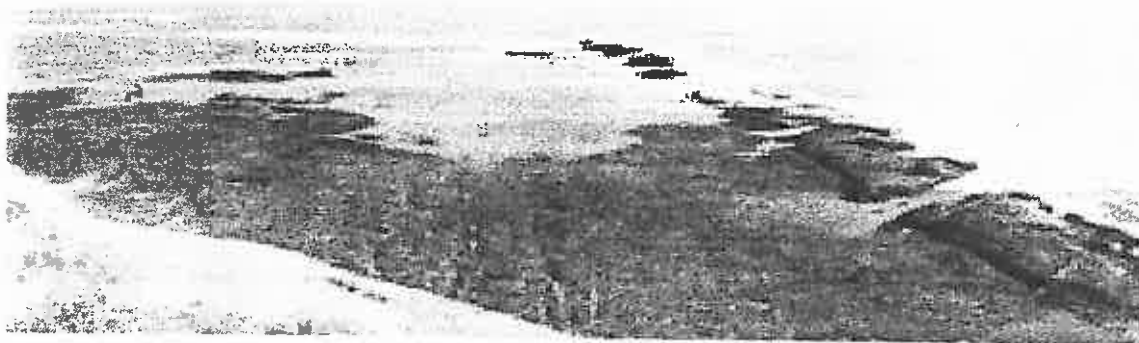


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**MONITORING THE ROCKY INTERTIDAL COMMUNITIES
WITHIN THE
GULF OF THE FARALLONES
AND MONTEREY BAY NATIONAL MARINE SANCTUARIES
Six Month Report**



Prepared by:

COSENTINO CONSULTING
2 Ash Lane
Petaluma, CA 94952

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Golden Gate National Recreation Area
San Francisco, CA

Under Contract No 1443CX8140-95-039

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SIX MONTH PROGRESS REPORT

By

Natalie Cosentino
COSENTINO CONSULTING
2 Ash Lane
Petaluma, CA 94952

and

James R. Chess

July 1997

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ABSTRACT

The assessment of natural and anthropogenic disturbances to rocky intertidal populations of algae and invertebrates requires the collection of baseline data on species abundance, diversity and distribution. In November 1995, baseline data collection was initiated within the Gulf of the Farallones National Marine Sanctuary (GFNMS) and the northern portion of the Monterey Bay National Marine Sanctuary (MBNMS). Seven sites along the central California coastline from Bodega Bay to Pigeon Point are assessed bi-annually. Eighty-four quadrats and twenty-one transects in high, middle and low intertidal zones were assessed for the winter 1997 sampling period. The methods of assessment included point-frame, photographic recording and shore reconnaissance. This second year six month report, describing winter 1997 data collection, contains species lists, an analysis of abundance data for each site.

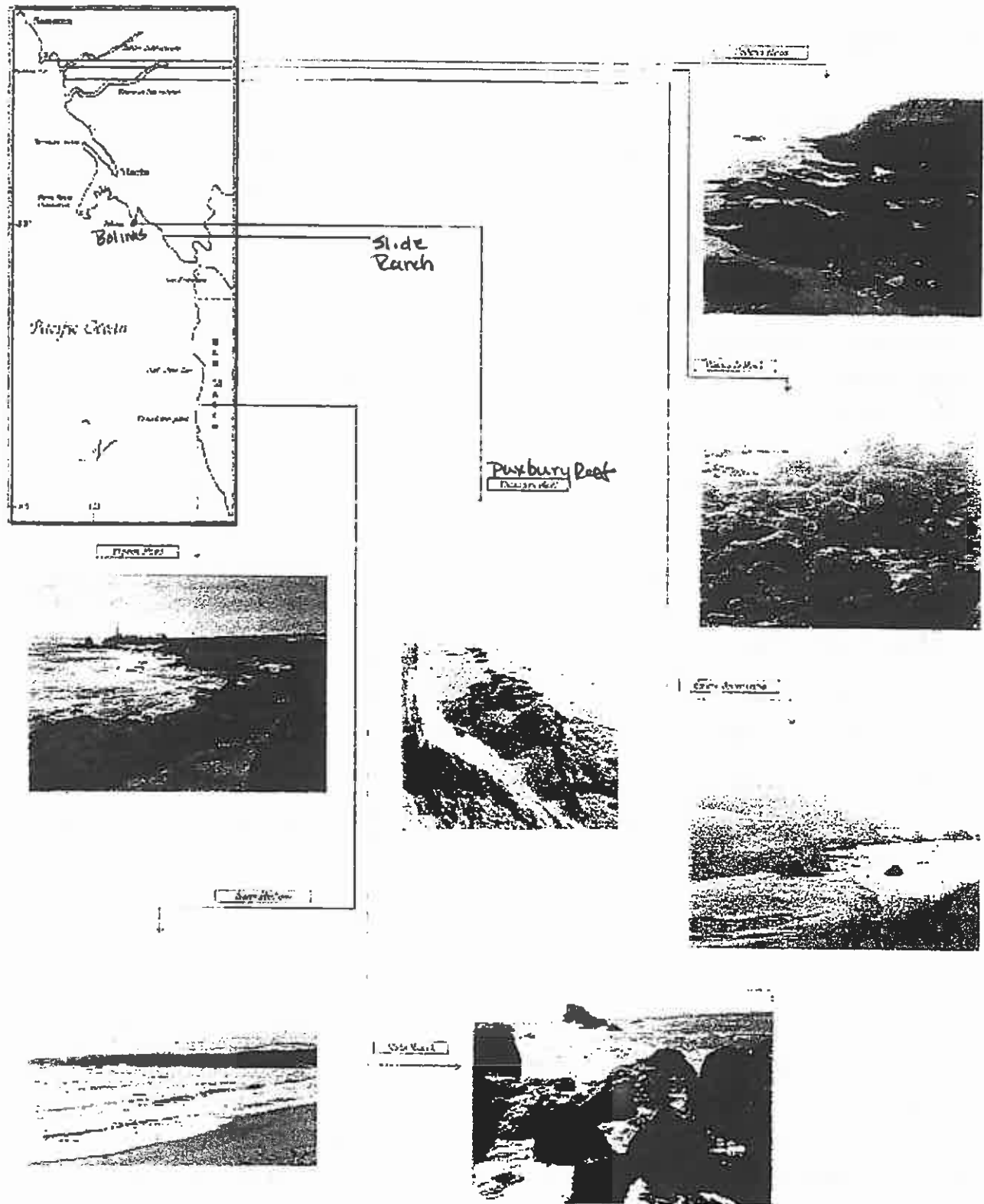


Figure 1. Locations and photographs of each site.

INTRODUCTION

The rocky intertidal zones within the Gulf of the Farallones National Marine Sanctuary (GFNMS) and Monterey Bay National Marine Sanctuary (MBNMS) support an extraordinarily rich assortment of plants and animals which are responsible for high near and offshore productivity. These trophically open ecosystems are accessible, easily observed and are known to be vulnerable to oil spills (Foster et al, 1986). Documentation and long term monitoring of the rocky intertidal communities along the mainland portion of the sanctuaries are needed in the event of a natural or human induced disturbances. Man made disturbances, such as oil spills, can generate widespread mortalities and negatively affect species composition, diversity, or local biogeography (Castilla, 1988). Creating a base-line record of species diversity and density of rocky intertidal algae and invertebrates will enable resource managers to manage, protect, and properly assess damages. The five primary goals of this baseline study were to:

- Establish non-destructive, stratified random and permanent sampling quadrats within the mainland intertidal areas of the GFNMS and MBNMS from Sonoma County, south through San Mateo County (Figure 1).
- To inventory species from the intertidal communities.
- Determine density and percent cover within permanent and stratified random quadrats.
- Determine the density of selected sessile organisms
- Photo-document, collect and archive voucher specimens from the intertidal areas for future reference.

