

INTERTIDAL STUDY OF THE
SOUTHERN CALIFORNIA BIGHT

VOLUME I

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Prepared by Science Applications, Inc.

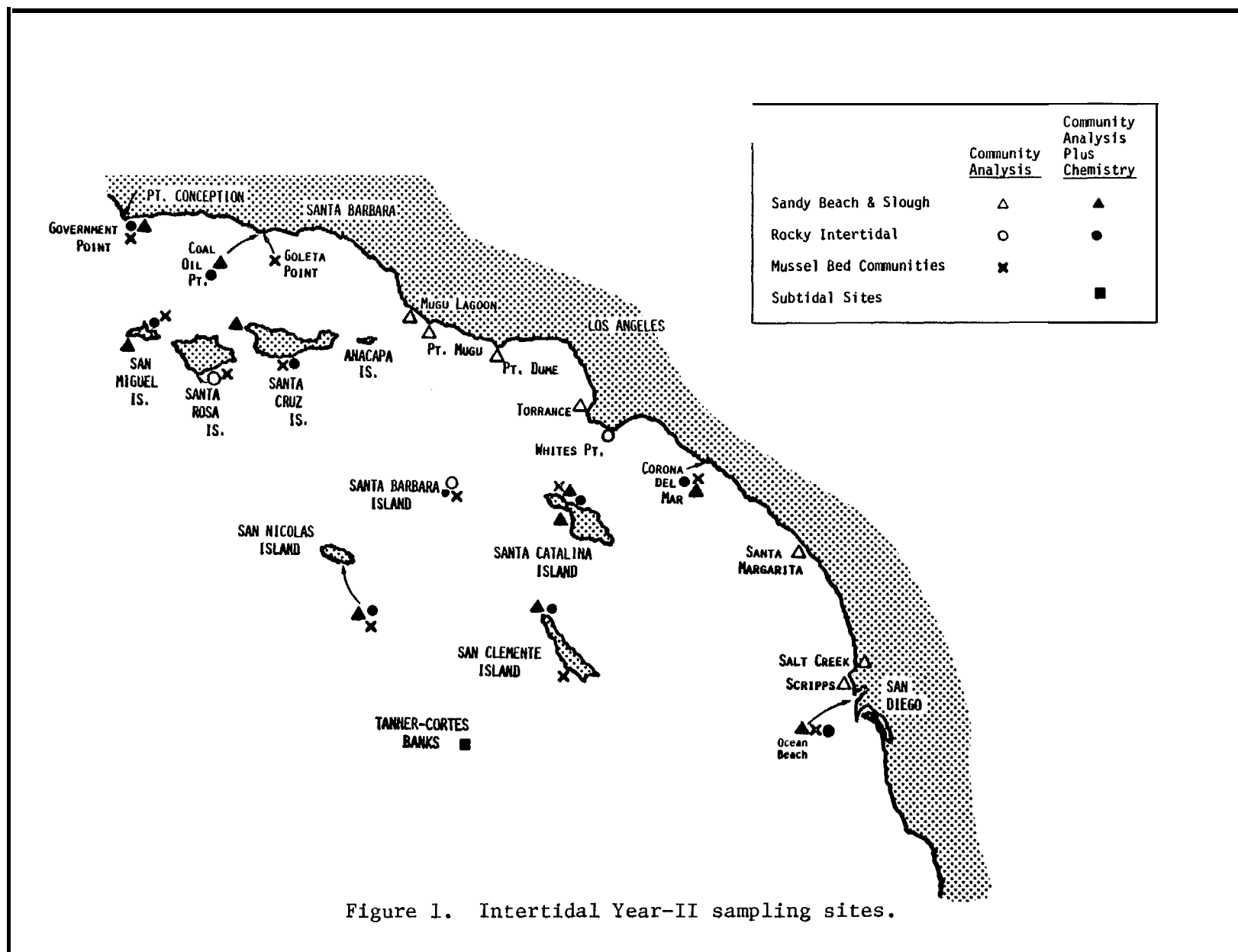
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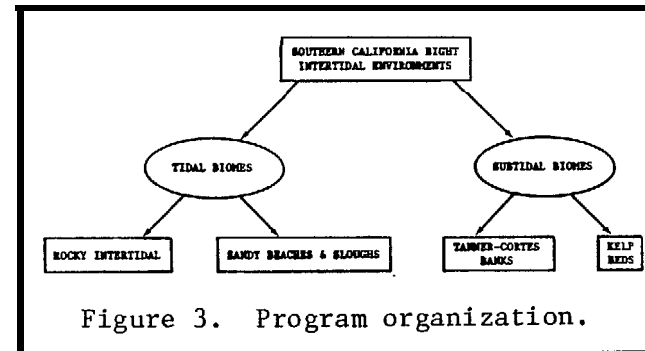
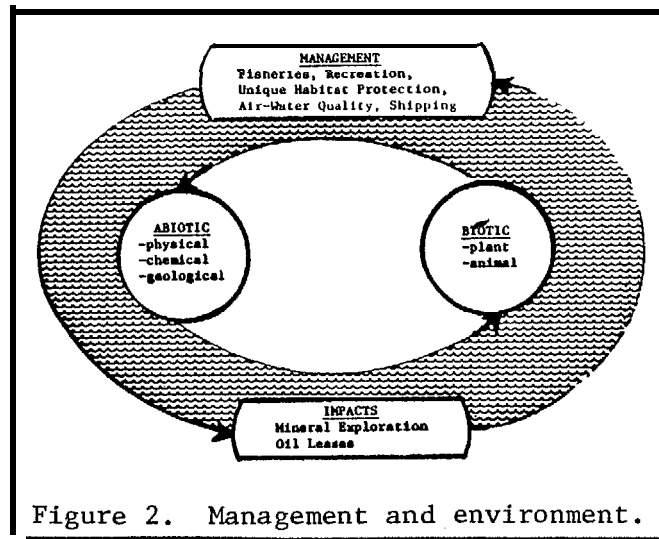
INTRODUCTION

