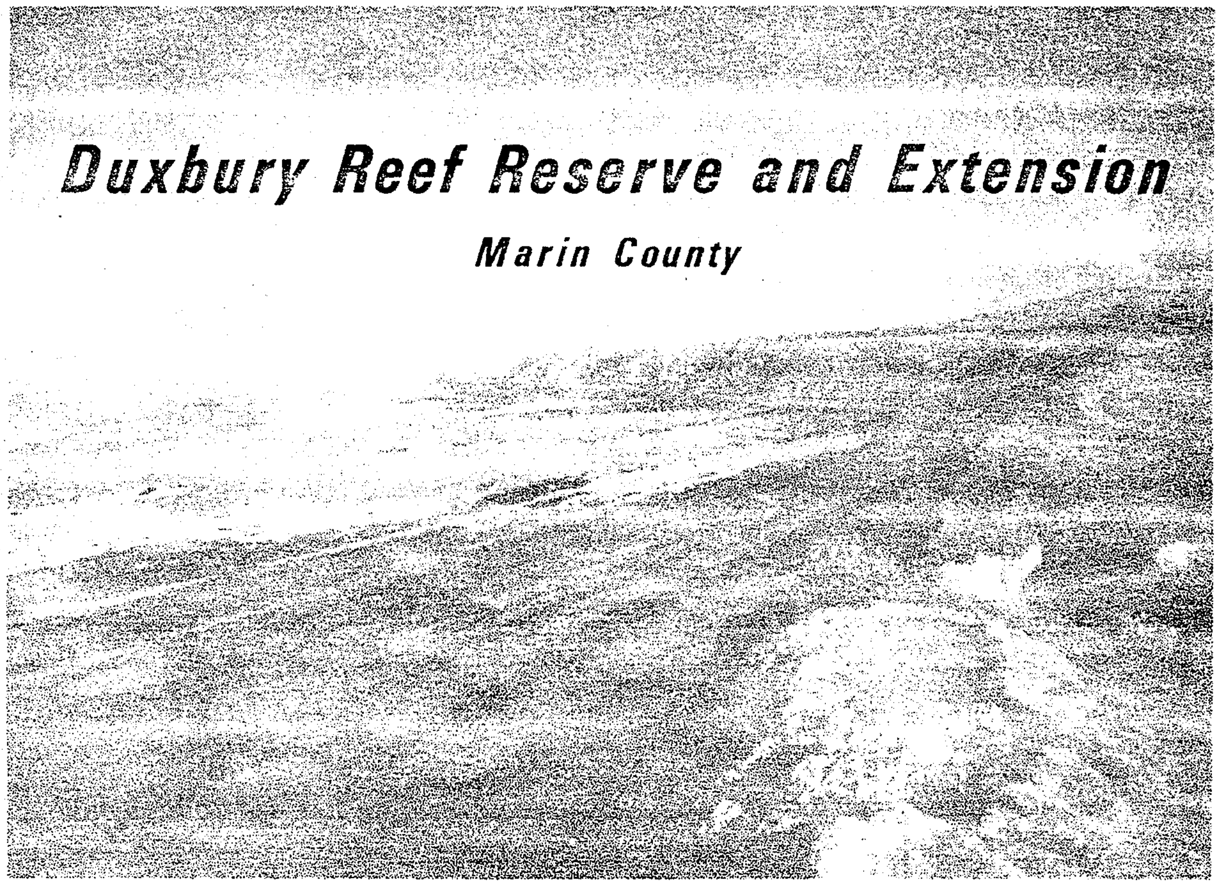
California Marine Waters
Areas of Special Biological Significance
Reconnaissance Survey Report



Duxbury Reef Reserve and Extension
Marin County

CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

DIVISION OF PLANNING AND RESEARCH

SURVEILLANCE AND MONITORING SECTION

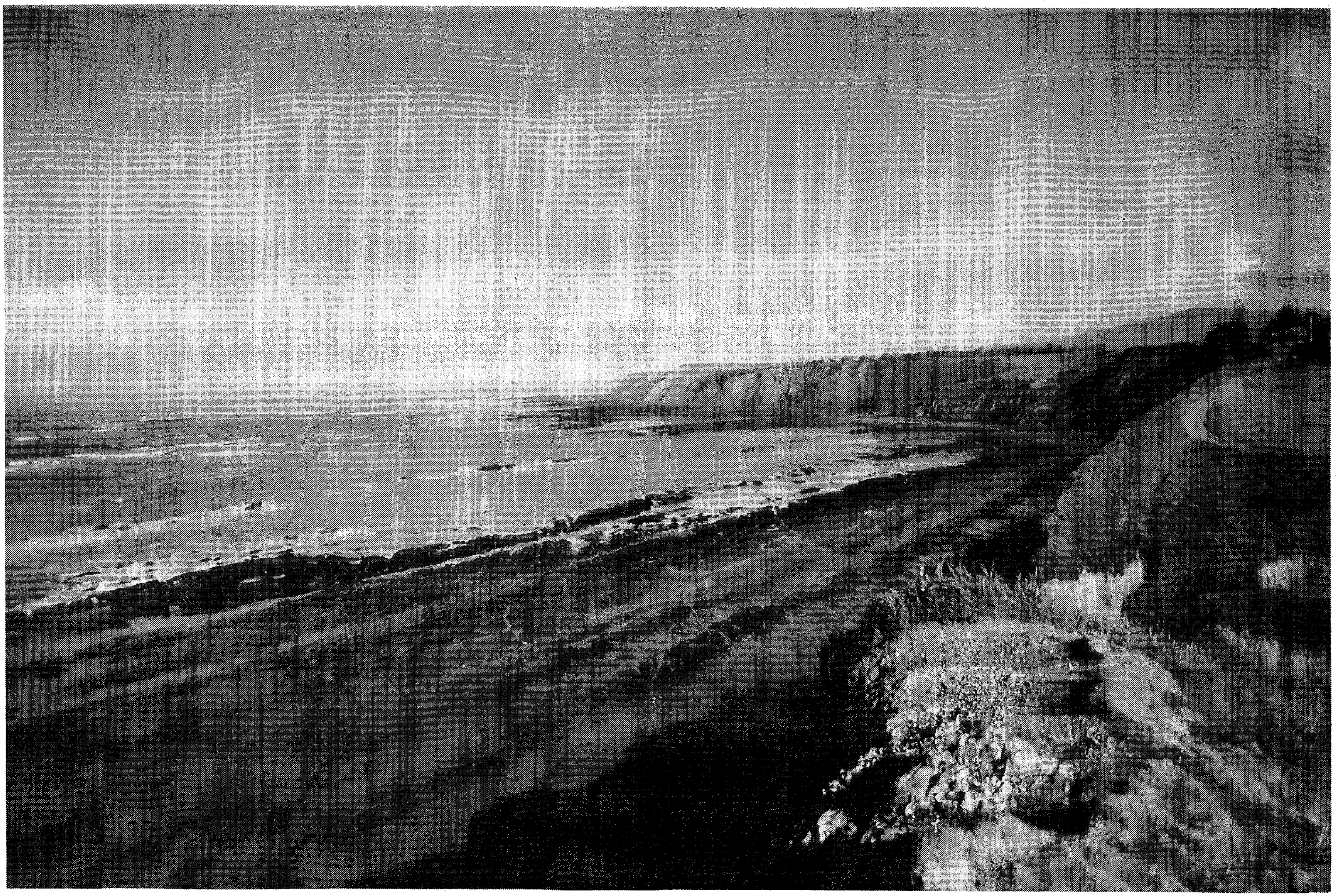
May 1979

WATER QUALITY MONITORING REPORT NO. 79-14

Cover Photograph:

Duxbury Reef Reserve And Extension

Area Of Special Biological Significance



Duxbury Reef Reserve And Extension 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

CALIFORNIA MARINE WATERS
AREAS OF SPECIAL BIOLOGICAL SIGNIFICANCE

RECONNAISSANCE SURVEY REPORT

DUXBURY REEF RESERVE AND EXTENSION
MARIN COUNTY

STATE WATER RESOURCES CONTROL BOARD

DIVISION OF PLANNING AND RESEARCH

SURVEILLANCE AND MONITORING SECTION

MAY 1979

WATER QUALITY MONITORING REPORT 79-14

ACKNOWLEDGEMENTS

This State Water Resources Control Board Report is based on a reconnaissance survey report submitted by James A. Blake of the University of the Pacific in May, 1978. The latter 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 Board under an Interagency Agreement.

ABSTRACT

Duxbury Reef and Extension Area of Special Biological Significance (ASBS) includes the nearshore waters extending south about 3.8 miles (6.1 km) from the southern boundary of Point Reyes National Seashore to Duxbury Point near the town of Bolinas, Marin County. The Area is located approximately within the coordinates 37°53' - 56', N Latitude, 122°41' - 44' W Longtitude.

Duxbury Reef is a large outcrop of Monterey shale, situated at the base of a high sandstone cliff called the Bolinas Mesa. Erosion of these cliffs is continually exposing new shale rock. The surrounding hillsides provide approximately 8,320 acres (3,370 ha) of watershed runoff through several drainages to the Reef. Landside vegetation consists largely of grasses and stands of brush, including poison oak, coyote brush, and sticky monkey flower. The area is characterized by dry, cool, foggy summers and cool, rainy winters.

The Reef is open to Pacific Ocean swells. Heavy surf conditions occur during storms when winds drive out of the south. The area is swept much of the year by the southerly flowing California Current; however, during the late winter and during spring months, the nearshore Davidson Current strengthens and sweeps the area with a northward flowing current. In addition, a gyre in the Gulf of the Farallons carries water leaving San Francisco Bay toward the Reef during ebb tide conditions.

The intertidal biota are the most interesting aspect of the reef. Rocks on the wave-exposed shores are inhabited by the typical Pacific Coast faunal assemblage of seastars, mussels, and barnacles. Mollusks include some species of clams which in the past were eagerly sought by clammers using hammer and chisel. Designation of the area as a Marine Life Reserve by the California Fish and Game Commission has substantially reduced this activity. Several particularly unusual inhabitants of the Reef include a remarkable large nudibranch (sea slug) and several

invertebrate species, a burrowing sea anemone and a hemichordate (acorn worm). The latter invertebrates are apparently unique to the site.

The subtidal area has not been well surveyed due to hazardous diving conditions. In the vicinity of the Reef, the rocky bottom is interspersed with sand and mud. These sediments contain polychaetes and crustacea common to such similar habitat along the Central Coast. Subtidal rocks off the main reef have a variety of attached sponges, anemones, bryozoa, and algae.

Duxbury Reef was partially covered by "Bunker C" fuel oil following the San Francisco Oil Spill of 1971. Several species of invertebrates were greatly reduced in numbers at that time but have since recovered. In general, the Reef appears to be in excellent health at this time.

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FINDINGS AND CONCLUSIONS

Findings

1. Duxbury Reef ASBS is the largest shale reef in California formed entirely of rocks of the Monterey Formation.

2. Duxbury Reef contains a rich intertidal biota which has several unique components of opisthobranch mollusks (sea slugs), rock inhabiting clams and worms, a rare burrowing anemone and a unique acorn worm.

3. The area is enjoyed by sport fishermen, students, nature study groups, scientists and the general public.

4. Water quality problems could arise if the sewage pumping system in Bolinas fails and raw sewage enters Bolinas Lagoon.

5. The site is healthy with only a seasonal turbidity problem resulting from heavy runoff from the surrounding hillsides.

6. Land development which alters runoff and erosional patterns could increase the silt load entering the ASBS with unknown effects on the biota.

Conclusions

1. The sewage treatment pumping system in Bolinas requires improvement to safeguard against failure and resulting contamination of Bolinas Lagoon.

2. Proposals to alter watercourses and drainage patterns on the mesa will require careful review to ensure that an extra silt burden will not be carried to the waters around the reef.

3. To monitor for effects of sewage and silt discharges, the Regional Water Quality Control Board will need to take samples from the intertidal zones of the reef, especially during the rainy season.

4. Scientific investigation of Duxbury Reef needs to be encouraged. The discovery of several species, heretofore unrecorded, from the area during the course of this survey demonstrates that the microhabitats of the reef remain largely unexplored in terms of marine life.