STUDY SITES

All of the study sites were selected on the criteria that they be accessible by foot, have good zonation and accumulate drift material. Seven of the eight initial sites selected for monitoring were accessible and had good zonation. Rodeo Cove was eliminated from the study due to high human visitation and inaccessibility to some zones. Elimination of this site allowed for a more complete habitat assessment of the other seven sites. From north to south, the sites were Bodega Head, Pinnacle Rock, south end at the mouth of the Estero Americano, Duxbury Reef, Slide Ranch, Bean Hollow and Pigeon Point. Each description is accompanied by general map and a photo (Figure 1).

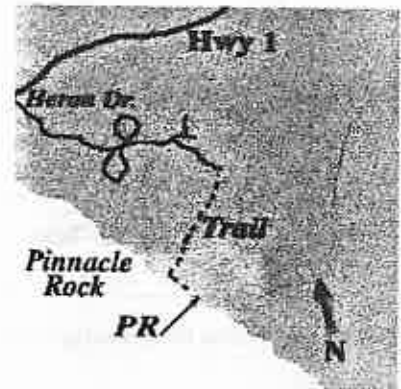
BODEGA HEAD (38°18' N. Latitude, 123° 03' W. Longitude)

This site, within GFNMS, is the furthest north and is located on the south side of Bodega Head on the seaside of the breakwater. It receives very little wave action and is mainly composed of granite boulders and small sandy pockets. The intertidal zone is fairly narrow with a predominant middle intertidal zone. At the onset of winter, a heavy accumulation of algal drift (approximately .9 to 1.5 meters deep) at the juncture of the breakwater and beach denotes the possibility that other substances (i.e. oil and wastes) could gather there as well.



PINNACLE ROCK (38°17' N. Latitude, 123°01' W. Longitude)

Within GFNMS, this site is located approximately 1.8 km south of Bodega Head. It is accessed via a trail to a semi-protected beach composed of terraces, vertical walls, sandy pockets as well as stable boulder fields of granite composition. There is a wide intertidal band with all intertidal zones well represented.



ESTERO AMERICANO (38°17'30" N. Latitude, 123°00' W. Longitude)

This site is accessed by crossing the Estero Americano and walking south approximately .3 km down the beach. Located within GFNMS, this site is pristine and is occasionally visited by abalone divers and anglers. It is an exposed beach but some areas are protected by large rock formations. Many small to large tidepools are formed by smaller stable boulders which remain full with water when the tide recedes. Estero Americano is the sandiest of all the seven sites.



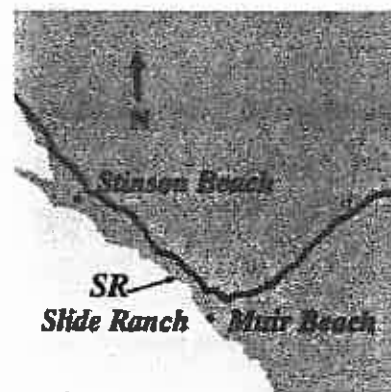
DUXBURY REEF (37°52' 30" N. Latitude, 122° 42' 30" W. Longitude)

Located just west of the town of Bolinas, within GFNMS, Duxbury Reef is represented by a mudstone reef that extends southward and peaks to create two distinct habitats. The leeward side is protected from the waves by the reef and is characterized by a vast *Phyllospadix* bed with many cobble filled channels and shallow tidepools. The seaward side of this reef is exposed, but because the reef extends further out westward, this site does not receive high energy waves. The edges of the reef are cut sharply by deep surge channels that cut the reef perpendicularly and empty to the leeward side



SLIDE RANCH (37°53' N. Latitude, 122° 37' W. Longitude)

This site is located approximately 2.4 km south of Stinson Beach within GFNMS. It is accessed by a steep trail down to a beach mainly composed of large serpentine and graywacke boulders. Most of these boulders are debris from the steep cliff. This site is predominantly exposed, but the large stable boulders provide good protection for some large tidepools (13.4 x 20.6 meters). The middle to upper intertidal zone is wide with a low intertidal zone only defined in the large tidepools and along the outer most seaward rocks.



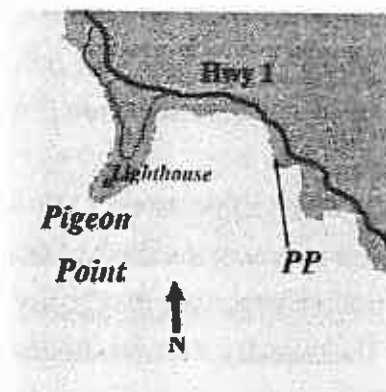
BEAN HOLLOW (37°13' N. Latitude, 122° 24' W. Longitude)

Bean Hollow is a California State Park, located south of Half Moon Bay approximately 12.4 km and within the MBNMS. The site is composed of a porous sandstone and shale substrate which has been formed into large exposed reefs. This area receives high amounts of wave action which is apparent by the large *Postelsia palmaeformis* (sea palm) beds on the outer parts of the reef. Many higher and lower tidepools, vertical faces as well as surge channels compose this site.



PIGEON POINT (37°11' N. Latitude, 122°23' W. Longitude)

This site is within the (MBNMS) and located 3 km south of the Pigeon Point Lighthouse. It is accessed by traversing down a sea bluff to a beach characterized by low flat benches which are cut longitudinally by small channels. The substrate is composed of sandstone and conglomerates and middle to lower intertidal zones dominate with the high zones found closer to the shore.



MATERIALS and METHODS

Each of the seven sites were assessed by establishing twelve quadrats, six permanent and six random; in low, middle and high algal zones. Each 30x50 cm quadrat was established and assessed for the winter sampling period. All permanent quadrats were established by clearing a 5x5 cm area at the outside corners of each quadrat and applying a small amount of Super Mend® underwater epoxy to each of the cleared areas on the rock. The permanent quadrats have uniquely numbered, 8x11 cm, steel plates (furnished by GFNMS) pressed onto the epoxy at the upper left corner (when viewed from the seaward side). The lower right corner has a uniquely numbered plastic disc (furnished by GFNMS) while the other two corners have only epoxy. At Slide Ranch, the six permanent quadrats were nested within the Golden Gate Recreational Area's study site. Two of the permanent quadrats from this project were placed within two of GGNRA's permanent quadrats (#216 and #219) and are noted respectively.

