Zone contains coralline algae. The above scheme will be employed here because of its simplicity and applicability to this study.

DESCRIPTION OF STUDY AREA

San Nicolas Island is one of the eight Southern California Islands (fig. 1). Topographically it belongs to the southern group including Santa Catalina, Santa Barbara, and San Clemente. Geologically, San Nicolas Island lies atop the Santa Rosa-Cortez Ridge which parallels the mainland from Ventura to Los Angeles. San Nicolas lies 61 statute miles from Laguna Point, Point Mugu. Santa Barbara Island, 28 statute miles to the northeast, is the closest land area to San Nicolas. The island is 9.7 miles long, 3.7 miles wide, and 22 square statute miles in total area (fig. 2). The coastline is composed of short sandy pocket beaches separated by broad headlands of thick-bedded sandstone. This sandstone lies exposed along the shoreline because of the erosion produced by the shearing forces of wave action. The erosion has exposed inclined, rocky bedding planes that dip seaward. Two of these rocky planes were selected for this study.

The important climatic conditions at San Nicolas Island include: (1) a low annual rainfall of 6.14 inches, (2) a high mean relative humidity of 76 per cent, and (3) a mean wind speed of 13 knots from the northwest. The humidity produces conditions in the intertidal which aid in maintaining moisture during prolonged periods of exposure. The continual wind brings about sea surface conditions which affect the zonation patterns differently at various parts of the island.

Current patterns in this area have been investigated by Fleming (1940) and Sverdrup and Fleming (1941). For some distance from the Southern California coast there is a well-defined flow directed

toward the southeast, which more or less parallels the coastline; this is the California Current. A second current, the Southern California Counter-current runs northward (or northwest) inside the California Current. San Nicolas Island is influenced by both of these currents.

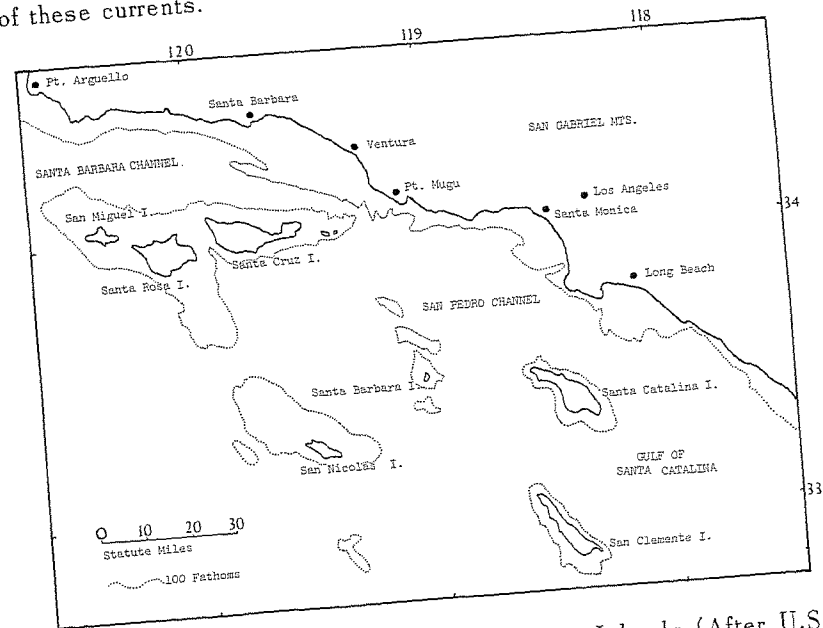


Fig. 1. Diagram of the Southern California Islands (After U.S. Coast and Geodetic Survey Map 520, 1959.)

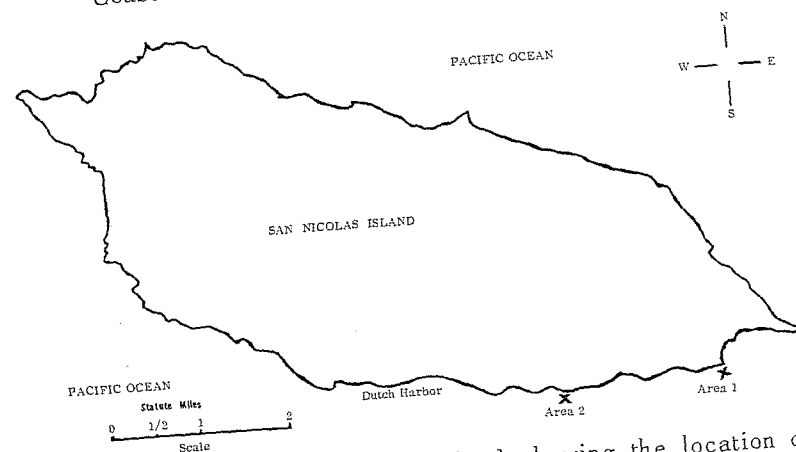


Fig. 2. Outline of San Nicolas Island showing the location of each study area.