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 quality 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 spoil.

In order for the State Water Resources Control Board to evaluate the status of protection of Duxbury Reef Reserve and Extension ASBS, a reconnaissance survey integrating existing information and additional field study was performed by staff of the University of the Pacific. That survey report was one of a series prepared for the State Board under the direction of the California Department of Fish and Game and provided the information compiled in this document.

PHYSICAL AND CHEMICAL DESCRIPTION

Location and Size

Duxbury Reef, named after the sailing ship Duxbury which was shipwrecked on the rocks August 21, 1849, is located near the town of Bolinas in Marin County, approximately 14 nautical miles (26 km) northwest of San Francisco. The ASBS is located within 37°53' to 37°56' N latitude and 122°44' W longitude. The official boundary description is stated in the California State Water Resources Control Board publication Areas of Special Biological Significance (1976). Figure 1 depicts the location of the ASBS.

The center of the municipality of Bolinas is located approximately 3/4 mi. (1.2 km) from the Agate Beach entrance to Duxbury Reef. Subdivisions extend much closer, with some homes actually overlooking the reef from the surrounding mesa.

The reef lies at the base of a high headland, called the Bolinas Mesa. This entire mesa and the reef itself are composed of shales of the Monterey Formation.

According to contours shown in the most recent geologic map of the Point Reyes Peninsula (Galloway, 1976), there are at least 8,320 acres (3,367 ha) of watershed providing drainage to the ASBS (Figure 2).

There are approximately 3.8 mi. (6.1 km) of shoreline from the northern boundary to the southernmost boundary at the high tide line. The inlets and sculptures provided by the reef outcrops increase the distance to approximately 5.7 mi. (9.2 km) at low tide.

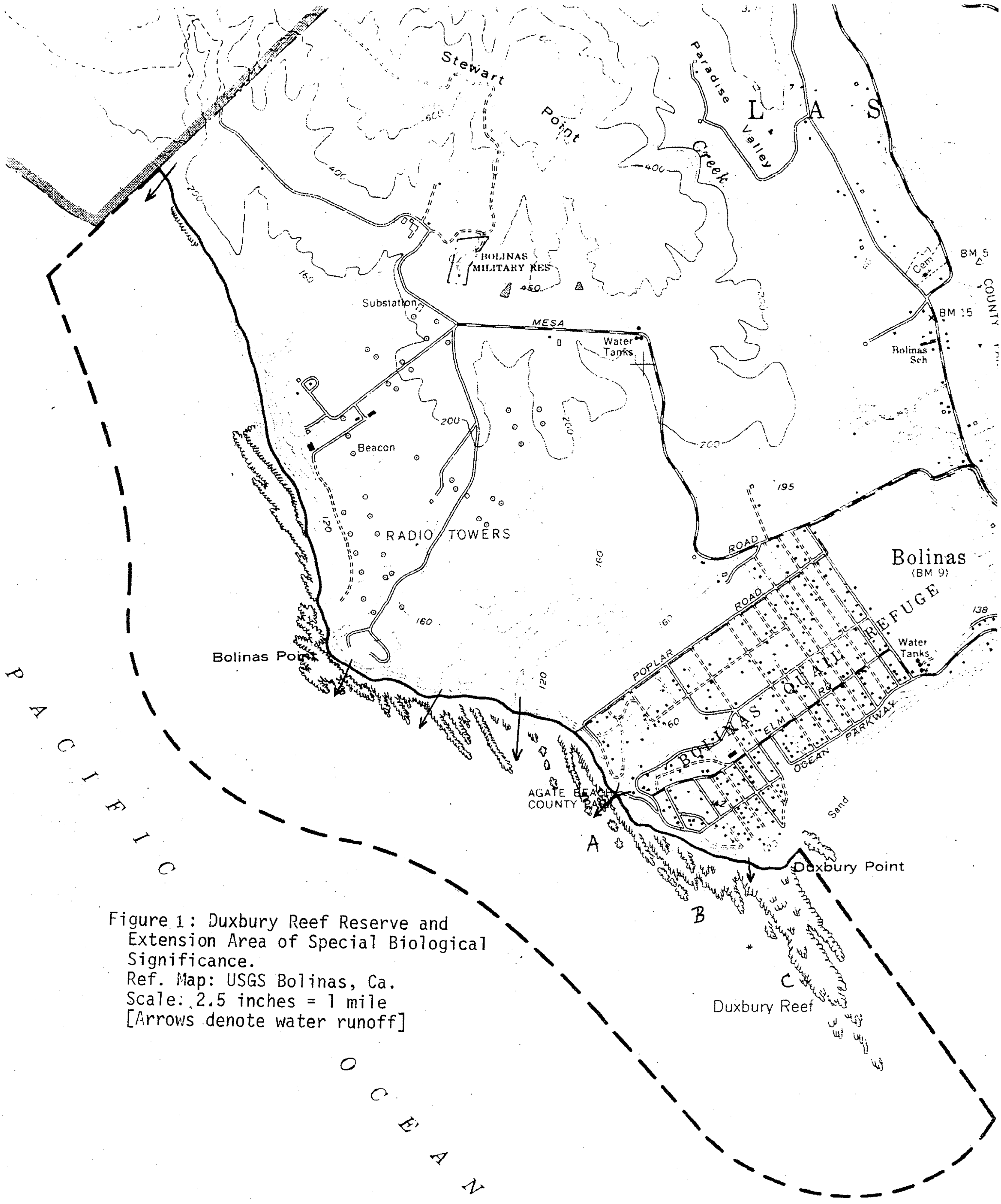

Figure 1: Duxbury Reef Reserve and Extension Area of Special Biological Significance.
Ref. Map: USGS Bolinas, Ca.
Scale: 2.5 inches = 1 mile
[Arrows denote water runoff]

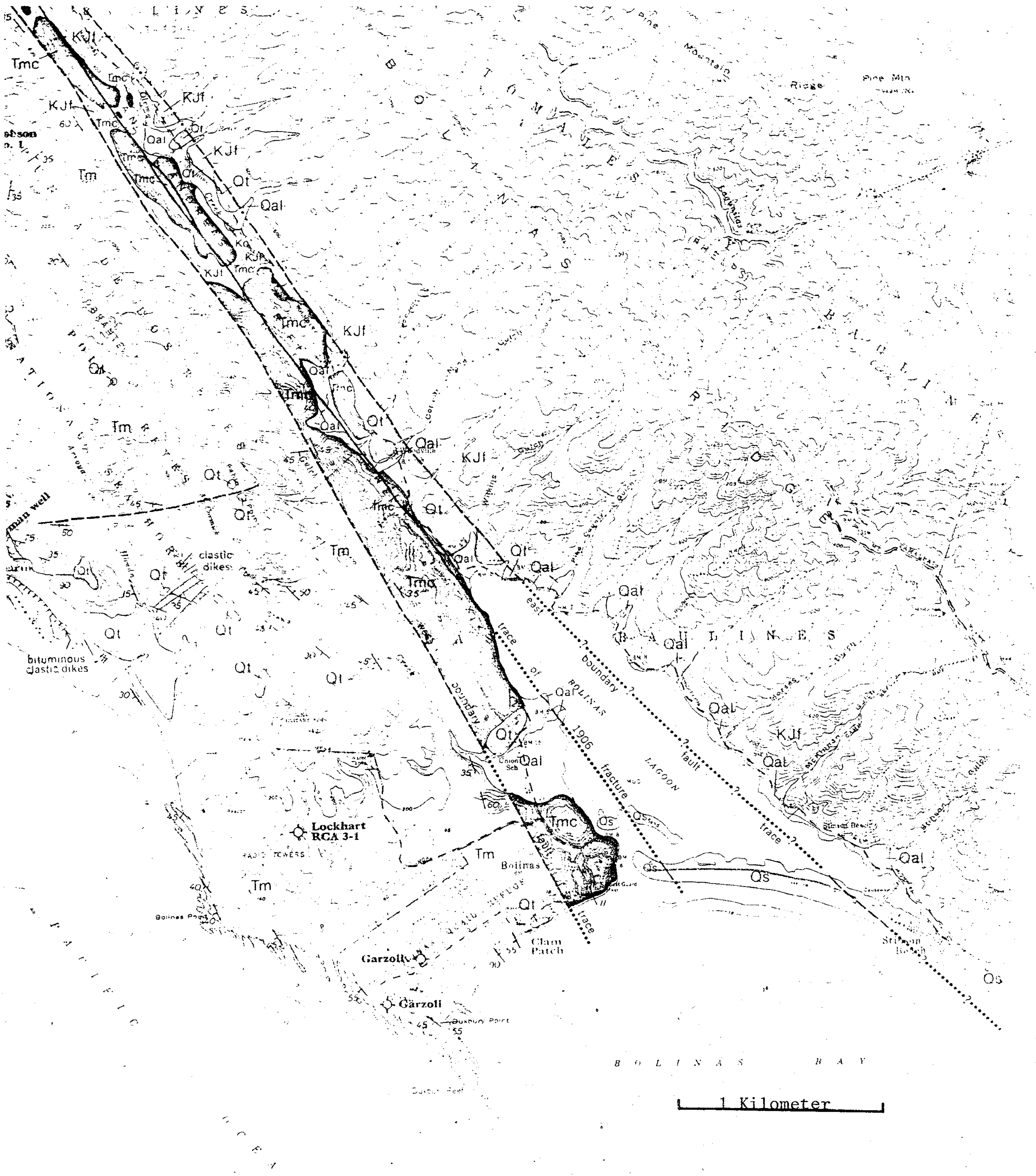

Figure 2. Map showing relationship of Duxbury Reef, Bolinas Lagoon, and the San Andreas Fault. (From Galloway, 1976).

Nearshore Waters

The bottom topography immediately offshore from the ASBS consists of eroded reef remnants interspersed with sand bottoms. Depth increases to 30 ft. (9.1 m) about 1/2 mi. (0.8 km) from shore and to 60 ft. (18 m) at a distance of 1 mi. (1.6 km). The bottom types in this outer area beyond the ASBS were not investigated, but probably consist of sand.

The reef is subjected to unbroken Pacific Ocean swells. During times of winter storms, enormous waves crash onto the outermost rocks; the inner areas are protected except at the highest tides. The California Current system provides a general southerly movement of water along the northern coast of California. This movement becomes very complex in the vicinity of San Francisco Bay, where large volumes of water are continually being exchanged by the tides. To complicate matters, the prevailing northwest winds tend to push the surface water away from the coast. This water is replaced by deep, colder water which upwells from depths of several hundred feet. Upwelling is most intense during the summer months, resulting in very cold sea temperatures during the summer. During winter and spring, a northward flowing surface current develops, bringing warmer waters near to shore. This northward current (called the Davidson Current) results from a weakening of the southward flow. The complexities of these current systems and the tidal exchange with San Francisco Bay create a highly complex picture with regard to water movement in and around Duxbury Reef. Probably the water washing the reef varies seasonally in its origin. Nevertheless, there is a general northwesterly eddy which carries water from San Francisco Bay towards Duxbury Reef on ebb tides. It was this drift which carried oil onto the reef in January, 1971. A good general account of the complexities of the California Current system may be found in Ricketts, Calvin & Hedgpeth (1968).

Circulation of water around and within the reef has not been investigated. However, it is obvious that strong currents are produced by wave backwash and treacherous rip currents are fairly obvious in some areas. Strong currents are also noted in the larger tidal channels which separate wave-swept outer rocks from more protected terrace areas.

Water temperatures from the Golden Gate show an average (40 years) of 55.8°F (13.1°C) with a maximum of 68°F (20°C) and minimum of 41°F (5.7°C). The warmest months are July-October and the coldest are December-February.

Topographic and Geomorphic Characteristics

Except for a small area of unconsolidated terrace deposits at the northern boundary of the ASBS, the whole of the area consists of Monterey shales. The Monterey shale formation was first described by Blake (1856) from Monterey, California (Fide, Galloway, 1977). Rocks from this Point Reyes area in Marin County are referred to this well-known formation because they are so similar lithologically (Galloway, 1977).