Recent exploration has indicated that the Southern California outer continental shelf (OCS) may be a source of potential oil and mineral reserves. As a result, the BLM has contracted SAI to undertake the first comprehensive survey of this geographic locale over a three year period. The study focused on a region known as the Southern California Bight (Figure 1). This is an area with many diverse habitats harboring unique associations of marine plants and animals. Sport fishing, recreation, diving, commercial fisheries and kelp harvesting are all common activities in the Bight. Proper management and protection of such a vital and complex resource requires an extensive information base in order to address specific questions and problems that will arise. This paper (Vol. I) will serve as an overview of the second-year study carried out in 1976-1977. Its purpose was to extend the first year's research (1975-76) in order to establish a two year data base of the major biological, chemical and physical factors of the Bight. Volume I should not be viewed as a substitute for the detailed material which may be found in Volumes II (Summary and Synthesis) & III (Principal Investigator Reports).

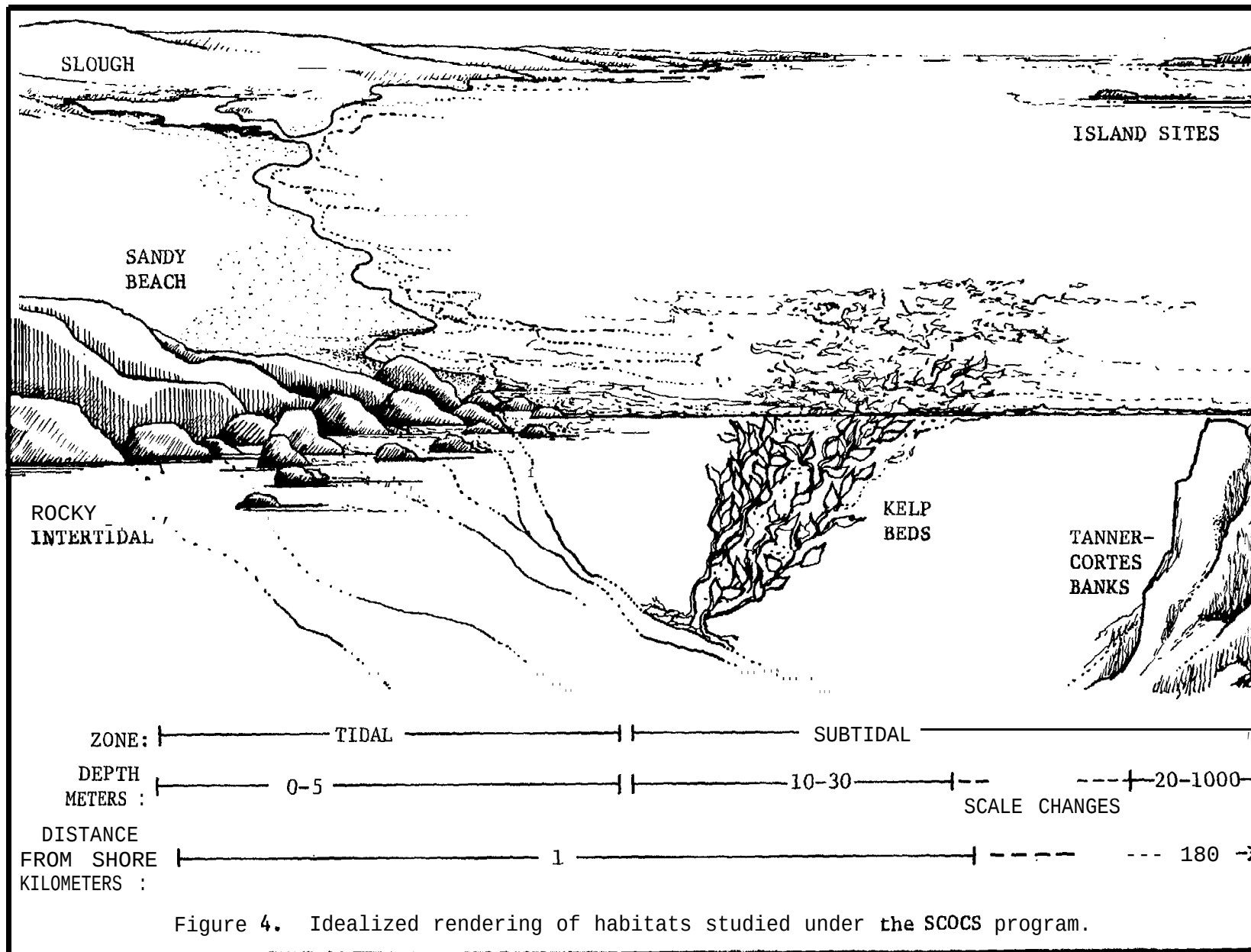
The first step in predicting potential effects of oil development is to obtain a descriptive knowledge of the region. Towards that end SAI has brought together