The tidal cycle at San Nicolas is similar to the one on the Pacific Coast of North America. This cycle consists of semi-daily inequalities in which the highs and lows of successive tides are of unequal amplitude; thus producing conditions of exposure and immersion which have important biological significance in terms of zonation. The tides vary from those noted on the mainland coast as they occur 19 minutes later and have an amplitude ratio of 0.90 as compared to those at Los Angeles, California.

METHODS AND MATERIALS

The two intertidal areas studied at San Nicolas Island (fig. 2) are located on semi-exposed rocky substrates that are subjected to moderate wave action. A transect in each area was selected to include the longest possible rocky surface subjected to tidal exposure. The location of each transect was determined by the number of different types of physical features that could be included. A vertical profile of each area (fig. 3) was obtained by making measurements at six inch intervals along the transect with a surveyor's transit. These relative measurements were corrected to known heights of tidal bench marks placed in each area by the Public Works Department, Point Mugu.

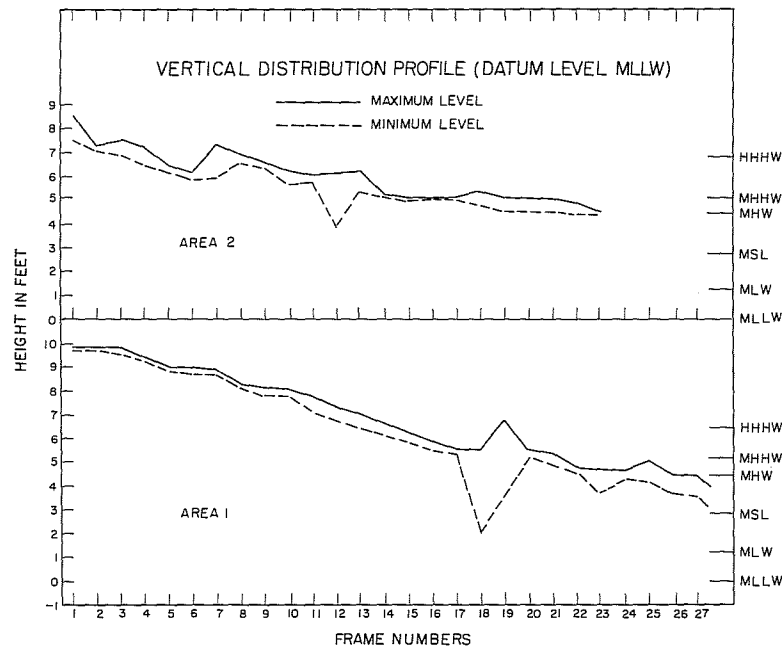


Fig. 3. Vertical distribution profile for the two areas of study. The highest (solid line) and lowest (broken line) point in each frame is indicated. In frames with maximum deviation in height, a pool or channel is present.