Point assessments were conducted for the winter sampling season by the following method; a 30x50 cm Plexiglas quadrat with 50 randomly selected pinholes was placed above each quadrat and a thin metal pointer inserted through each of the 50 points (Figure 2), as described by Foster et al. (1991). The observer records all algae and sessile invertebrates under the point of contact. Multiple layers of the same species (taxon) under a single point were tallied only once. Points that hit rock and sand, unoccupied space, were also recorded. Point quadrat assessments were entered into an Excel, Macintosh version 5.0, spreadsheet containing species accounts, distribution, percent cover, primary and secondary cover for each quadrat and species richness. Percent cover was calculated by taking the frequency, the number of times a species occurred in the quadrat or site, and dividing it by the total number of occurrences within the quadrat or site. Mean percent cover is the average of the percent cover values for all the quadrats at each site. Dominant algal and invertebrate species are

organisms that are conspicuous in the community and high in one of the importance values such as cover, frequency or biomass (Whittaker 1978). Species richness is a measurement of the total number of different species encountered in each quadrat or site. In addition to point assessments, 2 photographic slides were taken of each quadrat using Kodachrome 200 and a flash f-stop of 5.6 and 8.0 for all documentation (Figure 3).

Three transects were also assessed at each location. Transects are useful in describing maximum variation over the shortest distance in the minimum time (Kent and Coker 1992). For this project the transects assessed the density of predominant species of mussels, echinoderms, limpets and chitons. The transects were positioned by a tape measure either perpendicular to the shore line or horizontally, depending on the dimensions of the site. The transects coincided with at least three of the permanent quadrats and a minimum of one transect began at the highest point devoid of vegetation and extended through each zone to the waterline. The length of each transect was 12 meters and a 30x50 cm quadrat was positioned at each meter mark. The total area covered by the each transect was $1.8/m^2$ and the total area covered was $5.4/m^2$ at each site. Transects were analyzed using abundance measurements, which account for the relative abundance of each species along the transect. Both subjective and objective measurements were taken along the transects. Subjective measurements were used to visually determine the percent cover of sessile invertebrates, such as mussels and barnacles, in each quadrat along the transect. Objective measurements, entailed counting each motile invertebrate in each quadrat along the transect. The results of both measurements were then compared to an ACFOR (abundant, common, frequent, occasional and rare) scale. An ACFOR scale designed by Crisp and Southward (1958) and expanded by Crapp

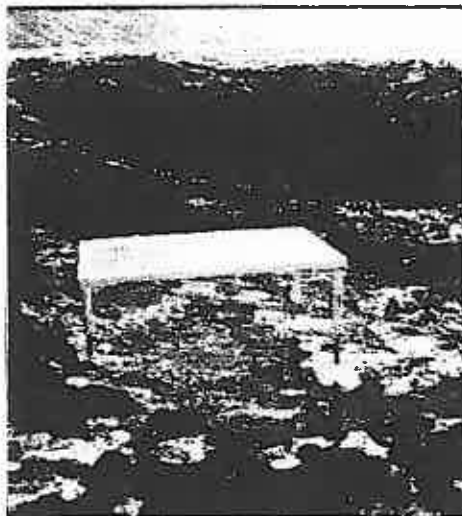


Figure 2. Photograph of point quadrat placed over a permanent quadrat at Duxbury Reef, Ca.



Figure 3. Photograph of photo-documentation taken of a permanent quadrat at Pigeon Point, CA.

(1973), was used to determine the abundance of organisms at each site (Table 1). This scale provides efficient semi-quantitative (ordinal) information that yields data better suited to understanding of the complexities of the rocky intertidal.

Table 1. ACFOR scale devised by Crisp and Southward (1958).

Abundance Categories		Abundance Scale for Some Common Littoral Organisms	
EX (Extremely abundant)		ENCrustING SPECIES	
S (Super abundant)	Ex	> 80% cover	
A (Abundant)	S	50-80% cover	
C (Common)	A	20-50% cover	
F (Frequent)	C	1-20% cover	
O (Occasional)	F	Large scattered patches	
R (Rare)	O	Widely scattered patches, small	
	R	Only one or two patches	
		BARNACLES	
	Ex	>5/cm ²	
	S	3-5/cm ²	
	A	1-3/cm ²	
	C	10-100/dm ²	
	F	1-10/dm ² , not more than 10cm apart	
	O	1-100/m ² , few w/in 10 cm	
	R	< 1/m ²	
		LIMPETS	
	Ex	>200/m ²	
	S	100-200/m ²	
	A	50-100/m ²	
	C	10-50/m ²	
	F	1-10/m ²	
	O	1-10/dam ²	
	R	< 1/dam ²	
		TOP SHELLS	
	Ex	> 100/m ²	
	S	50-100/m ²	
	A	10-50/m ²	
	C	1-10/m ² locally sometimes more	
	F	< 1/m ² ,	
	O	always < 1/m ²	
	R	< 1/dam ²	
		MUSSELS	
	Ex	> 80% cover	
	S	50-80% cover	
	A	20-50% cover	
	C	Large patches, < 20% cover	
	F	scattered individuals, small patches	
	O	Scattered, no patches	
	R	< 1/m ²	

Detailed descriptions, compass bearings and color photographs were used to help relocate the quadrats and transects. Shoreline reconnaissance was also performed, specimens that were not observed in the quadrats or transects were collected and recorded. Important habitat descriptions such as tidal range, exposure, and substrate composition were also noted (Table 2). During the

months of March-June 1997, maps of each site were generated. Each hand drawn map was constructed using Global Positioning System (GPS) observations that were taken in the field. A Trimble GPS receiver and radio/modem along with a rover unit were used to gather three dimensional coordinates within one centimeter accuracy in real time. World geodetic positions (latitude and longitude) were determined for each quadrat and transect. Two PK™ nails, standard galvanized steel surveying nails and washers, were placed above the mean high tide mark at each site to assure accuracy for future surveying, either by traditional methods or by use with a GPS system. Latitude and longitude were also determined for the two PK™ nails. These maps will be included in the second year final report.

TAXONOMIC METHODS and NOMENCLATURE

All algal and invertebrate species were identified to the lowest taxon possible by using Abbott and Hollenberg (1976) or Smith and Carlton, third edition (1975). Recent taxonomic revisions have been included into this report and are found in table 3. Voucher specimens were collected from outside the quadrats and transects. Algal specimens (Figure 4) were pressed onto 100% rag permanent herbarium mounting paper (Univ. of California type) and invertebrates were fixed in 70% isopropyl alcohol. Specimens that were not identifiable in the field were collected from outside the quadrats and transects and identified in the lab at Humboldt State University, Arcata, California. All voucher specimens are archived at the GFNMS office.

