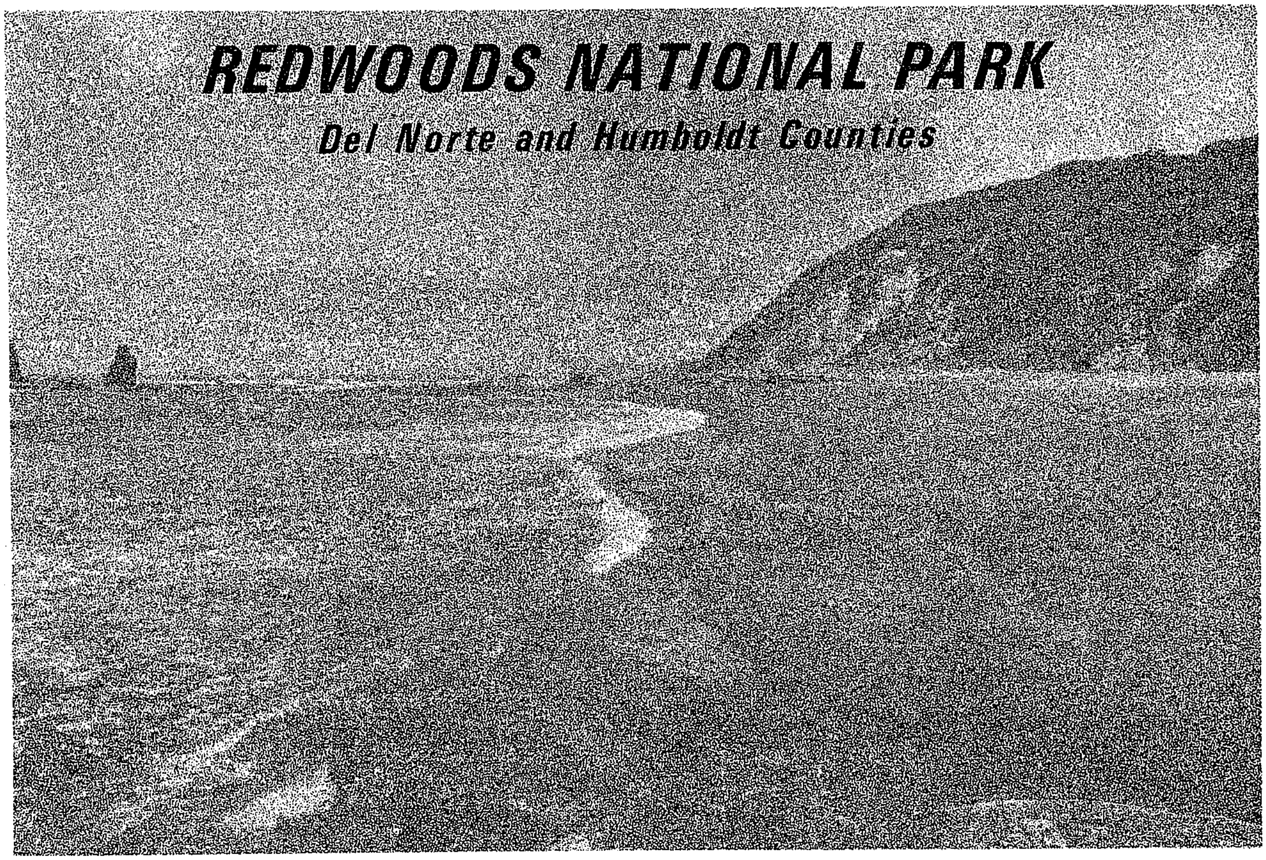
California Marine Waters
Areas of Special Biological Significance
Reconnaissance Survey Report



CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

SURVEILLANCE AND MONITORING SECTION

AUGUST 1981

WATER QUALITY MONITORING REPORT NO. 81-5

STATE OF CALIFORNIA
Edmund G. Brown Jr., Governor

STATE WATER RESOURCES CONTROL BOARD

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Cover Photograph:

Redwood National Park ASBS

Printed September 1981

CALIFORNIA MARINE WATERS
AREAS OF SPECIAL BIOLOGICAL SIGNIFICANCE
RECONNAISSANCE SURVEY REPORT

REDWOOD NATIONAL PARK
DEL NORTE AND HUMBOLDT COUNTIES

STATE WATER RESOURCES CONTROL BOARD
SURVEILLANCE AND MONITORING SECTION

August 1981
WATER QUALITY MONITORING REPORT NO. 81-5

Redwood National Park Area Of Special Biological Significance

STATE WATER RESOURCES CONTROL BOARD

AREAS OF SPECIAL BIOLOGICAL SIGNIFICANCE

Designated March 21, 1974, April 18, 1974, and June 19, 1975

1. Pygmy Forest Ecological Staircase
2. Del Mar Landing Ecological Reserve
3. Gerstle Cove
4. Bodega Marine Life Refuge
5. Kelp Beds at Saunders Reef
6. Kelp Beds at Trinidad Head
7. Kings Range National Conservation Area
8. Redwoods National Park
9. James V. Fitzgerald Marine Reserve
10. Farallon Island
11. Duxbury Reef Reserve and Extension
12. Point Reyes Headland Reserve and Extension
13. Double Point
14. Bird Rock
15. Ano Nuevo Point and Island
16. Point Lobos Ecological Reserve
17. San Miguel, Santa Rosa, and Santa Cruz Islands
18. Julia Pfeiffer Burns Underwater Park
19. Pacific Grove Marine Gardens Fish Refuge and Hopkins Marine Life Refuge
20. Ocean Area Surrounding the Mouth of Salmon Creek
21. San Nicolas Island and Begg Rock
22. Santa Barbara Island, Santa Barbara County and Anacapa Island
23. San Clemente Island
24. Mugu Lagoon to Latigo Point
25. Santa Catalina Island – Subarea One, Isthmus Cove to Catalina Head
26. Santa Catalina Island – Subarea Two, North End of Little Harbor to Ben Weston Point
27. Santa Catalina Island – Subarea Three, Farnsworth Bank Ecological Reserve
28. Santa Catalina Island – Subarea Four, Binnacle Rock to Jewfish Point
29. San Diego–La Jolla Ecological Reserve
30. Heisler Park Ecological Reserve
31. San Diego Marine Life Refuge
32. Newport Beach Marine Life Refuge
33. Irvine Coast Marine Life Refuge
34. Carmel Bay

ACKNOWLEDGEMENTS

This State Water Resources Control Board Report is based on a reconnaissance survey report submitted by Dr. Milton J. Boyd, Dr. John D. DeMartini and Greg Pic'l of the Fred Telonicher Marine Laboratory, Trinidad, California.

Several individuals gave freely of their help and advice in the field work and preparation of this report. Timothy Stebbins, Dennis Thoney, and Timothy Pennington assisted in the field work and in many of the identifications. Robert Plank and Susan Shaw were most helpful in the preparation of cartographic materials. John Ladd of the California Department of Fish and Game provided helpful administrative advice during preparation of the report.

The reconnaissance survey report was prepared in fulfillment of an agreement with the California Department of Fish and Game, which has coordinated the preparation of a series of Area of Special Biological Significance Survey Reports for the State Water Resources Control Board under an interagency agreement.

ABSTRACT

The Redwood National Park Area of Special Biological Significance is located in northern Humboldt County and southern Del Norte County. Thirty-four miles of coastline are within the ASBS and a variety of intertidal and subtidal habitats occur. The most common habitat is sand beaches or sand bottoms immediately seaward of the beaches. Rocky intertidal or subtidal habitats are found in the northern part of the ASBS.

Wave impact and materials discharged from creeks or rivers significantly affect marine habitats within the ASBS; except in the lee of Point St. George to the north, the coast is fully exposed to waves generated in the north Pacific. Particularly during winter months, algae and animals may be torn from rock surfaces by wave impact. Sand scour around intertidal rocks is severe. The Klamath River and Redwood Creek discharge fresh water and silt or larger particles into the nearshore zone of the ASBS. Water turbidity in nearshore waters is frequently high during winter months because of this bedload discharge. Many smaller creeks drain the coastal bluffs along the shore and may also contribute to erosion and turbidity.

The intertidal biota is dominated by species that settle and grow each year or regenerate from perennial holdfasts. Populations of algae on subtidal rocks are sparse, probably reflecting the high turbidity of coastal waters for much of the year. Offshore rocks have abundant populations of suspension-feeding invertebrates covering essentially all available surfaces. Sand scouring around the bases of subtidal rocks has an important influence on the survival of sessile species. Animal populations were most dense above an obvious scour line. Sand habitats were dominated by populations of motile animals. Wave action prevents the establishment of animals which occupy permanent burrows except at depths greater than 45 ft.

Water quality in the streams, rivers, and coastal waters of the

ASBS is generally high. The only chemical contaminant of significance in fresh water is iron, probably a result of its presence in native soils. There are no industrial activities within the ASBS which have a potential for degrading water quality in the near future. Past logging practices have contributed to erosion within watersheds adjacent to the ASBS, but forest rehabilitation and slope stabilization should result in decreased erosion. Coastal lands within the ASBS are federal or state parklands and there is little likelihood that development of these areas will occur. Recreational activities are currently consistent with the maintenance of high water quality standards.

The biological character of the marine habitat is apparently transitional between the biota of central California and the biota of the boreal eastern Pacific basin in the north. A number of species approach the limits of their distribution in northern California. The high turbidity of coastal waters has also resulted in the development of an unusual assemblage of plants and animals that is unique to this area of the California coast.

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FINDINGS AND CONCLUSIONS

Findings

State and federal agencies having jurisdiction over lands adjacent to the ASBS have been vigilant in their responsibility to maintain the scenic and biological character of the coast. Management plans currently under review seek to enhance public awareness of the biological value of resources within the ASBS. These efforts should be encouraged. No additional legislation or regulations appear necessary at this time.

The California State Water Resources Control Board should act immediately to re-define the northern boundary of the ASBS so that it coincides with the northern coastal boundary of Redwood National Park.

Conclusions

Development within the coastal zone of the Redwood National Park ASBS has historically been limited in scope and local in impact. Some coastal portions of the Park have been in a protected status for more than 50 years (Prairie Creek Redwoods State Park was established in 1923). The last major attempt at development, the mining of Gold Bluffs, ended in the early part of this century. The coastal zone has been largely protected from direct encroachment by commercial activities. Inland from the coast, however, logging activities in the major watersheds of the area have resulted in erosion and transport of sediments into nearshore waters. The impacts associated with these activities are largely unknown. With the initial establishment and recent expansion of Redwood National Park, logging activity has been greatly diminished. It can be anticipated that watershed rehabilitation, particularly in the Redwood Creek drainage, will result in a significant increase in water quality as turbidity decreases. If the recent federal "Wild River" designation for the Klamath and Smith Rivers is upheld, even further improvement of water quality can be anticipated.

The striking natural setting of the coastline of the ASBS is not significantly threatened by future developments. Water quality is high and should remain so because of the protected status of lands in the coastal zone. Future prospects for maintaining the pristine character of the coastline within the ASBS are excellent.

INTRODUCTION

The California State Water Resources Control Board, under its Resolution No. 74-28, designated certain Areas of Special Biological Significance (ASBS) in the adoption of water quality control plans for the control of wastes discharged to ocean waters. The ASBS are intended to afford special protection to marine life through prohibition of waste discharges within these areas. The concept of "special biological significance" recognizes that certain biological communities, because of their value or fragility, deserve very special protection that consists of preservation and maintenance of natural water quality conditions to practicable extents (from State Water Resources Control Board's and California Regional Water Quality Control Board's Administrative Procedures, September 24, 1970, Section XI. Miscellaneous--Revision 7, September 1, 1972).

Specifically, the following restrictions apply to ASBS in the implementation of this policy.

1. Discharge of elevated temperature wastes in a manner that would alter natural water conditions is prohibited.

2. Discharge of discrete point source sewage or industrial process wastes in a manner that would alter natural water quality conditions is prohibited.

3. Discharge of wastes from nonpoint sources, including but not limited to storm water runoff, silt and urban runoff, will be controlled to the extent practicable. In control programs for wastes from nonpoint sources, Regional Boards will give high priority to areas tributary to ASBS.

4. The Ocean Plan, and hence the designation of Areas of Special Biological Significance, is not applicable to vessel wastes, the control of dredging, or the disposal of dredging spoils.

ORGANIZATION OF SURVEY

Intertidal Survey

Several investigative approaches were used in gathering information or data on the Redwood National Park Area of Special Biological Significance. A review of both published and unpublished literature was carried out to obtain environmental data applicable to the Redwood National Park ASBS. Field observations at several sites within the ASBS were done using methods developed in an earlier study of intertidal and subtidal biota of the Redwood National Park ASBS (Boyd and DeMartini 1977). Sand beach habitats were sampled with a 0.10 m^2 cylinder excavated to a depth of 20 cm. All organisms retained on a 1.0 mm screen were identified and counted. A stratified random sampling technique was used, with a transect established from 10 m above the high tide mark to the swash zone during spring low tides in June, July, and August 1980. Paired samples were taken at 10 m intervals along the transect.

The biota at two rocky intertidal habitats within the ASBS, False Klamath Cove and Endert's Beach Cove, were sampled in June and August 1980 using a modification of the transect technique developed by Boyd and DeMartini (1977). At low tides transects were established in the same locations sampled from 1974-1976, but the entire transect was not censused. Rather, ten randomly selected points on each transect were used as center points for overlaying a 0.25 m^2 sheet of thin plexiglass. The plexiglass sheet had 50 randomly placed dots on it, and species under these dots were identified and recorded. Later, each species was assigned a cover value of 2% for each dot under which it occurred. Species which were in the plot, but did not happen to be under any of the dots, were assigned cover values of 1%. This method has been shown by others (Lubchenko and Menge 1978) to yield highly quantitative, repeatable observations of population levels of intertidal plants and animals. At both False Klamath Cove and Endert's Beach Cove, two separate transects were censused in June and again in August, 1980. These data were reduced to a numerical format and compared with data collected in 1974-1976 (Boyd and DeMartini 1977).

Color slide transparencies of the rocky intertidal and sand beach study sites were taken. In some transparencies, intertidal markers placed in 1975 were shown. The marked sites, approximately 1 m^2 in area, were compared with transparencies of the same sites made in 1974-76.

Several rocky intertidal sites that were surveyed qualitatively in 1974-1976 were revisited, re-surveyed, and additional transparencies were taken in July-August 1980 for comparison to early photographs. At some of these sites, color infra-red transparencies were taken to assess degree of algae cover.

Subtidal Survey

Subtidal surveys using SCUBA were conducted from August 11 to August 14, 1980. Dives were performed at different locations according to oceanic conditions with an attempt to survey as much area as possible (Figure 1).

During a given dive, topography, visibility, depth, habitat and relative abundance of observed species were recorded. A debriefing was conducted immediately after each dive. Taxonomically difficult specimens were either photographed or collected for subsequent identification in the laboratory (Appendix 4). Collected specimens were relaxed in $MgCl_2$ isotonic with seawater. Subsequently, they were fixed in 10% formalin and labeled as to both time and site of collection. In the laboratory, invertebrates were transferred to a 70% ethanol solution while vertebrates and algae were kept in 10% formalin. Specimens were identified by using several identification manuals.

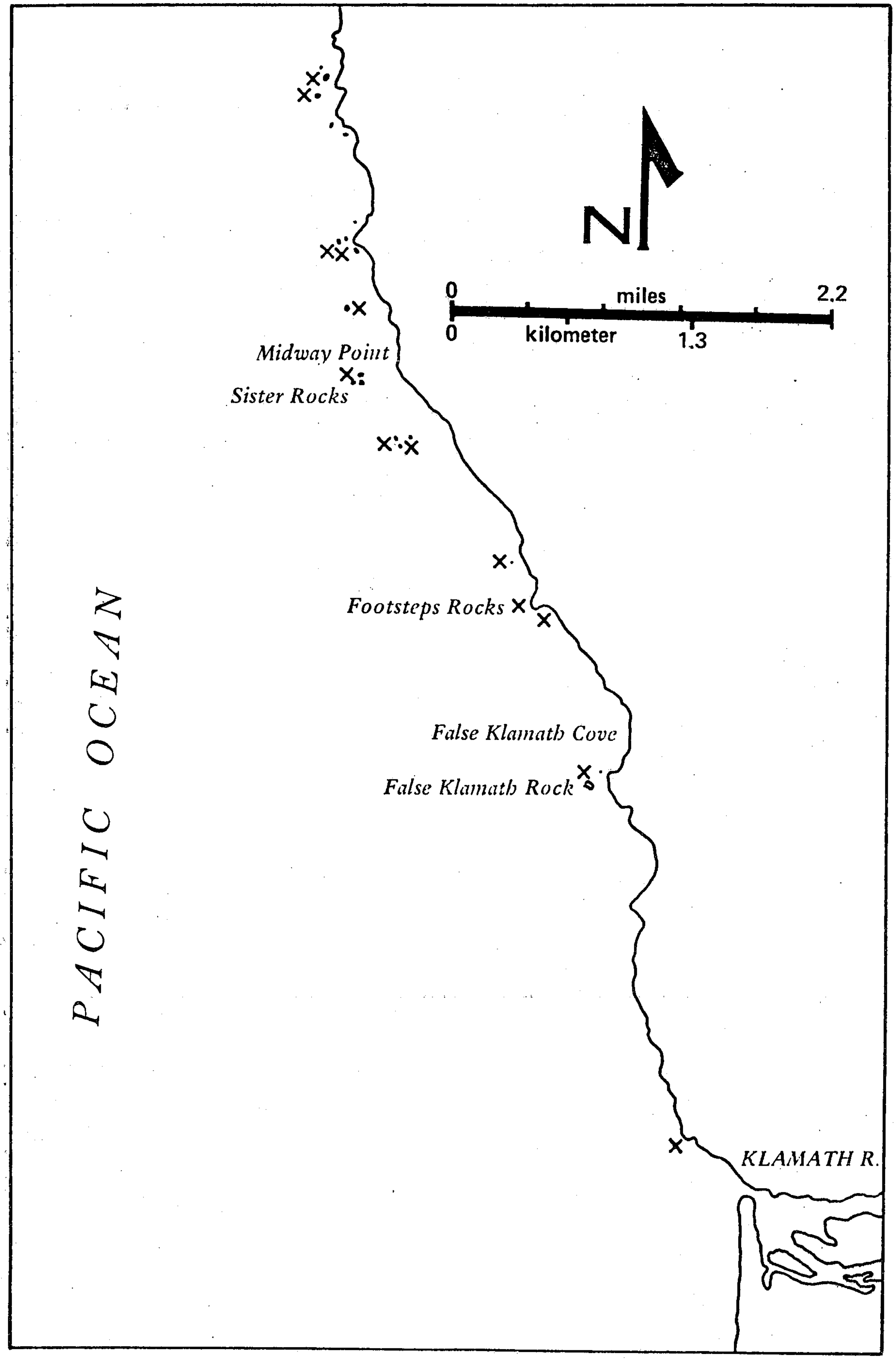


Figure 1: Dive Locations and Landmarks, Redwood National Park ASBS

PHYSICAL AND CHEMICAL DESCRIPTION

Location and Size

Redwood National Park lies along the coast of northwestern California in Humboldt and Del Norte Counties. Inland, a series of overlapping jurisdictions include Federal Park Lands and three California State Parks: Jedediah Smith Redwoods State Park, Del Norte Coast Redwoods State Park, and Prairie Creek Redwoods State Park. Coastal tidelands are under the jurisdiction of the California Coastal Commission. The coastal boundaries of Redwood National Park are just south of Crescent City in the north (latitude 41° 44.1' N, longitude 124° 9.5'W) and just to the north of Stone Lagoon in the south (latitude 41° 15.7'N, longitude 124° 5.7'W). The legal description of the Redwood National Park ASBS (California State Water Resources Control Board 1976) is as follows:

> Ocean waters bounded by a line extending from Point 1, the intersection of the mean high tide line and the southern border of Section 7, T10N, R1E, HB & M; thence northerly following a meander line along the mean high tide line to the intersection of the southern boundary of Section 2, T15N, R1W, HB&M, and the mean high tide line; thence due west to the 100-foot isobath; thence southerly following the 100-foot isobath to a point due west of Point 1; thence due east to Point 1 (see Figures 2,3).

It should be noted that this description and the maps accompanying the description do <u>not</u> correspond to the northern coastal boundary of Redwood National Park. That boundary of the Park is fixed at the northern boundary of Section 2, T15N, R1W, HB&M by Park authorities (National Park Service 1979). If the boundaries of the ASBS were, in fact, meant to overlap the Park boundaries, about 1.1 additional miles of coastline, the southern part of Crescent Beach, would be added to the ASBS. In this report, it is assumed that the boundaries of the ASBS and Redwood National Park are identical, despite this apparent discrepancy.

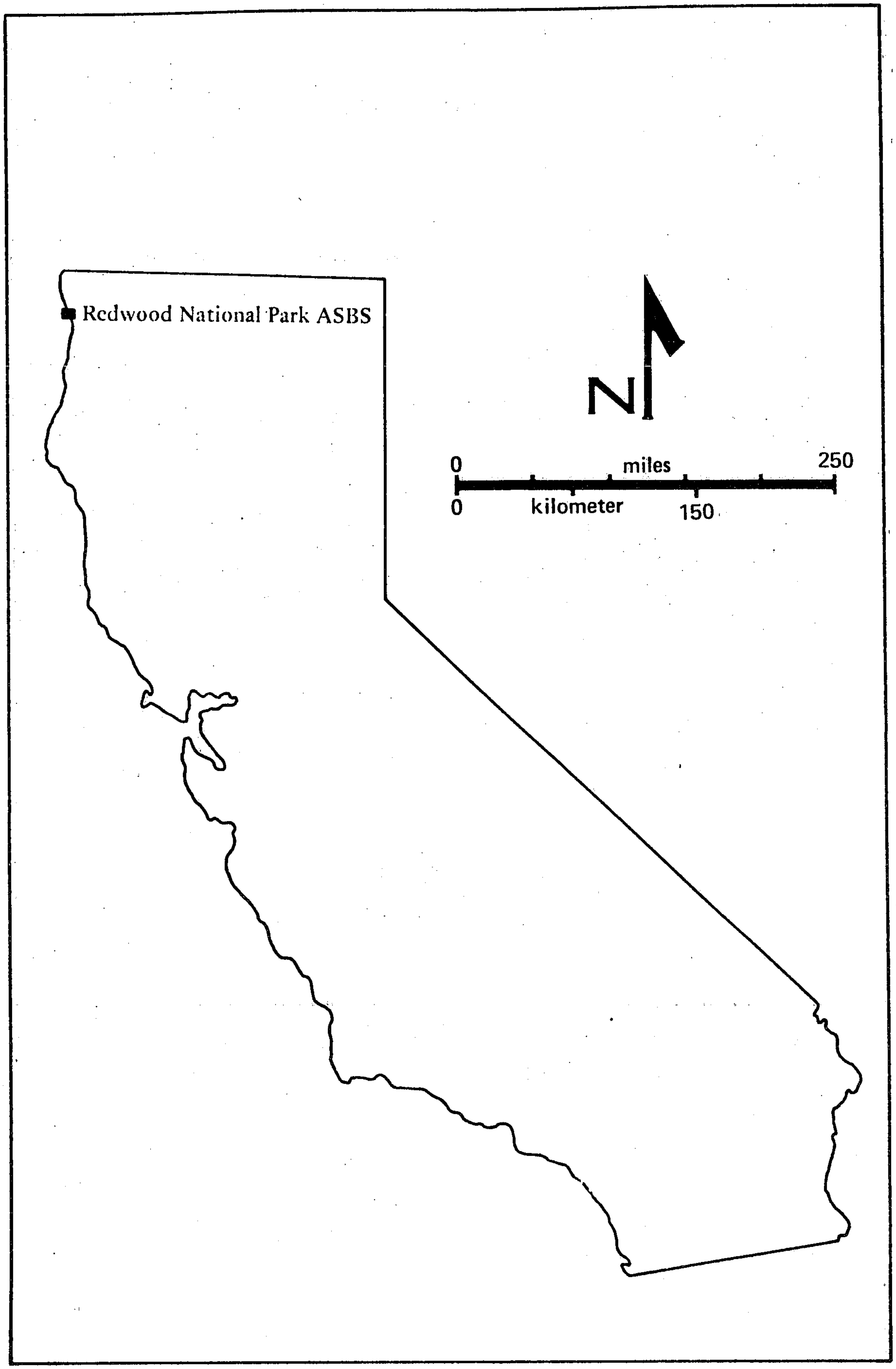


Figure 2: Location Map, Redwood National Park Area of Special Biological Significance

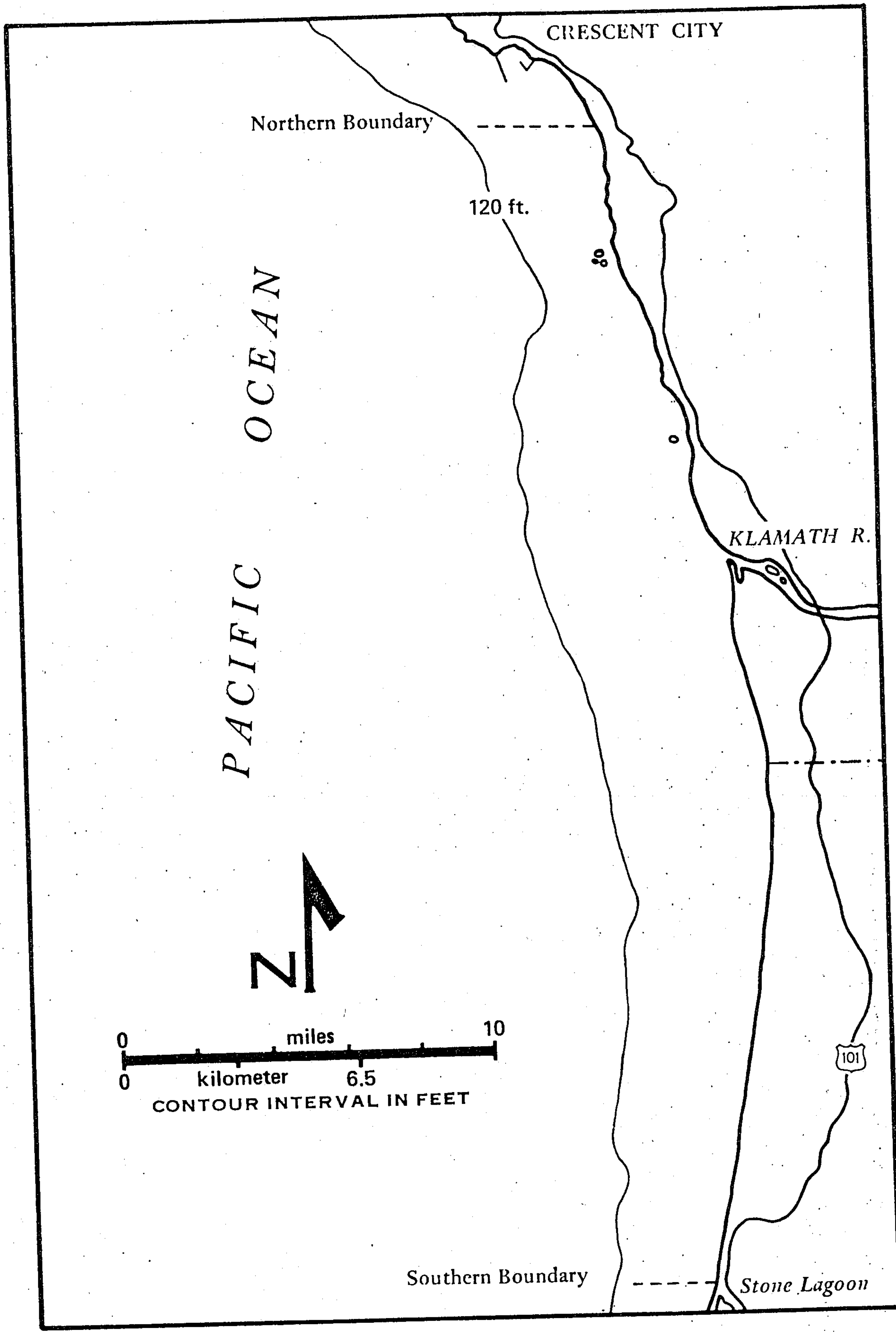


Figure 3: Boundary Lines, Redwood National Park ASBS

The ASBS encompasses 34 miles of various coastal habitats and extends 1000 yards offshore.

Nearshore Waters

The nearshore environment of the Redwood National Park ASBS is influenced by a seasonally variable current pattern, by large amounts of fresh water entering the nearshore zone at the mouth of the Klamath River and at the mouth of Redwood Creek, and by seasonal changes in the temperature of nearshore waters.