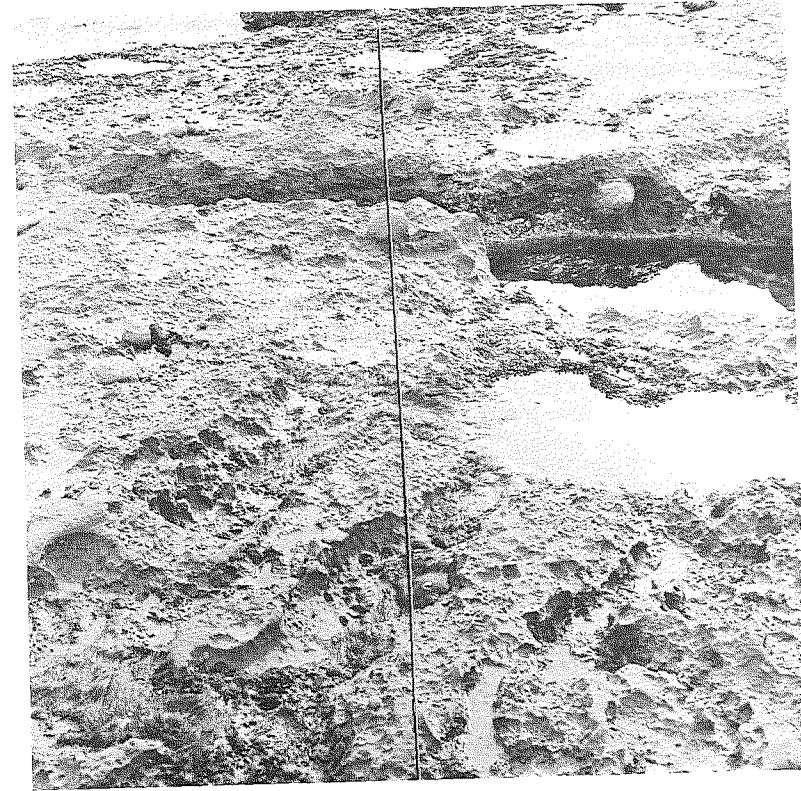


Fig. 4. Area 1 at low tide (+0.5 feet) showing the transect line from +10.0 to +2.0 feet above Mean Low Low Water. The direction of the transect is ESE.

The transect in Area 1 is 28 meters long by 1 meter wide (fig. 4). The highest and lowest points in this transect are +10.0 and +2.0 feet above Mean Low Low Water (MLLW). The substrate contains many small pools as well as larger and more permanent tide pools. A large surge channel is also present. The transect in Area 2 is 24 meters long by 1 meter wide. The highest and lowest points in this transect are +10.0 and +2.0 feet above Mean Low Low Water (MLLW). Large tide pools are conspicuously absent; however, small pools and large surge channels are present (fig. 5).

Zonation patterns were determined by placing a one-square meter aluminum frame serially along the transect. To facilitate counting and estimating algal density, this frame was subdivided by fine wires (20 gauge) into 100 squares, 10 centimeters on a side. The frames were numbered according to their position in

the transect; the first frame, or frame number 1, is located at the highest region of each transect.

The main emphasis was to obtain a complete account of the major macroscopic species without destroying the habitat within each frame. Only those individuals were counted that could be seen without removing any attached algae or animals. The infauna of *Mytilus* beds or algal holdfasts were not included in this study because to have included them would have destroyed the natural habitat. All specimens taken for identification of species were collected from areas adjacent to the transects. The invertebrates were identified by the authors, and the algae were identified by Dr. Paul C. Silva, University of California, Berkeley.

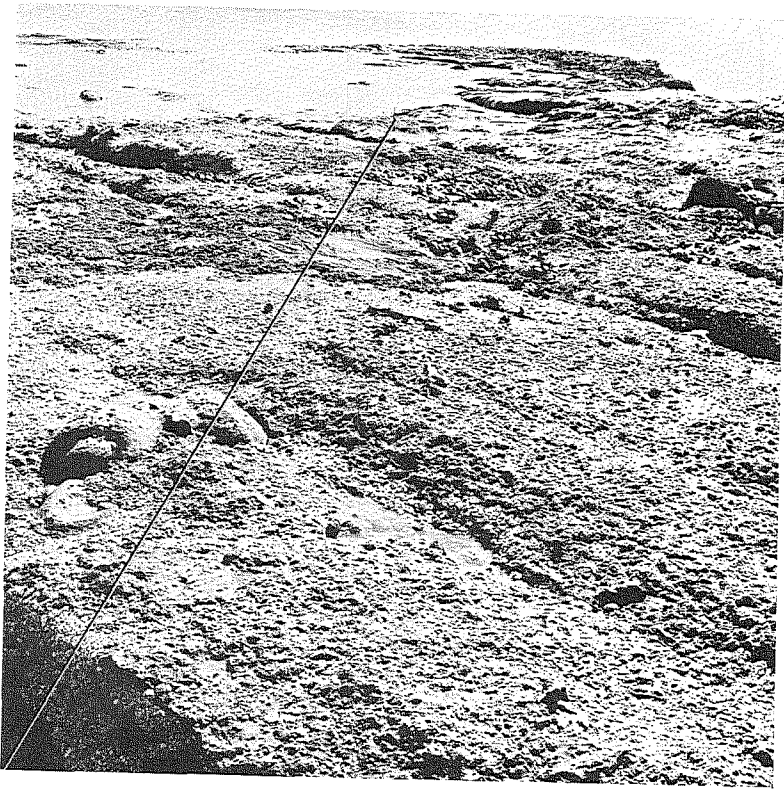


Fig. 5. Area 2 at low tide (-0.1 feet) showing the transect line from +10.0 to +2.0 feet above Mean Low Low Water. The direction of the transect is SE.