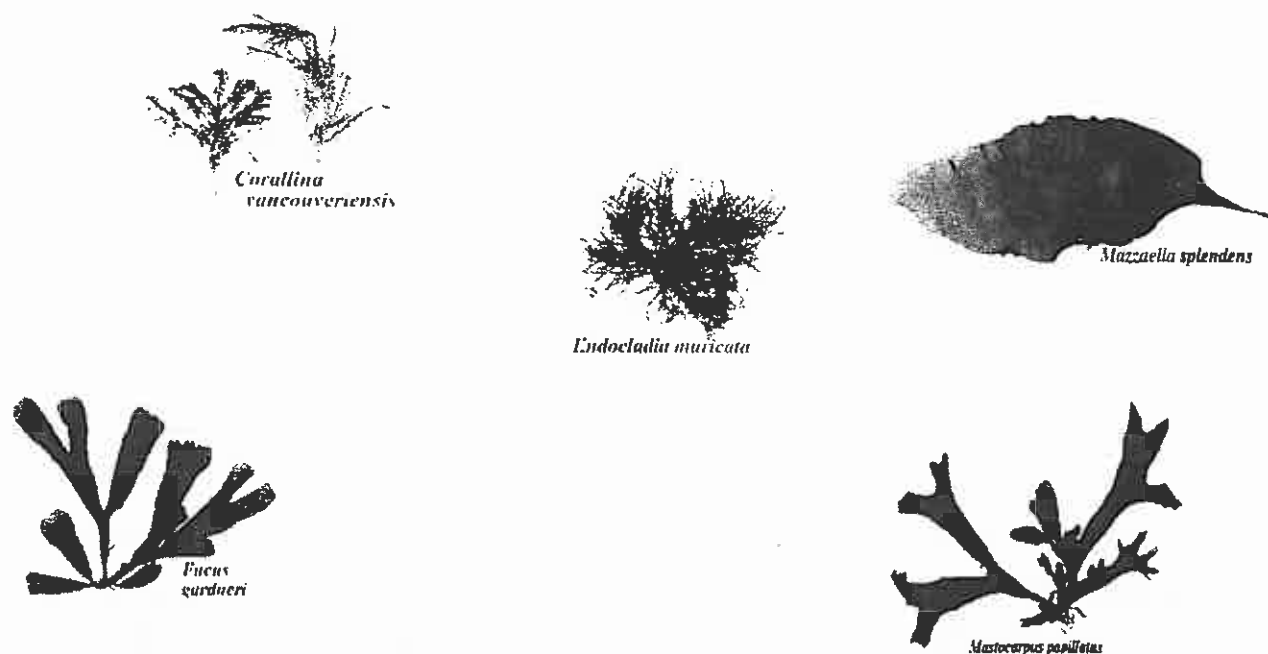


Figure 4. Some common algal specimens found within Gulf of the Farallones and Monterey Bay National Marine Sanctuaries. Plants not to scale.

Table 2. Physiographic attributes of the 7 rocky-intertidal habitats studied

Study Area	Latitude and Longitude	Substrata	Tidal Range (m)	Wave Exposure	Sand Cover
Bodega Head	38°18'N 123°03'W	Granite Diorite	-0.3—+1.2	Protected	Low to mid intertidal
Pinnacle Rock	38°17'N 123°01'W	Granite Marine terrace deposits	0.0—+2.0	Semi-exposed	Low intertidal (sparse)
Estero Americano	38°17'30"N 123°00'W	Graywacke Shale Conglomerate	0.0—+1.5	Exposed (moderate)	Low intertidal (extensive in some places)
Duxbury Reef	37°52'N 122°42'30"W	Smooth Mudstone/sandstone	-0.3—+1.2	Semi-exposed	none
Slide Ranch	37°53'N 122°37'W	Serpentine Graywacke boulders	-0.3—+1.6	Exposed (heavy)	upper intertidal (sparse)
Bean Hollow	37°13'N 122°24'W	Sandstone Siliceous shale	-0.2—+2.1	Exposed surge (moderate)	none
Pigeon Point	37°11'N 122°23'W	Sandstone Conglomerate	0.0—+1.5	Semi-protected	upper intertidal cobbles

Table 3. Recent taxonomic revisions to algae and invertebrates¹

Previous Taxon	Current Taxon
Algae	
<i>Fucus distichus</i>	<i>Fucus gardneri</i>
<i>Gastroclonium coulteri</i>	<i>Gastroclonium subarticulatum</i>
<i>Gigartina agardhii</i>	<i>Mastocarpus jordinii</i>
<i>Gigartina papillata</i>	<i>Mastocarpus papillatus</i>
<i>Gigartina canaliculata</i>	<i>Chondracanthus canaliculatus</i>
<i>Iridaea flaccida</i>	<i>Mazzaella flaccida</i>
<i>Iridaea heterocarpa</i>	<i>Mazzaella heterocarpa</i>
<i>Iridaea cordata</i> var. <i>cordata</i>	<i>Mazzaella splendens</i>
<i>Laminaria dentigera</i>	<i>Laminaria setchellii</i>
<i>Laurencia spectabilis</i>	<i>Osmundea spectabilis</i>
<i>Rhodomela larix</i>	<i>Neorhodomela larix</i>
Invertebrates	
<i>Collisella digitalis</i>	<i>Lottia digitalis</i>
<i>Collisella ochracea</i>	<i>Lottia ochracea</i>
<i>Collisella pelta</i>	<i>Lottia pelta</i>

¹ Algal changes are from Scagel et al.(1993), Guiry et al. (1984), Hommersand et al. (1993). Masuda (1982), Silva (1954), Nam et al(1994). Invertebrate changes are from Kozloff (1987).

RESULTS and DISCUSSION

A total of 155 taxa (Tables 4 & 5) have been recorded from all 7 study areas. Fifty-seven macrophyte taxa were identified and most were represented by the Rhodophyta. A total of 98 macroinvertebrate taxa were most represented by the Mollusca (Table 6). Of these 155 taxa, 112 were collected as voucher specimens (Appendix 3, Tables 1 & 2).

The combined mean percent cover at all the sites during the winter sampling period ranged from 132% to 162%. Algae ranged from 93% to 114% and invertebrates from 30% to 61%. Algae within high, middle and low zones during the winter ranged from 52% to 134%, 72% to 145% and 79% to 132% respectively. Mean percent cover for invertebrates during winter in the high, middle and low zones ranged from 18% to 81%, 14% to 75% and 7% to 53%.

Table 4. List of algal species identified at the seven mainland monitoring sites. Species found within quadrats or transects are indicated with an asterisk.

RHODOPHYTA

Ahnfeltiopsis linearis *
Bornetia californica
Bossiella californica
Botryoglossum farlowianum
Callithamnion pikeanum *
Ceramium eatonianum *
Chondracanthus canaliculata *
Crustose corallines *
Cryptopleura rosacea *
Cryptopleura violacea *
Endocladia muricata *
Erythrophyllum delesserioides
Farlowia mollis
Gastroclonium subarticulatum *
Gelidium coulteri *
Gelidium purpurascens *
Gigartina exasperata
Gloiosiphonia verticillaris *
Gracilaria sjoestedtii
Halosaccion glandiforme *
Hildenbrandia occidentalis *
Hymenena cuneifolia
Hymenena flabelligera
Mastocarpus jardinii *
Mastocarpus papillatus *
Mazzaella flaccida * (Iridaea)
Mazzaella heterocarpa * (Iridaea)
Mazzaella splendens * (Iridaea)
Microcladia borealis *
Microcladia coulteri (epiphyte) *
Neoptilota hypnoides *
Neorhodomela larix *
Odonthalia floccosa *
Osmundea spectabilis *
Plocamium cartilagineum *
Polyneura latissima *
Polysiphonia hendryi *
Porphyra perforata *
Prionitis lanceolata *
Rhodomenia californica
Smithora naiadum (epiphyte)

PHAEOPHYTA

Alaria marginata
Analipus japonicus *
Cystoseria osmundacea
Egregia menziesii *

Fucus gardneri *
Laminaria setchelli (dentigera)
Laminaria sinclairii
Leathesia difformis
Pelvetia fastigata *
Pelvetiopsis limitata *
Postelsia palmaeformis *

CHLOROPHYTA

Bryopsis corticulans
Cladophora columbiana
Cladophora graminea
Cladophora sp.
Ulva expansa
Ulva sp.

ANTHOPHYTA

Phyllospadix scouleri

Table 5. List of invertebrate species identified at the seven mainland monitoring sites. Species found within quadrats or transects are indicated with an asterisk.