These shales cover most of the area from Duxbury Point to Double Point in the Point Reyes National Seashore, and extend as far north as some areas in the Tomales Quadrangle. The surfaces of outcrops are normally smooth and covered with vegetation, but where the shale is chert, a crag or pinnacle may be formed by differential erosion (Figure 3).

Monterey shale includes cherts, porcelanites, organic shales and thin hard sandstones, with considerable variation between these types (Galloway, 1977). The headlands (Bolinas Mesa) overlooking the Duxbury Point area are composed of sandstones which are undergoing continuous erosion by winds. The reef itself is composed of harder organic shales and some cherts. These harder rocks are continually being exposed by rapid erosion of the mesa. Since 1859, Duxbury Point has eroded about 200 ft. (60 m), Bolinas Point about 160 ft. (50 m) and an unnamed point about 4,000 ft. (1200 m) north of Bolinas Point has eroded about 200 ft. (60 m). These measurements by the U.S. Coast and Geodetic Survey indicate an average erosional rate of about 2 1/2 ft. (0.76 m) per year. Along the stretch of coast adjacent to the ASBS, the Monterey sandstones and mudstones are well bedded and dip at an angle of about 45° seaward. Thus when bedding planes are lubricated with rainwater or drainage, landslides are apt to occur at the sea cliff. Waves during high tides quickly remove the material at beach level, with the slide gradually being eroded back to reach a stable angle of repose (Galloway, 1977).

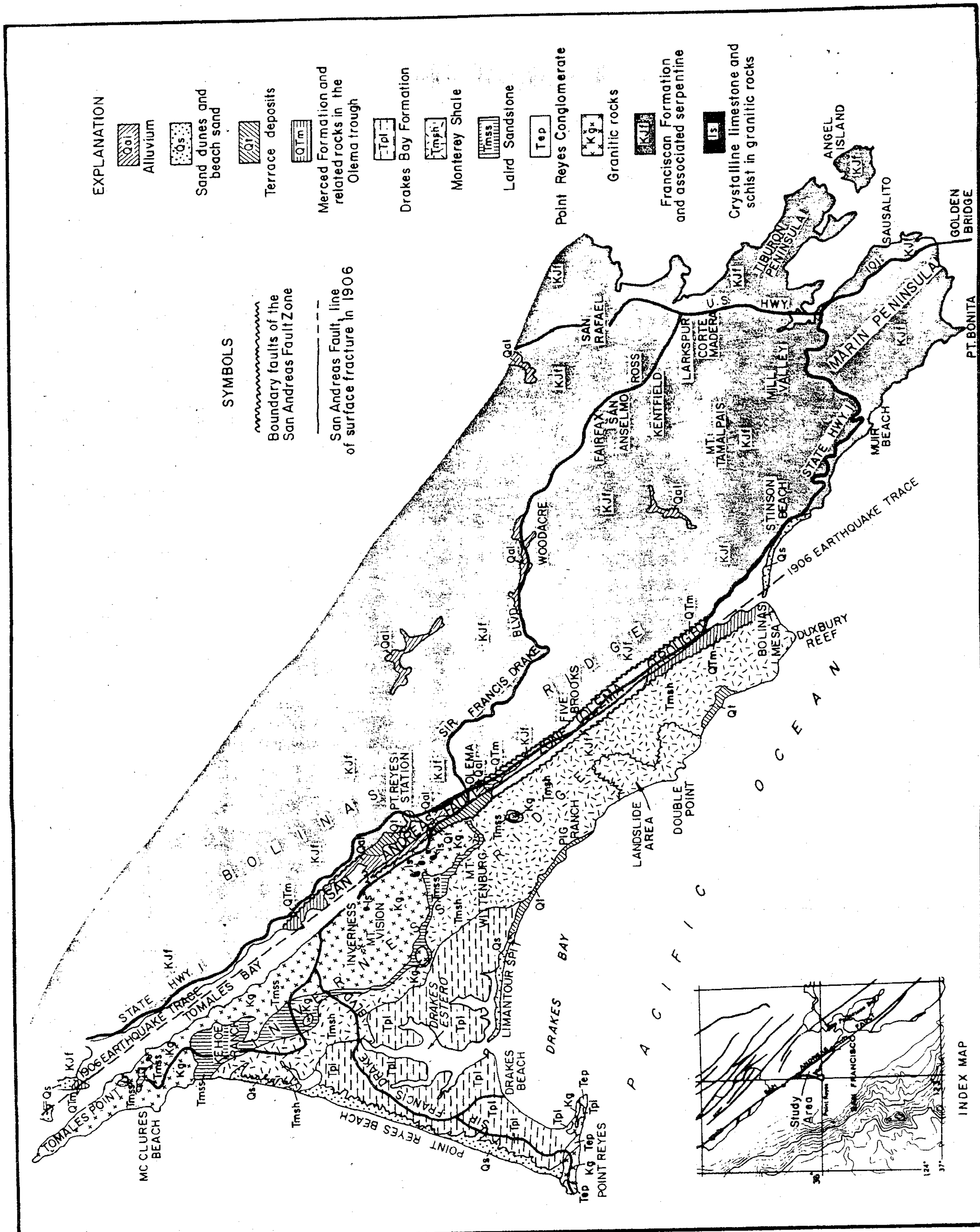

Figure 3. Generalized geological map of Point Reyes Peninsula and adjacent area. Marin County, California. (After Galloway, 1977)

The submarine geology of the area is not well known. Wave eroded remnants of former reefs extend some distance offshore and are interspersed with sand bottoms. Beyond these outcrops, sand bottoms predominate to the edge of the ASBS.

Duxbury Reef itself is the largest exposed shale reef in California. Its prominences extend up to 1 mi. (1.6 km) out to sea at Duxbury Point, and from 1/4 to 1/2 mi. (0.4 to 0.8 km) from the high tide line in other areas. Wave action has carved channels and depressions in the rocks, but more resistant ridges have remained as high protusions, resembling small islands. Most of these islands or prominences can be reached by foot at very low tides, but intervening channels are often deep and treacherous. Presumably, as the waves erode the outer reef rocks, new areas are continuously being exposed at the base of the cliffs. The reef then is slowly moving in a northeasterly direction as new rocks are exposed by wind erosion and old rocks are eroded down by waves. The rocks making up the reef itself contain calcium carbonate. Boring organisms such as clams and worms also contribute to the destruction of the reef as do humans who chip away the rocks to extract the clams.

Details of the features of various areas near Duxbury Point are described in the biological section of this report.

As noted previously, the surrounding land mass has at least 8,320 acres (3,367 ha) of drainage leading into several streams. The location of these streams is shown in Figure 1. Most conspicuous in the Agate Beach area is a large pipe and stream which join at the access trail and flow across the intertidal zone to the channel between the outer rocks and inner terrace. This water comes from roadsides and land occupied by subdivisions on the mesa. The water mixes rapidly with seawater and its diluting effect is quickly minimized. A very large stream is located about 2/3 of the distance to Bolinas Point from Agate Beach. Two small waterfalls were observed in the Bolinas Point area. This water flows directly into tide pools on the reef. Another very large stream is located at the extreme northern end of the ASBS. At various points along the ASBS, ground water is observed seeping from the cliffs into the beaches or over the rocks.

Climate

The Point Reyes Peninsula and the entrance to San Francisco Bay are characterized by cool, dry, foggy summers and cool, rainy winters. This coastal climate keeps summer temperatures well below those found a few miles inland. The Pacific Ocean tends to reduce the seasonal temperature range. Measurements taken at the Point Reyes Lighthouse indicate that the daily mean temperatures fluctuate less than 7°F (3.9°C) from January to September (52 year average). The lowest mean average for a month is for January, 49.8°F (9.9°C) and the highest is 56.5°F (13.8°C) for September. Although there is no weather station in Bolinas or otherwise close to Duxbury Reef, these values from Point Reyes should approximate conditions at Duxbury Reef. Yearly rainfall averages from Point Reyes Station inland are 29.90 in. (760 mm) for a 13 year period and 19.55 in. (497 mm) at the Point Reyes Lighthouse (64 year average). The rainy season is from November to March.

Wind patterns reflect seasons. During winter storms, winds originate from the south, while high pressure systems generally bring brisk northwesterly winds in the spring and summer. Offshore breezes are warmer and bring calm to the reef which is protected by the high mesa.

BIOLOGICAL DESCRIPTION

Subtidal Biota

The subtidal environment surrounding Duxbury Reef is difficult to study due to its limited access from the shore, the seasonally high turbidity of the water and the dangerous wave and current patterns in the shallow depths near the reef. Underwater visibility is limited during the winter and spring months at Duxbury Reef. The beaches consist of sand and gravel which has eroded from the cliffs. This is mixed with a fine red silt, which clouds the nearshore water, especially during the rainy season from November to March. This silt, combined with the silt load of the freshwater runoff, produces highly turbid water. At such times visibility in the ASBS is nearly zero. By early June 1978, the water had cleared sufficiently to allow dives from a boat. Visibility was 5 to 8 ft. (1.5 to 2.4 m). The optimal time for diving is in September and October, when seas are generally moderate, and before winter storms arrive. The bottom deepens very gradually from shore to a depth of 8 to 12 ft. (2.4 to 3.7 m) about 200 yards (180 m) from shore.

Observations of the subtidal waters were mostly restricted to those areas around the main reef (Area C, described in the section entitled Intertidal Biota). The bottom consists of rocks interspersed with sand. A substantial portion of the deeper rock surfaces did not support animal encrustations, possibly because of sand movement, burial or scouring actions. Underwater visibility was nearly zero following winter storms, 1 ft. (0.3 m) or less in April, and was approximately 5 to 8 ft. (1.5 to 2.4 m) in June. Attached algae occurred sparsely at depths of 15 to 20 ft. (4.6 to 6.1 m), becoming more abundant at 10 ft. (3 m) and then becoming very diverse as the subtidal rocks merged with the low intertidal zones. Most of the ASBS is underwater and deepens gradually 1/2 mi. (0.8 km) offshore to about 30 ft. (9 m). The entire area from 20 to 30 ft. (6 to 9 m) in depth is a sandy bottom with few rocks. Grabs and dredges were used from the boat to sample the benthic infauna. Areas closer to the reef ranged from 8 to 10 ft. (2.4 to 3 m) in depth in the surge channels and between rock pinnacles.

Subtidal and intertidal invertebrates are listed in Appendix 1, with subtidal components denoted by an "S". In many respects the attached subtidal fauna resembles that from the lowest intertidal zone. Such species occurring in both regimes are denoted by "S,I" in the faunal list. Many other species on the list are known to also occur in both the subtidal and intertidal zones elsewhere, and will probably be found to do so at Duxbury Reef when additional samples are taken.

The shallow bottom around Duxbury Reef endangers more than just divers. Following a storm in February, 1978, large numbers of gumboot chiton, Cryptochiton stelleri, the largest chiton in the world and the gigantic pink-skinned sea star, Pisaster brevispinus were observed stranded high up on the beaches. Heavy seas must have dislodged these animals from their normal habitat and cast them into shallower areas where the wave action eventually carried them on to the beaches. In May 1978, a large calcareous rock, formed by the colonial tube building polychaete, Dodecaceria fewkesi, was found rolling in a tide pool. This rock still contained the living worms and was unlike any that had been observed during the course of the intertidal survey. It was concluded at the time that it must have been carried by the waves from a subtidal locality.

The subtidal rocks observed off the main reef have a variety of attached sponges, anemones and bryozoa, which were not observed in the intertidal zone. Many of these species, however, may be expected to occur in the lowest intertidal zones. Some echinoderms such as the red starfish, Henricia leviuscula, and the more delicate and symmetrical starfish, Pisaster giganteus, were observed only in the subtidal zone, but are known from intertidal zones elsewhere. Many of the nudibranches observed in the intertidal zone (Appendix 1) undoubtedly are also found in the subtidal zone. The same is true of many of the bristle worm species and boring clams.