RESULTS: ZONATION PATTERNS OF FLORA AND FAUNA

In Area 1, the Chlorophycophyta (green algae) occur in the upper two zones of the transect. *Ulva* is present in the Littoral Fringe (+10.0 to +7.5 feet), and *Cladophora trichotoma* and *Chaetomorpha aerea* are present in the Upper Eulittoral Zone (+7.5 to +4.5 feet). The Phaeophycophyta (brown algae) are represented by *Ralfsia pacifica*, Upper Eulittoral Zone (+7.5 to +4.5 feet), and *Scytosiphon attenuatus*, Lower Eulittoral Zone (+3.0 to 0.0 feet). The Rhodophycophyta (red algae) are represented by one or more species in each zone of the transect. *Hildenbrandia occidentalis* is present in the Littoral Fringe (+10.0 to +7.5 feet) with *Endocladia muricata* occurring in the Upper Eulittoral Zone (+7.5 to +4.5 feet). *Plocamium coccineum* (+4.5 to +3.0 feet), and *Corallina vancouveriensis*, *Bossiella insularis*, and *Lithothamnium* (+3.0 to 0.0 feet) occur in the Middle Eulittoral and Lower Eulittoral zones, respectively.

In Area 2, the Chlorophycophyta, *Ulva* and *Chaetomorpha aerea*, occur in the Littoral Fringe (+10.0 to 7.0 feet); *Cladophora trichotoma* exists in the Upper Eulittoral Zone (+7.0 to +4.0 feet). *Ralfsia pacifica* occupies a position in this area which is similar to the one it occupies in Area 1 (+7.0 to +4.0 feet). Several other Phaeophycophyta occur in the Lower Eulittoral Zone (+3.0 to 0.0 feet) including *Egregia laevigata*, *Pelvetia fastigiata*, and *Haldrydys dioica*. In the Rhodophycophyta, the position of *Hildenbrandia occidentalis* and *Endocladia muricata* is reversed from the pattern in Area 1, with the former in the Middle Eulittoral Zone (+7.0 to +4.0 feet). *Plocamium coccineum*, *Corallina vancouveriensis*, *Bossiella insularis*, and *Lithothamnium* are present in the Middle and Lower Eulittoral zones, respectively. Other species found in Area 2 in the Lower Eulittoral Zone are *Prionitis andersoniana* and *Gigartina spinosa* (+3.0 to 0.0 feet).

The animal species can similarly be grouped into several zones as defined by tidal levels. In the Littoral Fringe of Area 1 (+10.0 to +7.5 feet), the barnacle, *Chthamalus fissus*, and the snail, *Littorina planaxis*, occur. In the Upper Eulittoral Zone (+7.5 to +4.5 feet), three species are common: *Littorina scutulata*, *Acmaea digitalis*, and *Acanthina spirata*. The Middle Eulittoral Zone (+4.5 to +3.0 feet) contains *Mytilus californianus*, *Lottia gigantea*, *Acmaea scabra*, *Balanus glandula*, and *Acmaea persona*. The Lower Eulittoral Zone (+3.0 to 0.0 feet) contains *Anthopleura xanthogrammica*, *Pachygrapsus crassipes*, *Nuttalina californica*, *Fissurella volcano*, and *Phragmatopoma californica*. *Tetraclita squamosa rubescens* and *Acmaea fenestrata cribaria* have the widest distributional range (+7.0 to +2.0 feet).