a large scale, multi-disciplinary group of researchers. This unique association of oceanographers, biologists, chemists and geologists is investigating various aspects of the natural history of the Bight. The task has required numerous observations in the field and in the laboratory and the accumulation of extensive descriptive data. It is like looking at a very ornate woven tapestry. Even though it may have numerous design elements, its ultimate visual appeal lies in the overall pattern which unites the pieces. A natural environment is a living tapestry, in which the biologic and physical (non-living) factors continually interact. Everything in nature is intricately linked, and man is part of the web of action and reaction. Ideally, these interactions could be visualized as a series of interdependencies (Figure 2).



Researchers at SAI recognized two main objectives. The first was to accumulate the baseline data. The second objective was to look for regular patterns which would aid the BLM in its management of the Bight. Or, stated another way, the distribution of biologic and physical variables in space and time must be understood before management can properly delineate sensitive or critical areas and seasons. Moreover, such patterns constitute precursors to predictive studies required for impact analysis. In order to achieve these objectives, research surveys were conducted in specific habitats to help organize the accumulated data for subsequent analysis and interpretation. Thirty-three sites were surveyed. These can be grouped into two main categories, each with habitat subdivisions (Figure 3). Figure 4 schematically depicts the different habitats. They include the rocky intertidal, sandy beaches and sloughs, island sites, kelp beds and offshore underwater pinnacles (Tanner and Cortes Banks). These locales are spread over a 600-mile stretch of



coastline extending from Pt. Conception to the Mexican Border.

PRINCIPAL FINDINGS

General

The second year of this project has resulted in considerable advances in methodology in the study of biologic, chemical and physical factors. The requirement for community studies motivated innovative and improved methods of site and quadrat relocation. Bolts and other position markers were permanently emplaced, even at the depths of the Tanner-Cortes Banks. Sophisticated navigational equipment was employed in establishing and relocating remote study sites. Sample collection was aided by the development of a new SCUBA-powered vacuum system. This technique permitted thorough harvesting of even rare and well hidden species. Biologic data were collected and analyzed photographically; the photographs provide a permanent, incontrovertable data record.

Laboratory and data analysis methods were also improved. One useful development was the creation of a single index known as the BOP (Bodega Oil Pollution) Index. It enables investigators to assess the origin and strength of hydrocarbon contamination by simultaneous consideration of several relevant factors. Other technical advances included an overall increase in the resolution of hydrocarbons especially in biologic tissues. This

improvement was made possible by the attenuation of problem-causing interfering substances.

Laboratory procedures for the analysis of trace metals, which are difficult to measure precisely, were also revised and improved over the first year. What resulted was an increase in the overall resolution of these tests. An innovative test introduced into this program was the use of ratio estimation for metal levels in organisms. The latter method uses the ratio of two metals, rather than the more common single metal value. The result is an indicator which is much more sensitive to change.