ANNELIDA

Polychetes

Cheilonereis cyclurus
Nereis grubei
Phragmatopoma californica *
Platynereis bicanaliculata
Serpula vermicularis
Terrellidae

ARTHROPODA

Amphipods

Hyale frequens
Polycheria osborni
Metacaprella kennerlyi

Barnacles

Balanus glandula *
Pollicipies polymerus *
Semibalanus cariosus
Tetraclita rubescens *

Crabs

Pachycheles rudis
Pachygrapsus crassipes
Pagurus granosimanus *
Pagurus samuelis *
Pinnixa franciscana
Pugettia producta

Isopods

Cirolina harfordi
Iotea fewkesi
Exosphaeroma rhomburum

CNIDARIA

Anenomes

Anthopleura elegantissima *
Anthopleura xanthogramma *
Epiactis prolifera *

Hydroids

Abietinaria sp.
Aglaophenia inconspicua
Aglaophenia sp.
Eudendrium californicum
Garveia annulata
Sertularella turgida
Sertularia sp.

ECHINODERMATA

Stars

Dermasterias imbricata
**Henricia leviuscula* *
Leptasterias aequalis
Leptasterias hexactis
Leptasterias leviuscula *
Leptasterias pusilla *
Pisaster ochraceus *
Patiria miniata *
Strongylocentrotus purpuratus *

ECTOPROCTA

Bryozoans

Bugula californica *
Crisia maxima *
Dendrobeania laxa
Dendrobeania lichenoides
Flustrellidra corniculata
Membranipora tuberculata *
Tricellaria sp.
Tricellaria ternata *
Tricellaria occidentalis *

MOLLUSCA

Bivalves

Mytilus californianus *
Hiatella arctica
Penitella turnerae
Petricola carditoides
Pododesmus cepio *
Protothaca staminea

Chitons

Katharina tunicata *
Lepidozona sinudentata
Mopalia muscosa *
Nuttallina californica *
Tonicella lineata

Limpits

Collisella scabra *
Fissurella volcano
Lottia digitalis *
Lottia ochracea
Lottia pelta *
Onchidella borealis

Notoacmace inessa

Nudibranchs

Acanthodoris nanaimoensis
Antipella barbarensis
Diaulula sandiegensis

Snails

Amphissa versicolor
Calliostoma ligatum
Crepidula adunca
Epitonium tinctorum
Haliotis cracherodii *
Lacuna marmorata *
Lacuna porrecta
Littorina keanae *
Littorina sp. *
Littorina scutulata *
Lottia gigantea
Mitrella carinata *
Nucella emarginata *
Ocenebra interfossa
Ocenebra lurida
Tegula brunnea *
Tegula funibralis *

PORIFERA

Sponges

Ciona celata
Haliclona sp. *
Ophlitaspongia pennata *

PYCNOGONIDA

Pycnogonum stearnsi *

SIPUNCULA

Phascolosoma agassizii

UROCORDATA

Tunicates

Aplidium arenatum
Aplidium californicum *
Cystodytes lobatus
Polyclinum planum
Ritterella aequalisiphonis *
Styela montereyensis

Table 6. Numbers of taxa by major taxonomic groups compiled from all seven monitoring sites.

Major groups		Numbers of taxa
Macrophytes		
Anthophyta		1
Chlorophyta		4
Phaeophyta		11
Rhodophyta		41
Total		57
Macroinvertebrates		
Annelida	- Polychaeta	6
Arthropoda	- Crustacea	16
Cnidaria	- Anthozoa	10
Urochordata	- Ascidiacea	6
Echinodermata	- Asteroidea	8
Echinodermata	- Echinoidea	1
Ectoprocta (Bryozoa)		9
Mollusca	- Bivalvia	6
Mollusca	- Gastropoda	27
Mollusca	- Polyplacophora	5
Porifera	- Demospongiae	3
Sipuncula		1
Total		98

Table 7. Mean percent cover for algae and invertebrates during the winter of 1997 for all sites. The mean percent cover values were based on 12 quadrats (6 permanent and 6 random) per site.

SITES	ALGAE	INVERTEBRATES	COMBINED
Bodega Head	93	46	139
Pinnacle Rock	92	56	147
Estero Americano	98	46	141
Duxbury Reef	113	30	142
Slide Ranch	101	61	162
Bean Hollow	114	19	132
Pigeon Point	106	31	137

Along the winter 1997 transects (Appendix 2, tables 1-21) *Mytilus californianus* was found to be rare at some sites and common at others with a mean percent cover ranging 0% to 14%. Pinnacle Rock had the most abundant assemblage of mussels (Table 10). Barnacles such as *Balanus glandula*, *Tetraclita rubescens* and *Pollicipies polymerus* ranged in mean percent cover from 6% to 20% and were most abundant at Slide Ranch (Table 10). Densities for chitons ranged from 0.0m² to 0.93m² and were rare to occasional (Table 11). Duxbury Reef had the highest densities of chitons. Limpets were common to abundant with densities ranging from 9.4 m² to 32.4 m² (Table 11). Pigeon Point had the highest density of limpets. Echinoderms were rare to frequent along the transects. Echinoderm densities ranged from 0.55m² to 5.3m² and were most abundant at Estero Americano.

The dominant algal species encountered during the winter 1997 sampling were *Cladophora sp.*, *Corallina vancouveriensis*, crustose coralline algae, *Egregia menziesii*, *Endocladia muricata*, *Mazzaella flaccida*, *Mastocarpus papillatus*, *Neorhodomela larix*, *Phyllospadix scouleri* (Appendix 1, Tables 1-56). The dominant invertebrate species found were *Anthopleura elegatissima*, *Balanus glandula*, *Collisella scabra*, *Mytilus californianus*, *Phragmatopoma californica* and *Pollicipies polymerus* (Appendix 1, Tables 1-56). Numbers of algal taxa recorded for the winter ranged from 17 at Estero Americano to 30 at Slide Ranch. (Table 12). Invertebrate taxa ranged from 3 at Estero Americano to 14 at Pinnacle Rock (Table 12). A list all species at each site can be found in appendix 3 tables 1-7. Bare rock accounted for .4% to 7% of the unoccupied and sand accounted for 0% to 4.3% of the unoccupied space during the winter (Table 12).

BODEGA HEAD

At Bodega Head, the site farthest north, quadrats 35-40 are located on the south facing side of the

Table 8. Mean percent cover for algae at high, middle, and low zones during the winter 1997 sampling period. The mean percent cover values were based on 12 quadrats (6 permanent and 6 random).

	HIGH	MIDDLE	LOW
Bodega Head	52	96	130
Pinnacle Rock	85	86	105
Estero Americano	53	122	120
Duxbury Reef	63	145	132
Slide Ranch	121	72	112
Bean Hollow	134	129	79
Pigeon Point	114	104	100

Table 9. Mean percent cover for invertebrates at high, middle, and low zones during the winter 1997 sampling period. The mean percent cover values were based on 12 quadrats (6 permanent and 6 random).

	HIGH	MIDDLE	LOW
Bodega Head	81	41	16
Pinnacle Rock	56	58	53
Estero Americano	80	30	28
Duxbury Reef	67	16	7
Slide Ranch	65	75	44
Bean Hollow	31	14	12
Pigeon Point	18	39	37

Table 10. Mean percent cover from three transects, at each site, across all zones for sessile invertebrates *Mytilus californianus* and barnacles, *Balanus glandula*, *Pollicipies polymerus* and *Tetraclita rubescens*. Percent cover values are based upon the winter 1997 sampling period. n=36.