In Area 2, a similar pattern of zonation occurs with additional species in each region. The Littoral Fringe (+10.0 to +7.0 feet) contains *Chthamalus fissus* and *Littorina planaxis*. *Littorina*

scutulata, *Acmaea digitalis*, *Acmaea paradigitalis*, and *Tegula funebris* occur in the Upper Eulittoral Zone (+7.0 to +4.0 feet). *Acmaea scabra*, *Lottia gigantea* and *Tetraclita squamosa rubescens* occur in the Middle Eulittoral Zone (+4.0 to +3.0 feet). In the Middle Eulittoral Zone as well as the upper portion of the Lower Eulittoral Zone (+3.0 to 0.0 feet), the gregarious anemone, *Anthopleura elegantissima*, and the mussel, *Mytilus californianus*, are common; the former occurs in less exposed areas. Other species in the Lower Eulittoral Zone include *Nuttalina californica*, *Fissurella volcano*, and *Phragmatopoma californica*. In this area, *Acmaea persona* and *Nuttalina californica* have the widest distributional range (+6.0 to +1.0 feet).

DISCUSSION

The zonation patterns, including both flora and fauna, are summarized in fig. 6 (Area 1) and fig. 7 (Area 2). The species indicated here represent the dominant organisms in the Littoral Zone, i.e., their densities exceed 100 individuals per square meter in the animal species or they occupy 10 to 100 percent of the substrate per square meter in the algal species.

In Area 1, there are four zones. The Littoral Fringe is dominated by *Chthamalus fissus*, *Littorina planaxis*, and *Hildenbrandia occidentalis*. The transitional species between the Littoral Fringe and the Upper Eulittoral Zone is *Cladophora trichotoma*. *Littorina scutulata*, *Acmaea digitalis*, and *Ralfsia pacifica* are the dominant elements of the Upper Eulittoral Zone. The transitional species between the Upper and Middle Eulittoral zones is *Tetraclita squamosa rubescens*. The Middle Eulittoral Zone contains an association of *Acmaea scabra*, *Lottia gigantea*, *Mytilus californianus*, *Acmaea persona*. There is no transitional species between this zone and the Lower Eulittoral Zone. The major components of this zone are *Nuttalina californica*, *Strongylocentrotus purpuratus*, *Corallina vancouveriensis*, *Gelidium*, and *Lithothamnium*.

The distributional pattern in Area 2 can similarly be divided into four zones. The dominant and transitional species located in the two areas show differences. The Littoral Fringe contains *Endocladia muricata*, instead of *Hildenbrandia occidentalis*, as well as *Chthamalus fissus* and *Littorina planaxis*. There is no transitional species between this zone and the Upper Eulittoral Zone, which contains *Acmaea paradigitalis*, *Tegula funebris*, and *Bossiella insularis*. *Acmaea digitalis*, *Littorina scutulata*, and *Ralfsia pacifica* are also present. The transitional species between this zone and the Middle Eulittoral Zone is different from its counterpart in Area 1 in that the anemone, *Anthopleura elegantissima*, is common. *Acmaea testudinalis scutum*, *Plocamium pacificum*, *Cladophora trichotoma*, and *Mytilus californianus* also occur. There are three transitional species between the Middle