The soft bottom environment around Duxbury Reef is very similar in fauna to areas in Monterey Bay, the Gulf of the Farallons and Bodega Bay. Sand and sand-mud sediments contain common species of polychaetes (also called bristle worms) and small crustaceans which apparently are typical for such environments along the central California coast. For example, Magelona sacculata, Nephtys caecoides, N. cornuta franciscana, and Nothria elegans are all common species of bristle worms occurring in the same habitats in Monterey Bay (Hodgson & Nybakken, 1973), Gulf of the Farallons (Walton, 1974), Duxbury Reef and Bodega Bay (Blake, unpublished data). The sand dollar, Dendraster excentricus, is another common inhabitant of such sandy bottoms.

Intertidal Biota

The rich intertidal biota and its easy access at Agate Beach have made Duxbury Reef a favorite site for school groups to visit. In the past, extensive collecting of marine organisms by these groups threatened to deplete the fauna; establishment of the site as a marine preserve has made the routine collection of specimens against the law. At present, groups visiting the reef are instructed only to look. Collection of specimens is, however, permitted for scientific purposes.

The exposed portions of the reef have a faunal assemblage characteristic of the exposed rocky shore habitat (Ricketts, Calvin & Hedgpeth, 1968). Such rocks have dense populations of mussels, Mytilus californianus, gooseneck barnacles, Pollicipes polymerus, and the ochre star, Pisaster ochraceus. These three species are characteristic of wave-swept, rocky habitats all along the Pacific coast of North America. Beyond this general classification of the outer, exposed areas of the reef, the intertidal zone contains some very unique aspects; in particular, the mineral composition of the shale allows the existence of a unique boring fauna.

In most areas the tidepools are devoid of large movable boulders. Such rocks, so characteristic of other north coast intertidal areas, normally have a fauna on their underside which can be exposed by rolling them over. Microfauna at Duxbury Reef are best observed under the mussel canopy, in rock crevices, around algal holdfasts and in the gravel filled bottoms of tidal channels. Appendix 1 is a composite list of the marine invertebrates that have been encountered at Duxbury Reef. Marine algae are listed in Appendix 2.

Dr. Gordon Chan of the College of Marin has observed the distribution and abundance of marine organisms at Duxbury Reef for many years and has divided the reefs near Agate Beach and Duxbury Reef into three main areas (A,B,C). As his publications are the only ones containing quantitative baseline data on animal assemblages at Duxbury Reef, these area designations are adopted here (Figure 4).

Area A: Area A is the first portion of Duxbury Reef observed when entering from the trail leading down from the public parking lot at Agate Beach. The base of the cliffs has a series of large rock outcrops forming a high berm or spray zone. Below this berm, there is a relatively flat, gently sloping series of rock terraces which gradually lead to a shallower channel. Throughout this terrace there are small pools, narrow channels and crevices, but no prominent relief, aside from erosion contours or intrusions of harder rocks. Across from the channel at the base of this terrace are larger, more prominent wave-swept rocks containing the characteristic open coast faunal assemblage. Their strong surf action breaks the effect the waves have on the terrace and berm areas. Chan & Molina (1969) estimate that Area A covers about 13.16 acres (5.33 ha).

The high berm contains a typical assemblage of invertebrates commonly found in spray zone environments along the Pacific coast. These include the isopod, Ligia occidentalis, the barnacles, Chthamalus dalli and Balanus glandula, the limpets, Collisella digitalis and C. scabra, and the periwinkles, Littorina scutulata and L. planaxis [the latter species was apparently more common before the oil spill of January, 1971 (see below)].

The rock terraces characteristically have large populations of black turban snails, Tegula funebralis, and sea anemones, Anthopleura elegantissima. Both species tend to aggregate along crevices or against the sides of small ridges. Aggregations of the anemone tend to follow fractures or crevices; only rarely do they cover entire rock surfaces as they do in other localities.

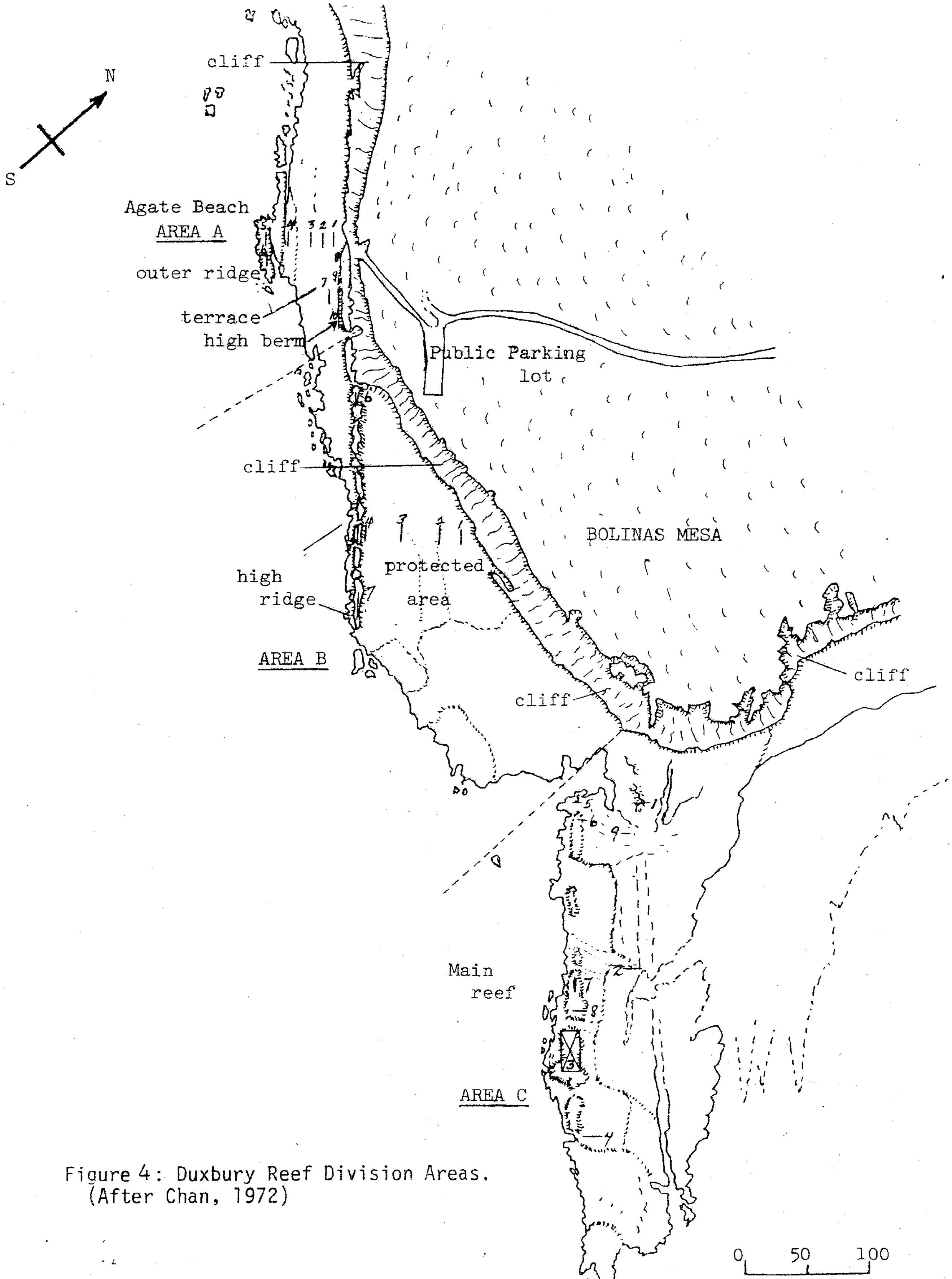

Figure 4: Duxbury Reef Division Areas.
(After Chan, 1972)

Observations were made on the density of black turban snails in this area; an average density of 81.7 snails per square meter was estimated throughout the shale terrace, but due to the tendency of the species to aggregate in crevices and small pools, sample sizes ranged from 0 to 288 snails per square meter.

In the lower half of the terrace many turban snail shells are occupied by hermit crab, Pagurus samuelis. Other macroinvertebrates in this area are rare. These include chitons, Mopalia muscosa, and an occasional solitary anemone, Anthopleura xanthogrammica. One of the periwinkles, Littorina scutulata, may be locally abundant, especially on the higher parts of the terrace. An occasional little rock crab, Pachygrapsus crassipes, is encountered. The ochre starfish, Pisaster ochraceus, according to Paine (1969), is the "keystone species" of the north coast rocky intertidal community. In his model, the keystone species is largely responsible for maintaining diversity among its prey species. However, when this area was sampled by a transect, it was found to support a very sparse starfish population. Data from this area are shown in the first column of Table 1. Numbers are so low that average densities are less than 1 per $10m^2$. This fractional notation is retained for easier comparison to samples from the northern portion of the ASBS, shown in the second column. Although the standard deviations for column 1 are of questionable accuracy, it is possible to compare the sites without further data.

One possible explanation for the low numbers of starfish in this area is the ease of public access. Starfish are characteristic marine animals, and they are often carried away by uninformed people. The remoteness of the northern site may in itself be a protection from this sort of predation. Further study is needed to prove or disprove this hypothesis.

The rock crevices contain a hidden fauna. When chipped open with a hammer, a variety of worms and clams are encountered. Two polychaetes, the hairy-gilled worm, Cirriformia luxuriosa, and the long thin worm, Naineris dendritica are found in these crevices, with the latter species

TABLE I

Number of *Pisaster ochraceus* counted per $10m^2$ section at two sites at Duxbury Reef.[1]

Tidal Level	AREA A (Agate Beach)		Northern ASBS site	
	Mean number	Standard Deviation	Mean number	Standard Deviation
1 (low)	.666	.516	30.166	13.31
2	.500	.547	18	12.32
3	.333	.516	5.166	7.05
4 (high)	0	0	2	4.89

1/ Six transects taken at each site.

being fairly common. Clumps of the bushy red alga, Endocladia muricata, are common throughout the area. The rockweeds, Pelvetia fastigiata and Fucus distichus, were scattered throughout the area during the winter months, but appeared to be growing and spreading rapidly by early summer. Occasional clumps of surf grass, Phyllospadix, are seen throughout the area, especially in areas of water movement.

The open coast across the channel contains a typical outer coast fauna, including the mussel, Mytilus, the barnacle, Pollicipes, and the starfish, Pisaster. Algae in this region are mostly encrusting and upright corallines, including: Corallina vancouveriensis, C. chilensis and Lithothamnion pacificum. Occasional specimens of the bladderlike red alga, Halosaccion glandiforme, the dark purple alga, Iridaea splendens are also seen. The split whip algae, Laminaria spp., do not appear until the very lowest zone, with Laminaria sinclairii, which has slender, mucilaginous blades and stipes, being most common. An occasional specimen of the large red alga, Gigartina corymbifera, is also encountered in the low zone.

Area B: Area B is located just south of the Agate Beach entrance and below the cliffs below the parking lot. A line of tall rock outcrops projecting at an angle of about 60° from the Area A line separates this area from Area A. The tall rocks are wave-swept, and contain a typical open coast fauna. At the bases of these rocks are frequently seen large populations of the purple sea urchin, Strongylocentrotus purpuratus. These urchins abrade holes into the rock in which they reside. Some urchins abrade holes from which they are then unable to escape, having gouged out a cavity larger than the entrance hole made when they were young. These urchin holes when abandoned provide refuge for smaller invertebrates such as chitons and limpets and may also provide the initial site for secondary borers to become established in the rocks. There are heavy crusts of coralline algae and holdfasts of the split whip alga, Laminaria sinclairii, in this low zone. These crusts and holdfasts provide refuge for a variety of small worms and crustaceans. One such was a bristle worm, Pseudopotamilla socialis, that formed burrows through the calcified algae crusts and into the underlying shale. This species has not previously been known to bore.