Three distinct oceanic "seasons" have been recognized off the coast of Redwood National Park (Pirie et al. 1975). During the "Oceanic Period" from July to November, the California Current dominates the nearshore current pattern. The current moves southward at about 0.8 ft. (0.25 m) per second, but its general pattern of flow is interrupted by projecting headlands. Point St. George, just to the north of Redwood National Park ASBS, tends to push the southward flowing waters offshore, and a large gyre forms south of this headland (Figure 4). This gyre appears to extend about 24 miles (40 km) south, trapping within it much of the sedimentary material entering the ocean from the Klamath River and Redwood Creek. Some of the finer material entering the ocean at the mouth of the Smith River, north of Crescent City, is transported around Point St. George and deposited on Crescent Beach within the ASBS (Pirie et al. 1975).

In the November to February period each year, nearshore current patterns are complex and are greatly affected by winter storms. Large volumes of fresh water are discharged into the nearshore waters with heavy silt loads. Small local gyres are evident when observing stream discharge plumes and fine particulate silts may move either north or south dependent on the local current pattern (Figure 5). Indirect evidence of an inshore, northward flowing current, perhaps an extension of the Davidson Current, is provided by annual differences in the settlement of some sand beach invertebrates. In 1974-76, the sand crab Emerita analoga was rare on sand beaches within the ASBS. In the summer of 1980, 188-228 E. analoga/m^2 were found at Redwood Creek Beach and at

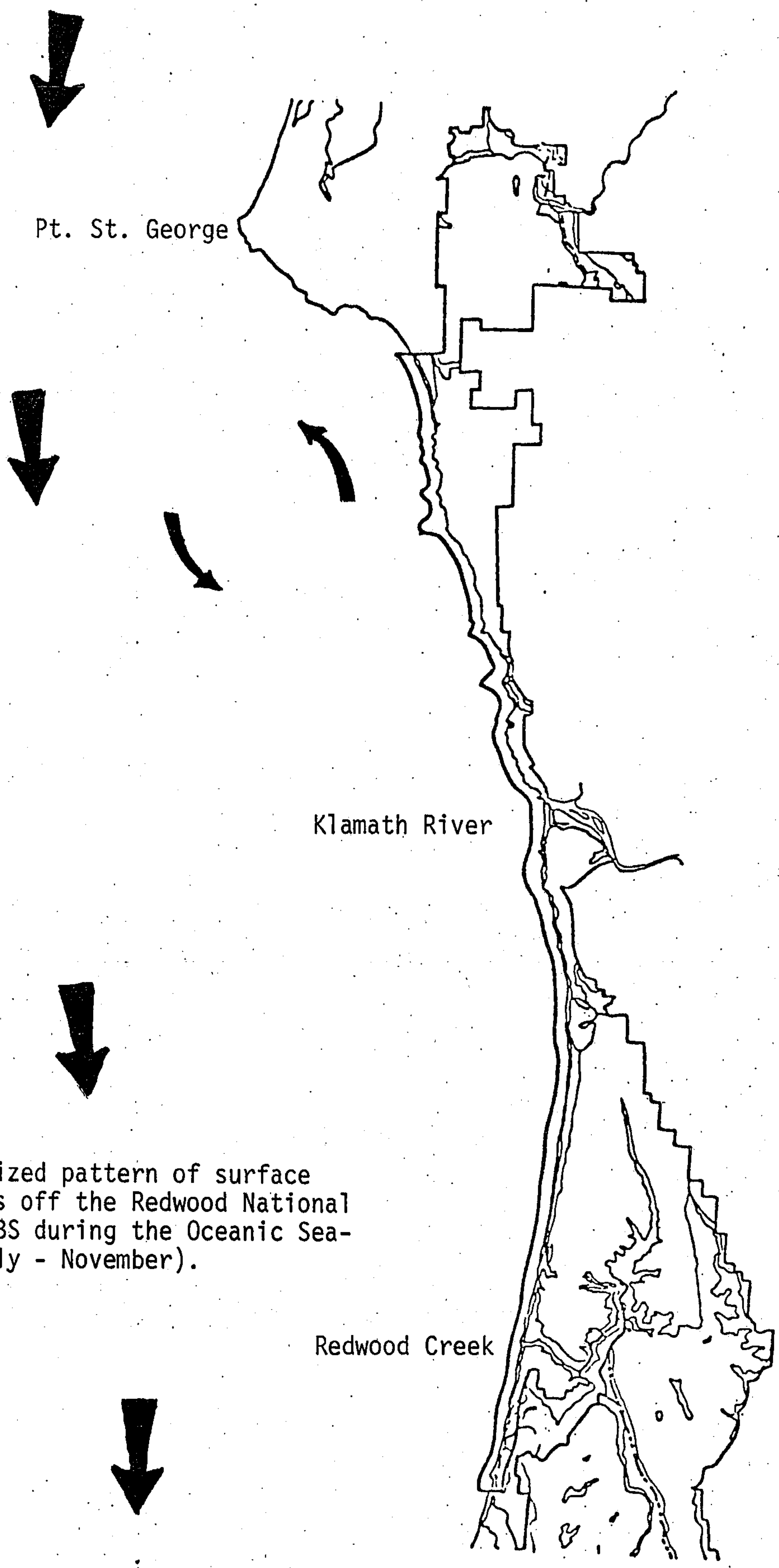


Figure 4. Generalized pattern of surface currents off the Redwood National Park ASBS during the Oceanic Season (July - November).

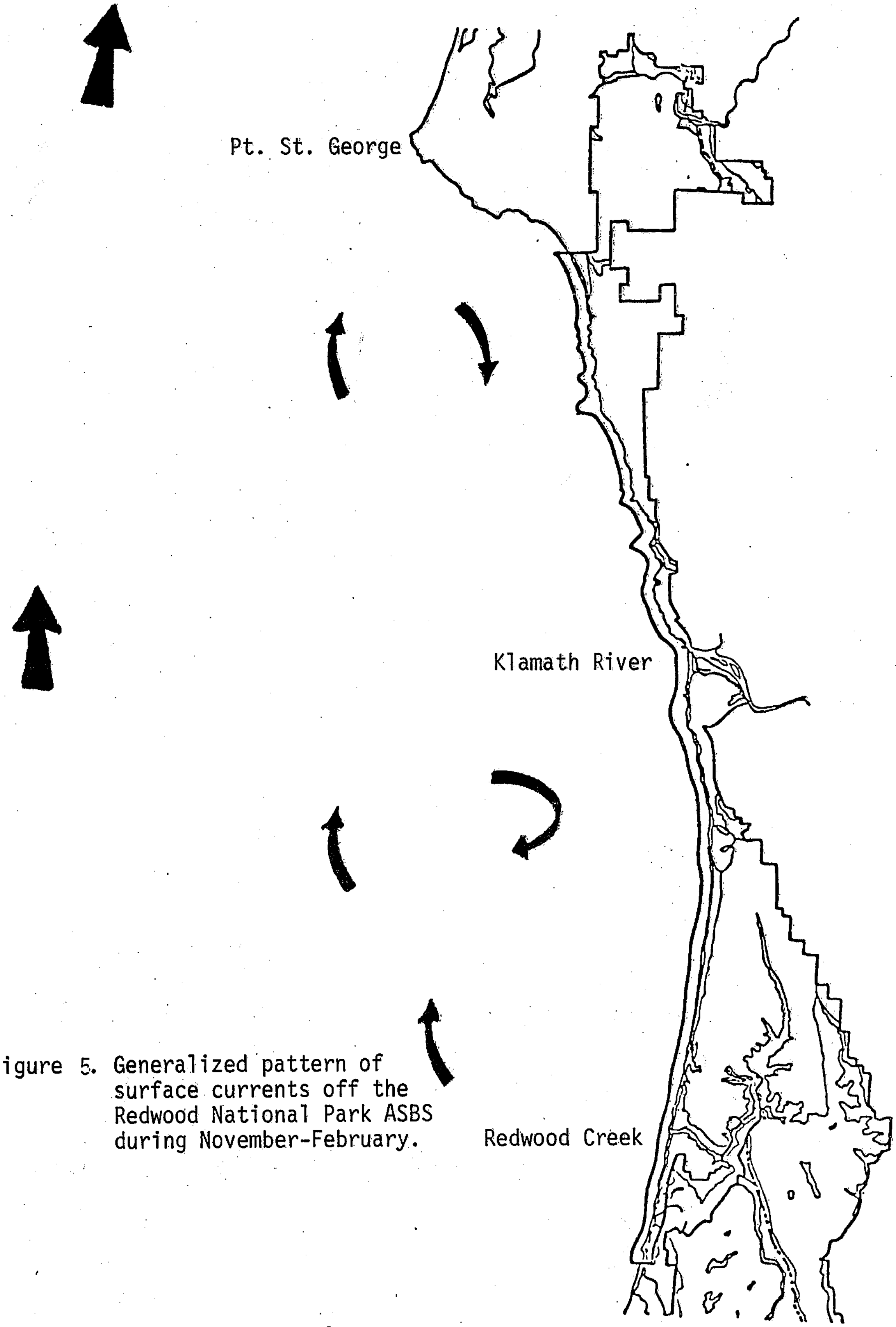


Figure 5. Generalized pattern of surface currents off the Redwood National Park ASBS during November-February.

False Klamath Cove. This species has been shown by Efford (1970) to be distributed northward from populations in central and southern California by the Davidson Current. Pirie et al. (1975) were unable to definitively indicate the northward limit of Davidson Current, but felt it extended to "some point beyond Cape Mendocino."

An upwelling period is evident along the coast of the ASBS during March through August (Figure 6). Upwelling is a result of wind movement generally parallel to the coast moving waters offshore, with replacement by deeper, cooler, nutrient rich waters. Nutrient enriched nearshore waters are particularly evident south of capes or headlands, such as Point St. George. Pirie et al. (1975) described an area of upwelling south of Crescent City; increased chlorophyll concentrations during the March to August period in 1974-76 support the existence of nutrient-rich waters in the nearshore zone of the ASBS (Boyd and DeMartini 1977).

The salinity of nearshore waters fluctuates markedly depending on patterns of local rainfall. Near major stream discharge points, surf zone waters are frequently below 1 part per thousand salinity - essentially fresh water. The extent of the fresh water influence is dependent on the volume of stream discharge and is difficult to pinpoint exactly. Surf zone waters were below 1 part per thousand for ¼ mile north and south of the mouth of Redwood Creek during periods of high stream flow in 1974-76, but beach waters at Gold Bluffs Beach, 4½ miles north, were never below 30 parts per thousand. It seems likely that a similar pattern of low salinity during peak discharge periods (winter months) is also in existence near the mouth of the Klamath River. The only regular measurements of surface salinities along the Humboldt-Del Norte Counties coastline are made at the Telonicher Marine Laboratory operated by Humboldt State University at Trinidad (Table 1). These data suggest a pattern of modest variation in the salinity of nearshore waters, except in areas where stream discharge may have a major influence.

Surface water temperatures fluctuate annually, with the lowest water temperatures in late winter or early spring and the highest water

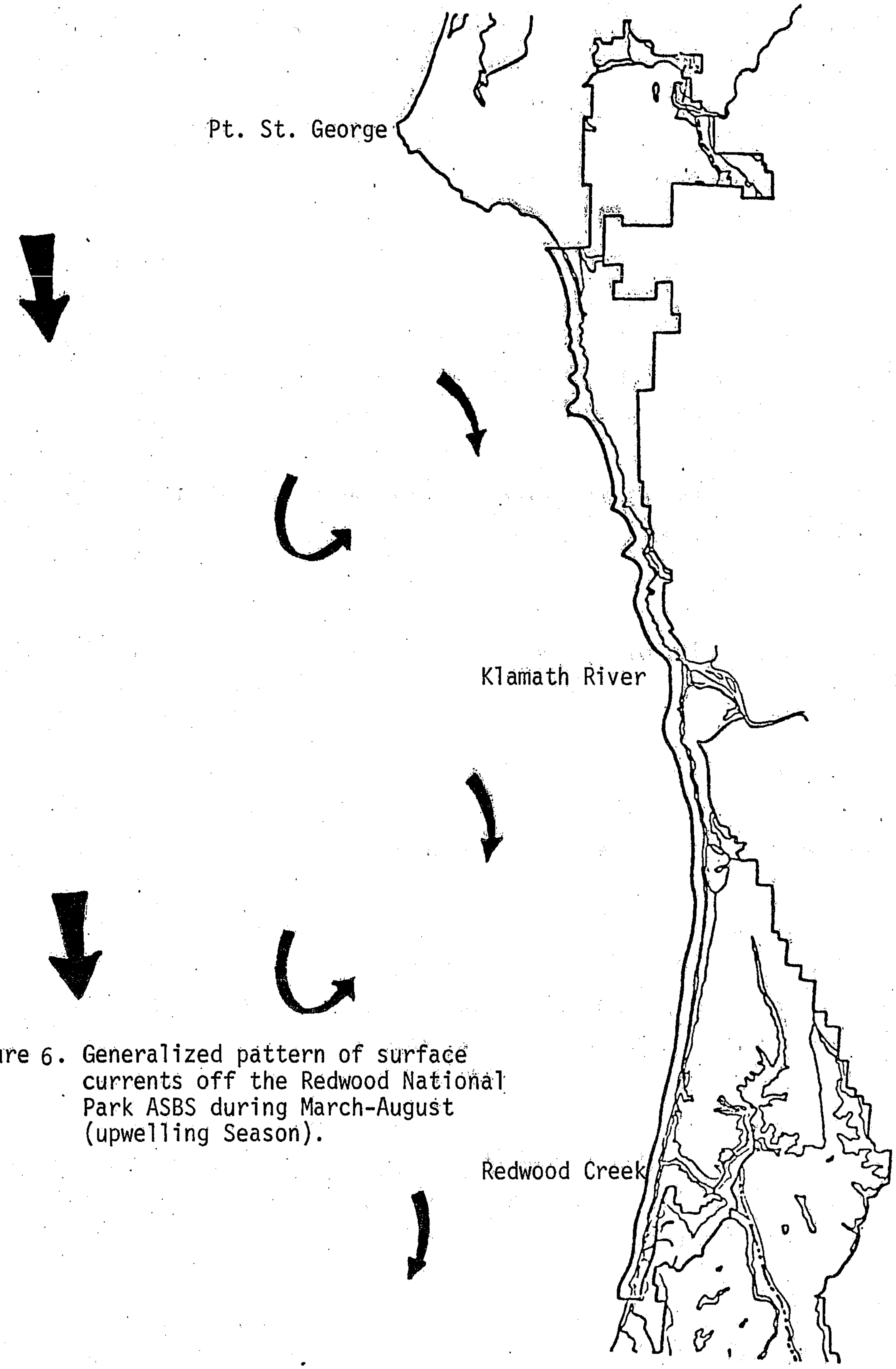


Figure 6. Generalized pattern of surface currents off the Redwood National Park ASBS during March-August (upwelling Season).

Table 1. Surface water salinity in parts per thousand at Trinidad Bay, California by month for 1978 (SIO 1978).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Monthly mean Salinity	27.79	29.89	30.72	31.43	33.56	33.63	33.73	33.73	33.59	33.41	33.51	33.32
Maximum value in month	31.22	31.96	32.68	33.07	34.88	33.84	33.86	33.88	33.74	33.53	34.24	33.61
Minimum value in month	22.61	28.12	26.54	29.75	32.52	33.19	33.57	33.62	33.39	33.29	32.48	32.70
Range	8.61	3.84	6.14	3.32	2.36	0.65	0.29	0.26	0.35	0.24	1.76	0.91

temperatures in late summer or early fall. Water temperatures are recorded regularly at Crescent City and Trinidad Bay (Table 2).

Geophysical Characteristics

Geomorphology

The coastal geology of the ASBS is a mixture of three major components: the Franciscan assemblage, Quaternary deposits, and modern beach sands. Within the Franciscan assemblage occur a variety of sedimentary formations, including sandstones, siltstones, and conglomerates. Most of the intertidal rocks and sea stacks are derived from Franciscan rock types. At a few points volcanic greenstones and cherts can be found (Figure 7). The Franciscan assemblage originated as a series of geosynclinal deposits laid down between 100-150 million years ago. Continental drift and plate movements have extensively sheared, faulted, and metamorphosed these deposits. These changes have made it extremely difficult to interpret the local geological history of Redwood National Park (National Park Service 1979).

Along Gold Bluffs Beach, a fluvial deposit (probably about 2 million years old) was laid down in an ancient delta fan of the Klamath River. In the 1850's Gold Bluffs Beach had only a narrow beach between the base of the cliffs and the surf zone. Erosion of the cliffs by wave action resulted in erosion of the old fluvial deposits and a concentration of fine gold flakes in intertidal beach sands. Several commercial ventures were mounted to recover these gold deposits, without notable success. The beach is, today, wider than it was during the 19th Century and includes dunes that are a result of sand deposition along the shoreline. The beach extending southward from Crescent City to Nickel Creek is composed entirely of modern beach sands and is intermixed with boulders and rocks near White Knob at the south end of the beach. These sands at this beach, as at other beaches within the ASBS, are indicative of erosion of nearby coastal formations, or have their source in erosion within the major drainage basins of the Park and adjacent areas.

Table 2. Surface water temperatures in ^{o}C, at Crescent City and Trinidad Bay, California by month for 1978 and 1979.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Crescent City 1978													
Monthly mean	11.78	11.95	13.22	12.57	12.41	13.65	14.74	15.17	15.00	13.86	10.23	9.05	Annual
Maximum value	12.7	13.3	15.3	15.6	17.2	16.1	16.7	18.3	18.6	15.0	12.5	10.6	Mean 12.80
Minimum value	10.5	10.8	11.7	11.1	10.0	10.6	11.1	12.2	12.5	11.9	8.3	8.1	Max 18.6
Range	2.2	2.5	3.6	4.5	7.2	5.5	5.6	6.1	6.1	3.1	4.2	2.5	Min 8.1
Crescent City 1979													
Monthly mean	9.62	9.73	11.25	11.78	11.59	12.35	15.28	16.27	17.07	14.84	13.13	11.55	Annual
Maximum value	11.1	11.1	13.9	16.1	14.4	14.4	16.7	18.2	20.0	16.9	15.0	13.3	Mean 12.87
Minimum value	7.5	8.6	10.0	10.0	10.0	10.1	10.0	15.5	15.6	13.2	10.6	10.6	Max 20.0
Range	3.6	2.5	3.9	6.1	4.4	4.3	6.7	2.9	4.4	3.7	4.4	2.7	Min 7.5
Trinidad Bay 1978													
Monthly mean	11.96	11.77	12.54	12.36	9.67	10.19	10.80	11.69	10.78	11.75	9.32	8.70	Annual
Maximum value	13.5	13.2	14.6	13.6	12.5	11.5	14.0	14.0	12.6	13.4	11.0	10.0	Mean 10.96
Minimum value	10.6	10.8	11.2	10.9	7.7	8.7	9.1	9.5	8.9	10.1	8.2	7.8	Max 14.6
Range	2.9	2.4	3.4	2.7	4.8	2.8	4.9	4.5	3.7	3.3	2.8	2.2	Min 7.7
Trinidad Bay 1979													
Monthly mean	9.41	9.46	10.53	10.97	10.01	10.03	12.59	12.68	14.87	12.75	12.83	11.09	Annual
Maximum value	10.6	10.0	11.0	13.2	11.9	12.0	14.0	15.1	17.7	14.0	14.3	12.3	Mean 11.44
Minimum value	7.7	8.1	9.0	9.2	8.4	8.6	9.0	11.0	12.0	11.9	10.6	9.3	Max 17.7
Range	2.9	1.9	2.0	4.0	3.5	3.4	5.0	4.1	5.7	2.1	3.7	3.0	Min 7.7

Figure 7. Coastal geological formations in the Redwood National Park ASBS (redrawn from National Park Service 1979).

Legend:

Qal	Dune Sand alluvium
Qt	Quaternary nonmarine terrace deposits
Qc	Pleistocene nonmarine
Qm	Pleistocene marine (Battery formation)
Qp	Plio-Pleistocene nonmarine (Gold Bluffs formation)
Mu	Upper Miocene
Tc	Tertiary nonmarine
KJf	Franciscan formation (predominantly Mesozoic sandstone)
Ub	Ultrabasic intrusive rocks (serpentine)
JTrv	Jura-Triassic metavolcanic rocks
Ms	Pre-Cretaceous metasedimentary rocks (Franciscan schist)

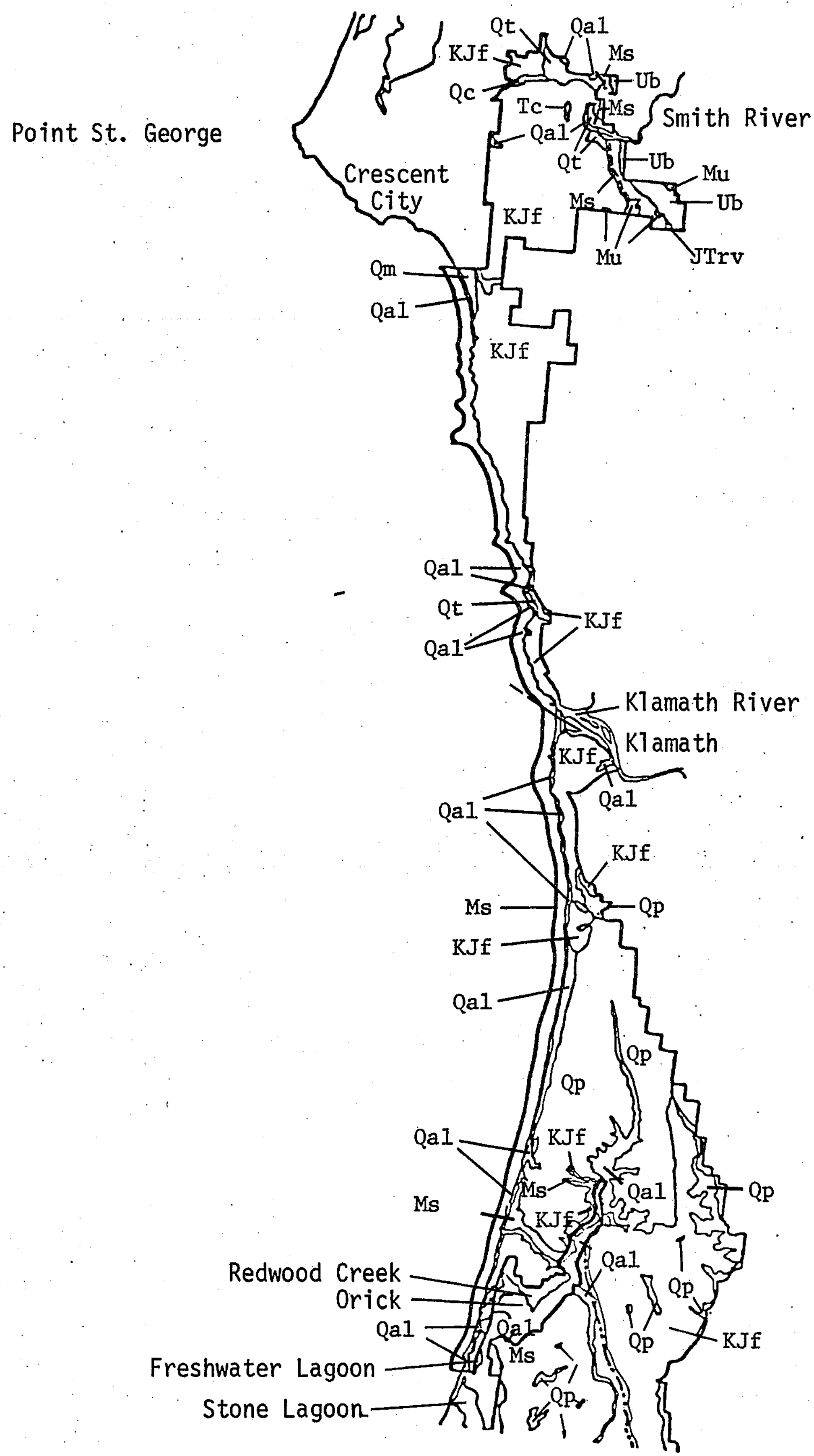

Point St. George
Crescent City
Smith River
Qt
Qal
KJf
Ms
Ub
Qc
Tc
Mu
JTrv
Qm
Klamath River
Klamath
Qp
Redwood Creek
Orick
Freshwater Lagoon
Stone Lagoon

FIGURE 7

Redwood National Park lies within three major river basins. The inland, northern portion of the Park lies within the Smith River drainage basin, the middle portion within the Klamath River basin and the southern portion within the Redwood Creek drainage basin. Numerous small coastal streams drain directly into the ocean at several points (Fig. 8). The high suspended sediment load of streams and rivers emptying into the coastal waters of the ASBS are a reflection of the unstable soils on the coast and inland combined with recent logging operations. Erosion within the Redwood Creek drainage basin is a serious problem that is being addressed by the National Park Service in its management plan.

Subtidal Geology

A variety of subtidal substrates exist within the ASBS (Figure 9). North of the Klamath River, substrates composed of a mixture of sands, gravels and rocks ranging in size from boulders (5 feet (1.5m) or greater in diameter) to giant sea stacks were observed. South of the Klamath River, substrates appear to be composed of chiefly sands and finer sediments (Field, Clarke and White 1980).

Lithological information concerning the ASBS was taken from Field, Clarke and White 1980. Offshore surface sediments are dominantly terrigenous, with minor amounts of biogenous and authigenic grains. The principle source of terrigenous sediments lies in the granitic and metamorphic rocks of the adjacent Klamath Mountains and Franciscan rocks in the northern California Coast Ranges. Within the ASBS, the Klamath River is the primary source of sediment input. The terrigenous fraction of sand and silt-size particles is dominated by quartz and feldspar, with lesser amounts of heavy minerals.

Analysis of smear-slides prepared from surface samples shows the following: Diatoms range from rare (1-5%) to abundant (25-75%) and are generally common (5-25%). Sponge spicules are rare to common in concentrations. Foraminifera, calcareous nannofossils, radiolarians, fish remains, volcanic glass and glauconite grains are also present in trace (1%) to common (5-25%) quantities.

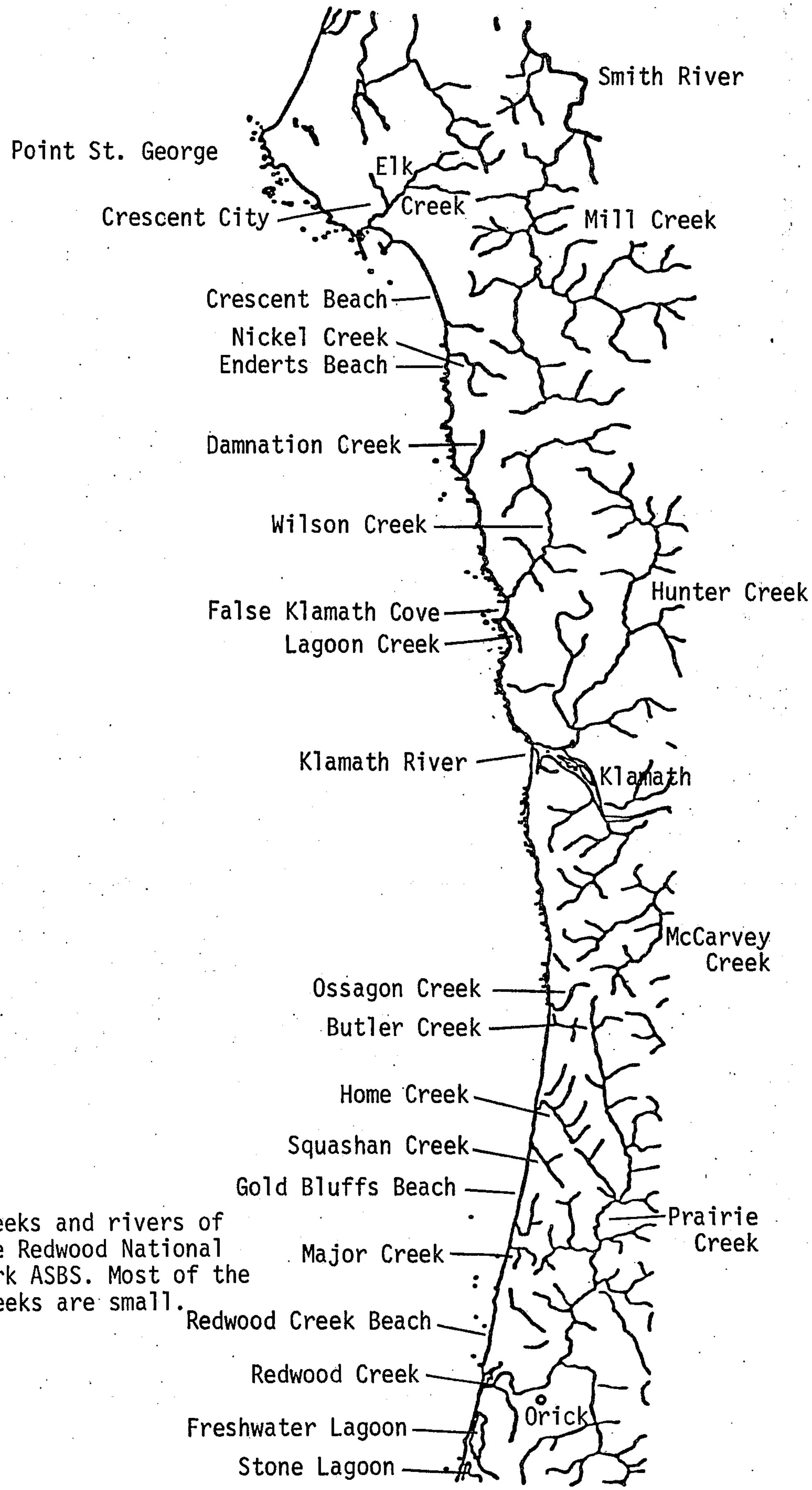
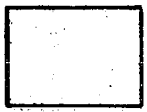
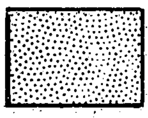
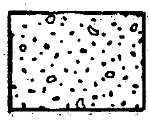


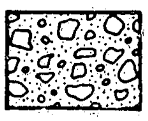
Figure 8. Creeks and rivers of the Redwood National Park ASBS. Most of the creeks are small.