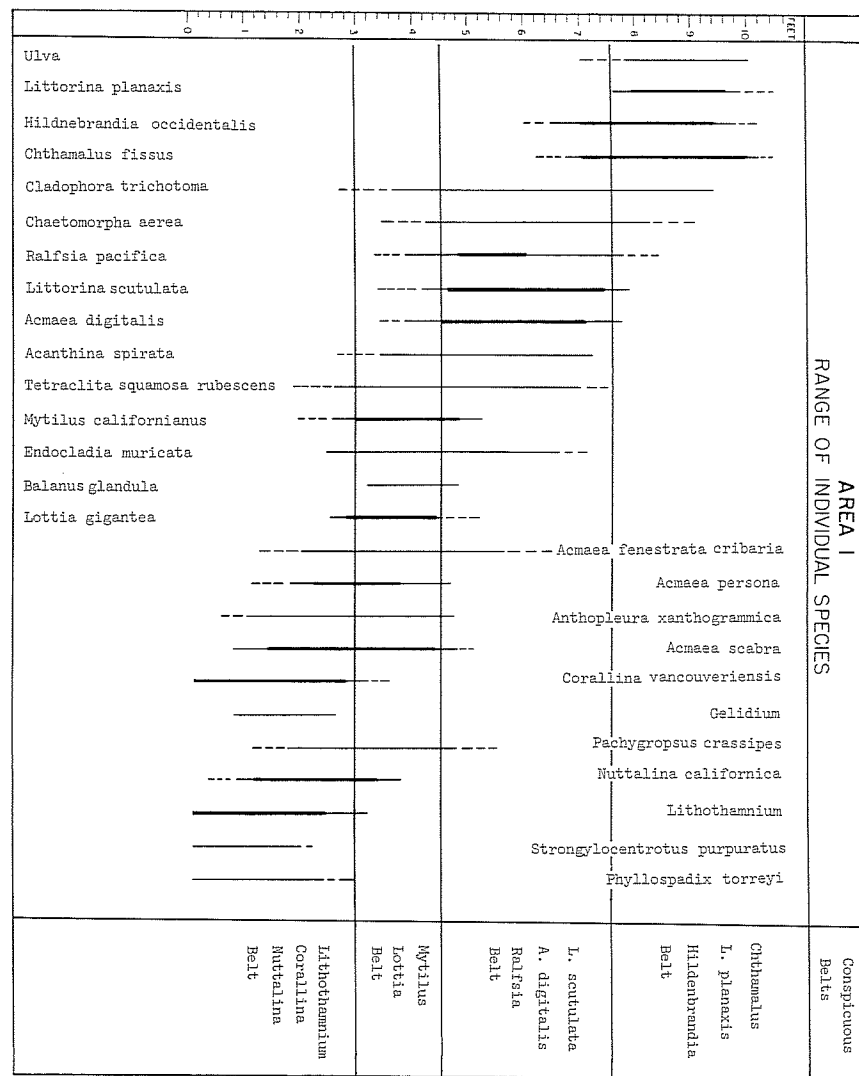


Fig. 6. Zonation pattern of major flora and fauna in Area 1. The wide black solid bar indicates position of maximum abundance or dominance. The narrow black line indicates presence, but not dominance. The broken line shows the limits of distribution.

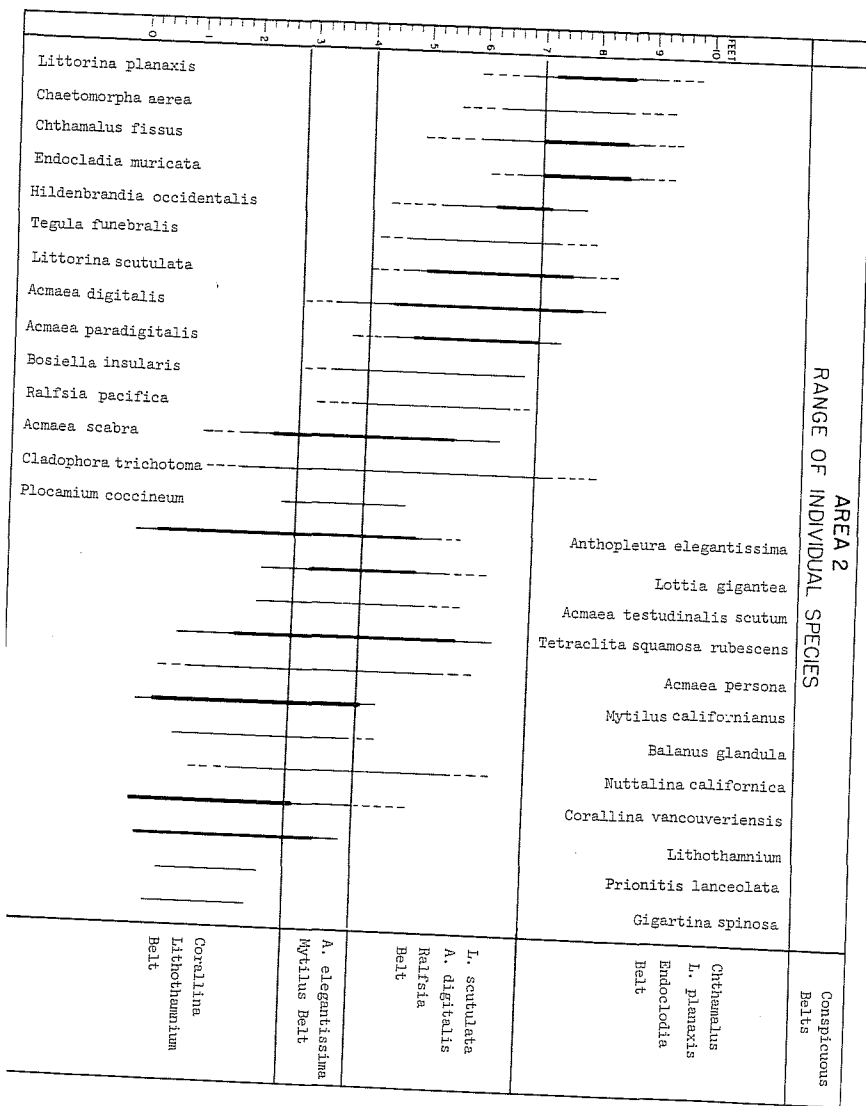
and Lower Eulittoral zones, namely *Anthopleura elegantissima*, *Mytilus californianus*, and *Acmaea persona*. In this lowest zone, *Prionitis lanceolata*, *Gigartina spinosa*, *Corallina vancouveriensis*, and *Lithothamnium* predominate.