Landward of the line of rocks separating Areas A and B is a relatively flat area containing surge channels lined with luxuriant algal growth, (Egregia menziezii and smaller red and brown algae), and a fauna characteristic of a protected outer coast. Included here are nudibranches, the most common of which is sea slugs, Archidoris montereyensis, rock jingles, Pododesmus macrochisma, and assorted limpet species, Collisella pelta, C. strigatella and Acmaea mitra. Shoreward of these channels toward the cliffs are several large sand-gravel filled pools containing several species of amphipods and polychaetes (bristle worms). Bristle worms were identified as: the burrowing worm, Cirriformia spirabrancha, the sandy mud and silt worm, Armandia brevis, and the long, thin worm, Arabella iricolor. Chitons throughout the area nestle into depressions on rock surfaces. In all cases where a feeding ochre star, Pisaster ochraceus, was encountered, it was feeding on chitons, Mopalia muscosa. These chitons excavate a shallow depression in which they reside. Closer to the cliffs are shallow channels filled with gravel and smooth rocks riddled with the burrows of a spionid worm, Boccardia proboscidea. This species forms U-shaped burrows in the soft shale. When one walks across this rock, water seeps from the many burrow openings. There is a distinct "sound" to the water as it departs the area on a low tide and the burrows of Boccardia are drained. Another spionid worm, Polydora nuchalis, also occupies this high rock area, but is rare. The gravel lined channels in this high intertidal area have populations of the cirratulid burrowing worm, Cirriformia spirabrancha. Another cirratulid worm, Tharyx parvus, is rare.

Area C: Area C is the main portion of Duxbury Reef which extends seaward for about 2/3 mi. (1.7 km). Enormous mussel beds occur here and provide a canopy which protects many species of smaller invertebrates living between the mussels and their byssal threads. The fauna contained in these beds is probably the largest per unit area of any location on the reef. The mussel worm, Nereis vexillosa, and the procelain crabs, Petrolisthes cinctipes, Pachycheles rudis and P. pubescens, are very common under the mussel canopy. Over 26 species of invertebrates are listed by Chan & Molina (1969) as being associated with the mussels. This figure is probably conservative, however, as small species are conspicuously absent from the list. This site is a favorite site for rock clammers seeking the larger boring clams. Collection of these food items has apparently slowed with designation of the area as a marine preserve. Species of rock boring clams commonly encountered are: Platyodon cancellatus, Parapholas californica, Botula falcata and Penitella penita. The first two species are sought by clammers. There are many additional species of clams and mussels which may be found nestling in the shale rock. Counts of the boring clam, P. cancellatus exceeded $53/m^2$ in some transects (Chan & Molina, 1969).

Shallow gravel filled tidal pools in this area contain two very unusual invertebrates. One is Mesoglossus sp., a small, undescribed acorn worm (hemichordate) which is apparently unique to Duxbury Reef and the other, a small, burrowing anemone, Halcampa crypta, which is known only from Duxbury Reef and Puget Sound (Siebert & Hand, 1974).

Bolinas Point and the Reef Extension: By following the shoreline north from Agate Beach, one observes areas of sand beach and low terrace-like shale rock outcrops. Bolinas Point is a larger reef, similar to Areas B and C. Large upright pinnacles take most of the wave force; these exhibit the open coast faunal assemblage. A large rocky area behind these pinnacles is protected from the waves and contains tide pools and other assorted habitats. Harbor seals, Phoca vitulina, haul out on these rocks. Over 30 have been counted on one day. The shale rocks appear to have more relief than in areas near Agate Beach, suggesting that there has been less destruction by rock clammers. Several species of bristle worms were encountered in the rock and rock crevices which were not encountered elsewhere. These include: Branchiomaldane vincentii, Exogone lourei, Typosyllis adamanteus and Cirratulus cirratus. An unknown fabricid (family Sabellidae) may be undescribed in the literature. The ribbon worms, Paranemertes peregrina and Nemertopsis gracilis, were also found in rock crevices. Many other small crustaceans were encountered along with other invertebrates, which suggests that microinvertebrates might be more diverse at Bolinas Point than in some areas near Duxbury Point.

The beaches are composed of coarse sand mixed with reddish silts. Most of this sediment comes from the surrounding cliffs. Shoveling and sieving did not yield any invertebrates during the survey, and coring devices did not operate in the loose sediment. Disturbance of the beach sediment resulted in considerable silt entering the water.

Beyond Bolinas Point, there are a series of low shale outcrops and cleaner sand beaches above the rocks. The beaches are generally too high to support a fauna and the reefs are too low in profile to break the wave force. These rocks bear evidence of scouring. Similar scouring at Dillon Beach results from sand deposition and removal. It is possible that some of these exposed rocks may be repeatedly buried and uncovered by shifting sands. One would, at least expect barnacles to live on these rocks, but they appear to be completely barren.

At the northernmost limit of the ASBS and on towards Palomarin Beach, tide pool life appears to be very rich, with species appearing commonly in mid-intertidal zones which are only seen in lower zones elsewhere. The black turban snail is common although the brown turban snail, T. brunnea, is also present. The great green anemone, Anthopleura xanthogrammica, is common along with a red anemone, Tealia crassicornis. Numerous dead and dying gumboot chiton and pink-skinned sea stars were noted at various points. These were apparently stranded after storms, and remained to die. Some additional specimens of these two species were, however, alive in the lowermost tide pools. Most of the rock inhabiting bristle worms found at Bolinas Point were also found here. One additional species taken from a tide pool was the onuphid, Nothria elegans. The worm, Naineris dendritica, was especially common here, as was the small nereid, Nereis latescens. Another nereid, N. grubei, was taken from a high intertidal crevice.

Land Vegetation

The relative dryness of the soil formed over the Monterey shale apparently accounts for the absence of redwoods and other forest flora. The slopes along the windswept coastal margins are largely grasslands grazed by cattle. Local stands of coastal brush also occur. These plants normally form conspicuous shrubs, but are reduced to depressed or creeping forms in windswept areas. These plants include poison oak, *Rhus diversiloba*, coyote brush, *Baccharis pilularis*, sticky monkey flower, *Mimulus aurantiacus*, wild lilac, *Ceanothus thrysiflorus*, California sagebrush, *Artemisia californica*, and coffeeberry, *Rhamnus californica*. The vegetation of the area has been described by Howell (1949).

Unique Components

Invertebrates: Several species of marine invertebrates are known only from Duxbury Reef or from areas immediately adjacent. Others have a wider distribution, but their northern and southern ranges seem to end at Duxbury. Approximately 47 species of opisthobranch mollusks have been recorded from the area by Fosliner and Williams (1970; 1973; 1975). Of these, 20 are either unique to the area, or to one or the other of the range extremes. These are:

Anuncula pacifica	Duxbury Reef to Point Loma
Aplysiopsis oliviae (Sacoglossa)	Duxbury Reef to Monterey Bay
Cadlina luteomarginata (Nudibranch)	Palomarin to La Jolla
Catriona alpha (Nudibranch)	Double Point to San Diego
Coryphella pricei (Nudibranch)	Duxbury Reef to Monterey
Dendronotus diversicolor (Nudibranch)	San Juan Island to Duxbury Reef
Diaphana californica (Gastroped)	Duxbury Reef to Coronado Island
Doto columbiana (Nudribranch)	Vancouver Island to Duxbury Reef
Eubranchus rustyus (Nudibranch)	Duxbury Reef to Bahia de Los Angeles
Hallaxa chani (Nudibranch)	Bird Rock and Duxbury Reef to San Luis Obispo
Onchidella borealis (Pulmonata)	Alaska to Duxbury Reef
Spirula oliviae	Duxbury Reef to Santa Barbara
Trinchesia abronia (Nudibranch)	Palomarin to Pismo Beach
T. virens (Nudibranch)	Duxbury Reef to San Luis Obispo
T. albocrusta (Nudibranch)	Palomarin to Santa Barbara
T. flavovulta (Nudibranch)	Palomarin to Shell Beach

T. fulgens (Nudibranch)	Duxbury Reef to Pismo Beach
T. lagunae (Nudibranch)	Palomarin to Rosarito Beach
Triopha sp. (Nudibranch)	Duxbury Reef and Palomarin

Other unique or unusual invertebrates from Duxbury include a suite of rock boring clams of which Penitella turnerae, (Evans and Fisher, 1966) may only be known from Duxbury Reef. A sea spider, Achelia chelata, a parasite of the California mussel, Mytilus californianus, was observed. Apparently this sea spider is not known north of Duxbury Reef. The anemone, Halcampa crypta, is known only from Duxbury Reef and the San Juan Islands (Seibert and Hand, 1974). This species is associated in tide pools at Duxbury Reef with an undescribed species of acorn worm, (Hemichordata), Mesoglossus.

The Rock Boring Habitat: Duxbury Reef is the largest shale reef in California; the large variety of rock boring invertebrates present in the rocks may be considered a unique faunal component. The various types of rock boring clams have already been mentioned. Several species of bristle worms found in the rocks or crevices are evidently boring either primarily or secondarily. Several have not previously been reported to occupy such habitats. These include the spionid worm, Polydora nuchalis, not previously reported to bore (Duxbury Reef appears to be its most northern locality); the segmented worm, Naineris dendritica, usually found in crevices and with algal holdfasts, was here observed penetrating rock; the rare bristle worm, Branchiomaldane vincentii was found penetrating rock at Bolinas Point; the small, pale, bristle worm, Pseudopotamilla socialis, usually associated with tubes in coralline algae and algal holdfasts, was also observed penetrating into the shale rock.

Intertidal fish: No fish species is unique to Duxbury Reef. A list of various fish encountered in tide pools and by shore fishing is presented in Appendix 3.

Biological Effects of the 1971 San Francisco Bay Oil Spill on Duxbury Reef Fauna

During the early morning hours of January 18, 1971, two Standard Oil tankers, the ARIZONA STANDARD and OREGON STANDARD, collided in thick fog under the Golden Gate Bridge. Approximately 840,000 gallons (3,200 m^3) of "Bunker C" fuel oil was spilled into the waters of San Francisco Bay. Standard Oil officials estimated that approximately 525,000 gallons (2,000 m^3) were recovered by their skimming operations. Figure 5 shows the fate of the remaining 315,000 gallons (1,200 m^3) as it was carried with tidal currents to areas northward in Marin County and southward along the San Mateo Coast. Duxbury Reef, located approximately 12 mi. (19 km) from the collision site, began receiving oil about 24 hours later at 4:00 AM on January 19. Oil continued to be deposited on the reef until January 23. High tides caused heavy deposits to cover the high berm of Area A and major portions of the mussel beds of Area C. Areas receiving oil are shown in Figure 6.

The oil tended to remain in higher concentrations at the higher intertidal level, where it eventually formed rather resistant tar deposits. These remained intact for several months. Wave action was less severe in these areas and natural scouring was slower than in lower intertidal areas which were cleansed more rapidly. "Bunker C" fuel oil is used to fire boilers of ships and power plants and tends to congeal and form globules when in seawater. This behavior accounts for the formation of tar deposits.

The immediate effect upon the reef was principally visual, and it was not possible to assess biological damage on a quantitative basis for several months, owing to the fact that the rock surfaces were barely visible beneath the oil deposits (Chan, 1972).