LEGEND FOR FIGURE 9

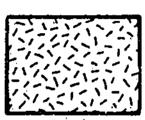
 Fine Sand

 Sand (greater than 75% Sand-undifferentiated)

 Muddy Sand (50%-75% Sand)

 Sandy Mud (25%-50% Sand)

 Mud (less than 25% Sand)

 Outcrop

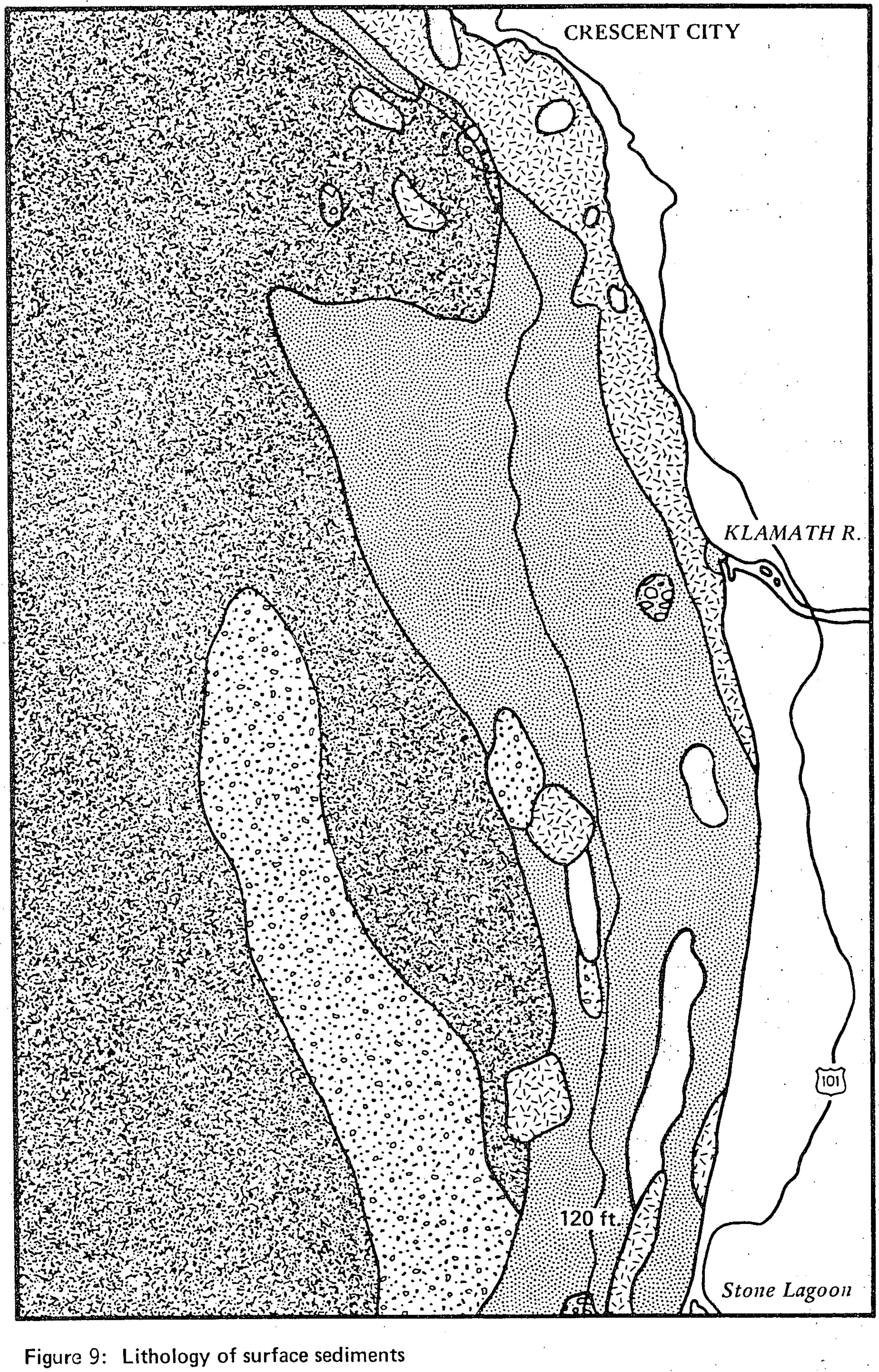


Figure 9: Lithology of surface sediments

Climate

Weather conditions along the coast of the Redwood National Park ASBS reflect a mild maritime climate. Winters are generally wet with rainfall concentrated between October and April. There are 60-100 days with rainfall each year. Summer months are cool with frequent fog along the coast. Precipitation and temperature data for three locations near the coast of the ASBS are presented in Tables 3, 4, and 5.

The maritime climate is influenced significantly by the cool California current offshore. During May, June, and July, tides of maximum variation ("spring tides") occur during morning hours. These are months of maximum solar insolation and sunlight striking intertidal surfaces at low tide could cause significant mortality to plant and animal populations due to high temperatures. The warming and upward movement of air masses inland, however, result in a landward flow of cool, humid marine air. As these air masses pass over the California Current and cool, a band of fog forms along the coast which serves as a protective blanket. Thus, plant and animal populations are spared the stress of high temperature during periods of prolonged exposure. Air temperatures along the coast rarely exceed 75^{o}F (24^{o}C) in summer or drop below 45^{o}F (7.7^{o}C) in winter.

Table 3. Average monthly precipitation and air temperature at Klamath, California, 1970-1979.

Month	Average Air Temperature	Average Rainfall
January	46.0°F (7.8°C)	13.45 in (34.16 cm)
February	47.8°F (8.8°C)	11.11 in (28.22 cm)
March	48.3°F (9.1°C)	11.61 in (29.49 cm)
April	49.0°F (9.4°C)	5.80 in (14.73 cm)
May	53.1°F (11.7°C)	2.61 in (6.63 cm)
June	56.5°F (13.6°C)	1.02 in (2.59 cm)
July	58.9°F (14.9°C)	0.26 in (0.66 cm)
August	59.4°F (15.2°C)	1.03 in (2.62 cm)
September	58.5°F (14.7°C)	3.27 in (8.31 cm)
October	54.5°F (12.5°C)	5.69 in (14.45 cm)
November	49.9°F (9.9°C)	13.77 in (34.98 cm)
December	46.0°F (7.8°C)	13.08 in (33.22 cm)

Annual mean temperature
52.3°F (11.3°C)

Annual mean precipitation
82.70 in (210.06 cm)

Table 4. Average monthly precipitation and air temperature at Orick Prairie Creek Park, California, 1970-1979.

Month	Average Air Temperature	Average Rainfall
January	44.7°F (7.1°C)	10.52 in (26.72 cm)
February	47.2°F (8.4°C)	9.02 in (22.91 cm)
March	47.8°F (8.8°C)	9.05 in (22.99 cm)
April	48.2°F (9.0°C)	4.98 in (12.65 cm)
May	52.5°F (11.4°C)	2.49 in (6.32 cm)
June	56.1°F (13.4°C)	0.85 in (2.16 cm)
July	58.4°F (14.7°C)	0.22 in (0.56 cm)
August	59.2°F (15.1°C)	0.81 in (2.06 cm)
September	58.9°F (14.9°C)	2.60 in (6.60 cm)
October	53.7°F (12.1°C)	4.57 in (11.61 cm)
November	48.5°F (6.9°C)	11.20 in (28.45 cm)
December	44.5°F (6.9°C)	10.34 in (26.26 cm)

Annual mean temperature

51.6°F (10.9°C)

Annual mean precipitation

66.65 in (169.29 cm)

Table 5. Average monthly precipitation and air temperature at Crescent City, California, 1970-1979.

Month	Average Air Temperature	Average Rainfall
January	47.2°F (8.4°C)	10.59 in (26.90 cm)
February	48.3°F (9.1°C)	8.98 in (22.81 cm)
March	49.3°F (9.6°C)	9.09 in (23.09 cm)
April	49.5°F (9.7°C)	4.17 in (10.59 cm)
May	53.1°F (11.7°C)	2.23 in (5.66 cm)
June	56.0°F (13.3°C)	0.99 in (2.51 cm)
July	58.4°F (14.7°C)	0.32 in (0.81 cm)
August	59.1°F (15.1°C)	0.99 in (2.51 cm)
September	59.0°F (15.0°C)	2.49 in (6.32 cm)
October	55.3°F (12.9°C)	4.57 in (11.61 cm)
November	50.7°F (10.4°C)	10.59 in (26.90 cm)
December	47.4°F (8.6°C)	10.82 in (27.48 cm)

Annual mean temperature

52.8°F (11.5°C)

Annual mean precipitation

65.83 in (167.21 cm)

BIOLOGICAL DESCRIPTION

Intertidal Habitats

Two major types of intertidal habitats found along the coast of Redwood National Park ASBS are rocky shores and sand beaches (Table 6). Sand beaches composed of medium to coarse sand grains (0.5-1.0 mm median diameter) are the most common intertidal habitat within the Park. It is most convenient to examine major habitats within the Redwood National Park ASBS by a narrative summary, beginning at the southern Park boundary near the south end of Freshwater Lagoon. Southern Boundary to North End of Gold Bluffs Beach : The beach is relatively steep and is found in a strip 100-200 yards (90 to 185 m) wide between U.S. Highway 101 to the east and the ocean. This is a popular beach for recreational camping and fishing. Hook-and-line fisherman catch mostly Redtail Surfperch (*Amphistichus rhodoterus*), during spring and summer months, Surf Smelt (*Hypomesus pretiosus*) and Night Smelt (*Spirinchus starksi*) are taken by both commercial and sport fishermen. A modification of the old Indian fishing nets, basically a large triangular net attached to a frame, is used. The sand crab (*Emerita analoga*) is sporadically abundant in sands of the low beach. During 1974-76, this animal was never encountered on the beach near Freshwater Lagoon, but during the summer of 1980, large numbers of juveniles had settled on the beach. Mortality was obvious during August and September 1981, with many young of the year cast onto the upper beach. By early October, sand crabs were no longer numerous on this beach.

The beach is continous to the mouth of Redwood Creek. Dependent upon season and stream flow, the mouth may be closed or open. It was never closed in 1974-76, but with reduced stream flow in 1977 and 1978, the mouth closed several times, forming a lagoon behind the barrier beach. In 1980, the mouth closed in May and did not open until early July, when a large amount of water had become impounded behind the beach, and forced an opening. The mouth remained open for the rest of the year.

Table 6 . Intertidal habitats within the Redwood National Park ASBS.

A. Rocky Shores

Exposed points: Geological features drop directly into the intertidal zone; most surfaces are perpendicular. Wave impact is severe and the zone of intertidal growth is narrow. Example: Footsteps Rocks, north of False Klamath Cove. Extent within the ASBS about 2.06 miles (3.31 km).

Large boulder fields: Some boulders are large enough to remain in place despite wave action. Smaller boulders are rolled by waves and can only support annual plants and animals. An example of this habitat type can be seen at the south side of False Klamath Cove. Extent of this habitat type within the ASBS is about 2.20 miles (3.54 km).

Small boulder-cobble fields: These are usually found at the base of eroding cliffs. Boulders and cobble are frequently moved about by wave action. A few short-lived species of plants and animals may be found attached to rocks during the generally calm summer months. An example of this habitat type can be found at the mouth of Damnation Creek. Extent within the ASBS of this habitat type is about 6.05 miles (9.73 km)

Gravel (shingle) beaches: Undercutting and weathering of recent sedimentary formations along coastal cliffs result in poorly sorted materials accumulating in a narrow strip between exposed points. Smaller sand particles are carried sea-ward, leaving behind gravels. Examples can be seen at Endert's Beach and just south of False Klamath Cove. Extent of this habitat type is about 2.79 miles (4.49 km)

B. Sand Beaches

Coarse to medium grain sand beaches: The entire southern coastal portion of the ASBS may be characterized as exposed beaches. Beach materials have been derived from coastal cliffs, along shore transport,

Table 6 (Cont.)

and from stream waters. The northern end of Gold Bluffs beach is the terminus of this extensive habitat type. Coarse to medium grain sand beaches account for approximately 20.66 miles (33.24 km) of coastline within the ASBS.

Fine grain sand beaches: The beach materials are of smaller grain size and are derived from coastal cliffs, alongshore transport, and stream discharge. Crescent Beach, terminating at White Knob, is the only fine grain beach within the ASBS and covers approximately 1.32 miles (2.12 km) from the northern Park border to White Knob.

The fauna of burrowing animals on the beaches in the southern part of the ASBS is relatively sparse (Table 7). Driftwood typically accumulates on the upper beach and burrowing in the sand under the woody debris are the semi-terrestrial amphipods Orchestoidea spp. and a few insects. A few polychaetes, the most numerous of which is the small bloodworm (Euzonus spp.) are found on the mid and low beach. Crustaceans are sparsely distributed. Emerita analoga was common in 1980, but rare in previous years. Smaller crustaceans, particularly burrowing amphipods (Eohaustorius spp.) are occasionally found if beach sands are carefully screened. At low tides, small mysid shrimp (Archaeomysis maculata) are abundant on the sand surface in the swash zone.

The beach at the mouth of Redwood Creek displays cycles of progradation (sediment accumulation) and erosion dependent on wave activity and stream discharge of sediments. During winter months, heavy rainfall results in high stream discharge and accumulation of beach sediments. Typically,the beach shows accumulation of sediments until the beach face becomes steep and unstable. A late winter storm in February or March undercuts the beach and the accumulated beach material slumps into the swash zone. Finer materials are resuspended and transported southward by alongshore drift, accumulating on the beach seaward of Freshwater Lagoon. Turbidity in nearshore waters is frequently high near Redwood Creek because of this erosion-accumulation cycle, and because of the heavy amount of bedload discharged into coastal waters.

A rock outcrop at the north end of Redwood Creek Beach is the demarcation between Redwood Creek and Gold Bluffs Beach to the north. This outcrop, known locally as Mussel Point, cannot be rounded to seaward even at low tides. Local residents are permitted to drive vehicles onto the beaches in the southern part of the ASBS (not at Crescent Beach in the north), but Mussel Point is an effective barrier between Redwood Creek Beach and Gold Bluffs Beach. Even in years when Emerita analoga was rare elsewhere on these two beaches, a small population persisted in the immediate southern lee of Mussel Point. The rocks of the point

TABLE 7.

ANIMALS OF SAND BEACHES
IN THE REDWOOD NATIONAL PARK ASBS
(From Boyd and DeMartini 1977)

	Crescent	Gold Bluffs	Redwood Cr.
Phylum Nemertea			
Tubulanus pellucidus	X		X
Unknown green species	X		
Phylum Annelida			
Eteone dilatae	X		
Euzonus mucronata	X	X	X
Euzonus williamsi	X	X	X
Lumbrinereis zonata	X		
Nephtys californiensis	X		X
Nothria iridescens	X		
Orbinia johnsoni	X		
Pygospio californica	X		
Scololepis squamata	X		
Phylum Arthropoda			
Archaeomysis maculata	X	X	X
Armadilloniscus lindahli	X		
Atylus trideus	X		
Bathycopeia daltonae	X		
Cancer magister	X		
Crangon nigracauda	X		
Crangon stylorostris	X		
Dogielonotus loquax	X		X
Emerita analoga	X	X	X
Eohaustorius brevicuspus	X		X
Eohaustorius sawyeri	X		
Eohaustorius washingtonianus	X		
Excirolana linguifrons	X	X	X
Monoculoides sp.	X	X	
Orchestoidea californiana	X		
Orchestoidea columbiana	X	X	X
Orchestoidea benedicti	X		
Paraphoxus sp.	X	X	X
Phylum Mollusca			
Olivella biplicata	X		
Olivella pycna	X		
Siliqua patula	X		
Total no. sp. each beach	32	8	12

have eroded from the adjacent cliff and show only slight evidence of weathering. During summer months annual species of algae (Porphyra spp., Iridaea spp., Ulva spp.) are abundant on intertidal rocks. Patches of stalked barnacles (Pollicipes polymerus) and mussels (Mytilus californianus) are scattered in small clumps over rocks of the low and mid-intertidal zones. Driftwood, much of it massive logs, is found on the upper rocks of the point. Drift logs are a significant cause of mortality in intertidal populations of attached plants and animals in northwestern California and Washington (Boyd and DeMartini 1977; Dayton 1971). Seaward rocks of Mussel Point have abundant populations of sea-palm algae, Postelsia palmaeformis, growing on them. This annual species flourishes in the heavy surf on the outer rocks of the point.

From Mussel Point, Gold Bluffs Beach stretches northward 8½ miles (13.6 km) to the mouth of Ossagon Creek. Even small rock outcrops are absent from this section of beach, so the habitat is exposed or semi-exposed sand beach.

During late spring and summer months, sport and commercial fishing is common along all of Gold Bluffs Beach. Vehicle access points are maintained along Davison Road as it parallels the beach between Espa Lagoon and Fern Canyon. Redtail surfperch (A. rhodoterus) are taken on hook and line; Surf smelt (H. pretiosus) and Night smelt (S. starksi) are netted by both commercial and sport fishermen. The extent of the commercial fishery is unknown, since catch records are not maintained. Gold Bluffs Beach is known as a prime location for catching smelt (Fitch and Lavenberg 1971). The most common fishing technique utilizes a large triangular net which is planted in the swash zone of a receding wave. Males and females which have spawned are swept into the net as the wave recedes from the beach. Night smelt, as the name implies, aggregate off beaches at night during high tides. The females lay their eggs on the wet sands of the upper beach. Commercial fishermen account for most of the catch of this species. Surf smelt spawn at high tides during daylight hours, generally around noon or later in summer months. Gulls, pelicans, cormorants, harbor seals, sea lions, and fishermen capture the fish in the surf zone or on the beaches.

Burrowing invertebrates of the beach slope are widely dispersed and sparse in numbers. Sand crabs (*E. analoga*) were rarely seen in 1974-76, but were quite common along Gold Bluffs Beach in the summer of 1980. The most numerous animal found on the beach is the small mysid shrimp, *Archaeomysis maculata*, restricted to sands at the edge of, or in, the swash zone. Polychaetes and amphipods are occasionally sampled in mid-beach zones at low tide (Table 11), and beach hoppers (*Orchestoidea columbiana*) may be locally abundant near piles of algal wrack or drift-wood.

During winter months, storm waves apparently move offshore bottom sediments about, resulting in the appearance on the beach of dead or dying animals from deeper waters of the ASBS. The most common of these animals are sand-dollars (*Dendraster excentricus*), razor clams (*Siliqua patula*), and small sea-cucumbers (*Caudina chilensis*). The numerous remains encountered after winter storms suggest large infaunal populations in subtidal areas of the ASBS seaward of Gold Bluffs Beach.

Ossagon Creek to the Mouth of the Klamath River

Northward from Ossagon Creek scattered intertidal rocks are interspersed with pocket beaches of modest size. Rock faces are predominantly vertical, with patches of mussels (*M. californianus*), stalked barnacles (*P. polymerus*), and acorn barnacles (*Balanus glandula* and *B. cariosus*). A sharp line separating bare rock from colonized surfaces is often seen near the base of rocks and indicates extensive sand movement and resultant sand scour of these rocks. Even in summer, algae are sparse on rock surfaces. Algae species encountered have generally short life cycles (*Ulva* spp., *Porphyra* spp., *Fucus distichus*, *Pelvetopsis limitata*), perhaps indicating severe wave shock along this section of the coast. Seaward faces of the rocks are densely covered with sea-palm (*Postelsia palmaeformis*).

The mouth of the Klamath River shifts seasonally and from year-to-year. No regular measurements of coastal water salinities have been taken near the mouth, but it seems likely that salinity drops considerably during winter and spring months because of high river discharge. Intertidal rocks both to the north and south of the mouth have a sparse growth of intertidal plants and animals. The dominant plants were green algae (Enteromorpha spp. and Ulva spp.), with some red algae (Porphyra spp.). Acorn barnacles (Balanus glandula) occurred in clumps on the lower portions of some rocks. Physiologic stresses on both plants and animals would appear to be severe near the river mouth, with a resultant development of only annual species on intertidal rocks along this section of the coast.

A coarse to medium grain sand beach extends for about ¼-mile (0.4 km) south of the river mouth. This beach was sampled qualitatively in July 1974, and August 1980. In the swash zone, mysid shrimp were abundant, but burrowing worms or amphipods were not found at mid-beach elevations. On the high beach, sand hoppers (Orchestoidea spp.) were common under driftwood.

There is a seasonal fishing camp on the sand spit forming the southern bank of the river mouth that is a very popular and well-known fishing spot for salmon and steelhead. Salmon runs in July and August each year attract large numbers of anglers, even though runs have declined in recent years. These fishing activities do not appear to have an adverse effect on intertidal populations of plants or animals.

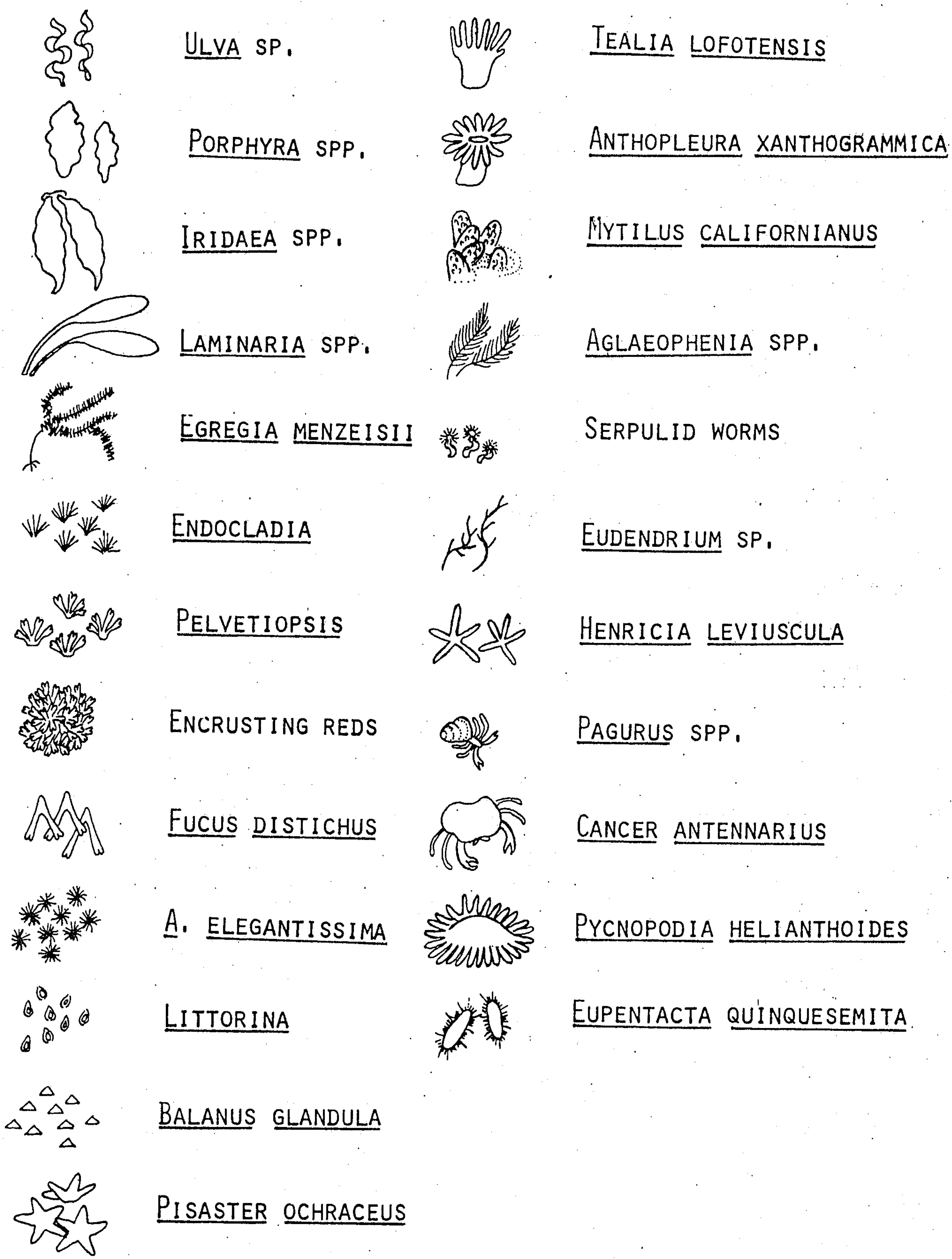
Klamath River Mouth to False Klamath Cove

Northward from the river mouth, the coast is steep and wave action is severe. The intertidal zone is virtually inaccessible and has been surveyed by boat. There are well developed beds of mussels and stalked barnacles on the seaward faces of rocks. Sea-palm algae (P. palmaeformis) is also very evident. Emergent rocks outside the surf-zone have similar dense growth down to the low water line. Just to the north of the river mouth, larger offshore rocks are used as haul-outs by harbor seals and sea lions. There are occasional instances of local residents shooting these animals because they believe they capture large numbers of salmon entering the river. The harbor seals and sea lions are fully protected under the Marine Mammals Act, but these illegal shootings have not resulted in legal prosecution because of enforcement difficulties.

Just south of False Klamath Cove, a pocket beach has developed. The beach material is coarse sand and gravel, unsuitable for the existence of beach infaunal organisms. Beach hoppers are common among the driftwood on the upper beach.

False Klamath Cove has a small steep beach that has been rip-rapped to prevent erosion of U.S. Highway 101. At the south end of the cove an extensive boulder field extends seaward. This site was extensively studied in 1974-76, and resurveyed in July and August 1980. Large boulders are permanently fixed in the substrate and are surrounded by small boulders, gravel, and sand. Wave shock is severe during much of the year. The sand and gravel sediments are disturbed continuously by wave action, so a burrowing fauna of polychaete worms and clams has not been able to develop. It has been demonstrated (Boyd and DeMartini 1977) that boulders from 1-3 feet in diameter are moved significant distances by wave forces which strike both the north and south sides of the boulder field. These movements of the rocks do not allow larger species of plants and animals to attach and mature, thus the biota of the boulder field is dominated by annual species (Figures 10,11).