The patterns of zonation at San Nicolas Island show both similarities to, and differences from, the typical patterns of the dominant mainland faunal species (Ricketts and Calvin, 1962) and floral species (Doty, 1946). The Littoral Fringe (Zone Number 1 of Ricketts and Calvin) has similar dominant animal species both at San Nicolas Island and on the mainland, i.e., *Chthamalus fissus* and *Littorina planaxis*. The algal components in Area 1 are most similar to those on the mainland; these are *Ulva* and *Hildenbrandia occidentalis*, the latter being an encrusting form. The major algal species in Area 2, *Endocladia muricata* and *Chaetomorpha aerea*, differ markedly from the mainland species in that they are normally found in a lower zone in the intertidal region.

The Upper Eulittoral Zone (Zone Number 2 of Ricketts and Calvin) contains similar dominant animal elements both at San Nicolas Island and on the California mainland; *Littorina scutulata* and *Acmaea digitalis* dominate in this zone. Again, the algal species in Area 1 are more typical of the mainland associations. The dominant species are *Chaetomorpha aerea* and *Cladophora trichotoma*. Most of the *Littorina scutulata* which occurs in this zone are located under the thalli of *Chaetomorpha aerea*. There is a dominant encrusting form, *Ralfsia pacifica*, in this zone also. In Area 2, both species of encrusting algae are present; *Hildenbrandia* occurs in the upper portion of the zone, and *Ralfsia* in the lower. The dominant faunal species in this zone are *Acmaea digitalis* and *Tetraclita squamosa rubescens*.

The Middle Eulittoral Zone (Zone Number 3 of Ricketts and Calvin) shows the greatest difference between the dominant species in Area 1 and Area 2. Area 1 is most representative of the mainland zonation pattern. The major animal components in Area 1 are *Mytilus californianus*, *Lottia gigantea*, and *Acmaea scabra*. A representative view of the transition between the Upper and Middle Eulittoral zones in Area 1 is presented in fig. 8. Typical species of algae found with these animals, both at San Nicolas Island and on the mainland, include *Iridophycus*, *Polysiphonia*, and *Collinisii*; the two former species are present in both transects on San Nicolas Island.

In Area 2, the anemone, *Anthopleura elegantissima*, is codominant with *Mytilus californianus*. As can be seen from fig. 9, these two species seem to compete for space in this zone. *Anthopleura elegantissima* appears to be more successful in semi-sheltered places; *Mytilus* attains its maximum densities in exposed places. *Lottia gigantea* and *Acmaea scabra* are not dominant elements in this zone of Area 2 as much of the substrate is occupied by either *Mytilus* or *Anthopleura*.



g. 7. Zonation pattern of major flora and fauna in Area 2. The wide black solid bar indicates position of maximum abundance or dominance. The narrow black line indicates presence, but not dominance. The broken line shows the limits of distribution.

The Lower Eulittoral Zone (Zone Number 3 of Ricketts and Calvin) contains algal species as its major components. In both study areas the dominant species are *Corallina vancouveriensis* and *Lithothamnium*. The chiton, *Nuttalina californica*, occurs in this zone in both study areas; however, it is more common in Area 1. In this region several other algal species occur which are found in similar regions of the Littoral Zone on the mainland. The most notable of these are *Rhodoglossus affine* and *Gelidium coulteri* (Area 1) and *Prionitis lanceolata* and *Gigartina spinosa* (Area 2). Both *Mytilus californianus* and *Anthopleura elegantissima* extend down into this zone in Area 2, but not in Area 1.