Site	<i>Mytilus californianus</i>	Barnacles
Bodega Head	1	6
Pinnacle Rock	14	17
Estero Americano	3	11
Duxbury Reef	9	14
Slide Ranch	2	20
Bean Hollow	10.	12
Pigeon Point	0.0	18

Table 11. Mean densities of motile invertebrates (chitons, limpets and echinoderms) along three transects at each site across all zones during winter 1997. n=3.

Site	Chitons/m ²	Limpets/m ²	Echinoderms/m ²
Bodega Head	.37	17.3	2.2
Pinnacle Rock	0.0	27	1.8
Estero Americano	0.0	2	5.3
Duxbury Reef	.93	30.8	.56
Slide Ranch	.4	30	2.8
Bean Hollow	.4	25.7	.57
Pigeon Point	.37	32.4	.55

Table 12. Species richness and substratum abundance at all 7 study sites during winter 1997. A dash (-) indicates that a substratum type did not get recorded within the quadrat.

	BH	PR	EA	DR	SR	BNH	PP
Species Richness							
Total No. of Macrophytes	28	27	17	21	30	26	23
Total No. of Macroinvertebrates	11	14	5	10	12	9	8
Total No. of taxa	39	41	22	31	42	35	31
Substratum % Cover							
Rock	2.3	-	.4	6.3	1.3	2.0	7.0
Sand	4.3	-	-	-	-	-	.7

BH= Bodega Head PR= Pinnacle Rock EA= Estero Americano DR= Duxbury Reef
 SR= Slide Ranch BNH= Bean Hollow PP=Pigeon Point

head on the northwest side of the jetty. This site is protected due to the curvature of the head which reflects the swell. Backed up to a steep cliff, the site is narrow and contains a dominant middle zone.

Quadrats

The combined mean percent cover of algae and invertebrates during the winter sampling period was 139.0 %. Algae accounted for 93% and invertebrates 46% of the mean cover at this site. The low intertidal zones had the highest mean percent cover values for algae (130%) and the high intertidal zones had a highest mean percent cover for invertebrates (81%).

The dominant algal species encountered within the quadrats during winter were *Corallina vancouveriensis*, *Neorodomela larix*, *Odonthalia floccosa*, and the angiosperm, *Phyllospadix scouleri*. The dominant invertebrate species for both seasons were, *Balanus glandula*, *Mytilus californianus*, and *Phragmatopoma californica*. (Appendix 1, tables 1-8). The accumulation of sand in the middle to lower intertidal accounted for the high percent cover of *Neorodomela larix* and *Phyllospadix scouleri*.

Transects

The area is generally not rich in invertebrates, but at certain locations in the lower zones, colonial forms including compound ascidians and crustose bryozoans are conspicuous. The most noticeable invertebrate at this site is the sessile sabelliid polychete *Phragmatopoma californica*. Since this site does not receive high wave action, there are small patches of *Mytilus*/barnacle assemblages in the high intertidal which account for only 7% of the cover along the transects. Limpets were found to be common with counts of 17/m². Chitons, such as *Katharina tunicata* and *Mopalia muscosa*, were occasional in the intertidal with counts of .4/m². Echinoderms, in particular *Pisaster ochraceus* and *Patria miniata*, were frequent with counts of 2.2/m².

PINNACLE ROCK

Pinnacle Rock is a semi-exposed site with a wide intertidal band in which all intertidal zones and habitats are represented. Quadrats 29-34, are arranged throughout the site on terraces, vertical faces in surge channels and on exposed granite boulders.

Quadrats

Pinnacle Rock had the second highest combined mean percent cover for winter (147%), same as in the winter of 1996. The algae covered 92% of the substratum and invertebrates during the winter had a mean percent cover of 56%. As was the case with Bodega Head, the highest mean percent cover for the algae occurred in the low intertidal zones (105%). The invertebrates, however, were most abundant in the middle intertidal zones (58%).

The dominant algal species found within the quadrats during the winter 1997 sampling were *Corallina vancouveriensis*, *Endocladia muricata*, *Mazzaella flaccida*, *Pelvetiopsis limitata*. The dominant invertebrate species found were *Balanus glandula*, *Mytilus californianus* and *Phragmatopoma californica* (Appendix 1, tables 9-16).

Transects

This site is one of the richest in invertebrate abundance and diversity. The diversity reflected in the transect data from the lower levels does not adequately represent the fauna. The low zone is flooded, even during minus tides, and quantification is near impossible when viewed from the surface. Upon viewing, however, it is apparent that colonial invertebrates such as bryozoans, hydroids, ascidians and sponges are very abundant.

Upper intertidal zones, especially the marine terraces, support *Mytilus*/baracle beds which accounted for 31% of the cover along the three transects during winter 1997. Limpets were common with counts of 27.9/m², chitons were not seen and echinoderms were frequent 1.8/m².

ESTERO AMERICANO

Quadrats 57-62 are located just south of the mouth of the Estero Americano and are situated among a vast boulder field. This site is exposed to the waves yet, some locations are protected by large rock formations or sea stacks. Estero Americano is the sandiest of all seven sites, however sand is not present within the quadrat sampling sites.

Quadrats

The combined mean percent cover of algae and invertebrates during the winter sampling period was 141%, this is up 13% from winter 1995/96 data. Mean percent cover for algae was 98% and

46% for invertebrates. The middle intertidal zones had the highest mean percent cover of algae (122%) and invertebrates had the highest mean percent cover in the high intertidal zones (80%).

The dominant algal species encountered within the quadrats at Estero Americano during winter and summer sampling were typical of those of a middle to lower intertidal zone. the most common were *Corallina vancouveriensis*, crustose corallines, *Cryptopleura rosacea*, *Endocladia muricata*, *Egregia menziesii*, and *Mazzaella splendens*. Because of the unique sand habitat at Estero Americano, other algal species unique to this site were *Gloiosiphonia verticillaris* and *Gracilaria sjoestedtii*. The dominant invertebrate species were *Anthopleura elegantissima*, *Balanus glandula*, *Mytilus californianus* and *Phragmatopoma californica* (Appendix 1, tables 17-24).

Transects

This site is rich in invertebrates in the middle and high zones. The lower intertidal zones were depauperate of organisms, perhaps due to sand scour. Winter 1997 transects show mussels and barnacles contributing to 14% of the mean cover and *Phragmatopoma californica* 4.1% of the cover. Limpets were frequent (9.4/m²), down significantly from summer counts (55.4/m²). Chitons were not encountered along the transect and echinoderms were frequent (5.3/m²).

DUXBURY REEF

Quadrats 41-46 are located along an expansive mudstone reef. Four of the quadrats are placed on the seaward side while the other two are placed on the leeward side.

Quadrats

The combined mean percent cover for Duxbury Reef was the third highest (142%) of all sites during the winter 1997 sampling. Algae had a mean percent cover 113% and invertebrates during the winter had a mean percent cover of 30%. The middle intertidal zones during winter had the highest mean percent cover for algae with a cover of 145% and the high intertidal zones contained the highest mean percent cover for invertebrates (67%).

The dominant algal species within the quadrats were *Corallina vancouveriensis*, crustose coralline algae, *Endocladia muricata*, *Fucus gardneri*, *Chondracanthus canaliculatus* and *Phyllospadix scouleri*. *Balanus glandula*, *Mytilus californianus* and *Pollicipies polymerus* were the dominant invertebrate species found within the quadrats (Appendix 1, tables 25-32).