Dr. Gordon Chan of the College of Marin, who had previously conducted surveys of the marine life at Duxbury Reef, initiated a study of the effect of the oil spill on marine life. Counts of organisms along the previously established transects (Figure 1) did not begin until April,

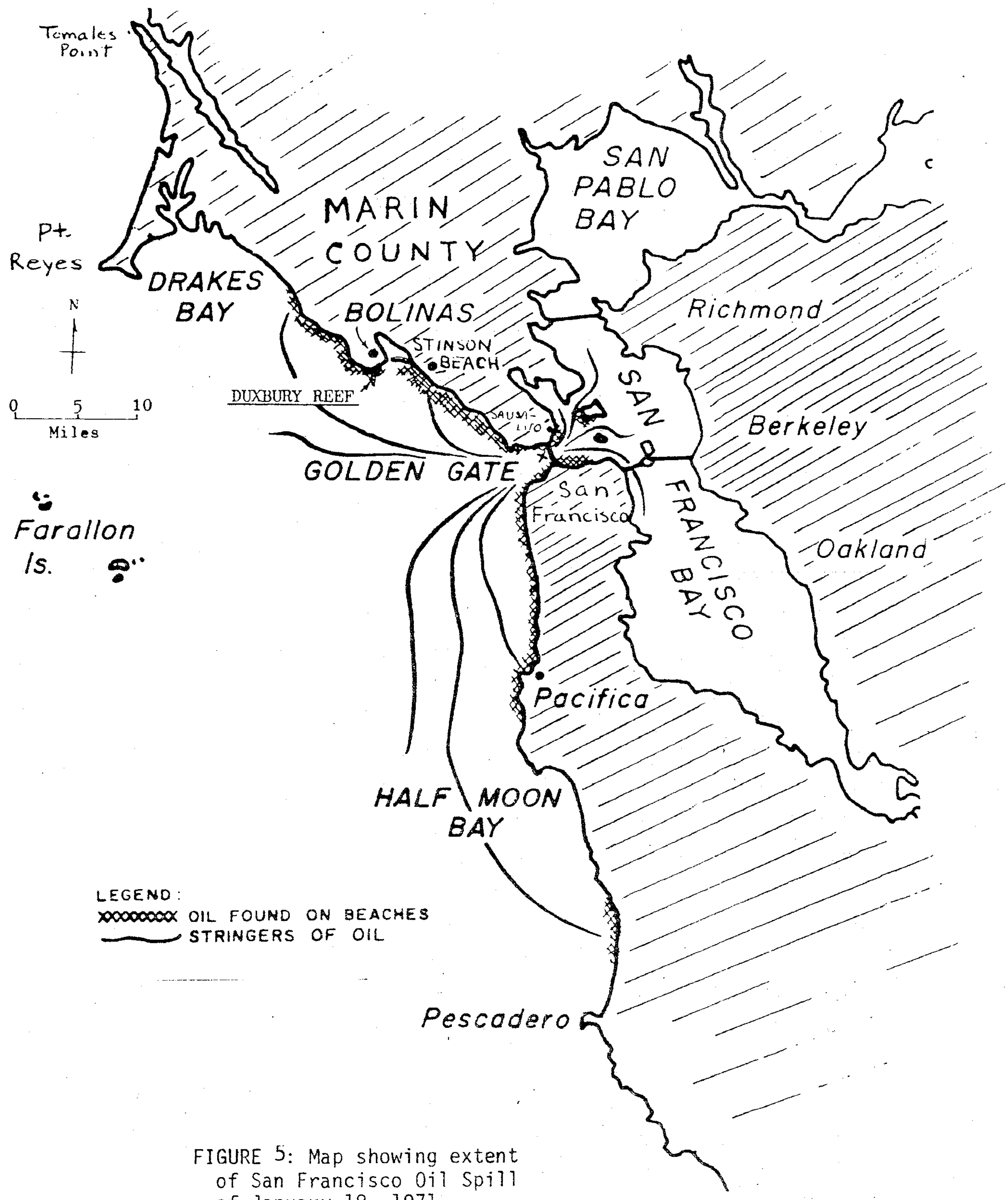

FIGURE 5: Map showing extent of San Francisco Oil Spill of January 18, 1971. Collision of ARIZONA STANDARD & OREGON STANDARD was approximately under the Golden Gate Bridge = X (After Chan, 1972)

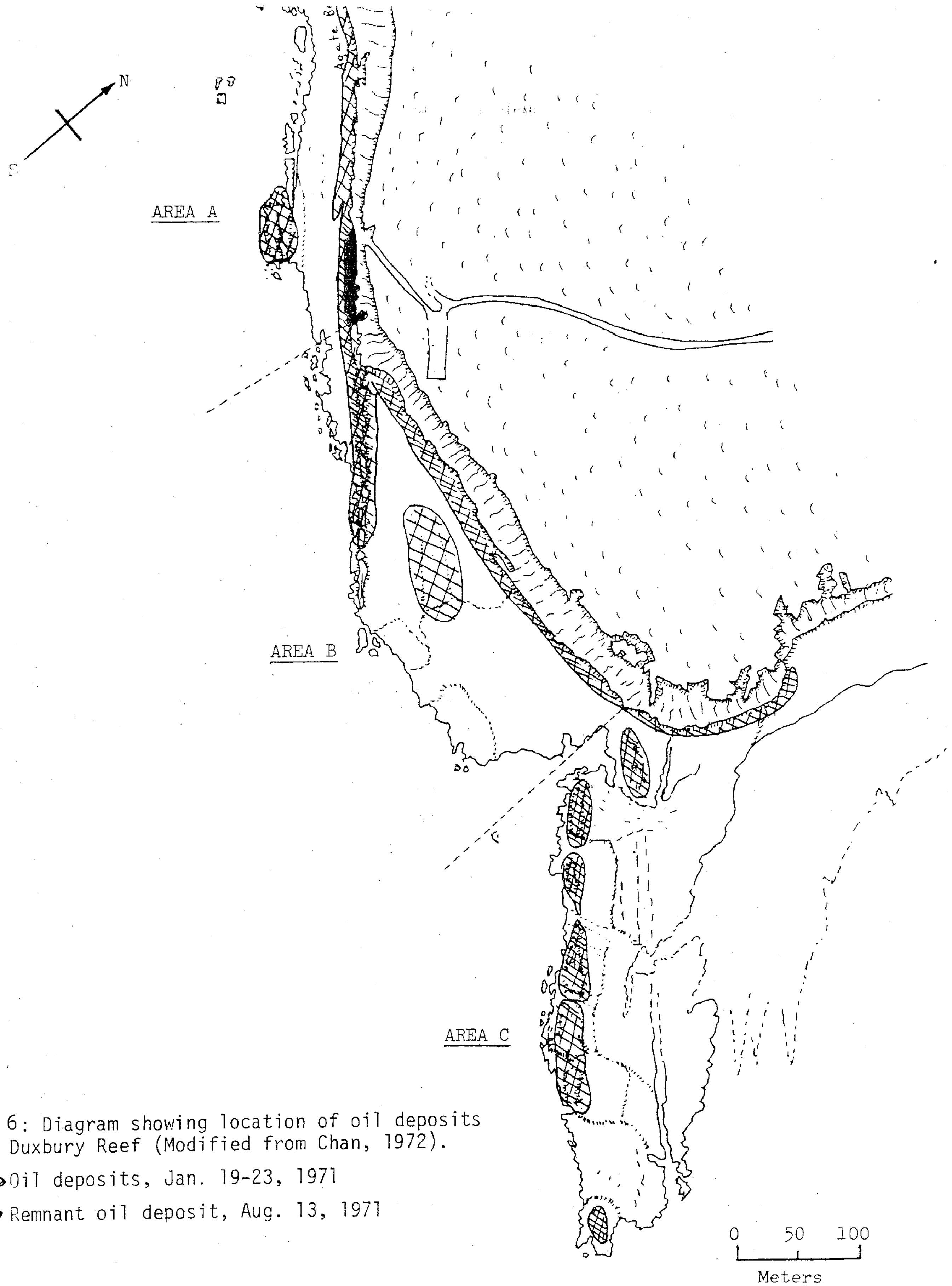

Figure 6: Diagram showing location of oil deposits on Duxbury Reef (Modified from Chan, 1972).

Oil deposits, Jan. 19-23, 1971

Remnant oil deposit, Aug. 13, 1971

however, owing to the difficulty of working in the oil deposits. Chan's qualitative observations suggested that the immediate adverse effect on the mussel beds was considerably less than expected. Most mussels seemed to remain alive, even when covered with oil. Exposed barnacles, limpets and snails, however, were smothered and suffered large die-offs. There also seemed to be a general depletion of the crab, Pachygrapsus crassipes, population.

Quantitative measurements confirmed these general observations. By comparing data of April, 1971, with pre-oil spill counts, Chan (1972) calculated a 45% mortality of limpets, Collisella digitalis and C. scabra, in high berm areas (Area A). The periwinkle, Littorina planaxis, was practically exterminated from the same area, while the smaller periwinkle species, L. scutulata, appeared to suffer only about 8% mortality. Barnacles, Balanus glandula and Chthamalus dalli, suffered heavy losses, up to 96% in some transects. The black turban snail populations from mid-intertidal zones dropped by as much as 50%. The mussel beds of Area C were covered with oil, but no mass mortality was experienced. A latent die-off of about 2% occurred in April. The large number of invertebrates which lived under the mussel canopy did not appear to suffer. Chan (1972) concluded that these invertebrates were probably protected from the oil by the mussels, but he does not indicate if any oil was observed in the interstices where these invertebrates live. Adjacent gooseneck barnacles, Pollicipes polymerus and balanoids, Balanus glandula suffered mortalities. Chan (1972) noted the appearance of a filamentous green alga, Urospora penicilliformis, growing over mussels with residual oil on their shells. This material presumably provided a substratum for the alga. The mussels were not affected by the algae, and it subsequently disappeared.

In a subsequent report on recruitment and recovery of the reef, Chan (1974) stated that most species had returned to pre-oil vigor and the reef's populations seemed near normal. One possible exception was the periwinkles, Littorina planaxis, which had not returned to pre-oil levels in the high berm Area A. Barnacles and limpets had, however, recovered.

In summary, the San Francisco Oil Spill of 1971 produced an immediate unpleasant visual effect and exterminated large numbers of sessile marine invertebrates. Largest die-offs were in high intertidal zones where oil tended to concentrate. Following a period of natural cleansing, the populations generally returned to pre-oil levels. It is not entirely clear if the limpet and black turban snail recoveries were due to recruitment or to migration from adjacent areas. Mussel beds did not appear to suffer heavy damage, presumably because they can close their valves, and can be cleansed by wave action. The favorable recovery of the reef after the 1971 oil spill does not preclude the possibility that a spill of another type of oil may have very different results. For details concerning the oil spill at Duxbury Reef see Chan (1972; 1974).

LAND AND WATER USE DESCRIPTIONS

Municipal Activities

The nearby town of Bolinas is located less than a mile (1.6 km) from Duxbury Reef. Subdivisions overlook the reef from the Bolinas Mesa. The Bolinas Lagoon is subjected to occasional pollution from the town at times and has on occasion been closed to fishing. Water from the lagoon enters the surrounding sea during tidal flushing. This water mixes with the seawater and by means of a northeast eddy reaches the reef at high tides. This is a potential source of coliform bacteria and nitrate enrichment. What effect, if any, such a nutrient source may have on local phytoplankton blooms is beyond the scope of this survey.

Agribusiness

Grazing on Hillsides: The lands surrounding the ASBS are mostly grass covered slopes with cattle. During periods of heavy rainfall, the drainage patterns will pick up nutrients and coliform bacteria from the manure on the meadows. This should not be any problem to the ASBS.

Governmental Designated Open Space

Ecological Reserve: Duxbury Reef is an ecological reserve, administered by the California Department of Fish and Game and the College of Marin (Marin County). Collection of marine organisms, other than those permitted under sport fishing regulations, are prohibited without special permission.

Recreational Use

Nature Study: Duxbury Reef has been the site of numerous field trips by groups of school children, college classes and nature study groups for many years. The intertidal biota is easy to observe and animals were formerly collected by these groups. The prohibition of collecting has not kept these groups away. They still come to study the tide pools and the animals in their natural habitat.

Sport Fishing: Duxbury Reef is a favorite locality for sport fishing from the rocks or into the surf or deep tidal pools. The monkeyface blenny or eel, *Cebidichthys violaceus*, surf perch, (several species), kelp greenling, *Hexagrammos decagrammus*, and the cabezon, *Scorpaenichthys marmoratus*, are the most commonly sought fish.

Mussels are common and available for collection during the winter months, but since they have not traditionally been common on the dinner plates of Californians, they are seldom harvested. Legal size abalone have not been seen at the reef for many years, according to Gordon Chan. They are present in the subtidal zone, however. Rock clams were taken in the past by clammers who chiseled them from the surrounding rocks. This destructive activity largely ceased with the designation of the Reef as an ecological reserve.

Scientific Study Use

Duxbury Reef has been the site of scientific investigation for many years. Its proximity to the Bolinas Marine Laboratory (College of Marin) has allowed Dr. Gordon Chan to establish permanent transects in the area which will continue to be monitored in the future. The invertebrate fauna is rich and in some cases unique. Several papers describing faunal components have appeared over the years (see Bibliography).

Transportation Corridors

The main shipping lanes into San Francisco Bay are only a few miles offshore from the ASBS.