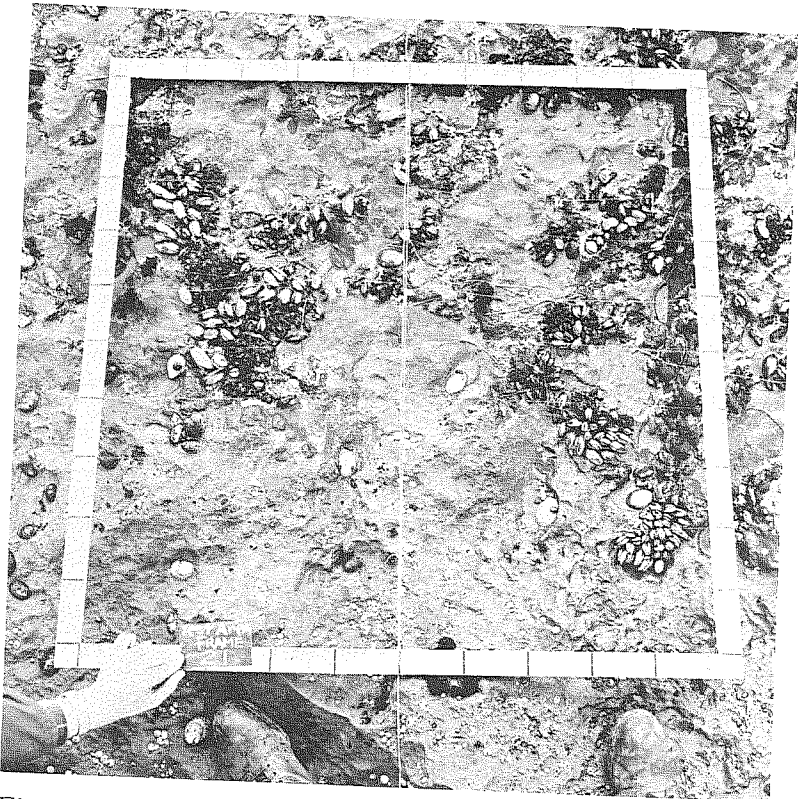


Fig. 8. A typical region in the Eulittoral Zone of Area 1. The white frame, one square meter in area, outlines an area in which there is a transition from the Upper Eulittoral Zone dominated by *Acmaea digitalis* (lower portion) to the Middle Eulittoral Zone dominated by *Mytilus californianus* (upper portion). (The card in lower left identifies frame and area.)

In comparing the patterns of zonation on San Nicolas Island with patterns of other Pacific Coast locations, the type of organization found in the Littoral Zone (with three subdivisions of the Eulittoral Zone, Upper, Middle and Lower) has been reported by Shelford et al. (1935), Hewatt (1937), Ricketts and Calvin (1962), and Stephenson and Stephenson (1961). Yet, to take one example, the three subdivisions of the Eulittoral Zone are dominated by *Acmaea digitalis*, *Mytilus californianus*, and *Corallina vancouveriensis* at San Nicolas Island, while their ecological counterparts on Vancouver Island (Stephenson and Stephenson, 1961) are *Balanus balanoides*, several species of *Fucus*, and *Mytilus edulis*. Other studies of coast in the Northern Atlantic (France) by Evans (1957) and the Southwestern Pacific (Australia) by Endean, Kenny,



Fig. 9. A typical region in the Middle Eulittoral Zone of Area 2. The white frame, one square meter in area, outlines a region in which the gregarious anemone, *Anthopleura elegantissima*, and the mussel, *Mytilus californianus*, seem to compete for space.

and Stephenson (1956a, 1956b) indicate that this three-fold subdivision of the Eulittoral Zone is present in locations other than along the Pacific Coast of North America.

CONCLUSION

The present study at San Nicolas Island represents the first of its type to deal specifically with the intertidal ecology of a Southern California Island. The zonation patterns discussed for San Nicolas Island are similar to those found on the California mainland with relatively few exceptions, indicating that the flora and fauna in the intertidal region are representative of both northern and southern Californian associations. The dominant species of algae and invertebrates in each of the zones discussed, the Littoral Fringe and the Eulittoral zones, are also similar to mainland species.

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