The Tidal Zone

The tidal zone is a region where the sea meets the land. It is often a very rich habitat occupied by unusually adapted organisms. Here the daily flux of high and low tides creates a life of extremes. Seaweeds and invertebrate animals must cope with wide ranges in the period of exposure to air, heat and desiccation, changes in salinity and wave action. The tidal zone has two main habitats: (a) the rocky intertidal and (b) sandy beaches and sloughs. Both were extensively studied. The rocky intertidal of the Southern California Bight is a surf-swept region exposed to constant agitation. The organisms here have evolved to endure exposure and the shock of pounding waves. Though the rocky intertidal has been

extensively studied in the past, the coordinated research of this project has further elucidated aspects of its ecology. The study of organism community structure revealed only a loose pattern at this stage. Each rocky intertidal site had its own distinct character. Nevertheless, a number of useful generalities are evident, and some may have management implications. One geographical consistency is the community similarity between northern mainland sites and their associated islands. This resemblance was also the case for southern mainland and island sites. Government Point is a unique site, in that it harbors uncommon assemblages of cold and warm water species. It was also observed that island rocky intertidal sites generally had more abundant populations of organisms. This may be due to their greater isolation from human activities.

One very common and ubiquitous marine invertebrate is the sea mussel, Mytilus (Figure 5). It is found at virtually all sites, where its dense beds create a three-dimensional micro environment made up of the myriad spaces between the mussels. This allows many other plants and animals to exist in and on the mussel beds. The particular organisms and their relative abundances are distinguishable from mussel bed to bed and site to site.

Some sites were found to have an unstable substrate or settling surface. Shifting rocks in the surf or heavy sand inundation makes life precarious for many

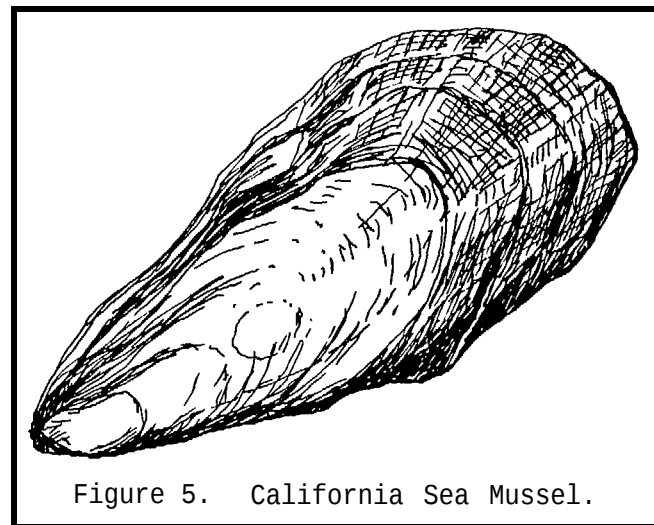


Figure 5. California Sea Mussel.

vulnerable algae or invertebrates. This disruption enables fast-growing, opportunistic or weed-like organisms to rapidly establish themselves. Community associations then develop which are ecologically immature. Simply stated, this means that an equilibrium exists between the disruptive forces of waves and scouring and the tendency for more mature communities to replace their predecessors. The implication of this situation is that at such sites immature communities might recover more rapidly from disturbances caused by nature or man. This is because the development time of these communities is relatively short. Recovery of the rocky intertidal from man-induced and natural disruptions seems to indicate that similar patterns exist from site to site. Seaweeds recover more rapidly than marine invertebrates. The lower intertidal zone re-

covers first. And, in general, disturbed areas tend to reestablish themselves by new species moving in, rather than invasion by organisms from older, undisturbed areas.

An analysis of the physical and chemical factors affecting the intertidal also revealed interesting observations. Those sites where natural oil seepage occurs (Government Point and Coal Oil Point) show high hydrocarbon levels in both animal tissues and in the sediments.

The sea mussel, Mytilus, is a cosmopolitan species which can serve as a bioindicator of contamination. By analyzing its tissues for hydrocarbons we can obtain a picture of where petroleum compounds are being incorporated in the environment. Mussels from sites with either natural or man made sources (such as the heavily used harbors of Corona del Mar or San Diego) all show moderate-to-high tissue levels of hydrocarbons. Mussels living in more isolated island sites have low levels. Mussel tissue hydrocarbon levels also vary within study sites. Those mussels found at the high end of the tidal zone appear to have a greater concentration of hydrocarbons, compared to those living in the lower intertidal. This variability is probably due to the greater deposition of oil on the upper rocks by stranding.