Survey data taken in July and August 1980 were very similar to data collected earlier in species composition and abundance. There is an evident pattern of zonation on large, permanently fixed boulders (Figures 10 and 11). Noticeably absent are well developed beds of mussels and stalked barnacles. Instead, annual species of plants and animals continually colonize available surfaces each year. Earlier work (Boyd and DeMartini 1977) has shown that algal cover on intertidal rocks is



Legend: Figures 10, 11, and 12

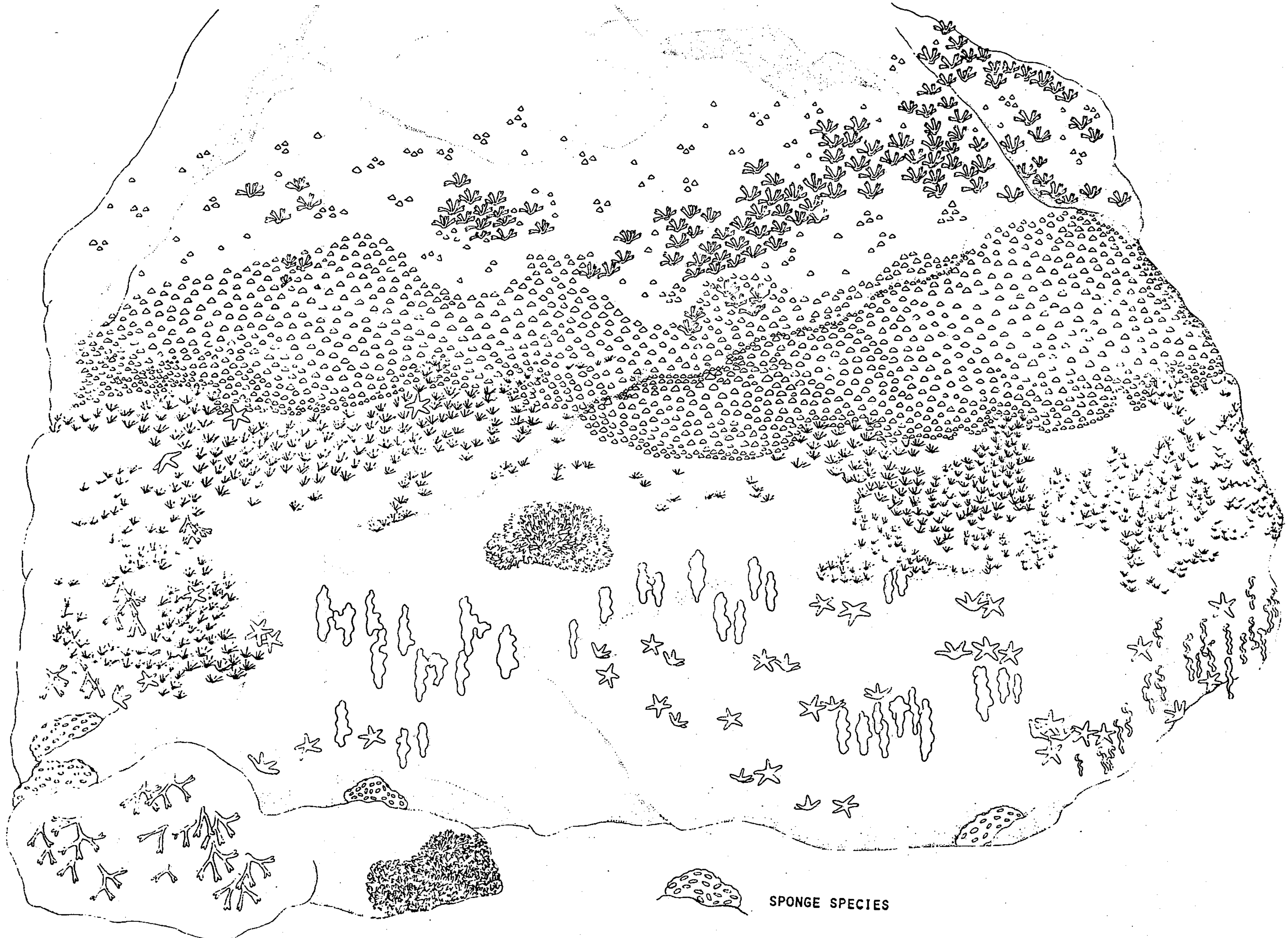


Figure 10. Intertidal zonation on a large boulder at False Klamath Cove, Redwood National Park ASBS. The biota is dominated by annual species of algae and animals and indicates the importance of severe wave shock in the rocky intertidal zone in coastal northern California.

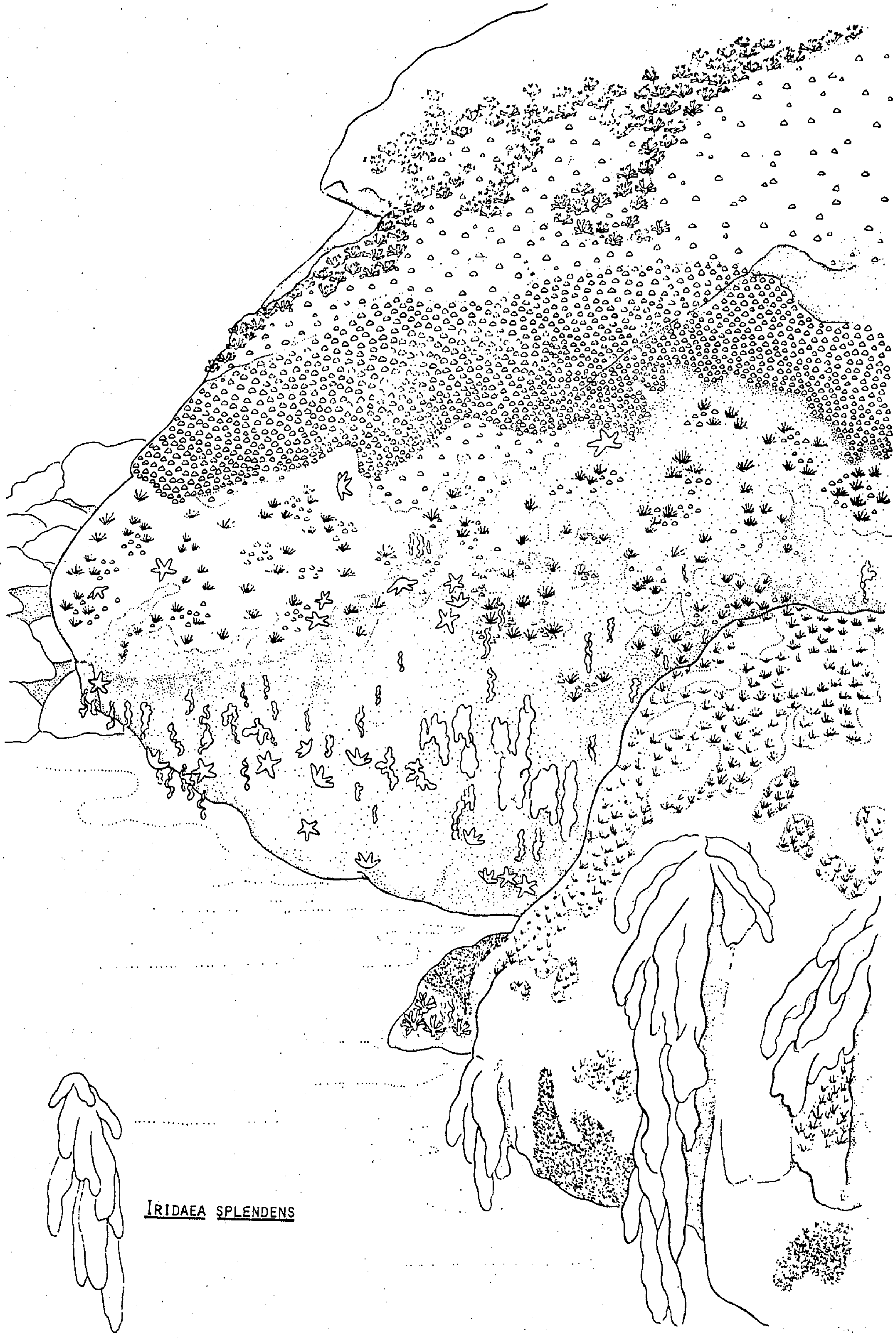


Figure 11. Intertidal zonation at False Klamath Cove, Redwood National Park ASBS. The lush growth of Iridaea splendens occurs on intertidal rocks during summer months each year.

particularly sparse during winter months because of high wave forces breaking algal holdfasts. This may be a possible explanation for the lack of large herbivores at most rocky intertidal sites within the Redwood National Park ASBS. Herbivores (*Strongylocentrotus purpuratus*, *Haliotis rufescens*, several species of chitons) common at other more protected sites along the northern California coast, apparently cannot secure enough algal biomass during winter months to sustain growth and reproduction. Juvenile specimens of these herbivores may be found occasionally, but adults are rarely seen. The densities of common intertidal animals are listed in Table 8 .

Intertidal populations of algae vary considerably on a seasonal basis. Maximum algal biomass is seen in the late summer or early fall and amounts to approximately 1600 gms dry weight per square meter. Minimum algal biomass is encountered in late winter following winter storms, when approximately 640 gms dry weight per square meter was recorded (Boyd and DeMartini 1977). The dominant intertidal algae at False Klamath Cove are recorded by percent cover in Table 9 .

False Klamath Cove to White Knob

The rocky intertidal zone from False Klamath Cove to White Knob covers 6.6 miles (10.6 km) and is a mixture of intertidal habitats. Most common are shingle or rock beaches, usually quite narrow and lying at the base of coastal cliffs. The beach rocks and gravels have been eroded from the adjacent cliffs, separating the beaches are small rocky points or rockfalls. Much of this section of the coast is virtually inaccessible, even to hikers, because points and rockfalls cannot be passed to seaward or climbed over. A trail from U.S. Highway 101 can be used for coastal access at the mouth of a small coastal stream, Damnation Creek. A narrow band of intertidal plants and animals can be found on larger rocks. On the seaward surfaces, species capable of withstanding severe wave shock (sea-palm algae, mussels, stalked barnacles) are seen. Landward rock surfaces are densely covered by acorn barnacles (*Balanus glandula*) and sparse red or green algae (*Porphyra* spp. and *Ulva* spp.).

Table 8. Macroinvertebrate densities at rocky intertidal sites. Data is from four sampling periods July 1975 - June 1976. The number of m^2 plots examined at each site was 40 at False Klamath Cove (FKC) and 35 at Endert's Beach Cove (EBC). Numbers in parentheses are ranks by abundance of each species at the two sites (From Boyd and DeMartini 1977)

Species	Overall Rank by Abundance	Density/m^2 at Intertidal Sites FKC	EBC
Anthopleura elegantissima	1	123.67(1)	344.25 (1)
Collisella spp.	2	41.67(2)	74.75 (2)
Petrolisthes cinctipes	3	16.11(4)	--
Tegula funebralis	4	6.78(7)	2.88(20)
Pisaster ochraceous	5	29.00(3)	46.00 (3)
Littorina scutulata	6	2.67(17)	4.37(19)
Pagurus spp.	7	13.89(5)	28.75 (5)
Eupentacta quinquesemata	8	1.67(18)	42.37 (4)
Idothea spp.	9	10.56(6)	23.00 (7)
Katharina tunicata	10	0.56(26)	27.00 (6)
Hemigrapsus nudus	11	1.56(19)	--
Anthopleura xanthogrammica	12	2.67(17)	15.37(10)
Cyanoplax harwegii	13	1.33(21)	16.75 (8)
Nucella emarginata	14	5.44(9)	9.00(14)
Tonicella lineata	15	2.89(15)	15.88 (9)
Sponge colonies	16	3.78(11)	8.50(15)
Bryozoan colonies	17	2.67(17)	11.12(11)
Mopalia spp.	18	1.44(20)	9.37(13)
Leptasterias spp.	19	1.67(18)	5.12(18)
Styela montereyensis	20	1.22(22)	10.75(12)
Mutilus californianus	21	4.33(10)	6.75(16)
Epiactis prolifera	22	3.00(14)	1.62(23)
Anthopleura artemisia	23	5.78(8)	0.50(26)
Nemerteans	24	3.33(12)	2.62(21)
Heptacarpus spp.	25	3.11(13)	0.12
Strongylocentrotus purpuratus	26	--	5.37(17)
Dermasterias imbricata	27	2.78(16)	0.50(26)
Hermissenda crassicornis	28	1.11(23)	1.75(22)
Nereis spp.	29	1.56(19)	0.88(25)
Pugettia producta	30	0.11(27)	1.50(24)
Cancer antennarius	31	0.89(25)	0.12(27)
Phascolosoma agassizii	32	1.00(24)	--
Diulula sandiegensis	33	--	--
Pachygrapsus crassipes	34	1.00(24)	--
Tubularia marina	35	0.11(27)	--

Table 9 . Percent cover of common intertidal plant species from transects at False Klamath Cove, Endert's Beach Cove, and Pt. St. George utilized in seasonal and site analyses.

OCCURRENCE AND ABUNDANCE

OF INTERTIDAL ALGAE

Occurrence at

Species	FKC 1	FKC 2	EBC 1	EBC 2
Ahnfeltia spp.	#	#	0	*
Alaria marginata	0	+	0	+
Botryglossum farlowianum	#	#	-	-
Callithamnion pikeanum	#	#	-	#
Cladophora trichotoma	#	#	-	-
Codium fragile	-	-	-	-
Constantinea simplex	#	#	#	#
Corallines	*	*	0	+
Cryptopleura violacea	#	#	#	#
Cryptosiphonia woodii	#	#	*	#
Desmarestia ligulata	-	#	-	-
Dilsea californica	*	*	#	*
Egregia menziesii	#	#	0	0
Endocladia muricata	0	0	#	#
Enteromorpha intestinalis	#	#	-	-
Farlowia mollis	#	#	-	-
Fucus distichus	+	+	*	-
Gelidium	*	*	*	*
Gigartina spp.	0	0	0	+
Gloiopeltis furcata	#	-	-	-
Gymnogongrus linearis	-	#	#	#
Halosaccion glandiforme	#	-	#	-
Halymenia	#	#	#	-
Hedophyllum sessile	*	*	0	+
Heterochordaria abietina	#	#	-	-
Iridaea spp.	0	0	+	+
Laminaria setchellii	#	#	*	*
Laurencia spectabilis	#	#	*	#
Leathesia nana	-	-	-	#
Lessionopsis littoralis	#	-	-	-
Microcladia borealis	#	*	#	*
Odonthallia spp.	*	0	0	0
Pelvetiopsis limitata	*	-	-	-
Phaeostrophion	#	*	-	-
Phyllospadix torreyi	*	0	0	0
Plocamium spp.	#	#	#	#
Polysiphonia spp.	*	#	*	#
Porphyra spp.	+	+	+	+
Prionitis lyalli	*	#	*	#
Pterosiphonia spp.	#	#	*	-
Ptilota filicina	#	#	#	#

(Table Cont.)

(Table 9 Cont.)

Species	FKC 1	FKC 2	EBC 1	EBC 2
Ralfsia spp.	*	*	-	#
Rhodomela larix	0	0	0	0
Rhodymenia	#	#	-	#
Schizymenia pacifica	*	-	-	-
Scutosiphon lomentaria	*	#	-	-
Spongomorpha coalita	*	0	#	0
Ulva sp.	0	0	*	*
Urospora	#	#	-	-

+ 15 - 25% at any one time
0 5 - 15% at any one time
* 1 - 5% at any one time
# 0.01 - 0.99% at any one time
- Absent

The cobble beaches are very depauperate intertidal habitats. The small rocks are rolled continually by wave action, precluding settlement and growth by plants or animals. When a few of these beaches were surveyed in June and August 1980, some of the rocks had sparse growths of newly settled acorn barnacles (B. glandula)and green algae (Enteromorpha spp.). These plants and animals cannot persist for any length of time because the rocks are overturned or jumbled about by wave action. Driftwood and algae wrack accumulates at the bases of the coastal cliffs. In this habitat, amphipods (Orchestoidea columbiana) could be found, but are not abundant. This cobble-beach habitat is simply too harsh for the survival of most intertidal organisms.

Endert's Beach Cove is about 4 miles (6.4 km) south of Crescent City and can be reached by a coastal trail. It is frequently visited by educational groups and Park Service personnel conducting tours of the intertidal zone with visitors. In this small area, geological formations extending from the base of the coastal cliffs are well lithified and resistant to erosion. It is the only accessible location within the ASBS where intertidal "benches" with lush growths of intertidal plants and animals can be seen. The site was surveyed at two-month intervals in 1974-76 and was resurveyed in July and August 1980.

The intertidal zones on the gradually sloping benches are very obvious and are similar to other locations where this type of formation occurs in northern California (Figure 12). The lowest zone, uncovered by only the lowest of low tides, has dense populations of plants, the most common of which are oar-blade algae (Lamineria dentigera), Hedophyllum sessile, and surf-grass (Phyllospadix scouleri). Numerous other species of algae can be found at this location (Appendix 3), which had the most diverse assemblage of plants and animals found within the ASBS. Only a few of the more striking organisms will be mentioned here. The small white holothuroid Eupentacta quinquesemita occurs in dense aggregations on rock and plant surfaces. There are no other sites in northern California where similar dense aggregations can be seen in

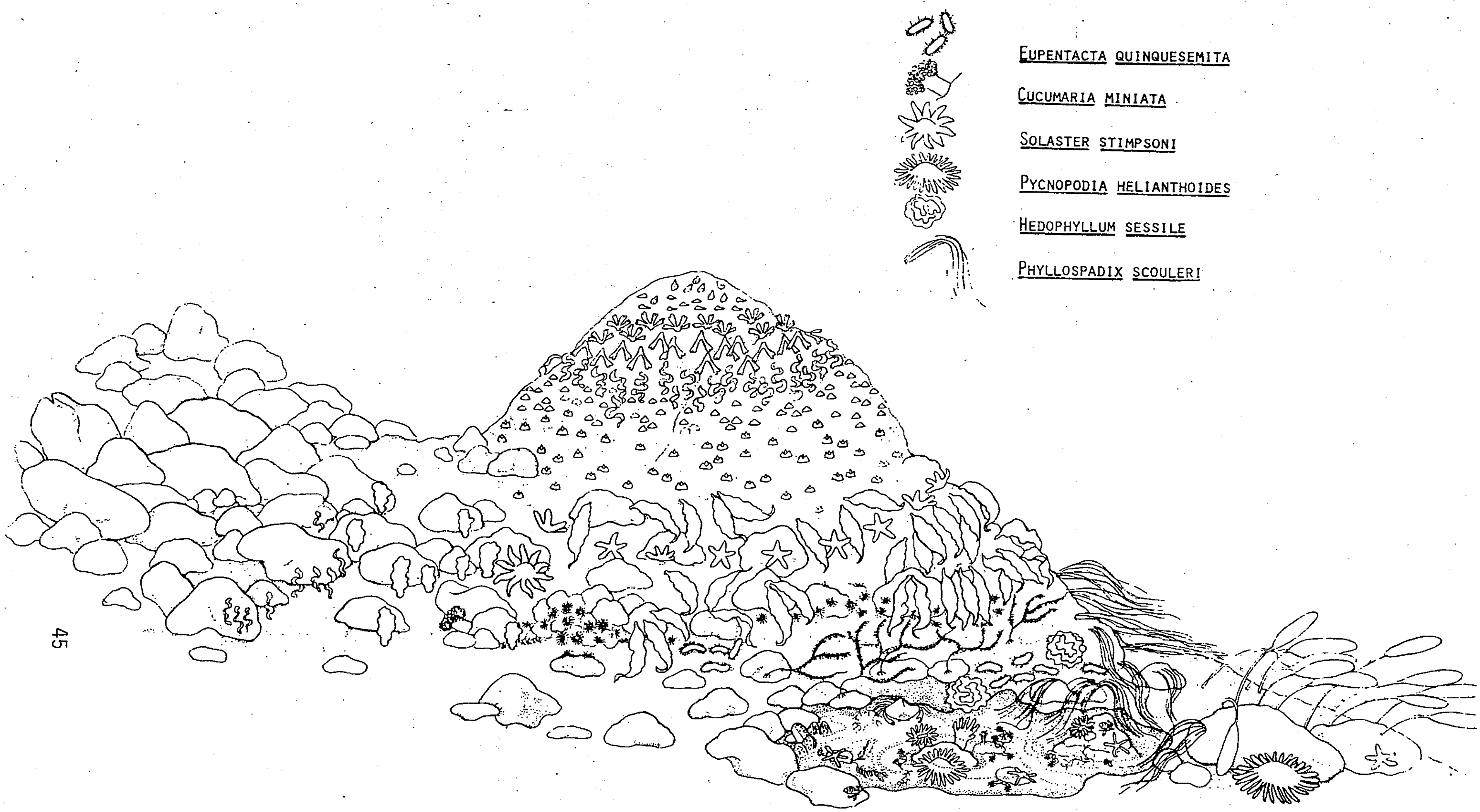


Figure 12. Intertidal zonation at Endert's Beach Cove, Redwood National Park ASBS. The substrate is a shelfing platform that offers permanent attachment sites for plants and animals. The intertidal biota at this site is the richest found within the ASBS.

the low intertidal zone. Crevices and overhangs provide shelter for many species, including sponges, bryozoans, tonicates, and many crustaceans (See Appendix 2). Large sea-stars are found in shallow pools and small channels. Particularly striking are the sun-star (Pycnopodia helianthoides) and the many-rayed star (Solaster stimpsoni). S. stimpsoni is very rare at other intertidal sites in California.

Slightly shoreward of this Laminarian Zone, another zone of slightly higher elevation can be detected. The dominant algae are long-bladed kelps (Egregia menziesii, Alaria marginata) and abundant foliose red and brown algae (Iridaea cordata var. Splendens, Desmarestia ligulata, Gigartina spp., Porphyra spp., Cystoseira osmundacea). On rock surfaces under the foliose species, coralline algae species are abundant and are particularly evident during winter months when the large "overstory" algae have been removed by wave shock. Chitons (Katharina tunicata, Cryptochiton stelleri, Tonicella lineata) are common among the fronds of the algae. During summer and early fall, a variety of showy nudibranches occur in pools and channels, including Hermissenda crassicornis, Diaulula sandiegensis, Dirona albolineata, and Archidoris montereyensis. Juvenile purple urchins (Strongylocentrotus purpuratus) are often seen in crevices, but adults are rare. Several species of anemones are also common (Anthopleura xanthogrammica, Tealia crassicornis, Epiactis prolifera), along with the bright orange solitary coral Balanophyllia elegans. Smaller hydroid colonies, bryozoans, encrusting polychaetes, tunicates, and crustaceans are easily found with a modest search of crevices and overhangs. The most evident sea-star of this zone is the ochre-star (Pisaster ochraceous), but others are also common (Leptasterias hexactis, Evasterias troschelii, Dermasterias imbricata, Henricia leviuscula).

As the rock benches increase slightly in elevation shoreward, plants and animals adapted to periodic drying at low tide are found on rock surfaces. The dominant algae is Endocladia muricata and the dominant animal species is the acorn barnacle Balanus glandula. Limpets (Collisella spp.) move over bare rock surfaces grazing on microscopic plants or small attached algaes. Much of the rock surface is covered by colonies of the aggregating anemone (Anthopleura elegantissima). In aggregations of the acorn barnacles, the gastropod species Nucella emarginata and N. canaliculata are found preying on the barnacles. Along with the ochre-star, these gastropods are the major predators on barnacles of mid-intertidal zones. Another gastropod, the black turban (Tegula funebralis) occurs in this zone, where it feeds on a variety of algal species.

The uppermost intertidal zone at Endert's Beach Cove is covered with large boulders eroded from the adjacent cliff. A light growth of green algae (Enteromorpha spp. and Ulva spp.) occurs on the rocks. Grazing on these algae and on diatoms are limpets (Collisella digitalis and C. scabra). The highest influence of sea water on the boulders is marked by scattered small gastropods, the periwinkle Littornia scutulata.

Piled among the rocks of the upper beach, large drift logs are always present in the cove. These usually come into the cove and are stranded during high tides and storm surges. As in all rocky locations along the coast, the influence of drift logs on the development of the intertidal biota is important. The logs roll over and crush intertidal plants and animals on sloping surfaces or directly impact against vertical surfaces. That this occurs frequently along this coast is suggested by the sparse populations of perennial plants and animals. Dense, well developed mussel beds, with a characteristic assemblage of plants and animals (Ricketts, Calvin, and Hedgpeth 1968) are not found on intertidal rocks along the coast. Mussel beds do occur on rocks offshore, where impact by drift logs is not a common event. When intertidal populations are destroyed by logs, colonization of the newly exposed surfaces is rapid. The resulting biota is highly dynamic, although a long-term stable assemblage never develops because of the continual destruction by drift logs. This sort of dynamic biological community has been studied along the Washington coast (Dayton 1971), where many of the same species of plants and animals are the dominant occupiers of intertidal space.

Northward from the cove, intertidal habitats are coarse-grained sand beaches, with occasional rock outcrops. Sand scour is severe on these rocks, allowing only development of annual populations of plants and animals. White Knob is a demarcation point between the high coastal cliffs, with mixed rocky intertidal habitats at their base, and the marine terrace which stretches northward 1.6 miles (2.5 km) to the northern border of Redwood National Park (this does not correspond to the northern border of the ASBS; see comment on location and size).

Fauna of Crescent Beach

Crescent Beach trends north northwest from White Knob and is composed of medium to fine sands. Beach deposits have accumulated in the lee of Point St. George to the north, which affords some protection from the waves generally striking the coast from the northwest.

Samples were collected monthly at Crescent Beach in 1974-76 and in June and late July 1980. Twenty-seven species of animals were encountered in beach sampling (Appendix 1). Most are small crustaceans or polychaete worms. Two species are regularly exploited by sport fishermen, the sand crab, *Emerita analoga*, and the razor clam, *Siliqua patula*. Sand crabs are taken for bait in surf fishing for Redtail surfperch. Populations of sand crabs were sparse in 1974-76, but were very abundant in the summer of 1980. This species has a long larval dispersal phase (Efford 1970) and populations on beaches of northern California fluctuate radically, apparently a result of shifts in the nearshore current pattern from year-to-year. Razor clams are taken by clammers for consumption in their own right. In recent years, Crescent Beach has been closed to clamming in alternate years in an attempt to lessen the impact of clamming on population numbers. No records of total catch on the beach are maintained.

The distribution of sand beach animals at Crescent Beach (Fig. 13) indicates that three major zones of adaptation are present. The high beach is covered by water only during spring tides each month and animals occupying this zone have adapted to an essentially terrestrial existence.

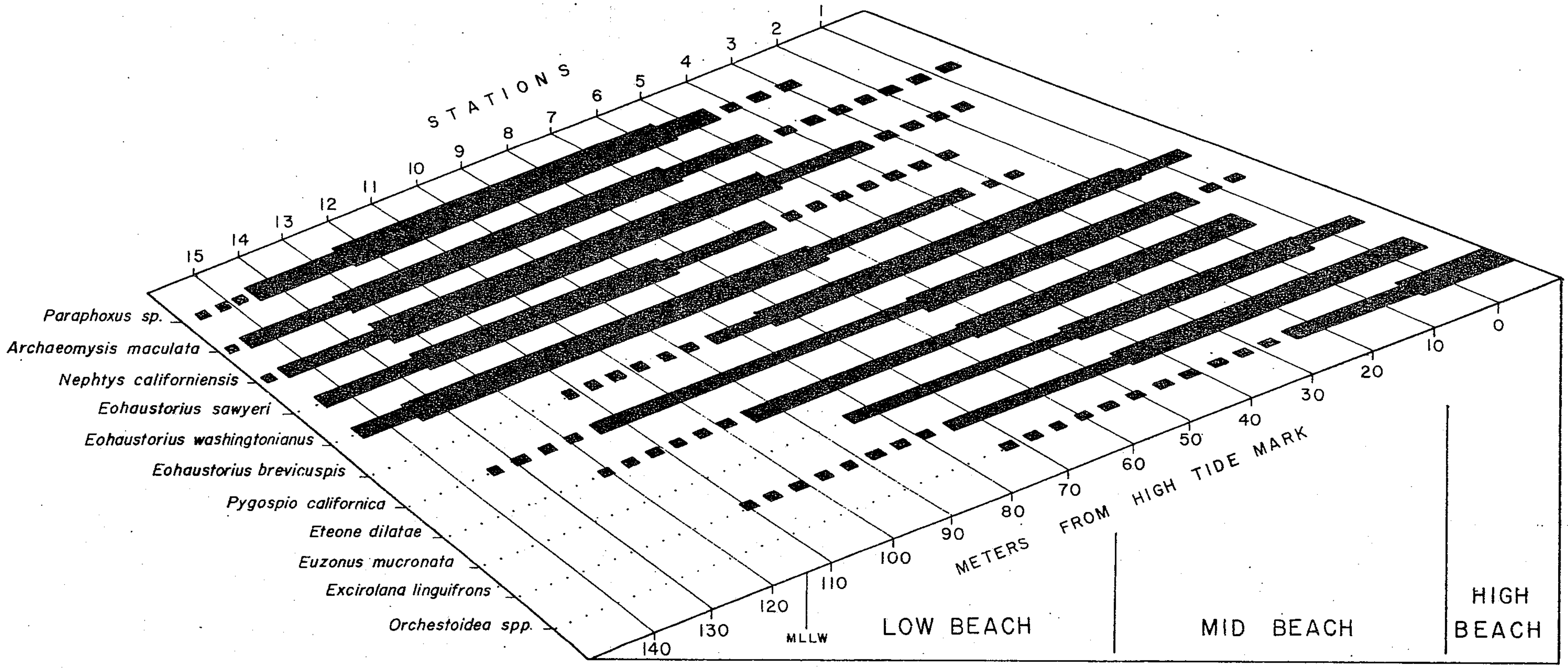


Figure 13. Vertical zonation of sand beach animals at Crescent Beach, Redwood National Park ASBS. The widest part of each band indicates the zone of maximum density for each species. Intermediate width bands indicate that animals may still occur, but at reduced densities. Broken bands are zones of sporadic occurrence. Low, mid, and high beach assemblages are evident (from Boyd and DeMartini 1977).