Transects

Along the transects *Mopalia muscosa* and certain acmaids, were thriving higher in the intertidal. They were more abundant in this zone because they are able to excavate the relatively soft substratum into pits and avoid dessication. At the middle to lower zones, the mudstone is riddled with boring clams (Pholads). The clams create a subsurface of bore holes which are occupied by an assemblage of nestlers (clams) and errant polychaetes. On the leeward reef flat, gastropods dominate. *Tegula funibralis* was the most abundant with counts of 42/m² along the winter transects. At the middle tidal level on the seaward side, there are small patches of *mytilus*/barnacle assemblages that occupied 23% cover along the transects. Limpets were common with counts of 30.8/m², both chitons and echinoderms were occasional with counts of .93/ m² and 0.56/m² respectively.

SLIDE RANCH

Although this site receives high wave action there are many semi-protected holes, caves and ledges among the large serpentine and graywacke boulders that characterize the area. Quadrats 216, 219 and 53-56 are located at this site and are placed throughout on protected boulders, exposed ledges and within the large 13.4 x 20.6 meter tidepool. This site is dominated by a wide middle to high intertidal zone with lower zones found within the large tidepools and exposed outer most seaward rocks.

Quadrats

The combined mean percent cover for the quadrats during winter sampling was 162%, the highest of all seven sites. Algae during the winter covered 101% of the substratum while invertebrates covered 61%. Mean percent cover for the algae was greatest in the high zones (121%) and for the invertebrates, mean percent cover was highest in the middle zones (75%).

The dominant algal species encountered within the quadrats were *Corallina vancouveriensis*, *Chondracanthus canaliculatus*, *Cryptopleura rosacea*, *Endocladia muricata*, *Fucus gardneri*, *Gastroclonium coulteri*, and *Mastocarpus papillatus*. For invertebrates the dominant species were, *Balanus glandula*, *Mytilus californianus* and *Bugula californica* (Appendix 1, tables 33-40).

Transects

Winter reveals a rich fauna of sessile colonial invertebrates, such as *Tricellaria californica* and *Bugula californica*. Other forms noted were the hydroids *Aglaophenia* sp. and *Garvia annulata*, crustose sponges such as *Ophlitaspongia pennata*, and the compound ascidian *Ritterella aequalisiphonis*. The solitary anenome, *Anthopleura xanthogrammica* were also present in high numbers along the transects. Abundance measurements taken during the winter sampling show patches of *Mytilus* /barnacle assemblages occupying 22% of the mean cover along the transects, and the scattered patches of *Phragmatopoma californica* accounting for 7% of the cover. Limpets such as *Collisella scabra*, *Lottia digitalis* and *Lottia pelta* were common along the transects with counts of 30/m². The echinoderms, *Herencia leviuscula*, *Leptasterias hexactis* and *Pisaster ochraceus* were all frequent along the transect with counts of 2.8/m². The aggregating anenome, *Anthopleura elegantissima*, was common along the transects with a cover of 11% counts. Inshore and on higher boulders, shore crabs *Hemigrapsus nudus* and *Pachygrapsus crassipes* were very abundant. A casual count recorded 115 crabs in five minutes, the most seen at any other site.

BEAN HOLLOW

This site is composed of a porous sandstone and shale substrate which has been formed into two large reefs. The outer reef is exposed to the waves and harbors a dense population of California sea palms, *Postelsia palmeformis*. The inner reef, where quadrats 23-28 are located, is semi-exposed and relatively flat with a predominant middle to upper intertidal zone. Lower zones are located along over hangs and within surge channels which cut the site longitudinally.

Quadrats

The combined mean percent cover for algae and invertebrates during winter was 132%. Algae had a mean percent cover of 114% and invertebrates covered 19%. The high intertidal zones at this site had the highest mean percent cover of algae (134%) and invertebrates (31%).

The dominant algal species found within the quadrats at Bean Hollow during winter 1997 were, *Corallina vancouveriensis*, crustose coralline algae, *Endocladia muricata*, *Fucus gardneri*, *Mazzaella flaccida*, *Mastocarpus jardinii*, *Mastocarpus papillatus*, *Petrocelis franciscana*, and *Porphyra perforata*. *Balanus glandula* and *Collisella scabra* were the dominant invertebrates found within the quadrats (Appendix 1, tables 41-48). The black abalone, *Haliotis cracherodii*, was also abundant at this site. A casual count revealed ten tucked under ledges and within crevices.

Transects

The most noticeable fauna that appeared along the transects were the large specimens of limpets, *Collisella scabra*, *Lottia digitalis* and *Lottia pelta* with counts of 25.7/m². On the outer margins of the reef flat there were patches of *Mytilus californianus* and barnacles. The *Mytilus californianus* /barnacle assemblage accounted for 22% cover along the transects. Both chitons and echinoderms were occasional with counts of .4/m² and .6/m² respectively.

PIGEON POINT

Within MBNMS, Pigeon Point is the site furthest south. It is composed of sandstone and conglomerates and is characterized by long, low flat benches which are cut longitudinally by cobble filled channels. A middle to lower intertidal zone dominates with high zones closer to shore or on sparse rock formations.

Quadrats

The combined mean percent cover at Pigeon Point was 137% during the winter period. Algae had a mean percent cover of 106% and invertebrates had a mean percent cover of 30%. The mean percent cover for algae (114%) was highest in the high intertidal zone, while the middle zone had the highest mean percent cover of invertebrates (39%).

The dominant algal species found within the quadrats during the winter sampling season were, *Corallina vancouveriensis*, *Endocladia muricata*, *Fucus gardneri*, *Gastroclonium subarticulatum*, *Chondracanthus canaliculatus*, *Mastocarpus papillatus*, *Mazzaella flaccida*, *Mazzaella splendens*, *Petrocelis franciscana*, *Pelvetiopsis limitata*, and *Phyllospadix scouleri*. *Anthopleura elegantissima*, *Balanus glandula*, *Phragmatopoma californica* and *Pollicipies polymerus* were the dominant invertebrate species found within the quadrats (Appendix 1, tables 49-56).

Transects

Across the transects, abundance measurements showed barnacles were common with 18% mean cover. Limpets were common with counts of 32.4/m². Chitons were rare (0.37/m²) and echinoderms were also rare (0.55/m²). *Mytilus californianus* did not appear across any of the

transects and had a very low mean percent cover within the quadrats. It is possible that there is not enough wave exposure and habitat to allow high numbers to exist. Colonial invertebrates such as sponges, ascidians or bryozoans were not noted in either transect or quadrat data. The instability of the low intertidal due to the cobbles and insufficient numbers of rocky clefts may be responsible for the lack of these invertebrates.

CONCLUSION

Detecting and monitoring the effects of anthropogenic disturbances may not be possible without and understanding of the natural variability at each site. The winter 1997 sampling data demonstrated that all quadrats and all sites had densities of at least 100 percent cover. Mean percent cover differed within and between sites and zones. The abundance of algae and invertebrates was differed only slightly from winter 1995/1996 with the greatest differences occurring at Estero Americano and Slide Ranch. In both cases mean percent cover increased. Mean percent cover during winter 1997 was still lower than summer 1996 cover, demonstrating a trend in seasonal abundance levels. Increasing sampling frequency is certain to make any changes in abundance or distribution not caused by seasonality, competition or predation more apparent.