ACTUAL OR POTENTIAL POLLUTION THREATS

Point Sources

There are no sewage outfall sites near Duxbury Reef. The town of Bolinas pumps its sewage to a treatment facility on the mesa which has four oxidation ponds. The effluent is sprayed on to the mesa following treatment. Failure of the pumping plant has resulted in raw sewage entering Bolinas Lagoon. At such times, the lagoon has been quarantined.

Vessel discharges are a possible point source, owing to the close proximity of the shipping lanes.

Nonpoint Sources

The San Francisco Oil Spill of 1971 is an example of how Duxbury Reef can be affected by such accidents. This danger can only be alleviated by protective measures at the source. Development of offshore oil leases on the northern California coast would constitute still another possible source of similar pollution.

Land development or alteration of water courses might possibly affect the reef if measures are not taken to ensure that undue erosion does not result. The ASBS does not seem in any immediate danger from current subdivision activity in the vicinity.

SPECIAL WATER QUALITY REQUIREMENTS

Other than possible contamination from Bolinas Lagoon at times of failure of the Bolinas pumping system, the reef seems relatively safe at present from pollution. The main effect of freshwater runoff from the surrounding hills is to deliver silt into the sea during periods of heavy rainfall. While this silt load is so heavy that the water is turned distinctly brown and visibility is reduced to 6 in. (15 cm) in the water, there does not appear to be any effect on the marine life. Nutrients delivered from hillsides with cattle would appear to have only a limited effect. In general, the reef and its extension are relatively healthy, and are at present not affected by any water quality problems.

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APPENDIX 1

Composite List of Subtidal and Intertidal Marine Invertebrates observed at Duxbury Reef*

TAXA	HABITAT*
PORIFERA	
Cliona sp.	S
C. celata californica de Laubenfels, 1932	S
Halichondria panicea (Pallas, 1766)	I
Leucilla nuttingi (Urban, 1902)	S
Mycale macginitei de Laubenfels, 1930	S
Xestospongia vanilla (de Laubenfels, 1930)	I
CNIDARIA: Hydrozoa	
Aglaophenia struthinoides (Murray, 1860)	S
Plumularia sp.	S
CNIDARIA: Anthozoa	
Anthopleura artemisia (Pickering, 1848)	S
A. elegantissima (Brandt, 1835)	I
A. xanthogrammica (Brandt, 1835)	S,I
Astrangia sp.	S
Balanophyllia elegans Verrill, 1864	S
Corynactis californica Carlgren, 1936	S
Epiactis prolifera Verrill, 1869	S,I
Metridium exilis Hand, 1955	S,I
Parazoanthus sp.	S
Tealia crassicornis (Müller, 1776)	I
PLATYHELMINTHES: Turbellaria	
Notoplana acticola (Boone, 1929)	I
NEMERTEA	
Nemertopsis gracilis Coe, 1904	I
Paranemertes peregrina Coe, 1901	I
ANNELIDA: Polychaeta	
Arctonoe vittata (Grube, 1855)	S,I
Harmothoe imbricata (Linnaeus, 1767)	I
Halosydna brevisetosa Kinberg, 1855	I
Pholoe minuta (Fabricius, 1780)	S
Sthenelais verruculosa Johnson, 1897	S
Anaitides williamsi Hartman, 1936	S
Eulalia aviculiseta Hartman, 1936	S
Eteone dilatae Hartman, 1936	S
Phyllodoce hartmanae Blake & Walton, 1977	S
Gyptis brevipalpa (Hartmann-Schroeder, 1959)	S
Exogone lourei Berkeley & Berkeley, 1938	I
Odontosyllis phosphorea Moore, 1909	S
Typosyllis aciculata Treadwell, 1945	S
T. adamanteus (Treadwell, 1914)	I
Neanthes succinea (Frey & Leuckart, 1847)	I
Nereis grubei (Kinberg, 1866)	I

APPENDIX 1 (Continued)

TAXA	HABITAT
Nereis latescens Chamberlin, 1919	I
N. vexillosa Grube, 1851	I
Glycinde polygnatha Hartman, 1950	S
Glycera americana Leidy, 1855	S
Nephtys caecoides Hartman, 1938	S
N. cornuta franciscana Clark & Jones, 1955	S
Diopatra ornata Moore, 1911	S
Nothria elegans (Johnson, 1901)	S,I
Lumbrineris tetraura (Schmarda, 1861)	S
Arabella iricolor (Montagu, 1804)	I
Leitoscoloplos pugettensis (Pettibone, 1957)	S
Naineris dendritica (Kinberg, 1867)	I
Boccardia columbiana Berkeley, 1927	I
B. proboscidea Hartman, 1940	I
Laonice cirrata (Sars, 1851)	S
Polydora giardi Mesnil, 1896	I
P. nuchalis Woodwick, 1953	I
Prionospio pygmaea Hartman, 1961	S
P. steenstrupi Malmgren, 1867	S
Spiophanes berkeleyorum Pettibone, 1962	S
Magelona pitelkai Hartman, 1944	S
M. sacculata Hartman, 1961	S
Chaetozone sp.	S
Cirratulus cirratus (Müller, 1776)	I
Cirriformia luxuriosa (Moore, 1904)	I
C. spirabrancha (Moore, 1904)	I
Tharyx parvus Berkeley, 1929	I
Pherusa inflata (Treadwell, 1914)	S
Armandia brevis (Moore, 1906)	S,I
Ophelia pulchella Tebble, 1953	S
Mediomastus californiensis Hartman, 1944	S
Branchiomaldane vincentii Langerhans, 1881	I
Owenia collaris Hartman, 1955	S
Pectinaria californiensis Hartman, 1941	S
Ampharete labrops Hartman, 1961	S
Ramex californiensis Hartman, 1944	S
Eudistylia vancouveri (Kinberg, 1867)	S,I
Pseudopotamilla socialis Hartman, 1944	I
Unknown fabricid	I
Serpula vermicularis Linnaeus, 1767	I
Spirobidae spp.	I
ANNELIDA: Oligochaeta	
Haplotaxis sp.	I
ARTHROPODA - CRUSTACEA	
Isopoda	
Cirolana harfordi Lockington, 1877	I
Ianiropsis analoga Menzies, 1952	S
Idotea (Pentidotea) montereyensis Maloney, 1933	I
Jaeropsis dubia Menzies, 1951	S
Janiralata occidentalis (Walker, 1898)	S
Ligia (Megaligia) occidentalis Dana, 1853	I

TAXA	HABITAT
Munna stephenseni Gurjanova, 1853	S
Synidotea pettiboneae Hatch, 1947	S
S. ritteri Richardson, 1904	S
Amphipoda: Gammaridea	
Ampelisca agassizi (Judd, 1896)	S
Aoroides columbiae Walker, 1898	S
Corophium sp.	S
Maera vigota Barnard, 1969	I
Photis californica Stout, 1913	S
Paraphoxus sp.	S
Amphipoda: Caprellidea	
Caprella angusta Mayer, 1903	S
C. californica Stimpson, 1857	S
C. equilibra Say, 1818	S
C. incisa Mayer, 1903	S
C. verrucosa Boeck, 1871	S
Metacaprella anomala Mayer, 1903	S
Tritella pilimana Mayer, 1890	S
Decapoda: Natantia	
Palaemon macrodactylus Rathbun, 1902	I
Decapoda: Brachyura	
Cancer antennarius Stimpson, 1856	S,I
Fabia subquadrata Dana, 1851	I
Hemigrapsus nudus (Dana, 1851)	I
Pachygrapsus crassipes Randall, 1839	I
Decapoda: Anomura	
Pachycheles rudis Stimpson, 1859	S,I
Pagurus hirsutiusculus (Dana, 1851)	I
Pagurus samuelis (Stimpson, 1857)	I
Petrolisthes cinctipes (Randall, 1839)	I
Cirripedia	
Balanus glandula Darwin, 1854	S,I
B. nubilis Darwin, 1854	S
B. tintinnabulum californicus Pilsbry, 1916	I
Chthamalus dalli Pilsbry, 1916	I
Pollicipes polymerus Sowerby, 1833	S,I
ARTHROPODA - PYCNOGONIDA	
Achelia chelata (Hilton, 1939)	I
Ammothella menziesi Hedgpeth, 1951	S
Anoplodactylus sp.	I
MOLLUSCA: Gastropoda	
Prosobranchia	
Acanthina spirata (Blainville, 1832)	I
Acmaea mitra Rathke, 1833	I
Alvania sp.	S

APPENDIX 1 (Continued)

TAXA	HABITAT
Barleeia marmorea (Carpenter, 1864)	S
Calliostoma supragranosum Carpenter, 1864	S
C. annulatum (Lightfoot, 1786)	S
Clathromangelia interfossa (Carpenter, 1864)	I
Collisella asmi (Middendorff, 1847)	S, I
C. digitalis (Rathke, 1833)	I
C. pelta (Rathke, 1833)	I
C. strigatella (Carpenter, 1864)	I
C. scabra (Gould, 1846)	I
Crepipatella lingulata (Gould, 1846)	S
Diodora aspera (Rathke, 1833)	S
Haliotus rufescens Swainson, 1822	S
Lacuna unifasciata Carpenter, 1857	I
Lirularia parcipicta (Carpenter, 1864)	I
Littorina planaxis Philippi, 1847	I
L. scutulata Gould, 1849	I
Notoacmaea persona (Rathke, 1833)	I
Nucella emarginata (Deshayes, 1839)	I
Odostomia sp.	S
Olivella biplicata (Sowerby, 1825)	S, I
Tegula funebralis (A. Adams, 1855)	I
T. brunnea (Philippi, 1848)	I
Opisthobranchia	
Berthella californica (Dall, 1900)	I
Alderia modesta (Loven, 1844)	I
Aplysiopsis oliviae (MacFarland, 1966)	I
A. smithi (Marcus, 1961)	I
Elysia hedgpethi Marcus, 1961	I
Acanthodoris hudsoni MacFarland, 1905	I
A. lutea MacFarland, 1925	I
A. nanaimoensis O'Donoghue, 1921	I
A. rhodoceras Cockerell & Eliot, 1905	I
Aegires albopunctatus MacFarland, 1905	I
Aeolidia papillosa (Linnaeus, 1761)	I
Ancula pacifica MacFarland, 1905	I
Anisodoris nobilis (MacFarland, 1905)	I
Antiopella barbarensis (Cooper, 1863)	I
Archidoris montereyensis (Cooper, 1862)	S, I
Armina californica (Cooper, 1862)	I
Cadlina flavomaculata MacFarland, 1905	I
C. luteomarginata MacFarland, 1966	S, I
C. modesta MacFarland, 1966	I
Catriona alpha (Baba & Hamatani, 1963)	I
Coryphella pricei MacFarland, 1966	I
C. trilineata O'Donoghue, 1921	I
Dendronotus diversicolor Robilliard, 1970	I
D. frondosus (Ascanius, 1774)	I
D. iris Cooper, 1863	S, I
D. subramosus MacFarland, 1966	I
Diaulula sandiegensis (Cooper, 1862)	S, I
Diaphana californica Dall, 1919	I