Three species of sandhoppers (Orchestoidea californiana, O. columbiana, and O. benedicti) were regularly encountered in samples taken in the upper beach. Occasionally, animals of the adjacent terrestrial foreshore, such as the isopod Armadilloniscus lindahli and several insects, were taken in samples from the upper beach. These are essentially vagrant occurrences in the beach fauna.

Numerically dominant organisms of the mid-beach are a small amphipod (Eohaustorius brevicuspus), a predatory isopod (Excirolana linguifrons) and two polychaetes (Pygospio californica, Euzonus mucronata). With the exception of the isopod, these species appear to feed on the microflora associated with sand grains. E. linguifrons, given the opportunity, will attack voraciously any of the other three species. It is an active burrower and swimmer. Another polychaete (Eteone dilatae) is occasionally seen in mid-beach samples; the morphology of its pharynx would suggest a predatory role (Dales 1963) (Table 10).

The low beach fauna is also dominated in numbers by amphipods and polychaetes. The most numerous animals are two species of amphipods (Eohaustorius washingtonianus and E. sawyeri). Another larger amphipod (Paraphoxus grandis) is much less abundant. The common polychaete encountered is Nephtys californiensis, a species which frequently occurs on outer coast beaches with fine sands along the California coast. The small mysid Archaeomysis maculata is abundant in the swash zone of the beach at low tide, and is probably more properly thought of as occurring in the surf zone waters rather than as uniquely characteristic of the beach itself. In 1974-76, very few sand crabs (Emerita analoga) were found in low beach samples, but this species was common in the summer of 1980. In August 1980, a qualitative sample of 255 animals was collected by shoveling sand from the low beach into a large bucket. Animals were then screened from the sample and carapace length measured. Two distinct age classes may have been present on the beach (Fig. 14), but the evidence is not convincing from these data. It is clear, however, that recruitment to beach populations of this species has been more successful within the past two years than was true in 1974-76 (Table 11).

Table 10. Mean abundance by depth of major species of the mid-beach. Abundance is the mean of ten 0.1 m^2 samples, followed by the percentage of a species found in a depth stratum (from Boyd and DeMartini 1977).

DEPTH DISTRIBUTIONS OF MID-BEACH SPECIES

	0-5 cm	5-10 cm	10-15 cm	15-20 cm
CRUSTACEANS				
Excirolana linguifrons	37.7 (84%)	7.0(15.9%)	0.3(0.1%)	
Eohaustorius brevicuspus	10.3(37%)	17.0(60%)	0.3(3%)	
POLYCHAETES				
Euzonus mucronata	124.3(67%)	53.0(29%)	15.3(3.9%)	0.3(0.1%)
Pygospio californica	0.3(4%)	6.3(83%)	0.3(4%)	0.7(8%)
TOTAL ANIMALS (mean/o.1 m^2)	173 (65%)	87.3(31%)	8.7(3%)	1.0(1%)

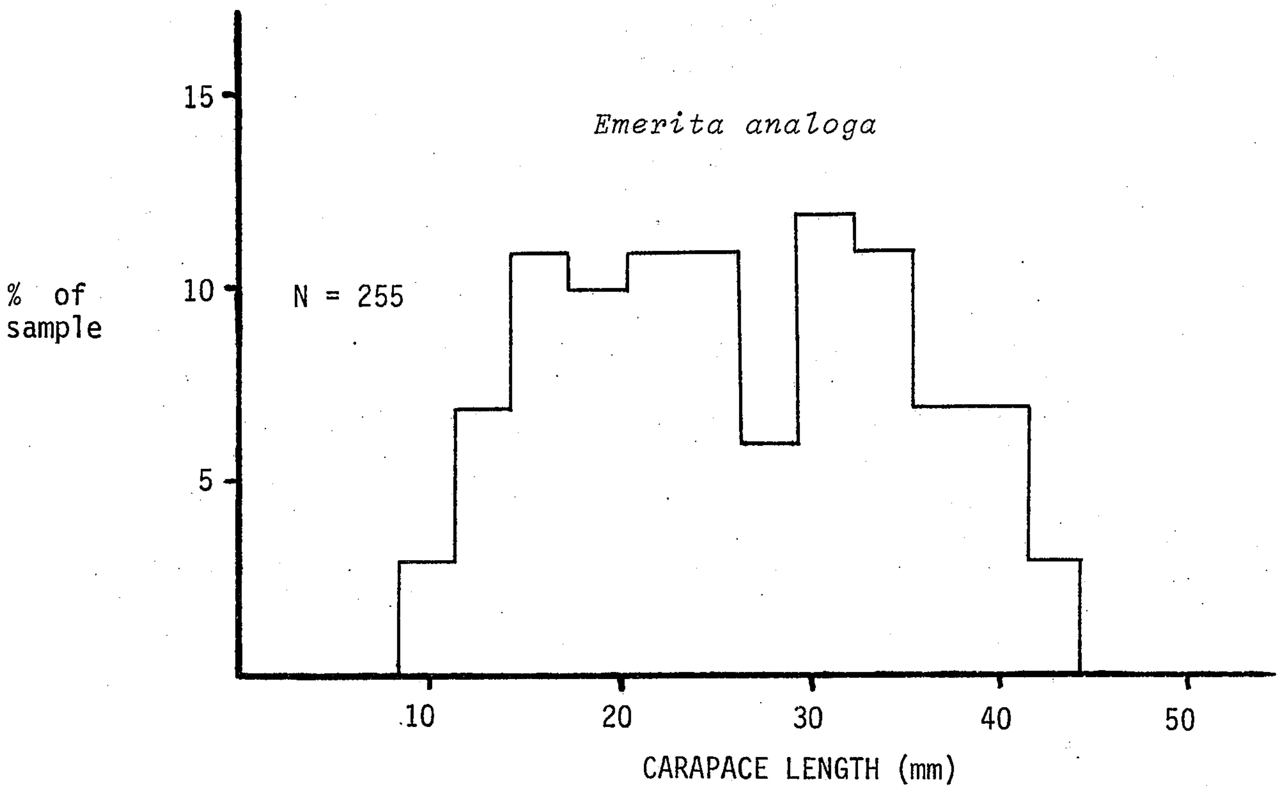


Figure 14. Carapace length distribution of a sample collected at Crescent Beach, Redwood National Park ASBS in August 1980. The decrease in abundance of animals at 28mm carapace length may indicate the presence of two age classes in this population.

Table 11. Mean abundance of sand beach animals, Crescent Beach. Means represents estimates from unequal numbers of samples, from a low of 59 samples containing *Orchestoidea* spp., to a high to 278 samples with *Nephtys californiense* present (from Boyd and DeMartini 1977).

RELATIVE ABUNDANCE -- SAND BEACH ANIMALS

	mean abundance per m^2
Eohaustorius brevicuspus	137.7
Euzonus macronata	135.2
Orchestoidea spp.	46.4
Eohaustorius washingtonianus	43.1
Excirolana linguifrons	33.8
Pygospio californica	23.7
Eohaustorius sawyeri	20.4
Paraphoxus sp.	16.2
Eteone dilatae	13.3
Archaeomysis maculata	12.8
Nephtys californieuse	11.9

Juvenile razor clams were taken occasionally in low beach samples, but an adult has never been taken in one of the $0.1m^2$ samples. Survey data suggest that both juveniles and adults occur at a density of about one animal per 2-3 square meters.

Other polychaete and crustacean species found on Crescent Beach were encountered only on rare occasions (See Appendix 1). The main populations of these species are probably in bottom sediments of the immediate nearshore waters.

In 1974-76, no clear trends in the seasonal abundance of sand beach animals could be discerned. In general, population densities were greatest in summer and early fall, falling to their lowest point in late winter and early spring. These changes in seasonal abundance are thought to be related to seasonal patterns of sand accretion or removal from the beach (Boyd and DeMartini 1977). Two factors probably interact to affect the density of sand beach animals: 1) some species may move with the sand as it is transported generally offshore in winter and onshore in summer; and 2) the rather small polychaetes and amphipod species may have short life cycles and sporadic recruitment patterns. Evidence to support the first notion is the occurrence of some sand beach species in sediments just outside the surf zone (Boyd, unpublished data). Sand beach populations in general are known to fluctuate widely in density and abundance elsewhere in California (Coe 1957).

The main food source for sand beach organisms is the phytoplankton production in adjacent near-shore waters or algal wrack from more distant rocky intertidal habitats. No attempt has been made to measure algal wrack on Crescent Beach, but chlorophyll content in swash zone waters can be correlated with periods of upwelling (Boyd and DeMartini 1977). Cholorphyll content of swash zone waters reaches a maximum (3.0-3.5 mg chlorophyll/m^3) in May or June each year and is at minimum values (0.1-0.5 mg chorophyll/m^3) during winter months. Combustible carbon levels in beach sands follows a similar trend.

In summary, Crescent Beach harbors the most diverse sand beach fauna within Redwood National Park ASBS. The abundance and density of animals is not as great as at beaches in central and southern California (Coe 1957), a finding that probably reflects well known relationships between species diversity and latitude (Valentine 1973). Because of the protection afforded by Point St. George to the north, the burrowing infauna of Crescent Beach are considerably more abundant and diverse than those found on more exposed beaches along the southern part of the ASBS.

Subtidal Biota

Redwood National Park ASBS extends along a highly exposed coast. Thus, water movements are typically very strong. Turbidity is high, resulting in a shallow photic zone.

Based on observations made during present and past surveys within the ASBS, four habitat types have been distinguished north of the Klamath River:

1) Rocky Habitat Not Influenced by Sand
2) Rocky Habitat Influenced by Sand
3) Rocky Habitat Influenced by Sediments Finer than Sand
4) Sandy Habitat

Rocky Habitat Not Influenced by Sand (Figure 15, 16, 17)

This habitat was observed on both nearshore and offshore rocks north of the Klamath River (Figure 1). An algal zone, a band containing evident macroalgae, generally did not extend deeper than 20 feet (6 m). Within the algal zone of nearshore rocky habitat, substrates consisted of bedrock and large boulders usually greater than 5 feet (1.5 m) in diameter. The topography was very irregular, and within a few feet exposure to illumination could vary greatly. Thus, within the algal zone locally subdued illumination would hinder algal growth. In nearshore habitat exposed to northwesterly swell the dominant algae were the coralline algae *Calliarthron tuberculosum*, *Lithophyllium* sp.,

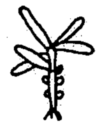
Figure 15: Diagramatic code for the macrobiota observed on Nearshore Rocky Habitat Not Influenced By Sand

Division Phaeophyta

 -*Iridaea cordata*

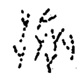
 *Laminaria sinclairii*

 *Laminaria dentigera*

 *Pterygophora californica*

Division Rhodophyta

 *Botryoglossum farlowianum*

 *Calliarthron tuberculosum*

Phylum Porifera

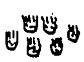
 *Leucilla nuttingi*

 *Suberites sp.*

Phylum Cnidaria
Class Hydrozoa

 *Hydractinia milleri*

Class Anthozoa

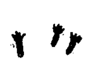
 *Anthopleura elegantissima*

 *Corynactis californica*

 *Balanophyllia elegans*

Phylum Annelida

 *Dodecaceria fewkesi*

 *Eudistylia polymorpha*

Phylum Mollusca
Class Gastropoda
Subclass Opistobranchia

 *Cadlina luteomarginata*

 *Hermissenda crassicornis*

Phylum Arthropoda
Class Crustacea
Subclass Cirripedia

 *Balanus crenatus*

Subclass Malacostraca
Order Amphipoda

 *Metacaprella kennerlyi*

Phylum Echinodermata
Class Asteroidea

 *Leptasterias hexactis*

Class Holothuroidea

 *Eupentacta quinquesemita*

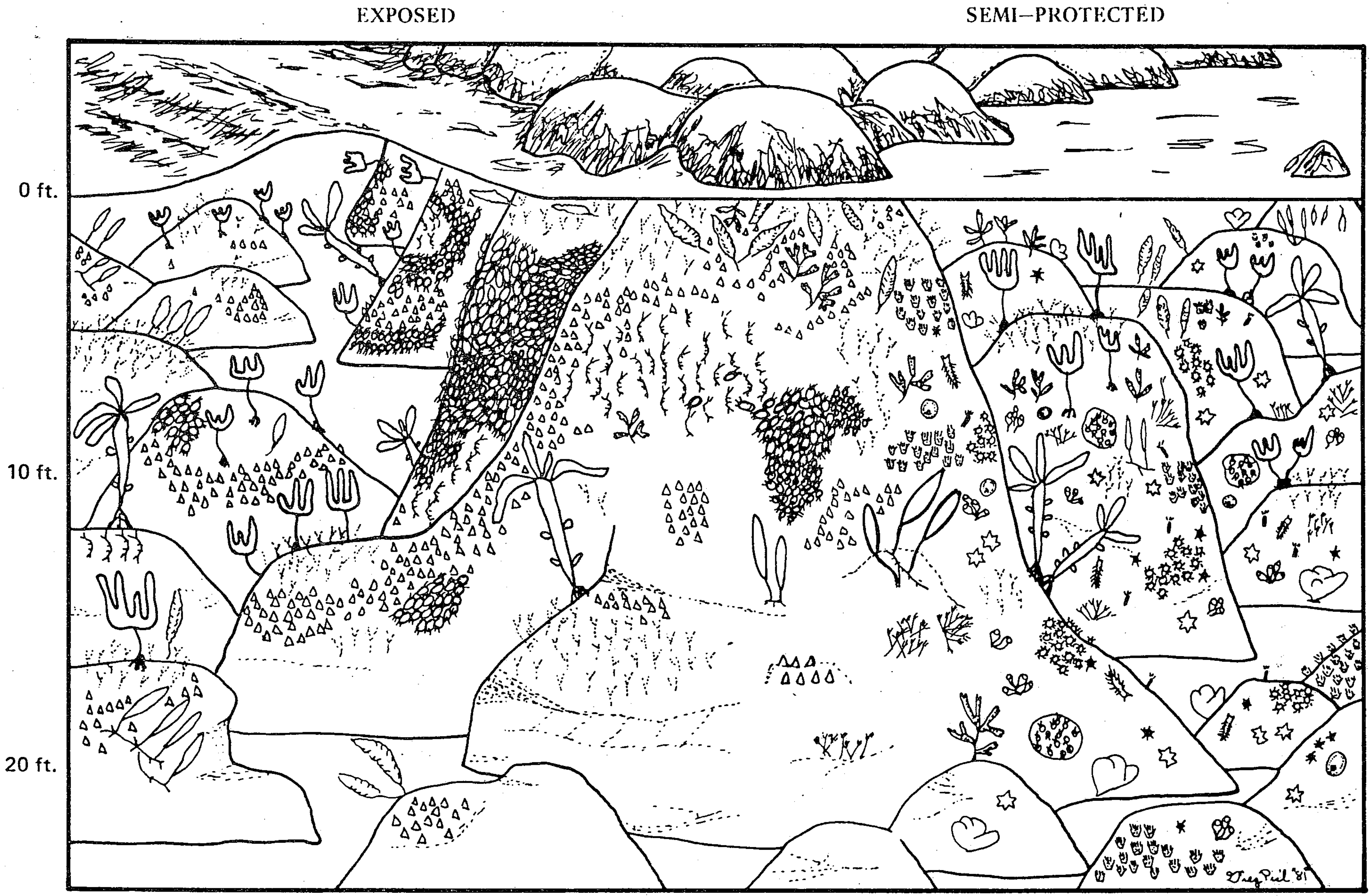


Figure 15: Schematic drawing of the macrobiota observed on Nearshore Rocky Habitat Not Influenced By Sand

Figures 16 and 17: Diagramatic code for the macrobiota observed on Offshore Rocky Habitat Not Influenced By Sand

Division Phaeophyta

 *Iridaea cordata*

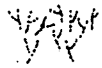
 *Laminaria sinclairii*

 *Laminaria dentigera*

 *Pterygophora californica*

Division Rhodophyta

 *Botryoglossum farlowianum*

 *Calliarthron tuberculosum*

Phylum Cnidaria
Class Hydrozoa

 *Hydractinia milleri*

Class Anthozoa

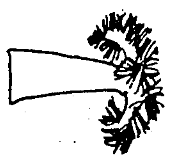
 *Anthopleura xanthogrammica*

 *Gersemia rubiformis*

 *Balanophyllia elegans or Paracyathus stearnsi*

 *Metridium ? exilus*

 *Corynactis californica*

 *Metridium ? senile*

 *Epizoanthus scotinus*

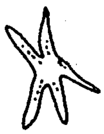
Phylum Annelida

 *Dodecaceria fewkesi*

 *Eudistylia polymorpha*

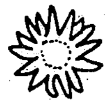
Phylum Echinodermata
Class Asteroidea

 *Dermasterias imbricata*

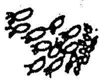
 *Evasterias troschelii*

 *Leptasterias hexactis*

 *Pisaster ochraceus*

 *Pycnopodia helianthoides*

Class Holothuroidea

 *Eupentacta quinquesemita*

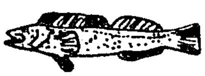
Phylum Chordata
Subphylum Urochordata

 *Cnemidocarpa finmarkiensis*

 *Trididemnum opacum*

Subphylum Vertebrata

 *Hexagrammos decagrammus*

 *Ophiodon elongatus*

 *Sebastes melanops*

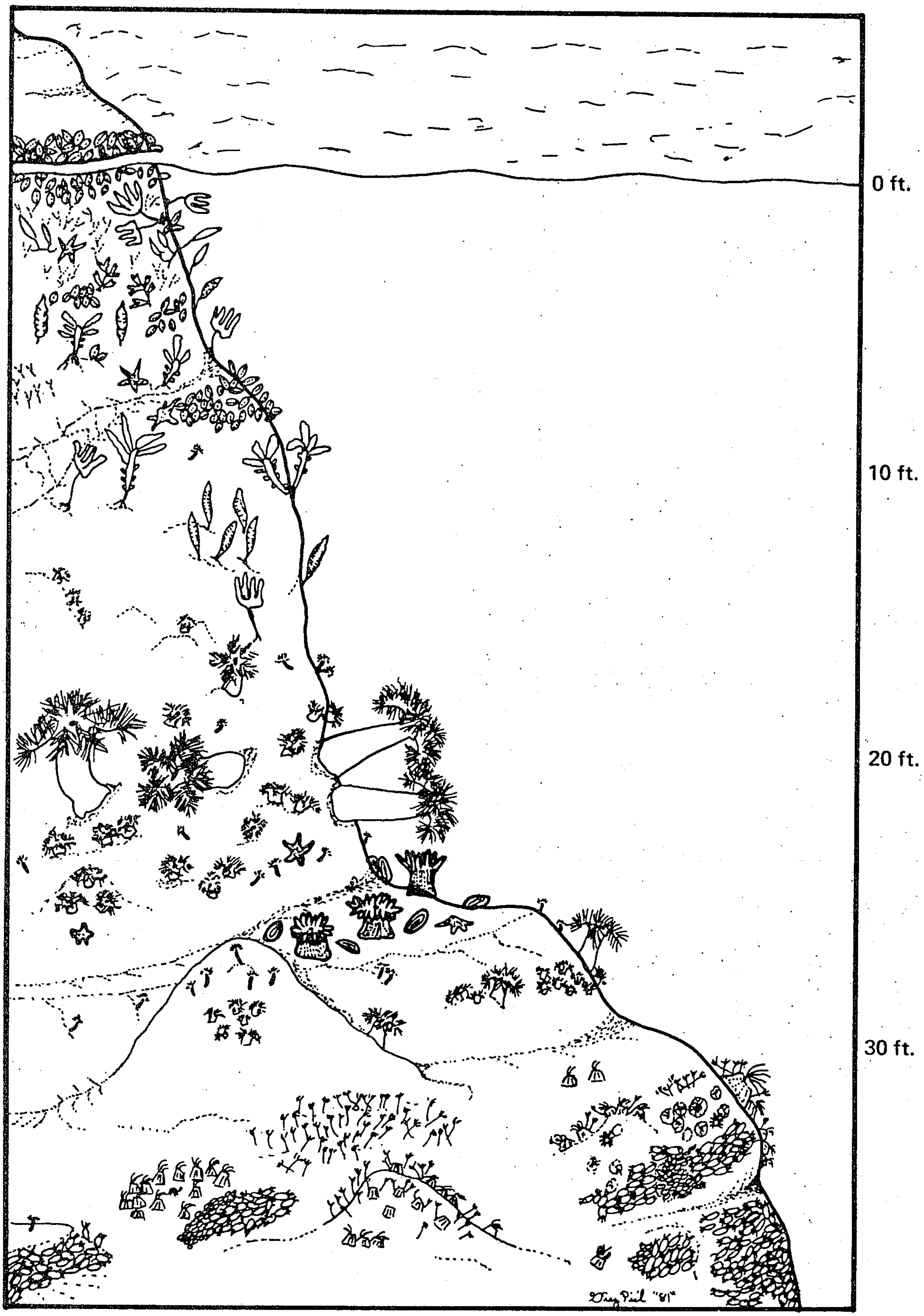


Figure 16: Schematic drawing of the macrobiota observed on Offshore Rocky Habitat Not Influenced By Sand (0-35+ feet)

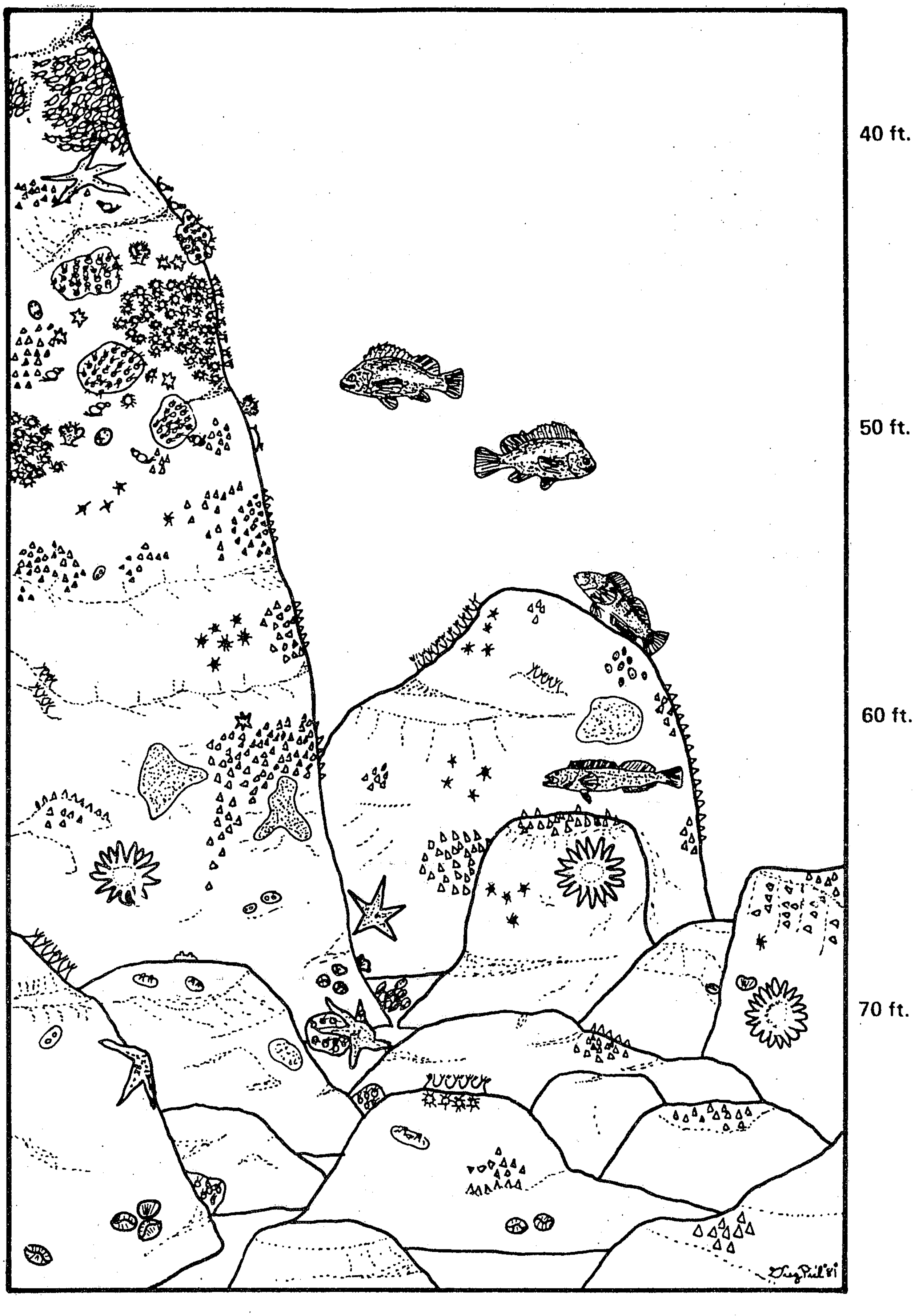


Figure 17: Schematic drawing of the macrobiota observed on Offshore Rocky Habitat Not Influenced By Sand (35-70 feet)

and the kelps Laminaria dentigera, Laminaria sinclairii and Pterygophora californica. The latter were also common in nearshore rocky habitat semi-protected from northerwesterly swell and on exposed offshore rocks (Figure 1) along with the following red algae: Botryoglossum farlowianum, C. tuberculosum, Callophyilis pinatta, Erythrophyllum delesserioides, Halymenia californica, Iridaea cordata, and Polyneura lattissima.

The nearshore rocky habitats which were surveyed within the ASBS were typically no greater than 20 feet (6 m) deep. Where these habitats were exposed to northwesterly swell (Figure 15) the invertebrate fauna was typified by numerous suspension-feeders like sponges, bryozoans, tunicates, the acorn barnacle, Balanus crenatus, and the sea cucumber, Eupentacta quinquesemita. The aggregations of the latter species were extensive and consisted of a given size range indicating a given age class. The skeleton shrimp, Metacaprella kennerlyi, also formed large aggregations on both rocks covered by attached organisms and on rocks that were relatively barren.

Where nearshore rocky habitats were semi-protected from northwesterly swell (Figure 15) the commonly observed invertebrates were the sponges Leucilla nuttingi and Suberites sp.; the hydrozoan, Hydractinia milleri; the sea anemones Anthopleura elegantissima and Corynactis californica; the cup coral, Balanophyllia elegans; the polychaetes Dodecaceria fewkesi, Eudistylia sp.; and Serpula sp.; the nudibranchs Cadlina luteomarginata and Hermissenda crassicornis; and the sea star Lepasterias hexactis.

Numerous large exposed offshore rocky habitats are located between 0.1 and 0.6 miles (0.2 and 1.0 km) offshore (Figures 2, 3). The sea mussel, Mytilus californianus, and one of its major predators, the sea star, Pisaster ochraceus, were commonly encountered within the algal zone. Invertebrates were typically sessile, low relief, suspension-feeding forms capable of tolerating water movement. Discrete boundaries separating one species from another were prevalent and gave the substrate the appearance of a biological mosaic. From 20 to 30 feet (6 to 9 m) deep, the white sea anemones Metridium exilus and Metridium senile dominated sharply sloping surfaces. On ledges and in furrows of vertical walls the giant green sea anemone, Anthopleura xanthogrammica, was abundant and was commonly surrounded by empty shells of the sea mussel, M. californianus. The polychaete Eudistylia polymorpha and the leather sea star, Dermasterias imbricata, were also common. From 30 to 40 feet (9 to 12 m) deep, the giant acorn barnacle, Balanus nubilus, was dominant and was commonly overgrown by the hydrozoan H. milleri. The anomuran crab, Oedignathus inermis, was locally abundant inside dead B. nubilus shells. The skeleton shrimp, M. kennerlyi, and the sea cucumber, E. quinquesemita, were also commonly encountered amongst B. nubilus. From 40 to 50 feet (12 to 15 m) deep the sea anemone, C. californica, was locally dominant. Large aggregations of the polychaete D. fewkesi were present. The sea strawberry, Gersemia rubiformis, and a known predator, the nudibranch Tochuina tetraquetra were also common. The acorn barnacle, B. crenatus, entended to approximately 70 feet (21 m) deep. Commonly the snails Ceratostoma foliatum and Oceanebra gracillima and the sea stars Evasterias troschelii and L. hexactis were observed feeding on B. crenatus. Only at the offshore rocks immediately south of Sister Rocks was the water clear enough for observations below 50 ft (16 m) deep. Here (15 m) the cup corals B. elegans and Paracyathus stearnsi; the sea anemone Epizoanthus scotinus; the amphipod Erichthonius brasiliensis; the tunicates Boltenia villosa, Cnemidocarpa finmarkiensis and Trididemnum opacum were common. At the base of vertical rock walls, large specimens of the sea stars P. ochraceus and Pycnopodia helianthoides were found feeding on the sea mussel, M. californianus, and the polychaete D. fewkesi which had become detached from shallower depths. Small aggregations of the brachiopod Terebratalia transversa were also observed.