Oil spills can negatively effect demography by decreasing reproduction in algae (Steele and Hanisak, 1978; Anderson and Hunt, 1988; Anderson et al., 1990). After the Exxon Valdez oil spill, *Fucus* produced fewer offspring at oiled compared to unoiled sites (Paine et al 1996). Future sampling will note the reproductive status of *Fucus gardneri* and *Laminaria spp.* at each site. The ripe, swollen receptacles of *Fucus* and sporangial sori on *Laminaria* are easily noted in the field. The prefertilization stages of these two species have been found to be very sensitive to a variety of petroleum products (Steele and Hanisak, 1978; Steele, 1977; Johnston, 1977). Since sexual reproduction is the only mechanism for establishing and maintaining a population, understanding when a species is reproductive may provide valuable information in the recovery of the organism after a disturbance.

REFERENCES

- Abbott, I.A., and G.J. Hollenberg. 1987. *Marine Algae of California*. Stanford University Press, Stanford, CA.
- Anderson, B.S., Hunt, J.W. 1988. Bioassay methods for evaluating the toxicity of heavy metals, biocides, and sewage effluent using microscopic stages of giant kelp *Macrocystis pyrifera*: A preliminary report. *Mar. Environ. Res.* 26:113-134.
- Anderson, B.S., J.W. Hunt., S.L. Turpen., A.R. Coulan, and M. Martin. 1990. Copper toxicity to microscopic stages of giant kelp *Macrocystis pyrifera*: interpopulations and temporal variability. *Mar. Ecol. Prog. Ser.* 68:1147-156.
- Castenholtz, R.W. 1967. Stability and stresses in intertidal populations. Pages. 15-28 *In* *Pollution and marine ecology*, Edited by T.A. Olson and F.J. Burgess. Interscience, New York.
- Castilla, Carlos. 1988. Earthquake-caused costal uplift and it's effects on rocky intertidal kelp communities. *Science*. 242: 440-443.
- Crapp, G.B. 1973. The distribution and abundance of animals and plants on the rocky shores of Bantry Bay. *Irish Fisheries Investigation, Stationary Office, Dublin, Ser. B*, 9: 35 pp.
- Crisp, D.J., A.J. Southward. 1958. The distribution of inter-tidal organisms along the coasts of the English Channel. *Journal of Marine Biology. Ass. U.K.*, 37: 157-208.
- Foster, M.S., A.P. De Vogelaere., C. Harrold., J.S. Pearse, and A.B. Thum. 1986. Causes of spatial and temporal paterens in rocky intertidal communities of central and northern California, Vol. 1 & 2, Executive Summary. POCS Region, Minerals Management Service, U.S. Dept. of Interior, Contract No. 14-12-0001-30057, Los Angeles, CA.
- Foster, M.S., C. Harold, and D.D. Hardin. 1991. Point vs. photo quadrat estimates of the cover of sessile marine organisms. *J. Exp. Mar. Bio. Ecol.* 146: 193-203.
- Guiry, M.D., J.A. West, D.H. Kim, and M. Masuda. 1984. Reinstatement of the genus *Mastocarpus* Kützing (Rhodophyta). *Taxon* 33: 53-63.
- Hawkes, M.W. 1986. Lectotypification of species names of Rhodymeniales (Rhodophyta) for the red algal flora of British Colombia and northern Washington. *Taxon* 35: 329-333.
- Hommersand, M.H., M.D. Guiry, S. Fredericq, and G.L. Lester. 1993. New perspectives in the taxonomy of the Gigartinaceae (Gigartinales, Rhodophyta). *Hydrobiologia* 260/261: 105-120.
- Jan Rong-Quen, Dai Chang-Feng, Chang Kun-Hsiung. 1994. Monitoring of hard substrate communities. Pages 285-303 *In* *Biomonitoring of Costal Waters and Estuaries*. Edited by Kees J.M. Kramer, CRC press, Boca Raton, Florida.
- Jones, W.E, S. Bennel., C. Beveridge., B. McConnel., S. Mack-Smith, and J. Mitchell. 1980.

- Methods of data collection and processing in rocky intertidal monitoring. Pages 137-170 *In* J.H. Price, D.E.G. Irvine and W.F. Farnham, eds. *The Shore Environment*, volume Vol 1: Methods. Academic Press, London and New York.
- Johnston, C.S. 1977. The sub-lethal effects of water soluble extracts of crude oil on the fertilisation and development of *Fucus serratus* (L) Rapp. P. Renu. Cons. Perm. Int. Explor. Mer. 171:184-185.
- Kozloff, E.N. 1983. *Seashore life of the northern pacific coast*. University of Washington Press, Seattle WA.
- Jones, W.E., S. Bennell., C. Beveridge., B. McConnell., S. Mack-Smith., J. Mitchell, and A. Fletcher. 1980. *Methods of Data Collection and Processing in Rocky Intertidal Monitoring*. Pages 138-170 *In* J.H. Price, D.E.G. Irvine and W.F. Farnham, eds. *The Shore Environment*, volume 2: Ecosystems. Academic Press, New York
- Kent, M, and P. Coker. 1991. *Vegetation description and analysis: a practical approach*. CRC Press, Boca Raton, Florida.
- Kützing, F.T. 1843. *Phycologia generalis*. XXXII + 458 pp., 80 pls.
- Levine, H.G. 1984. The use of seaweeds for monitoring costal waters. Pages 189 - 210 *In* *Algae as Ecological Indicators*. Edited by L.E. Shubert. Academic Press New York.
- Littler, Mark M. 1982. Southern California Rocky Intertidal Ecosystems: Methods, Community Structure and Variability. Pages 565-608 *In* J.H. Price, D.E.G. Irvine and W.F. Farnham, eds. *The Shore Environment*, volume 2: Ecosystems. Academic Press, New York.
- Nam, K.W., C.A. Maggs, and D.J. Garbary. 1994. Resurrection of the genus *Osmundea* with an emendation of the generic delineation of *Laurencia* (Ceramiales, Rhodophyta). *Phycologia* 33: 384-395.
- Rickletts, Edward., Jack Calvin, and Joel Hedgpeth. 1985. *Between pacific tides*, fifth ed. Stanford University Press, Stanford, California.
- Scagel, R.F. 1967. *Guide to common seaweeds of British Colombia*. British Colombia Prov. Mus. Handbook 27. 330 pp.
- Smith, R.I., J.T. Carlton., eds. 1989. *Lights Manual: Intertidal Invertebrates of the Central California Coast*, Third Edition. University of California Press, Berkeley, CA.
- Steele, R.L. 1977. Effects of certain petroleum products on reproduction and growth of zygotes and juvenile stages of the alga *Fucus edentatus*.. Pages 138-142 *In* *Fate and Effects of Petroleum Hydrocabons in Marine Ecosystems and Organisms*, edited by D.A. Wolfe Oxford: Pergamon.
- Steele, R.L. and M.D. Hanisak. 1978. Sensitivity of some brown algal reproductive stages to oil pollution. *Proceedings from the Ninth International Seeweed Symposium*. Edited by A. Jensen, and J.R. Stein. Science Press, Princeton.
- Whittaker, R.H. 1978. Dominance-types. Pages 65-79 *In* *Classification of plant communities*. Edited by R.H. Whittaker. W. Junk, The Hague.