TAXA	HABITAT
Dirona albolineata Cockerell & Eliot, 1905	S,I
D. picta MacFarland, 1905 [In Cockerell & Eliot, 1905]	I
Discodoris heathi MacFarland, 1905	I
Doriopsilla albopunctata (Cooper, 1863)	I
Doto amyra Marcus, 1961	I
D. columbiana O'Donoghue, 1921	I
D. kya Marcus, 1961	I
D. wara Marcus, 1961	I
Eubranchus rustyus (Marcus, 1961)	I
Flabellinopsis iodinea (Cooper, 1961)	I
Hallaxa chani Gosliner & Williams, 1975	I
Hermissenda crassicornis (Eschscholtz, 1831)	S,I
Hopkinsia rosacea MacFarland, 1905	I
Laila cockerelli MacFarland, 1905	I
Onchidella borealis Dall, 1871	I
Onchidoris hystricina (Bergh, 1878)	I
Polycera hedgpethi Marcus, 1964	I
Precuthona divae Marcus, 1961	I
Rostangia pulchra MacFarland, 1905	I
Spurilla oliviae (MacFarland, 1966)	I
Trinchesia abronia (MacFarland, 1966)	I
T. albocrusta (MacFarland, 1966)	I
T. flavovulta (MacFarland, 1966)	I
T. fulgens (MacFarland, 1966)	I
T. lagunae (O'Donoghue, 1926)	I
T. virens (MacFarland, 1966)	I
Triopha carpenteri (Sterns, 1873)	I
T. maculata MacFarland, 1905	S,I
T. sp.	I
Tritonia exsulans Bergh, 1894	I
T. festiva (Stearns, 1873)	I
MOLLUSCA: **Bivalvia**	
Adula falcata (Gould, 1851)	I
Hiatella arctica (Linnaeus, 1767)	S,I
Lithophaga plumula kelseyi Hertlein & Strong, 1946	I
Mytilus californianus Conrad, 1837	I
Parapholas californica (Conrad, 1837)	I
Penitella gabbii (Tryon, 1863)	I
P. penita (Conrad, 1837)	I
P. turnerae Evans & Fisher, 1966	I
Platyodon cancellatus (Conrad, 1837)	I
Pododesmus cepio (Gray, 1850)	S,I
Protothaca tenerrima (Carpenter, 1857)	S
MOLLUSKA: Polyplacophora	
Cryptochiton stelleri (Middendorff), 1846	S,I
Katharina tunicata (Wood, 1815)	S,I
Lepidozona cooperi (Pilsbury, 1892)	I
Mopalia ciliata (Sowerby, 1840)	I
M. muscosa (Gould 1846)	I
Tonicella lineata (Wood 1815)	I
SIPUNCULA	
Phascolosoma agassizii Keferstein, 1867	I

APPENDIX 1 (Continued)

TAXA	HABITAT
BRYOZOA	
Crisia maxima Robertson, 1910	S
Filicrisia franciscana (Robertson, 1910)	S
Flustrellidra corniculata (Smith, 1871)	S
Hippothoa hyalina (Linnaeus, 1767)	S
Membranipora membranacea (Linnaeus, 1767)	S, I
Scrupocellaria diegensis Robertson, 1905	S
ECHINODERMATA: Asteroidea	
Dermasterias imbricata (Grube, 1857)	S, I
Henricia leviuscula (Stimpson, 1857)	S
Leptasterias pusilla (Fisher, 1930)	I
Patiria miniata (Brandt, 1835)	S, I
Pisaster brevispinus (Stimpson, 1857)	S, I
P. giganteus (Stimpson, 1857)	S
P. ochraceus (Brandt, 1835)	S, I
Pycnopodia helianthoides (Brandt, 1835)	S, I
ECHINODERMATA: Ophiuroidea	
Amphiodia occidentalis (Lyman, 1860)	S, I
Ophioncus granulosus Ives, 1889	S
ECHINODERMATA: Echinoidea	
Dendraster excentricus (Eschscholtz, 1829)	S
Strongylocentrotus purpuratus (Stimpson, 1857)	S, I
HEMICHORDATA: Enteropneusta	
Mesoglossus sp.	I
CHORDATA: Urochordata	
Amaroucium californicum (Ritter & Forsyth, 1917)	S

*This compilation is based on the literature and observations during the course of this survey. Many additional species are to be expected. Intertidal hydroids, bryozoans and tunicates have not yet been identified.

**Subtidal (S); Intertidal (I).

APPENDIX 2

Composite List of Marine Plants Observed at Duxbury Reef

Chlorophyta

- Blidingia minima (Naeg.) Kylin
- Cladophora columbiana Collins
- Enteromorpha intestinalis (Linnaeus) Link
- Rhizoclonium tortuosum (Dillw.) Kuetz.
- Spongomorpha coalita (Rupr.) Collins
- Ulva lobata (Kutzing) Setchell & Gardner
- Urospora peniciliiformis (Roth) J. Aresch.

Phaeophyta

- Alaria marginata Postels & Ruprecht
- Cystoseira osmundacea (Menzies) C.A. Agardh
- Desmarestia ligulata (Lightfoot) Lamouroux
- Egregia menziesii (Turner) J. Areschoug
- Fucus distichus Linnaeus
- Haplogloia andersonii (Farlow) Levring
- Heterochordaria abietina (Rupr.) Setchell & Gardner
- Laminaria dentigera Kjellman
- L. sinclairii (Harvey) Farlow
- Melanosiphon intestinalis (Saunders) Wynne
- Nereocystis luetkeana (Mertens) Postels & Rupert
- Pelvetia fastigiata (J.G. Agardh) De Toni
- Pelvetiopsis limitata (Setchell) Gardner
- Postelsia palmaeformis Ruprecht
- Pterygophora californica Ruprecht
- Scytosiphon dotyi Wynne
- S. lomentaria (Lyngbye) Endl.

Rhodophyta

- Amplisiphonia pacifica Hollenberg
- Bossiella gardneri (Manza) Silva
- B. plumosa (Manza) Silva
- Botryoglossum farlowianum (J. G. Agardh) De Toni
- Calliarthron cheilosporioides Manza
- C. tuberculosum (Postels & Ruprecht) Dawson
- Callithamnion pikeanum Harvey
- Callophyllis megalocarpa Setchell & Swezy
- C. pinnata Setchell & Swezy
- Corallina chilensis Decaisne
- C. vancouveriensis Yendo
- Cryptopleura lobulifera (J.G. Agardh) Kylin
- C. violacea (J.G. Agardh) Kylin
- Cryptosiphonia woodii J.G. Agardh
- Dilsea californica (J. G. Agardh) Schmitz
- Endocladia muricata (Postels & Ruprecht) J.G. Agardh
- Erythrophyllum delesserioides J. G. Agardh
- Farlowia compressa J.G. Agardh
- F. mollis (Harvey & Bailey) Farlow & Setchell
- Gastroclonium coulteri (Harvey) Kylin
- Gelidium coulteri Harvey
- G. purpurascens Gardner
- Gigartina agardhii Setchell & Gardner

G. californica J.G. Agardh
G. canaliculata Harvey
G. corymbifera (Kutzing) J.G. Agardh
G. jardinii J.G. Agardh
G. papillata (C.A. Agardh) J.G. Agardh
Gonimophyllum skottsbergii Setchell
Gracilaria sjoestedtii Kylin
Grateloupia californica Kylin
Gymnogongrus leptophyllus J.G. Agardh
G. platyphyllus Gardner
G. linearis (Turner) J. Agardh
Halosaccion glandiforme (Gmelin) Ruprecht
Heteroderma nicholsii Setchell & L. Mason
Hymenena flabelligera (J.G. Agardh) Kylin
H. multiloba (J.G. Agardh) Kylin
Iridaea flaccida (Setchell & Gardner) Silva
I. heterocarpa Postells & Ruprecht
I. sanguinea (Setchell & Gardner) Hollenberg & Abbott
I. splendens (Setchell & Gardner) Pappenfuss
Janczewskia gardneri Setchell & Guernsey
Laurencia spectabilis Postels & Ruprecht
Lithothamnion pacificum Foslie
Melobesia marginata Setchell & Foslie
M. mediocris (Foslie) Setchell & L. Mason
Microcladia borealis Ruprecht
M. coulteri Harvey
Nienburgia andersoniana (J.G. Agardh) Kylin
Odonthalia floccosa (Esp.) Falk
O. oregona Doty
Opuntiella californica (Farlow) Kylin
Phycodrys setchellii Skottsberg
Phyllophora clevelandii Farlow
Pikea californica Harvey
Pleonosporium dasyoides (J.G. Agardh) De Toni
Plocamium pacificum Kylin
Polycoryne gardneri Setchell
Polyneura latissima (Harvey) Kylin
Polyporolithon conchatum (Setchell & Fosl.) L. Mason
Polysiphonia collinsii Hollenberg
Porphyra perforata J.G. Agardh
Porphyrella gardneri G.M. Smith & Hollenberg
Prionitis andersonii Eaton
P. lanceolata (Harvey) Harvey
Pterochondria woodii (Harvey) Hollenberg
Pterosiphonia bipinnata (Postells & Ruprecht) Falk
P. dendroidea (Mont.) Falk
Ptilota californica Ruprecht
P. densa C.Agardh
P. filicina (Farlow) J.G. Agardh
P. hypnoides Harvey
Ralfsia pacifica Hollenberg
Rhodochorton obscurum Drew
R. subimmersum Setchell & Gardner

APPENDIX 2 (Continued)

Rhododermis elegans Crouan
Rhodomela larix (Turner) C. Agardh
Rhodoptilum densum (Smith) Dawson
Rhodymenia pacifica Kylin
Schizymenia pacifica (Kylin) Kylin
Smithora naiadum (C.H. Anderson) Hollenberg
Spermothamnion snyderae Farlow
Stenogramma californica Harvey

Anthophyta (Flowering plants)
Phyllospadix torreyi Watson
P. scouleri Hooker

APPENDIX 3

Composite List of Marine Fish taken from Duxbury Reef*

Family Serranidae	Bass family
Roccus saxatilis (Walbaum) Morone lineatus	striped bass
Family Atherinidae	Silversides family
Atherinops affinis (Ayres)	topsmelt
Family Embiotocidae	Perch family
Cymatogaster aggregata Gibbons	shiner perch
Damalichthys vacca Girard	pile perch
Embiotoca jacksoni Agassiz	black perch
Amphistichus rhodoterus Agassiz	redtail surfperch
Hyperprosopon argenteum (Gibbons)	walleye surfperch
H. ellipticum (Gibbons)	silver surfperch
Hypsurus caryi (Agassiz)	rainbow seaperch
+Micrometrus minimus (Gibbons)	+dwarf perch
M. aurora (Jord n & Gilbert)	reef perch
Phanerodon furcatus Girard	white seaperch
Rhacochilus toxotes Agassiz	rubberlip perch
Embiotoca lateralis (Agassiz)	striped seaperch
Family Scorpaenidae	Rockfish family
Sebastodes melanops (Girard)	black rockfish
+S. rastrelliger (Jordan & Gilbert)	+grass rockfish
Family Hexagrammidae	Greenling family
Hexagrammos decagrammus (Pallas)	greenling seatrout
H. superciliosus (Pallas)	rock greenling
Family Ophiodontidae	Lingcod family
Ophiodon elongatus Girard	lingcod
Family Cottidae	Sculpin family
Artedius fenestralis (Jordan & Gilbert)	padded sculpin
A. harringtoni (Starks)	scalyhead sculpin
A. lateralis (Girard)	smoothhead sculpin
A. notospilotus Garard	bonyhead sculpin
Ascelichthys rhodorus Jordan & Gilbert	rubber sculpin
Clinocottus analis Girard	wooly sculpin
C. acuticeps (Gilbert)	sharpnose sculpin
C. globiceps (Girard)	mosshead sculpin
Enophrys bison (Girard)	buffalo sculpin
Hemilepidotus spinosus (Ayres)	reef Irish lord
Leptocottus armatus Girard	northern staghorn sculpin
Oligocottus maculosus Girard	johnny sculpin
O. rimensis (Greeley)	saddleback sculpin
+O. snyderi Greely	+chameleon sculpin
+Scorpaenichthys marmoratus (Ayres)	+cabezon
Liparididae	Snailfish family
Liparis florae (Jordan & Starks)	tidepool snailfish
L. rutteri (Gilbert & Snyder)	bandtail snailfish

Family Gobiescocidae	Clingfish family
Gobiesox maeandricus (Girard)	northern clingfish
Family Clinidae	Klipfish family
Gibbonsia metzi Hubbs	weed klipfish
Family Cebidichthyidae	Blenny family
Cebidichthys violaceus (Girard)	monkeyface blenny
Family Stichaeidae	Prickleback family
Anoplarchus purpurescens Gill	cockscomb
+Xiphister atropurpureus (Kittlitz)	+black prickleback
+Xiphister mucosus (Girard)	+rock blenny
Family Pholididae	Gunnel family
+Apodichthys flavidus Girard	+penpoint gunnel
Pholis ornata (Girard)	saddleback gunnel
+Xererpes fucorum (Jordan & Gilbert)	+rockweed gunnel

*Modified from a list prepared by Dr. S.H. Weitzman as presented in Chan & Molina (1969).

+Common species.

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