At this dive site, increased visibility facilitated observation or collection of the following fishes: the scalyhead sculpin Artedius harringtoni, the brown Irish lord Hemilepidotus spinosus, the kelp greenling Hexagrammos decagrammus, the ling cod Ophiodon elongatus and the black rockfish, Sebastes melanops.

Rocky Habitat Influenced by Sand (Figure 18)

This habitat is observed in water to about 20 feet (6 m) deep and consists of bedrock surrounded by sand (Figure 18). This habitat was encountered while running transects offshore in water up to 20 feet (6 m) deep and while diving near washrocks at similar depths. Sand surrounding such rock had depauperate biotas associated with the scouring and deposition of sand.

Scoured areas often extend more than 3 feet (1 m) above the bottom and were characterized by the crustose coralline algae Lithophyllum sp. Occasionally large aggregrations of the tubiculous polychaete Phyllochaetopterus prolifica were encountered. Upon close examination in the laboratory the following invertebrates were found attached to the tubes of this polychaete; the hydrozoan Phialidium sp., the proliferating sea anemone Epiactis prolifera, the peanut worm, Phascolosoma agassizii, the acorn barnacle B. crenatus, the amphipod E. brasiliensis, the skeleton shrimp, M. kennerlyi, and the bryozoan Cryptosula pallasina.

Typically most organisms were restricted to substrates which were above the scoured areas. Here the brown algae Desmarestia ligulata var., ligulata, L. dentigera and P. californica and the red algae C. tuberculosum, H. californica, and Hymenena flabelligera were observed. The common invertebrates observed were the sponges Hymendecton lyoni, L. nuttingi and Suberites sp.; the hydrozoans Campanularia urceolata, Eudendrium sp., Sertularella turgida and Tubularia sp.; the sea anemones Anthopleura artemisia, A. elegantissima, A. xanthogrammica, Tealia coriacea, Tealia crassicornis and Tealia lofotensis; the brittle

Figure 18: Diagramatic code for the macrobiota observed on Rocky Habitat Influenced by Sand

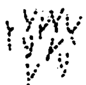
Division Phaeophyta

 *Desmarestia ligulata var. ligulata*

 *Laminaria dentigera*

 *Pterygophora californica*

Division Rhodophyta

 *Calliarthron tuberculosum*

Phylum Porifera

 *Leucilla nuttingi*

 *Suberites sp.*

 *Polymastia pachymastia*

Phylum Cnidaria
Class Hydrozoa

 *Eudendrium sp.*

 *Sertularella turgida*

Class Anthozoa

 *Anthopleura artemisia*

 *Anthopleura xanthogrammica*

 *Anthopleura elegantissima*

 *Tealia lofotensis*

Phylum Mollusca
Class Gastropoda
Subclass Prosobranchia

 *Ceratostoma foliatum or*
Ocenebra gracillima

Subclass Opisthobranchia

 *Tochuina tetraquetra*

Class Bivalvia

 *Mytilus californianus*

Phylum Arthropoda
Class Crustacea
Subclass Cirripedia

 *Balanus crenatus*

 *Balanus nubilus*

Subclass Malacostraca
Order Amphipoda

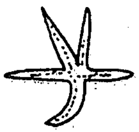
 *Metacaprella kennerlyi*

Phylum Brachiopoda

 *Terebratalia transversa*

Phylum Echinodermata
Class Asteroidea

 *Dermasterias imbricata*

 *Evasterias troschelii*

 *Pycnopodia helianthoides*

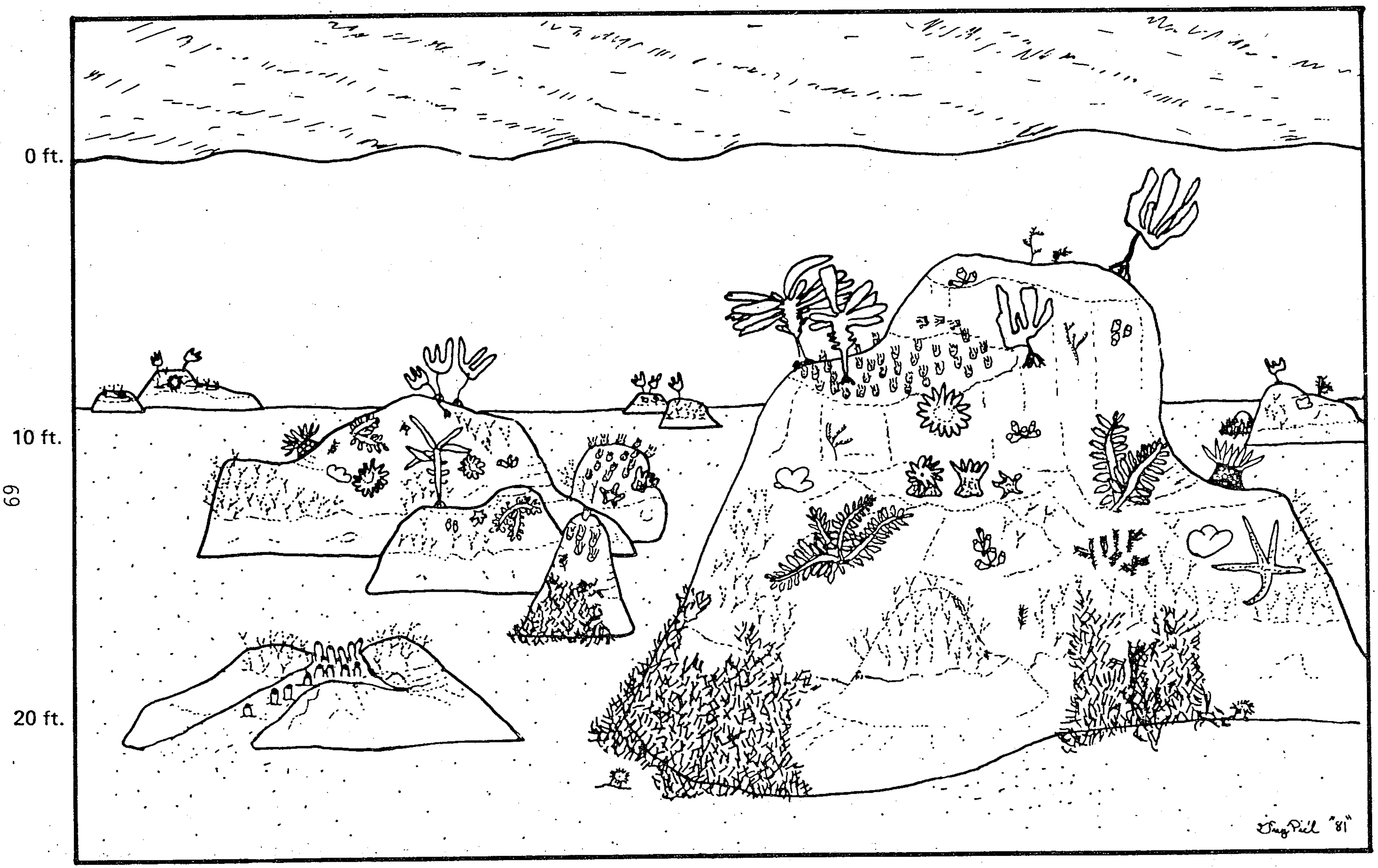


Figure 18: Schematic drawing of the macrobiota observed on Rocky Habitat Influenced By Sand

star *Ophiopholis aculeata* and the sea stars *D. imbricata* (often near cnidarians), *E. troschelii* and *P. helianthoides*.

Where sand was cast over rocks, the sponge *Polymastia pachymastia*, the brittle star *Amphiodia occidentalis* and the tunicate *Ritterella aequalisiphonis* were common in rocky depressions.

Rocky Habitat Influenced by Sediments Finer than Sand

Such habitat was only observed during the southernmost dive located about 0.25 miles (0.4 km) north of the mouth of the Klamath River (Figure 9). Constraints caused by both extremely poor visibility and inclement seas restricted diving to no deeper than 25 feet (8 m); however, the substrate was found to be a smooth rocky surface overlain by a thin silty veneer. Only one specimen each of the sponge *Suberites* sp. and one of the sea stars *L. hexactis* and *P. ochraceus* were collected.

Sandy Habitat (Figure 19)

Sand habitats throughout the ASBS range in extent from small deposits between boulders and bedrock to large subtidal expanses (Figure 18). Between 0 to 15 feet (0 to 5 m), only highly motile forms, the market crab, *Cancer magister*, the bay shrimp, *Crangon* sp., and the sanddab, *Citharichthys stigmaeus*, were observed.

Substrate stability increases with depth. From 15 to 40 feet (3 to 12 m) deep, in addition to the aforementioned species, the olive snail, *Olivella biplicata*, and slurries of organic material composed of bits of wood and decaying algae were observed. Associated with these slurries were the hydromedusa *Polyorchis* sp., the ctenophore *Pleurobrachia bachei* and a mysid shrimp. This latter association may well be ephemeral.

Ecological Considerations

Prior to the present study, Boyd and DeMartini (1977) reported on the biota of the rocky area just south of Endert's Beach. They noted

Figure 19: Diagramatic code for the macrobiota observed on Sandy Habitat

Phylum Cnidaria
Class Hydrozoa

 *Polyorchis sp.*

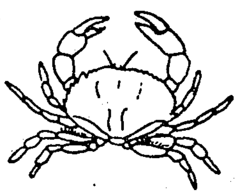
Phylum Ctenophora
Class Tentaculata

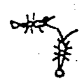
 *Pleurobrachia bachei*

Phylum Mollusca
Class Gastropoda
Subclass Prosobranchia

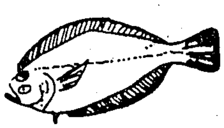
 *Olivella biplicata*

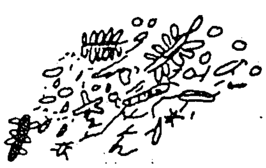
Phylum Arthropoda
Class Crustacea
Subclass Malacostraca
Order Decapoda

 *Cancer magister*

 *Crangon sp.*

Phylum Chordata
Subphylum Vertebrata

 *Citharchthys stigmaeus*

 *Organic Slurries*

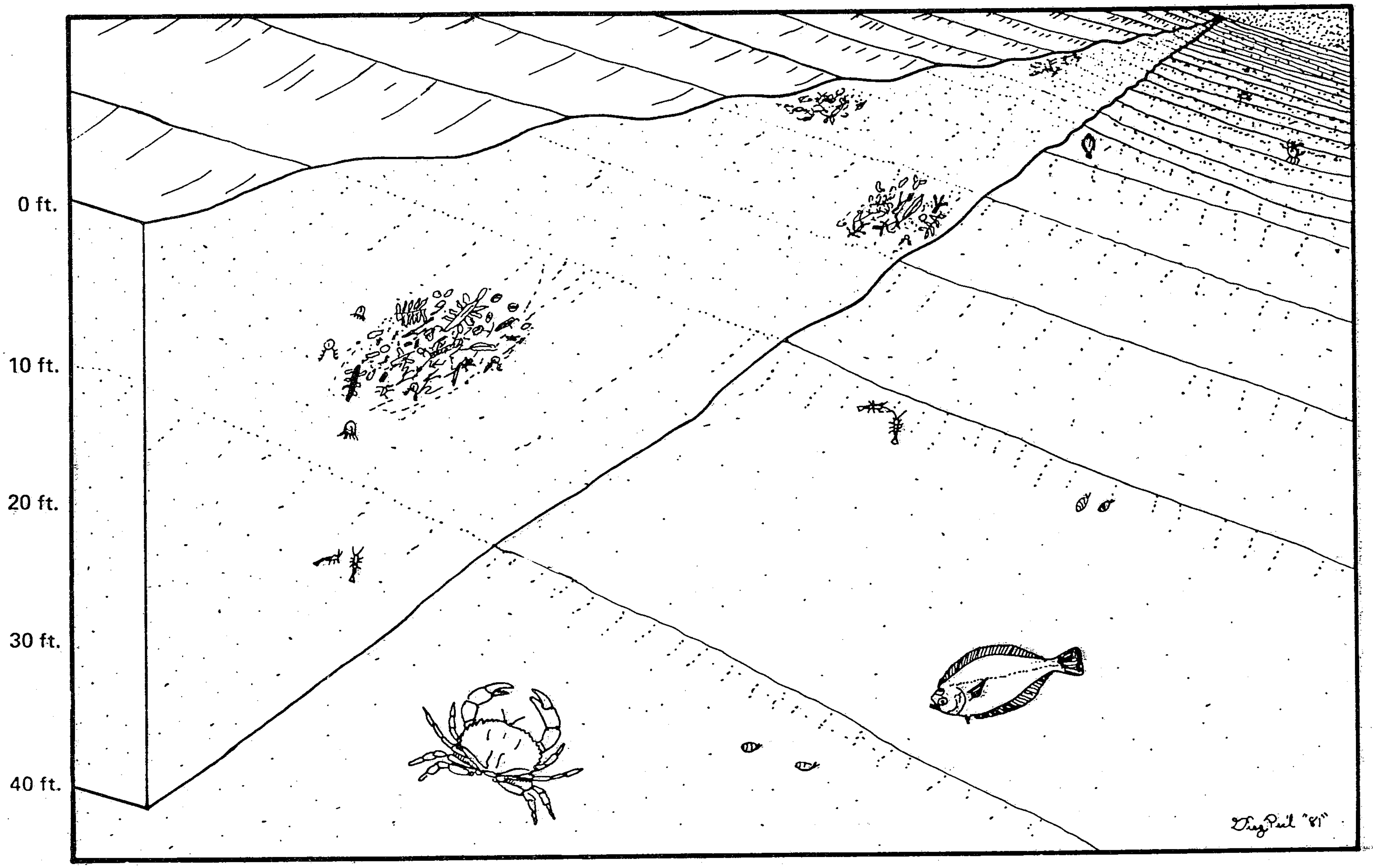


Figure 19: Schematic drawing of the macrobiota observed on Sandy Habitat

that the algal zone was no deeper than about 20 feet (6 m) and that large populations of the barnacle Balanus crenatus, of the skeleton shrimp Metacaprella kennerlyi, and of the sea cucumber, Eupentacta quinquesemita, were present. The observations made during this survey are in agreement with the aforementioned observations and expand further on habitats within the ASBS. DeMartini, Jones and Seltenrich (1977 and 1979) reported on the biotic assemblages of kelp beds at Trinidad Head ASBS. They noted similar observations for all of the aforementioned features. Observations made recently by the authors in the Trinidad area are also in agreement with the latter.

No observations were made south of the Klamath River. For rocky habitats the authors believe that the biota is probably similar to what has been observed north of the Klamath River and around Trinidad Bay.

Extensive sandy habitat is indicated for much of the ASBS south of the Klamath River (Figure 9). It is probable that the sand fauna off the southern portion of the ASBS probably resembles the sand fauna reported by DeMartini (1970) and by Boyd and DeMartini (1976).

In conclusion, the shallow subtidal rocky biota of Humboldt and Del Norte Counties are apparently similar. A comparison of the reports on Redwood National Park ASBS and Kelp Beds at Trinidad Head ASBS with those for Gerstle Cove ASBS, Pygmy Forest Ecological Staircase ASBS and the report of Seltenrich and DeMartini (1979) for Salt Point and Mendocino Headlands State Underwater Parks leads the authors to conclude that the Humboldt and Del Norte shallow rocky subtidal biota is distinct from that of Mendocino and Sonoma Counties.

Landside Vegetation

Five vegetation types are found within the coastal zone of the ASBS. Within the entire Park, twelve distinct vegetation types are recognized (Table 12, Fig. 20). The descriptions below closely match those developed by Park Service personnel (National Park Service 1979).

Table 12. Plant Species Commonly Found Among Vegetation Types Within Redwood National Park ASBS. (National Park Service 1979)

Vegetation Type	Approximate Acres	Percent of Total Park Acreage	Common Plants
Coastal Strand	1,000	0.9	European beach grass, beach primrose, sea rocket, sand verbena, beach morning glory
Freshwater Marsh	100	0.1	Sedges, cattail, bulrush, yellow pond lily, skunk cabbage, bur marigold, cinquefoil
Coastal Shrub	3,000	2.8	Coyote brush, blue blossom, silk tassel, twinberry, coastal wormwood, poison oak, miners lettuce, Indian paintbrush, foxglove, California figwort, coastal angelica, stunted Sitka spruce
Coastal Spruce Forest	4,000	3.8	Sitka spruce, red alder, sword fern, licorice fern, Salmonberry, salal, cow parsnip, wild finger, false lily, wild cucumber
Old-Growth Redwood Forest	39,000	36.8	Douglas-fir, western hemlock, grand fir, tanbark oak, rhododendron, salal, evergreen huckleberry, Oregon grape, sword fern, deer fern, redood sorrel, trillium, redwood violet
Second-Growth Redwood Forest	20,000	18.9	Redwood sprouts, Douglas-fir, western hemlock, tan oak, madrone, rhododendron, evergreen huckleberry, salal, Oregon grape, ferns
Recently Harvested Redwood Forest	20,550	19.4	Pearly everlasting, Australian fireweed, California blackberry, redwood seedlings, Douglas-fir seedlings

(Table 12 Cont.)

Vegetation Type	Approximate Acres	Percent of Total Park Acreage	Common Plants
Prairie	4,000	3.8	Vernal grass, dogtail, velvet grass, orchard grass, California catgrass, northern reed grass, blue wild rye, hazel
Jeffrey Pine Stands	1,000	0.9	Jeffrey pine, knobcone pine, Port Orford cedar, Douglas-fir, madrone, California laurel, western azalea, dwarf juniper, prostrate ceanothus, Idaho fescue, orchard grass, blue fleabane, phlox, buttercup
Chaparral	5,000	4.7	Knobcone pine, Douglas-fir, dwarf tanbark oak, rhododendron, huckleberry oak, manzanita, shrubby chinquapin, beargrass, wintergreen lily
Oregon White Oak	1,000	0.9	Oregon white oak, Douglas-fir, madrone, tanbark oak, California laurel, bayleaf maple, California hazel, poison oak, serviceberry, blackberry, velvet grass, orchard grass
Riparian Vegetation	1,000	0.9	Bigleaf maple, black cottonwood, California laurel, red alder, willow species

Figure 20. Vegetation units within the Redwood National Park ASBS (2 plates). Redrawn from National Park Service (1979).

Legend:

1	Old Growth Redwood Forest
2	Recently harvested Redwood Forest
3	Second-growth Redwood Forest
4	Prairie
5	Oak Woodland
6	Riparian vegetation
7	Coastal Shrub
8	Coastal Spruce Forest
9	Freshwater Marsh
10	Coastal Strand
11	Jeffrey Pine Woodland
12	Chaparral
13	Young Douglas Fir Forest
B	Unvegetated Bare Ground

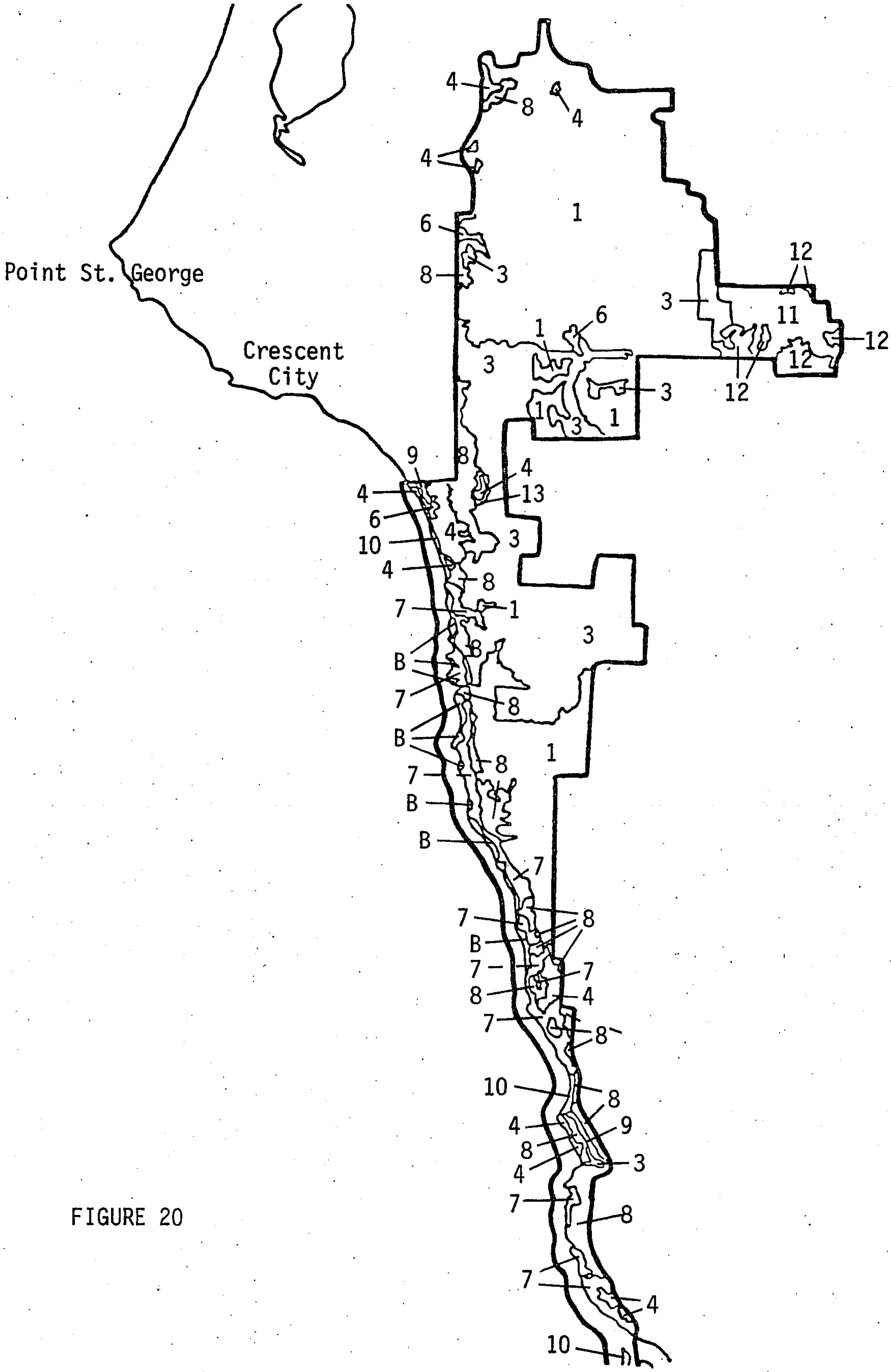


FIGURE 20

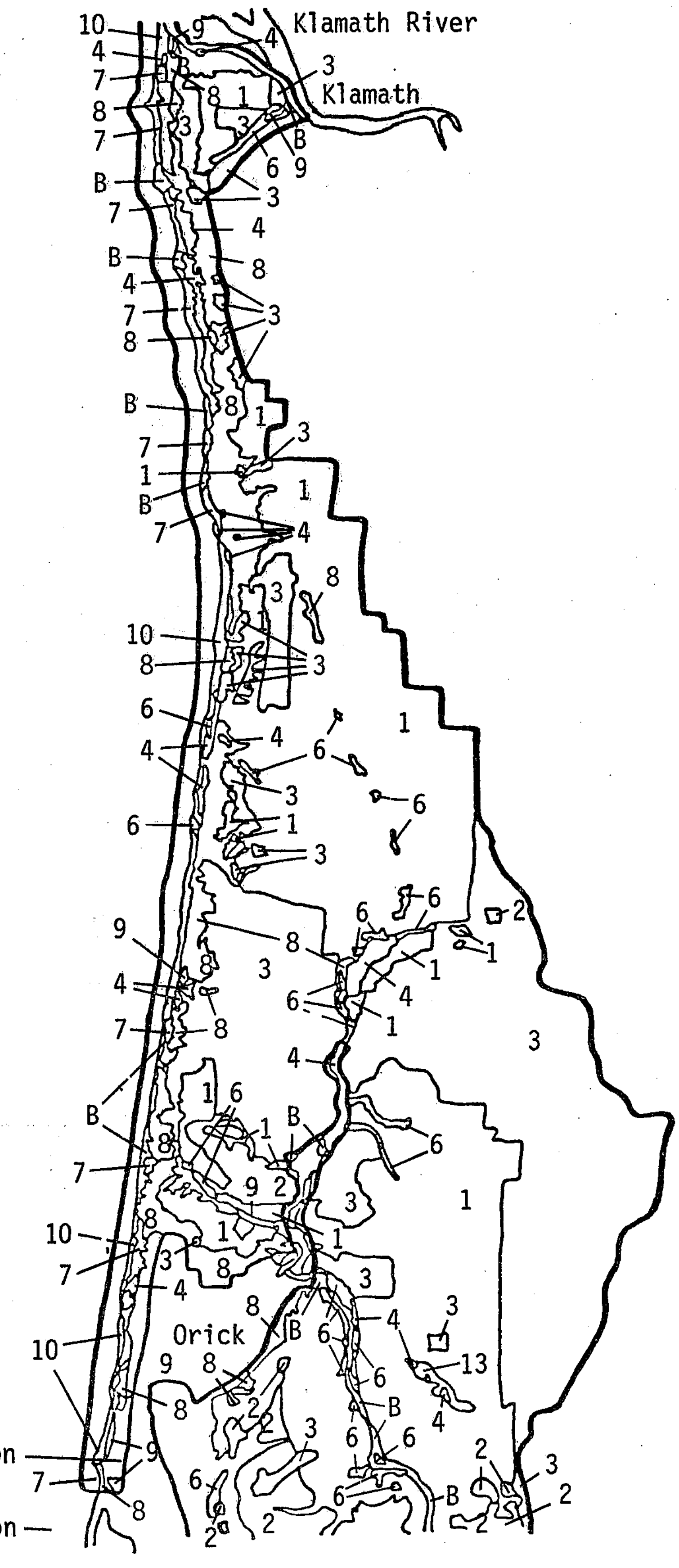


FIGURE 20 (cont.)

Coastal Strand vegetation occurs on upper beach sands above the influence of the highest high tides. This vegetation type is well developed at Crescent Beach and Gold Bluffs Beach. More restricted areas are found near the mouths of Redwood Creek and the Klamath River, at False Klamath Cove, and sparsely on Endert's Beach. At Gold Bluffs Beach, the introduced European beach grass (*Ammophila arenaria*) is an abundant element in coastal strand vegetation. It is less common at Crescent Beach.

Freshwater marshes are found near ponds, streams, and associated with temporary pools near the coast, small streams are often impounded behind the coastline by dams or by accumulated logs or other debris, with resultant development of a freshwater marsh. In the coastal zone, marshes are found behind Crescent Beach, at False Klamath Cove, around the mouth of the Klamath River, at Espa Lagoon behind Gold Bluffs Beach, and around the mouth of Redwood Creek.

Coastal shrub vegetation is found along the coast of Redwood National Park ASBS as a narrow and discontinuous band of low trees and shrubs. It is often intermixed with the coastal strand (particularly at Gold Bluff Beach), coastal prairies, or coastal spruce forest, resulting in a complex mixture of vegetation types. This vegetation type is seen on some disturbed soils, where it may eventually be replaced by coastal spruce forest.

Coastal spruce forest is recognized by the presence of the somewhat salt tolerant Sitka spruce. This species is intermixed with red alder on sites that show evidence of past logging, fire, or soil disturbance. Coastal spruce forest develops best on moderate slopes near lower stream drainage basins. Examples can be found along streams east of Gold Bluffs Beach, at Wilson Creek, and along Nickel Creek. Inland and at higher elevations, coastal spruce forest is replaced by Redwood Forest. Most coastal spruce stands within the ASBS were logged in the 1950's or were burned.

Coastal prairie vegetation occurs inland of the coastal strand at Gold Bluffs Beach and Crescent Beach. Steep slopes overlooking the coast may also have patches of coastal prairie on them. Along the coast, red alder and Sitka spruce are aggressive invaders of coastal prairies with flat to moderate slopes. Coastal prairies may be indicative of disturbed soil conditions (Figure 21) or areas where coastal spruce forest was logged or burned.

Three endangered plant species may occur within the coastal zone of the Redwood National Park ASBS (National Park Service 1979). These are the Black crowberry (Empetrum hermaphroditum), found on exposed slopes of north coastal shrub, the western lily (Lilium occidentale), found in coastal shrub and coastal prairies, and the coastal rein-orchid (Piperia mitima), also found in coastal shrub vegetation of northern California.

Unique Components

As far as is known, no marine species found along the coast are unique to the Redwood National Park ASBS. Significant aspects of the biology of intertidal species should be noted, however. Surf smelt and Night smelt support a significant local fishery of both commercial and sport importance. Probably the best smelt runs in Humboldt and Del Norte Counties occur along beaches in the southern half of the ASBS, although other locations in these two counties are also fished.

The rocky intertidal biota displays several interesting components. The large and showy sea-stars Solaster stimpsoni and Solaster dawsoni are regularly encountered in the low intertidal zone along the ASBS. Both these species are rare elsewhere in California. It would appear that both species are near the southern end of their ranges for intertidal occurrence along the coast of Redwood National Park. The sea-strawberry (Gersemia rubriformis) is also found in scattered low intertidal populations at Endert's Beach Cove and at False Klamath Cove. It appears that the southern limit of the intertidal distribution of this

Figure 21. Soils within the Redwood National Park ASBS. Redrawn from National Park Service (1979).

Legend:

Soil Group 1. Ridge tops, gentle slopes (less than 30%), stable, moderate to good drainage, slight to moderate erosion hazard.

Soil Group 2. Moderate to steep side slopes (30-50%), generally stable, moderate to good drainage and slight to moderate erosion hazard.

Soil Group 3. Steep to very steep sideslopes (greater than 50%), usually stream canyons; relatively stable, moderate to good drainage and high to moderate erosion hazard.

Soil Group 4. Unstable, erosive soils found on prairies, sections of coastal slope, and Atwell soils; also large landslides and bluffs, predominantly along the coast.

Soil Group 5. Alluvial soils, stream terraces, floodplains, and stream valleys.

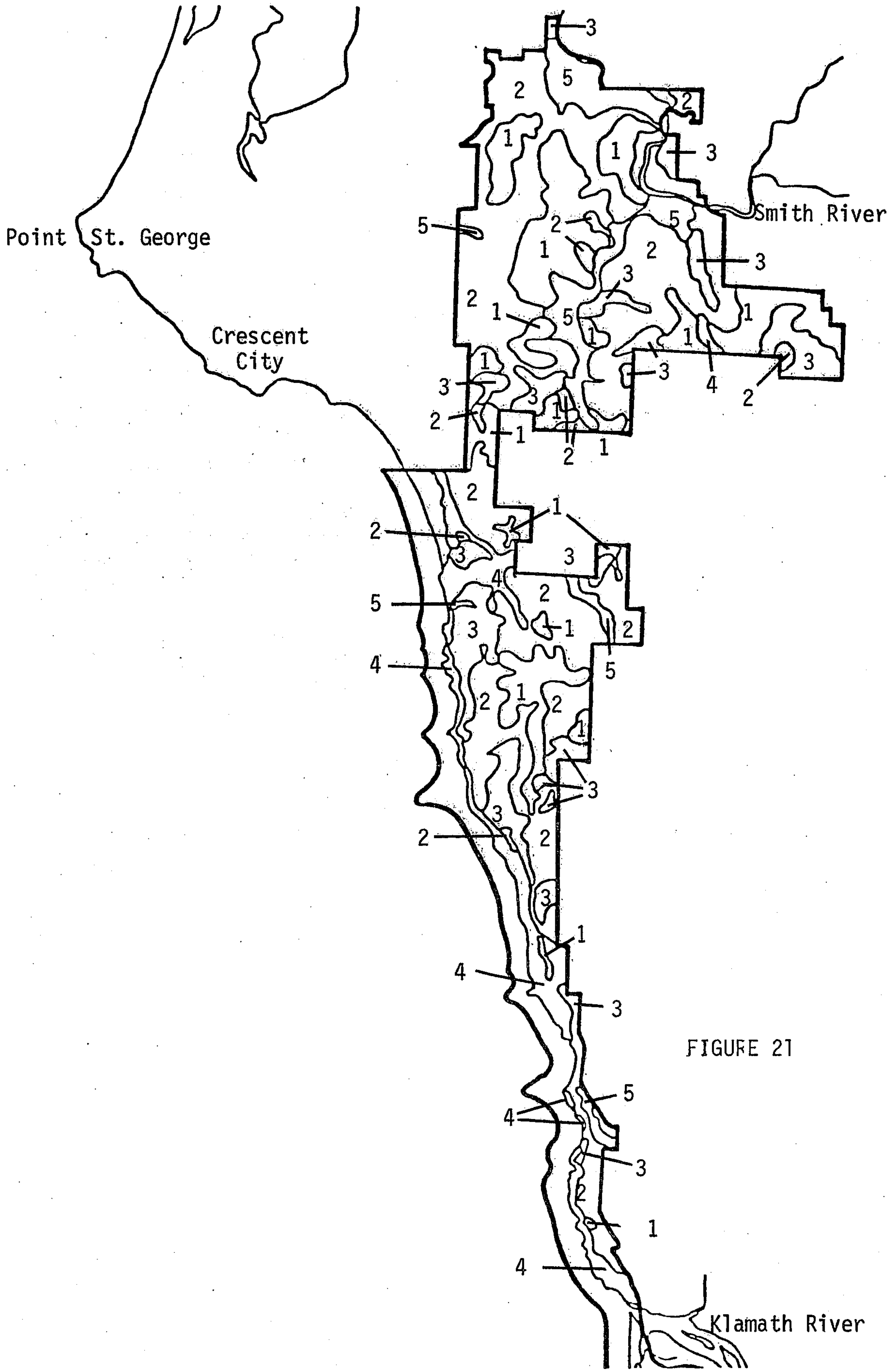


FIGURE 21

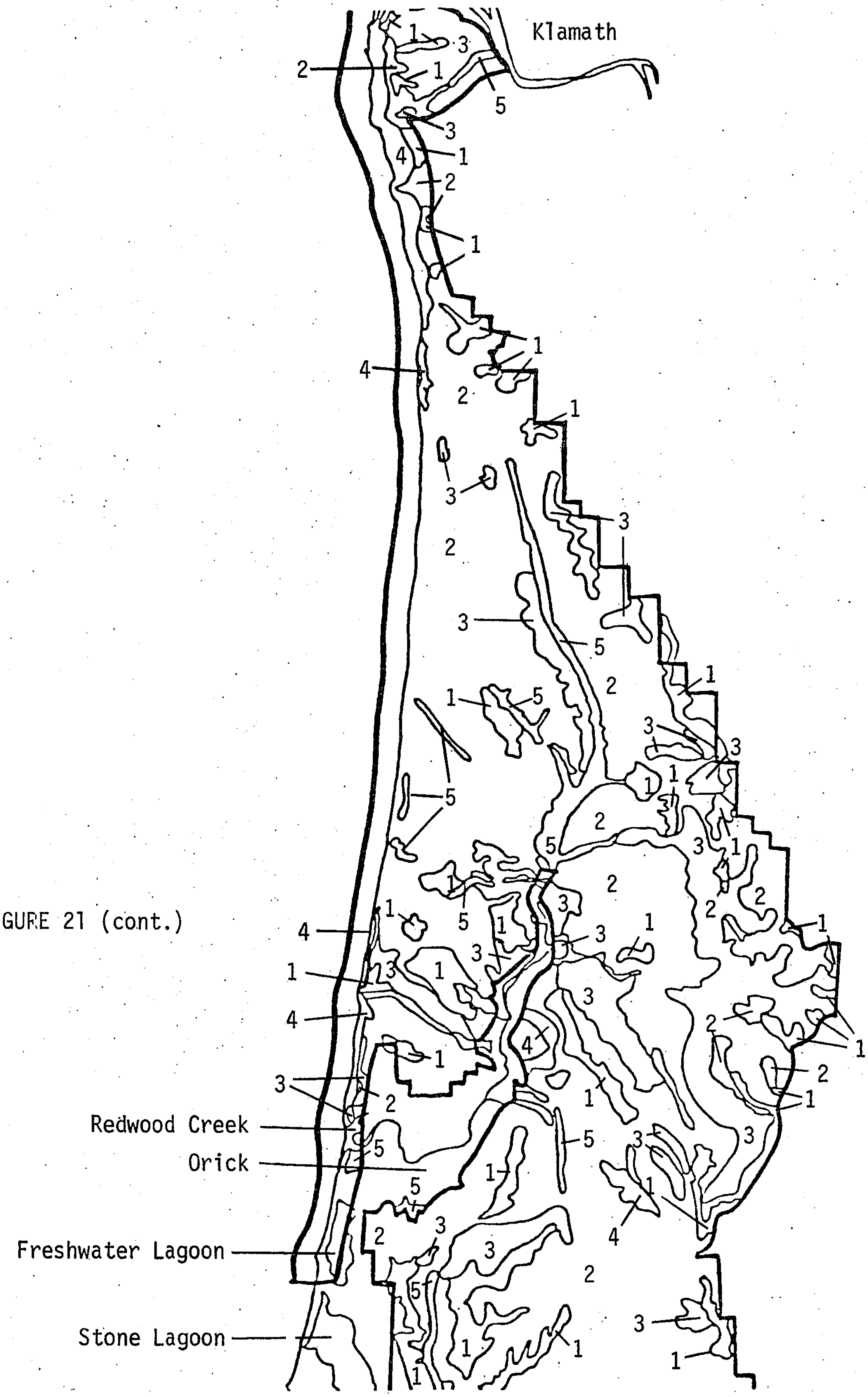


FIGURE 21 (cont.)

species is in Humboldt County, although it occurs subtidally southward into Mendocino County.

Three major streams or rivers discharge large amounts of silt and heavier particles into nearshore waters of the ASBS. Coastal waters are generally turbid and intertidal rocks frequently are coated by a fine covering of silt particles. The occurrence of these silts may inhibit settlement by many animal species or affect their metabolism by clogging respiratory structures. Whatever the underlying causes, intertidal herbivores are sparse within rocky intertidal areas. Impressive standing crops of foliose algae develop each year, probably because potential consumers are not particularly abundant. Each summer, intertidal rock surfaces are densely covered with red, green, and brown foliose algae. Severe wave shock along the coast during winter storms tears most of the foliose species from their rock holdfasts, however. The resulting flora is not rich in perennial species, but the standing crop year-to-year of annual species is impressive (Boyd and DeMartini 1977). Upwelling in adjacent ocean waters is probably significant in providing a source of necessary plant nutrients.

Thus, the overall ecological framework of the coastline of this ASBS is somewhat unique. Several species common in central California (Emerita analoga, Strongylocentrotus purpuratus) are rare or sporadic in occurrence in the ASBS. Other species appear to be close to the southern limits of regular intertidal occurrence (Siligua patula, Gersemia rubriformis). The intertidal biota, particular the fauna, is therefore transitional in character, containing both boreal and temperate marine elements.

LAND AND WATER USE DESCRIPTIONS

Marine Resource Harvesting

Crescent City, just north of the Redwood National Park ASBS, is the nearest commercial center for the fishing industry. In recent years, the number of persons employed in fishing has risen steadily. In 1977, 845 persons were employed in the fishing industry, not including shore based processing facilities (National Park Service 1979). The principal species landed are Silver salmon, Chinook salmon, and Market crab. These species may be taken in or close to the nearshore waters of the ASBS. A drag-boat fishery operates at greater depths off the coast and is outside the waters of the ASBS. The future of the fishing industry operating out of Crescent City is uncertain. Some projections indicate growth of the industry through the year 2000 (National Park Service 1979), but recently commercial catches of crab and salmon have declined slightly. In the summer of 1980, the ocean trolling season for salmon was closed for six weeks to ensure escapement of adequate spawning stock into the Klamath and Smith Rivers despite vigorous protests from local fishermen. It is anticipated that harvest of these marine resources will continue, although commercial fishing activities will be directly affected by regulatory decisions and economic factors, particularly increased costs for fuel.

With the exception of a small surf and night smelt fishery of unknown economic importance, no marine products are harvested directly from the intertidal or subtidal zones of the ASBS.

Municipal and Industrial Activities

No municipal or industrial activities occur within the boundaries of the Redwood National Park ASBS. The largest commercial center is Crescent City, just to the north. Along with its nearby unincorporated areas, the 1970 population was estimated as 5,639 persons. There was an estimated population growth rate of 1.2% in Del Norte County from 1970-1979 (National Park Service 1979). Two small unincorporated communities, Klamath and Orick, lie near the ASBS in its central and southern areas. Industrial activities at Crescent City are associated primarily with the timber and fishing industries. There is also a small cheese making factory in the town. None of these activities appear to directly affect water quality within the ASBS.

Agribusiness and Silviculture

The forest products industry has been the traditional mainstay of the local economy in both Del Norte and Humboldt Counties. Exploitation of forest resources began over a century ago and grew steadily throughout the first fifty years of this century. An all time high in log output was reached in 1959, when 1.9 billion board feet of lumber were harvested. Since that time output has declined, but the timber industry is still the most significant commercial activity in the two counties. Of the land area within Humboldt and Del Norte Counties, 84% is used for silviculture, 9.5% is rangeland, and 3.7% is crop or pasture land.

Despite the rather small amount of agricultural land, employment associated with agriculture was 2,250 in 1969 for the two county area. Employment has remained fairly constant in this sector since then (National Park Service 1979). With the exception of small family-owned dairy operations near the southern and northern parts of Redwood National Park, agribusiness activities are not significant near the ASBS.

Government Designated Open Space

The entire coastal zone of Redwood National Park is under either federal or state jurisdiction as parklands. Local coastal plans and the California Coastal Plan have designated the entire area as Open Space. The Redwood National Park Draft Management Plan indicates several existing uses of lands within the ASBS (Figure 22).

Figure 22. Existing management and use of lands within Redwood National Park. Redrawn from National Park Service (1979).

Legend:

- State controlled coastal lands (ASBS)
- Natural zone (open space)
- Natural (predominantly Redwood Forest)
- Experimental Research Area

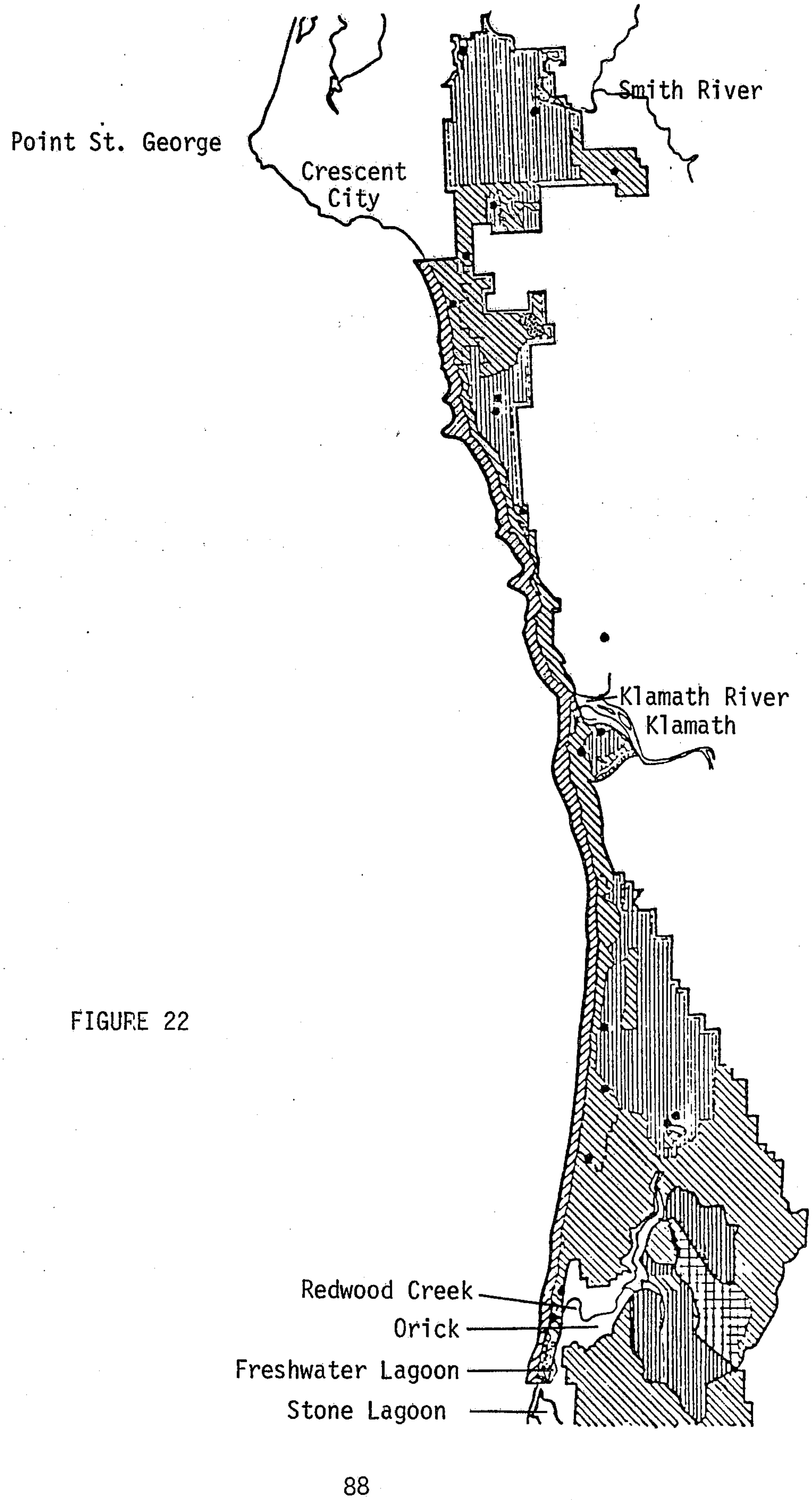

Smith River
Point St. George
Crescent City
Klamath River
Klamath
Redwood Creek
Orick
Freshwater Lagoon
Stone Lagoon

FIGURE 22

Recreational Uses

Information regarding recreational use of the coastal zone of Redwood National Park is not separately available from overall visitor information data (Table 13). Most visitors are interested in the large Virgin Coastal Redwood Stands inland from the coast, but a significant number of visitors do take advantage of recreational opportunities along the coast. Because accessibility to the coast is not possible at many points, recreational opportunities are confined to a limited number of locations.

At Crescent Beach, the National Park has set up picnic tables, portable toilets, and a source of potable water. This is a day-use area only, and principal recreational activities are clamming, beach-combing, sunbathing, and picnicing. South of Crescent Beach at Nickel Creek, a hike-in campground will accommodate six parties. Access is from a parking area about 0.25 miles (0.42 km) north of the camping area. This is also a gathering point for beach walks conducted by Park Naturalists during low tides in the summer months. Visitors are guided along Endert's Beach and into Endert's Beach Cove with its rich inter-tidal biota. Further travel southward along the coast is not possible. Visitors are discouraged from attempting to hike to False Klamath Cove because of dangerous surf and precipitous cliffs.

At False Klamath Cove, a coastal trail can be taken south along the bluffs to Requa, overlooking the mouth of the Klamath River. A parking area at roadside is often used by individuals surf fishing from the beach or observing intertidal life in the boulder field at the south end of the shallow cove. A small picnic area is maintained at the north end of the cove where Wilson Creek enters the ocean. Adjacent to False Klamath Cove, a larger parking area, picnic tables, and toilet facilities are maintained at the Lagoon Creek pond.

Just south of the mouth of the Klamath River, a scenic coastal road parallels the coast line about 0.25 mile (0.40 km) inland from the cliff

Table 13. Actual and Projected Visits to Redwood National Park (from National Park Service 1979)

Year	Visits	% Increase from Previous Period
1970	610,655	--
1975	865,926	41.2%
1977	1,122,537	29.6%
1980 (Projected)	1,312,756	16.9%
1985 (Projected)	1,641,605	25.0%
1990 (Projected)	1,970,452	20.0%

tops. Access to the coast is impossible except at Johnson Creek Beach, where a trail about 0.8 mile (1.3 km) long leaves the road and winds down to the beach. The north end of Gold Bluffs Beach is inaccessible except by trail. The old road from Fern Canyon can be used from the south as a hiking trail, or hikers can approach the beach from U.S. Highway 101 by using the Ossagon Creek Trail. The Ossagon Creek Trail is about 1.5 miles (2.4 km) long and the trail from Fern Canyon is about 2.2 miles (3.5 km) long.

Fern Canyon, at about the middle of Gold Bluffs Beach, is a popular site of recreational activity. It is approached by a dirt road which ultimately intersects with U.S. Highway 101 just south of Prairie Creek Redwoods State Park. This dirt road is the main access route to Gold Bluffs Beach. South of Fern Canyon, a beach campground with water, toilet facilities, and picnic tables accommodates overnight campers. This is the only publicly owned campground accessible to vehicles along the coast of the ASBS. Recreational activities along Gold Bluffs Beach include fishing for smelt, surf fishing, and beach combing. Access for four-wheel drive vehicles is maintained to the beach fore-slope for commercial smelt fishermen, who may travel along the entire beach in search of fishing spots during spring and summer months. The National Park Service is reviewing its current policies on vehicle access for all beaches within the ASBS (National Park Service 1979). The dirt road turns inland near Espa Lagoon, a popular trout fishing pond. The southern part of Gold Bluffs Beach is accessible to hikers and four-wheel drive vehicles travelling along the beach slope.

A paved road leaves Orick at Highway 101 and generally parallels Redwood Creek to a parking area near the mouth of the creek. Depending on the season, the beach is used for surf fishing, sun bathing, or driftwood collecting. There are no visitor facilities at this beach.

In summary, most recreational activities within the ASBS occur at or near sand beaches. Rocky intertidal habitats are not accessible in many locations, although Park Service personnel do provide guided walks at Endert's Beach Cove and False Klamath Cove during summer months.

Scientific Study Uses

Except for interpretative use by the National Park Service (Boyd and DeMartini 1977), no scientific studies have been conducted within the Redwood National Park ASBS. No continuing or long-term studies are currently in progress.

Transportation Corridors

The main transportation corridor in the ASBS is U.S. Highway 101. This north-south corridor is the only major highway in coastal northern California. Plans are underway to relocate a 12-mile section of the highway to a new route east of Prairie Creek Redwoods State Park. At present, heavy commercial traffic along this stretch of the highway is in conflict with the spectacular natural scenery of the area (National Park Service 1979).

ACTUAL OR POTENTIAL POLLUTION THREATS

Point Sources

Campgrounds and employee housing within the ASBS apparently do not constitute potential sources of pollution. Chemical recirculating toilets are used at campgrounds; employee residential structures have properly functioning septic systems (National Park Service 1979). Coastal streams have water quality generally in excess of state standards for drinking water (Table 14). A possible source of bacteriological water contamination is the Elk herd at Prairie Creek Redwoods State Park. Near the meadow where the herd grazes, excessive amounts of coliforms and streptococci have been recorded. There are no other structures or facilities in this area. The values recorded at this site have the highest bacteriological counts of any location within Redwood National Park.

There are no chemical sources of pollution within Redwood National Park. With the exception of iron, chemical contaminants in surface waters are within federal standards for drinking water. Both stream and well water within the Park frequently exceeded federal standards for iron in drinking water, probably as a result of high iron content in native soils of the area (National Park Service 1979).

Non-Point Sources

Activities in water sheds and drainages outside Redwood National Park have contributed substantial amounts of bed load materials to the Smith River, Klamath River, and Redwood Creek (see Table 15). Erosion accompanying and following logging activities has undoubtedly contributed substantially to the turbidity of near shore waters. With recent acquisitions of lands in the Redwood Creek drainage basin, the Park Service has undertaken slope stabilization and forest rehabilitation projects. Such efforts should decrease loss of soils and consequent problems with stream and nearshore water turbidity (National Park Service 1979). Most of the drainage basins of the Smith and Klamath Rivers lie

Table 14. Selected Bacteriological Water Quality Data, Redwood National Park (From National Park Service 1979)

Location	Dates	No. of Samples	Range		Mean	
			Fecal * Coliform	Fecal + Streptococci	Fecal * Coliform	Fecal + Streptococci
Redwood Cr. at Orick, U.S. 101 Bridge	1974,'75	5	4-46	6-62	25	34
Prairie Cr. near Orick	1974,'75	2	22-220	11-753	121	382
Home Creek (Fern Canyon) near mouth	1978	3	2-15	1- 2	10	2
Nickel Creek near campground	1978	1	5.1	Total Coliform 16	-	-

*Fecal coliform analyzed using multiple tubes procedures. Number recorded indicates most probable number of fecal coliforms per 100 ml.

+Fecal streptococci tested using plate count method. Number indicates colonies per 100 ml.

Table 15. Some characteristics of major streams and rivers emptying into the coastal waters of the Redwood National Park ASBS.

	Smith River	Klamath River	Redwood Creek at Orick
Origin	Oregon	Oregon	California
Approx. drainage area (miles)	719	15,500	278
In-park drainage area (miles)	20	5	85
Average discharge (cubic ft./sec.)	3,872	17,680	1,101
Maximum recorded discharge (cubic ft./sec.)	228,000	557,000	50,500
Maximum bedload discharge (tons/day)	unk	unk	1,070,000
Suspended sediment maximum concentrations (mg/liter)	unk	221	9,610

outside the control of Park authorities, however. As logging activities continue within the inland drainage basins of these rivers, water turbidity will continue to be a problem.

Future development of Park facilities could contribute to erosion because of construction activities. The development plan for future facilities has incorporated safeguards to prevent decreases in water quality coincident with such construction activities (National Park Service 1979).

Water and sediment samples from the nearshore waters of the ASBS have only recently been collected (Ecological Analysts 1980) from several locations off Crescent City. Analysis of these samples revealed that contaminant levels were at, or below, detection limits for hydrocarbons, heavy metals, or pesticide residues. Heavy metals were analyzed by atomic absorption spectrophotometry and organic residues by gas chromatography.

SPECIAL WATER QUALITY REQUIREMENTS

Water quality in nearshore waters, ground waters, and stream waters of the Redwood National Park ASBS appears to meet or exceed federal and state standards for recreational purposes. Most coastal streams exceed state water quality standards for drinking water. Provided present levels of water quality are maintained, there are no special water quality requirements in this ASBS.

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APPENDIX 1.

Animals of Sand Beaches in the Redwood National Park ASBS

Phylum Annelida

Class Polychaeta

Eteone dilatae Hartman, 1936

Euzonus mucronata (Treadwell, 1914)

Lumbrineris zonata (Johnson, 1901)

Nephtys californiensis Hartman, 1938

Nothria iridescens (Johnson, 1901)

Orbinia johnsoni (Moore, 1909)

Pygospio californica Hartman, 1936

Scolelepis squamatus (Muller, 1806)

Phylum Arthropoda

Class Crustacea

Archaeomysis maculata (Holmes, 1894)

Atylus tridens (Alderman, 1936)

Bathycopea daltonae (Menzies and Barnard, 1959)

Crangon nigricauda (surf zone) Stimpson 1856

Dogielinotus loquax Barnard, 1967

Emerita analoga (Stimpson, 1857)

Eohaustorius brevicuspus Bosworth, 1973

Eohaustorius sawyeri Bosworth, 1973

Eohaustorius washingtonianus (Thorsteinson, 1941)

Excirolana linguifrons (Richardson, 1899)

Monoculoides sp.

Orchestoidea californiana (Brandt, 1851)

Orchestoidea columbiana Bousfield, 1958

Orchestoidea benedicti Shoemaker, 1930

Paraphoxus sp.

Phylum Mollusca

Class Gastropoda

Olivella biplicata (Sowerby, 1825)

Olivella pycna Berry, 1935

Class Bivalvia

Siliqua patula (Dixon, 1789)

Phylum Nemertea

Tubulanus pellucidus (Coe, 1895)

APPENDIX 2.

Animals of Rocky Intertidal Areas in the Redwood National Park ASBS

Phylum Porifera

Class Demospongiae

- *Cliona celata* Grant, 1826, var. *californiana* de Laubenfels, 1932
- *Halichondria panicea* (Pallas, 1766)
- *Haliclona* sp.
- *Hymendectyon lyoni* Bakus, 1966
- *Hymeniacidon ungodon* de Laubenfels, 1932
- *Mycale macginitiei* de Laubenfels, 1930
- *Mycale richardsoni* Bakus, 1966
- *Ophlitaspongia pennata* (Lambe, 1895)
- *Pachychalina lunisimilis* (de Laubenfels, 1930)
- *Reniera* sp.
- *Sigmadocia* sp.
- *Suberites* sp.

Phylum Cnidaria

Class Hydrozoa

- *Abietinaria* sp.
- *Aglaophenia* sp.
- *Eudendrium californicum* Torrey, 1902
- *Garveia annulata* Nutting, 1901
- *Obelia geniculata* (Linnaeus, 1767)
- *Tubularia marina* (Torrey, 1902)

Class Anthozoa

- *Anthopleura artemisia* (Pickering in Dana, 1848)
- *Anthopleura elegantissima* (Brandt, 1835)
- *Anthopleura xanthogrammica* (Brandt, 1835)
- *Balanophyllia elegans* Verrill, 1864
- *Epiactis prolifera* Verrill, 1869
- *Tealia coriacea* (Cuvier, 1798)
- *Tealia crassicornis* (Muller, 1776)
- *Gersemia rubriformis* (Pallas)

Phylum Memertea

- *Amphiporus imparispinosus* Griffin, 1898
- *Paranemertes peregrina* Coe, 1901

Phylum Annelida

Class Polychaeta

Family Ampharetidae

- *Ampharete* sp.
- *Schistocomus hiltoni* Chamberlin, 1919

Family Arenicolidae

- *Branchiomaldane vincentii* Langerhans, 1881

Phylum Annelida

Class Polychaeta (Cont.)

Family Chrysopetalidae

Paleanotus bellis (Johnson, 1897)

Family Goniadidae

Glycinde polygnatha Hartman, 1950

Family Lumbrineridae

Lumbrineris sp.

Family Nereidae

Neanthes succinea (Frey & Leuckart, 1847)

Nereis vexillosa Grube, 1851

Nereis sp.

Platynereis bicanaliculata (Baird, 1863)

Family Onuphidae

Nothria elegans (Johnson, 1901)

Family Opheliidae

Armandia brevis (Moore, 1906)

Family Orbiniidae

Naineris dendritica (Kinberg, 1867)

Family Phyllodocidae

Anaitides williamsi Hartman, 1936

Eulalia aviculiseta Hartman, 1936

Family Polynoidae

Arctonoe vittata (Grube, 1855)

Halosydna brevisetosa Kinberg, 1855

Harmothoe imbricata (Linnaeus, 1767)

Family Sabellidae

Chone ecaudata (Moore, 1923)

Fabricia sp.

Pseudopotamilla sp.

Schizobranchia insignis Bush, 1904

Family Serpulidae

Serpula vermicularis Linnaeus, 1767

Family Sigalionidae

Sthenelais fusca Johnson, 1897

Family Spionidae

Boccardia proboscidea Hartman, 1940

Polydora giardi Mesnil, 1896

Polydora socialis (Schmarda, 1861)

Polydora sp.

Rhyncospio arenicola Hartman, 1936

Spiophanes sp.

Family Syllidae

Autolytus sp.

Exogone lourei Berkeley & Berkeley, 1938

Sphaerosyllis sp.

Syllis elongata (Johnson, 1901)

Typosyllis alternata (Moore, 1908)

Typosyllis sp.

Family Terebellidae

Eupolymnia crescentis Chamberlin, 1919

Neoamphitrite robusta (Johnson, 1901)

Phylum Mollusca

Class Polyplacophora

- *Chaetopleura gemma* Dall, 1879
- *Cryptochiton stelleri* (Middendorff, 1846)
- *Cyanoplax dentiens* (Gould, 1846)
- *Lepidozona mertensii* (Middendorff, 1846)
- *Katharina tunicata* (Wood, 1815)
- *Mopalia ciliata* (Sowerby, 1840)
- *Mopalia hindsii* (Reeve, 1847)
- *Mopalia lignosa* (Gould, 1846)
- *Mopalia mucosa* (Gould, 1846)
- *Tonicella lineata* (Wood, 1815)

Class Gastropoda

Subclass Prosobranchia

- *Acmaea mitra* Rathke, 1833
- *Amphissa versicolor* Dall, 1871
- *Barleeia* sp.
- *Bittium eschrichtii* (Middendorff, 1849)
- *Calliostoma ligatum* (Gould, 1849)
- *Ceratostoma foliatum* (Gmelin, 1791)
- *Collisella digitalis* (Rathke, 1833)
- *Collisella pelta* (Rathke, 1833)
- *Collisella scabra* (Gould, 1846)
- *Collisella strigatella* (Carpenter, 1864)
- *Diodora aspera* (Rathke, 1833)
- *Lacuna porrecta* Carpenter, 1864
- *Lacuna* sp.
- *Lamellaria* sp.
- *Littorina scutulata* Gould, 1849
- *Magarites pupillus* (Gould, 1849)
- *Mitrella carinata* (Hinds, 1844)
- *Notoacmaea personna* (Rathke, 1833)
- *Notoacmaea scutum* (Rathke, 1833)
- *Nucella canaliculata* (Duclos, 1832)
- *Nucella emarginata* (Deshayes, 1839)
- *Nucella lamellosa* (Gmelin, 1791)
- *Ocenebra lurida* (Middendorff, 1848)
- *Searlesia dira* (Reeve, 1846)
- *Tegula funebralis* (A. Adams, 1855)
- *Tricola* sp.

Class Cephalopoda

- *Octopus dofleini* Pickford, 1964

Phylum Brachiopoda

- *Terebratalia transversa* (Sowerby, 1846)

Phylum Bryozoa

- *Bicrisia edwardsiana* (d'Orbigny, 1839)
- *Bugula californica* Robertson, 1905
- *Crisia occidentalis* Trask, 1857
- *Filicrisia franciscana* (Robertson, 1910)
- *Flustrellidra corniculata* (Smith, 1871)

Phylum Arthropoda
  Class Crustacea
    Subclass Cirripedia
      Balanus balanus pugetensis Pilsbry, 1916
      Balanus cariosus (Pallas, 1788)
      Balanus crenatus Bruguiere, 1789
      Balanus glandula Darwin, 1854
      Balanus nubilis Darwin, 1854
      Chthamalus dalli Pilsbry, 1916
      Chthamalus fissus Darwin, 1854
      Pollicipes polymerus Sowerby, 1833
    Subclass Malacostraca
      Order Amphipoda
        Parallorchestes ochotensis (Brandt, 1851)
      Order Isopoda
        Gnorimosphaeroma oregonensis (Dana, 1854-1855)
      Order Decapoda
        Cancer antennarius Stimpson, 1856
        Cancer jordani Rathbun, 1900
        Cancer magister Dana, 1852
        Cancer productus Randall, 1839
        Cryptolithodes sitchensis Brandt, 1853
        Hapalogaster mertensii Brandt, 1850
        Hemigrapsus nudus (Dana, 1851)
        Hemigrapsus oregonensis (Dana, 1851)
        Pagurus granosimanus (Stimpson, 1859)
        Pagurus hirsutiusculus (Dana, 1851)
        Pagurus samuelis (Stimpson, 1857)
        Petrolisthes cinctipes (Randall, 1839)
        Pugettia producta (Randall, 1839)
        Pugettia richii Dana, 1851
        Scyra acutifrons Dana, 1851

Phylum Echinodermata
  Class Asteroidea
    Dermasterias imbricata (Grube, 1857)
    Evasterias troschelii (Stimpson, 1862)
    Henricia leviuscula (Stimpson, 1857)
    Leptasterias pusilla (Fisher, 1930)
    Leptasterias hexactis (Stimpson, 1862)
    Pisaster ochraceus (Brandt, 1835)
    Pycnopodia helianthoides (Brandt, 1835)
    Solaster dawsoni Verrill, 1880
    Solaster stimpsoni Verrill, 1878
  Class Holothuroidea
    Cucumaria miniata Brandt, 1835
    Eupentacta quinquesemita (Selenka, 1867)
  Class Echinoidea
    Strongylocentrotus purpuratus (Stimpson, 1857)
  Class Ophiuroidea
    Ophiopholis aculeata (Linnaeus, 1767)

Phylum Chordata
  Class Ascidiacea
    Styela montereyensis (Dall, 1872)

APPENDIX 3.

Marine Intertidal Algae of the Redwood National Park ASBS

Rhodophyta:

Rhodomela larix (Turner, 1819) C. Agardh, 1822
Constantinea simplex Setchell, 1901
Polyneura latissima (Harvey, 1862) Kylin, 1924
Laurencia spectabilis Postels & Ruprecht, 1840
Ptilota filicina J. Agardh, 1876
Odonthalia lyallii (Harvey) J. Agardh
Odonthalia floccosa (Esper, 1802) Falkenberg, 1901
Odonthalia oregona Doty, 1947
Iridaea cordata var. *splendens* (S&G, 1937) Abbott, 1971
Iridaea heterocarpa Postels & Ruprecht, 1840
Iridaea flaccida (Setchell & Gardner, 1937) Silva, 1957
Neoptilota hypnoides (Harvey, 1833) Kylin, 1956
Farlowia mollis (Harvey & Bailey, 1851) Farlow & Setchell, 1901
Prionitis lyallii Harvey, 1862
Prionitis lanceolata (Harvey, 1833) Harvey, 1853
Polysiphonia spp. (2) Greville, 1823
Bossiella orbigniana ssp. *dichotoma* (Manza, 1937) Johansen, 1971
Bossiella chiloensis (Decaisne, 1842) Johansen, 1971
Bossiella plumosa (Manza, 1937) Silva, 1957
Corallina vancouveriensis Yendo, 1902
Corallina officinalis var. *chilensis* (Decaisne, 1847) Kutzing, 1858
Calliarthron tuberculosum (Postels & Ruprecht, 1840) Dawson, 1964
Botryoglossum farlowianum (J. Agardh, 1898) DeToni, 1900
Dilsea californica (J. Agardh, 1876) Kuntze, 1891
Schizymenia pacifica (Kylin, 1925) Kylin, 1932
Gigartina agardhii Setchell & Gardner, 1933
Gigartina papillata (C. Agardh, 1821) J. Agardh, 1846
Grateloupia setchellii Kylin, 1941
Gymnogongrus linearis (C. Agardh, 1822) J. Agardh, 1851
Pikea robusta Abbott, 1968
Endocladia muricata (Postels & Ruprecht, 1840) J. Agardh, 1847
Gloiopeltis furcata (Postels & Ruprecht, 1840) J. Agardh, 1851
Callithamnion pikeanum Harvey, 1853
Cryptosiphonia woodii (J. Agardh, 1872) J. Agardh, 1876
Membranoptera dimorpha Gardner, 1926
Ahnfeltia plicata (Hudson, 1762) Fries, 1835
Ahnfeltia concinna Agardh
Plocamium cartilagineum (Linnaeus, 1753) Dixon, 1967
Plocamium violaceum Farlow, 1877
Hymenena flabelligera (J. Agardh, 1876) Kylin, 1924
Hymenena multiloba (J. Agardh, 1876) Kylin, 1935
Microcladia borealis Ruprecht, 1851
Porphyra perforata J. Agardh, 1883
Porphyra lanceolata Setchell & Hus, 1900
Porphyra smithii Hollenberg & Abbott, 1968

Rhodophyta (Continued
Cryptopleura violacea (J. Agardh, 1876) Kylin, 1924
Cryptopleura lobulifera (J. Agardh, 1898) Kylin, 1924
Callophyllis pinnata Setchell & Swezy, 1923
Erythrophyllum delesserioides J. Agardh, 1872
Opuntiella californica (Farlow, 1877) Kylin, 1925
Halosaccion glandiforme (Gmelin, 1768) Ruprecht, 1851
Neopolyporolithon reclinatum (Foslie, 1906) Adey & Johansen, 1972
Porphyropsis coccinea (Areschoug, 1850) Rosenvinge, 1909
Tenarea dispar (Foslie, 1907) Adey, 1970
Odonthalia washingtoniensis Kylin, 1925
Rhodomela larix (Turner, 1819) C. Agardh, 1822
Microcladia borealis Ruprecht, 1851
Plocamium oregonum Doty, 1947
Prionitis filiformis Kylin, 1941
Farlowia mollis (Harvey & Bailey, 1851) Farlow and Setchell, 1901
Ptilota filicina J. Agardh, 1876
Polyneura latissima (Harvey, 1862) Kylin, 1924
Pikea robusta Abbott, 1968
Petrocelis franciscana Setchell & Gardner, 1917
Gymnogongrus linearis (C. Agardh, 1822) J. Agardh, 1851
Hymenena flabelligera (J. Agardh, 1876) Kylin, 1924
Cryptopleura lobulifera (J. Agardh, 1898) Kylin, 1924
Hymenena cuneifolia Doty, 1947
Laurencia spectabilis Postels & Ruprecht, 1840

Phaeophyta:
Leathesia nana Setchell & Gardner, 1924
Leathesia difformis (Linnaeus, 1755) Areschoug, 1847
Soranthera ulvoidea Postels & Ruprecht, 1840
Hedophyllum sessile (C. Agardh, 1824) Setchell, 1901
Egregia menziesii (Turner, 1808) Areschoug, 1876
Laminaria dentigera Kjellman, 1889
Laminaria sinclairii (Harvey, 1846) Farlow, Anderson & Eaton, 1878
Analipus japonicus (Harvey, 1857 Wynne, 1971
Pelvetiopsis limitata Gardner, 1910
Alaria nana Schrader
Alaria marginata Postels & Ruprecht, 1840
Scytosiphon lomentaria (Lyngbye, 1819) J. Agardh, 1848
Haplogloia andersonii (Farlow, 1889) Levring, 1939
Lessoniopsis littoralis (Tilden, 1900) Reinke, 1903
Nereocystis luetkeana (Mertens, 1829) Postels & Ruprecht, 1840
Postelsia palmaeformis Ruprecht, 1852
Desmarestia ligulata (Lightfoot, 1777) Lamouroux, 1813, var. *ligulata*
Pterygophora californica Ruprecht, 1852
Cystoseira osmundacea (Turner, 1809) C. Agardh, 1820
Fucus distichus Linneaus, 1767
Petalonia fascia (Muler, 1778) Kuntze, 1898
Ralfsia sp. Berkeley, 1831

Chlorophyta:
Spongomorpha coalita (Ruprecht, 1851) Collins, 1909
Cladophora columbiana Collins, 1903
Ulva sp. Linaeus, 1753
Enteromorpha linza (Linnaeus, 1753) J. Agardh, 1883
Ulva taeniata (Setchell, 1901) Setchell & Gardner, 1920

APPENDIX 4.

List of subtidal invertebrates observed within Redwood National Park ASBS

Legend

Abundance refers to an organisms relative abundance

A = Abundant

C = Common

U = Uncommon

S = Scarce

	Abundance
Phylum Poritera - sponges	
Class Calcarea	
Leucilla nuttingi	C
Leucosolenia eleanor	C
Class Demospongiae	
Cliona celata	U
Halichondria panicea	C
Haliclona permollis	C
Haliclona sp.	C
Hymendectyon lyoni	
Hymendesima sp.	
Hymeniacidon ungodon	
Isodictya quatsinoensis	
Lissodendoryx firma	C
Mycale lingua	
Mycale mecginitiei	
Myxilla agennes	
Myxille incrustans	
Pachychalina lunisimilis	
Polymastia pachymastia	C
Spheciospongia confoederata	
Spongia idia	
Suberites sp.	
Xestospongia vanilla	
Zygherpe hyaloderma	
Unidentified Songe Species (#1-#7)	
Phylum Cnidaria	
Class Hydrozoa	
Abietinaria sp.	C
Aglaophenia sp.	C
Campanularia urceolata	U
Eudendrium sp.	C
Hydractinia milleri	A
Obelia sp.	C
Phialidium sp.	C
Plumularia sp.	C
Podocoryne sp.	
Polyorchis sp.	C
Sertularella turgida	C
Sertularia sp.	C
Stylantheca porphyra	C
Tubularia sp.	C
Class Anthozoa	
Anthopleura artemisia	C
Anthopleura elegantissima	A
Anthopleura xanthogrammica	C
Balanophyllia elegans	C
Clavularia sp.	C
Curynactis californica	A
Epiactis prolifira	C

	Abundance
Phylum Cnidaria	
Class Anthozoa (Cont.)	
Epizoanthus scotinus	A
Gersemia rubitormis	C
Metridium? exilis	A
Metridium? senile fimbriatum	A
Paracyathus stearnsi	C
Tealia coriacea	C
Tealia crassicornis	C
Tealia lofotensis	C
Class Scyphozoa	
Aurelia sp.	A
Chrysaora melanaster	C
Haliclystus auricula	U
Phylum Ctenophora	
Class Tentaculata	
Pleurobrachia bachei	C
Phylum Nemertea	
Class Anopla	
Cerebratulus californiensis	C
Tubulanus polymorphus	C
Tubulanus sexlineatus	C
Phylum Sipuncula	
Phascolosoma agassizi	U
Phylum Annelida	
Class Polychaeta	
Family Ampharetidae	
Schistocomus hiltoni	S-U
Family Chaetopteridae	
Phyllochaetopterus prolifica	A
Family Cirratulidae	
Dodecaceria concharum	A
Dodecaceria fewkesi	A
Family Euphrosinidae	
Euphrosine sp.	U
Family Nephtyidae	
Nephtys californiensis	C
Family Nereidae	
Neanthes succinea	
Nereis sp.	
Platynereis bicanaliculata	C
Family Phyllodocidae	
Phyllodoce? ferraginea	
Family Polynoidae	
Arctonoe vittata	C
Eunoe? barbata	
Halosydna brevisetosa	C

	Abundance
Phylum Annelida	
Class Polychaeta (Cont.)	
Family Sabellariidae	
Sabellaria cementarium	C
Family Sabellidae	
Eudistylia polymorpha	C-A
Eudistylia vancouveri	C
Schizobranchia insignis	U
Family Serpulidae	
Serpula vermicularis	C-A
Serpula sp.	C
Spirorbis sp.	C
Family Terebellidae	
Pista elongata	C
Streblosoma crassibranchia	
Unidentified Terebellid #1	
Phylum Mollusca	
Class Polyplacophora	
Cryptochiton stelleri	U
Lepidozona mertensii	C
Mopalia ciliata	A
Mopalia hindsii	C
Mopalia lignosa	C
Placiphorella velata	U
Tonicella lineata	A
Class Cephalopoda	
Octopus dofleini	U
Octopus rubescens	U
Class Gastropoda	
Subclass Prosobranchia	
Acemaea mitra	C
Amphissa columbiana	C
Calliostoma ligatum	A
Ceratostome foliatum	A
Crepidula abunca	U
Diodora aspera	C
Fusinus luteopictus	A
Lamellaria sp.	S
Margarites sp.	C
Nucella canaliculata	C
Nucella emarginata	A
Nucella lamellosa	C
Ocenebra gracillima	A
Olivella biplicata	S-A
Searlesia dira	C
Tegula brunnea	C
Subclass Opistobranchia	
Acanthodoris nanaimoensis	C
Anisodoris nobilis	C
Archidoris montereyensis	C
Archideris odhneri	C
Cadlina luteomarginata	C
Cadlina modesta	C
Dialula sandiegensis	C

Phylum Mollusca	Abundance
Class Gastropoda	
Subclass Opistobranchia (Cont.)	
Dirona albolineata	C
Hermissenda crassicornis	A
Onchidoris sp.	C
Rostanga pulchra	U
Tochuina tetraquetra	C
Triopha carpenteri	U-C
Tritonia sp.	O
Class Bivalvia	
Clinocardium nuttallii	S
Entodesma saxicola	C
Hinnites giganteus	S-C
Macoma inquinata	S
Mitrella tuberosa	
Modiolus carpenteri	U
Mytilimeria nuttallii	
Mytilus californianus	C
Mytilus edulis	U
Pododesmus copio	C
Protothaca staminea	U
Tresus sp.	U
Phylum Arthropoda	
Class Crustacea	
Subclass Cirripedia	
Balanus cariosus	S-C
Balanus crenatus	A
Balanus glandula	S-C
Balanus nubilus	A
Subclass Malacostraca	
Order Decapoda	
Cancer antennarius	C
Cancer magister	C
Crangon sp.	C
?Cycloxanthrops novemdentatus	
Oedignathus inermis	C
Oregonia gracilis	S-U
Pachycheles sp.	U
Pagurus granosimanus	U
Pugettia richii	C
Scyra acutifrons	C
Order Isopoda	
Idotea fewkesi	C
Idotea wasnesenskii	
Synidotea pettiboneae	
Order Amphipoda	
Erichthonius brasiliensis	A
Metacaprella kennerlyi	A
Unidentified amphipod	

	Abundance
Phylum Arthropoda	
Class Crustacea	
Subclass Cirripedia (Cont.)	
Order Mysidacea	
Unidentified mysid	C
Subclass Copepoda	
Pholiterides furtiva	
Phylum Bryozoa	
Bugula californica	C
Bugula pugeti	
Bugula sp.	
Crisia maxima	
?*Cyptosula palasiana*	
Dendrobeania laxa	
Diaperoecia californica	
Eurystomella bilabiata	C
Filicrisia franciscana	
Flustrellidra corniculata	
Heteropora sp.	C
Hippothoa sp.	
Membranipora membranacea	
Microporella californica	
Microporella ciliata	
?*Rhynchozoon rostratum*	
?*Tegella robertsonae*	
Tricellaria ternata	A
Tubulipora pacifica	
Unidentified bryozoan	
Phylum Phoronida	
?*Phoronis* sp.	
Phoronopis viridis	?
Phylum Entoprocta	
Barentsia ramosa	U
Phylum Brachiopoda	
Terebratalia transversa	C
Phylum Echinodermata	
Class Asteroidea	
Dermasterias inbricata	A
Evasterias troschelii	C
Henricia leviuscula	C
Leptasterias hexactis	A
Orthasterias koehleri	C
Patiria miniata	C
Pisaster brevispinus	C
Pisaster ochraceus	A
Pycnopodia helianthoides	C
Solaster dawsoni	C
Solaster stimpsoni	C

	Abundance
Phylum Echinodermata (Cont.)	
Class Ophiuroidea	
Amphiodia occidentalis	C
Ophiopholis acculeata	C
Class Echinoidea	
Strongylocentrotus franciscanus	U
Strongylocentrotus purpuratus	U
Class Holothuroidea	
Cucumaria miniata	C
Eupentacta quinquesemita	A
Phylum Chordata	
Subphylum Uirochordata	
Aplidium californicum	C-A
Aplidium solidum	C
Aplidium sp.	C
Archidistoma diaphanes	C
Archidistoma psammion	C
Archidistoma ritteri	C
Boltenia villosa	C
?*Botryllus tuberatus*	
Chelyosoma productum	C
Clavelina huntsmani	C
Cnemidocarpa finmarkiensis	C-A
Didemnum carnulentum	C-A
Distaplia occidentalis	C
Hymedesmia sp.	
Metandrocarpa dura	C
Metandrocarpa taylori	C
Perophora annectens	C
Polyclinum planum	U
Pyura haustor	C
Ritterella aequalisiphonis	U
Styela montereyensis	C
Trididemnum opacum	C-A

APPENDIX 5.

List of Subtidal fishes observed within Redwood National Park ASBS

<u>Abundance</u> refers to an organisms relative abundance

A = Abundant

C = Common

U = Uncommon

S = Scarce

*Astered species are based on personal communications with Ken Uchio, California Department of Fish and Game, Fish and Wildlife Seasonal Aid. Relative abundances are based on catch records and as such are probably bias reflecting selective fishing methods.

	Abundance
Family Carcharhindae	
**Prionace glauca*	S
Family Salmonidae	
**Oncorhynchus kisutch*	A
**Oncurhynchus tshawytscha*	A
Family Osmeridae	
**Hypomesus pretiosus*	C
Family Scorpaenidae	
**Sebestes avriculatus*	C
**S. cavrinus*	C
**S. flavidus*	A
**S. goodei*	U-C
**S. maliger*	U
S. melanops	A
**S. miniatus*	U
S. mystinus	U
**S. nebulosus*	U
**S. pinniger*	C
**S. ruberrimus*	C
Family Hexagrammidae	
Hexagrammas decagrammus	C
**Hecagrammos superciliosus*	C
Ophiodon elongatus	C
**Oxylebius pictus*	U
Family Cottidae	
Artedius currallinus	C
Artedius herringtoni	C
Artedius notospilotus	C
Ascelichthys rhodorus	U-C
Enophrys bison	U
Hemilepidotus spinosus	C
Rhamphocottus richardsonii	U-C
Scorpaenichthys marmoratus	O
Family Carangidae	
**Trachurus symmetricus*	U
Family Embiotocidae	
**Amphistichus rhodoterus*	C
**Embiotoca lateralis*	C
Family Pholididae	
Pholis schultzi	U
Family Bothidae	
Citharichthys stigmaeus	C

Family Pleuronectidae	Abundance
Plathichthys stellatus	U-C

APPENDIX 6.

List of subtidal flora observed within Redwood National Park ASBS

Abundance refers to an organism's relative abundance

A = Abundant

C = Common

U = Uncommon

S = Scarce

	Abundance
Division Phaeophyta	
Class Phaeophyceae	
Order Desmarestiales	
Desmarestia ligulata var. *ligulata*	C
Order Laminariales	
Laminaria dentigera	C-A
Laminaria sinclairii	C-A
Pterygophora californica	C-A
Division Rhodophyta	
Class Bangiophyceae	
Order Bangiales	
Porphyra sp.	C
Smithora naiadum	C
Class Florideophycease	
Order Nemaliales	
Gelidium coulteri	C
Order Cryptomemiales	
Bossiella californica	A
Bossiella sp.	C
Calliarthron tuberculosum	C
Callophyllis pinnata	U
Constantinea simplex	U
Corallina sp.	C
Erythrophyllum delesserioides	C
Grateloupia filicina	S
Halymenia californica	C
Halymenia coccinea	C
Lithophyllum sp.	C-A
Peyssonellia hairii	U
Prionitis filiformis	U
Order Gigartinales	
Gymnogongrus leptophyllus	
Gymnogongrus linearis	C.
Iridaea cordata	C
Iridaea sanguinea	U
Plocamium cartilagineum	C
Plocamium violaceum	C
Order Rhodymeniales	
Fryella gardneri	C
Maripelta rotata	C
Order ceramiales	
Botryoglossum farlowianum	C-A
Delesseria decipiens	U
Heterosiphonia erecta	U
Hymenena flabelligera	C
Neoptilota hypnoides	C
Odonthalia washingtoniensis	C
Polyneura latissima	C
Pterosiphonia dendroidea	U
Ptilota filicina	C
Division Spermatophyta	
Phyllospadix scouleri	C

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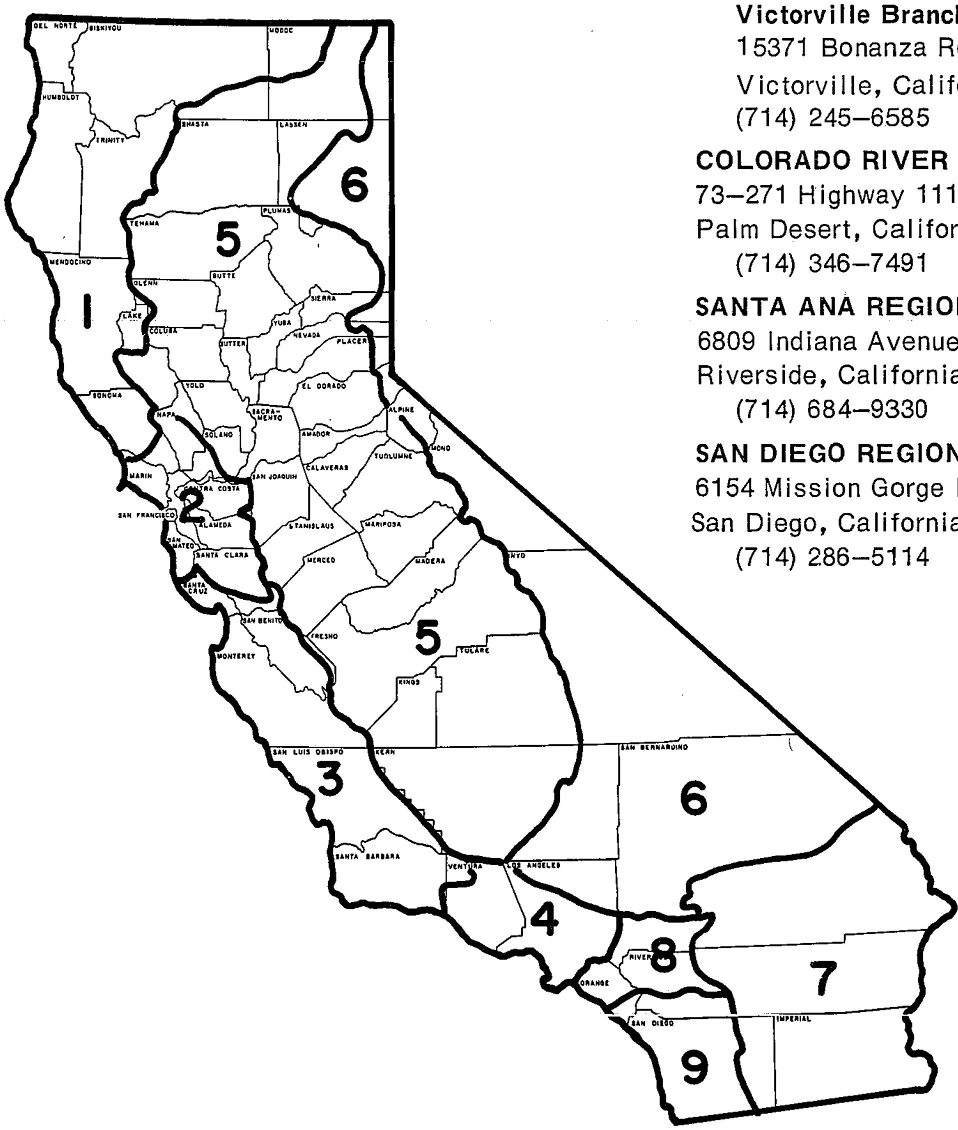

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