Mytilus was also investigated as a possible bioindicator for trace metals. Petroleum products and industrial pollu-

tion can be important sources of these metals. For example, it is evident that harbors which have heavy boating and shipping use show relatively high metal levels. However, regional mineralogy is often more important. This may account for the observation that metal levels in mussels from Coal Oil point (a region of high natural oil seepage) aren't unusually high.

While it is tempting to speculate on the influence of contaminants in rocky intertidal communities, effects of low-level hydrocarbon and trace metal pollution on marine community structure seem to be overshadowed by physical and geological factors. In other words, the influence of local wave exposure, desiccation, substrate stability (moving rocks, etc.) and water current conditions, may all have a greater effect on the community at a particular site than contamination. Local organisms appear to adapt to high pollutant levels and even some very sensitive seaweeds are able to thrive at Coal Oil Point. This indicates that more focused and intensive research is needed to understand oil pollution effects. The long and short-term results of massive oil pollution (e.g., Santa Barbara oil spill, 1969) are difficult to analyze because very little baseline data existed at the critical time. The 12 rocky intertidal sites studied on this program by the SAI team of scientists will provide a proper framework for comparison with any future environmental conditions.

Sandy beaches and sloughs constitute the other main tidal habitat. Their appearance offers a marked contrast to the rocky intertidal. One is not immediately impressed by any profusion of life. However, it is far from lifeless. In order to avoid the wave forces and desiccation, organisms have adapted to a life of burrowing. There is an overall decrease in the diversity of life compared to the rocky intertidal although many species do occur in great numbers. The effects of oil pollution could not only threaten biota in this habitat, but also the millions of people who daily enjoy the beaches of Southern California.

In contrast to the rocky intertidal, no geographic pattern or trend was observed. This has been confirmed over a two year period. The organisms found on sandy beaches are most influenced by local **physiography**. Specifically, a few key factors, such as beach profile (or slope) and sand grain **size**, can determine the basic community type. For example, long, gently sloping, **fine-grained** beaches usually harbor a diverse community with numerous worm species (Figure 6). Steep, **coarse-grained** beaches (which experience more focused wave action) tend to be populated by relatively few, larger animals. Here, the dominant animal is often the invertebrate sand crab, Emerita. It is also noteworthy that, in general, beach profiles tend to steepen in summer as sand accumulates.

Slough communities also appear to be governed by physical factors, rather than

Figure 6

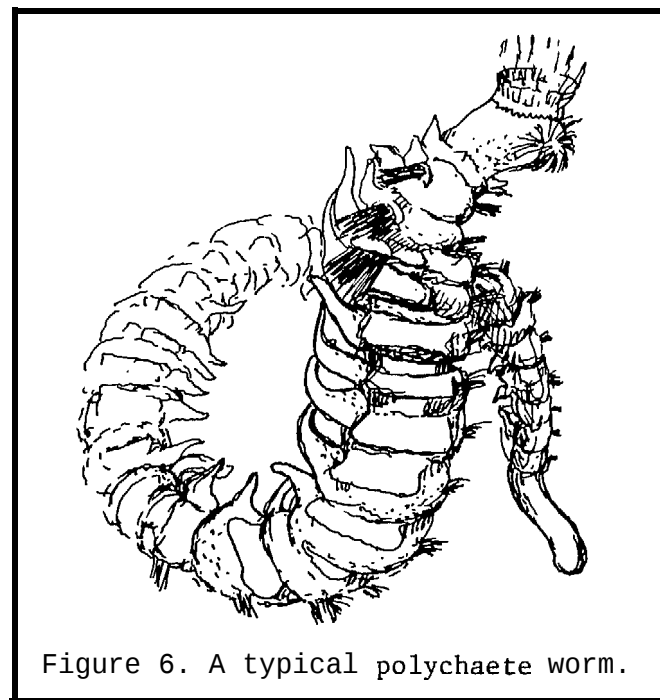


Figure 6

geographic trends. Sloughs are active or extinct drainage channels adjacent to the sea where the tide ebbs and flows. In these sites the annual salinity range acts as a major force determining community structure. The duration of mixing with the ocean and the amount of fresh water runoff, among other factors, controls the salinity variation. Some sites are open to the ocean year round and have almost constant salinity, while others may become blocked periodically and show considerable change during the year. These phenomena, in turn, effect the type of organisms capable of sustaining life in the muddy substrates of sloughs.

One sheltered site (Twin Harbors) is inhabited by a unique combination of organisms which defies either beach or slough categorization. Twin Harbors is protected from wave action and is characterized by muds of local origin. However, runoff is the only freshwater source. The relative stability of the environment appears to favor the consistent presence of the same species from year to year.

Scientists believe that sandy beaches are not likely to be altered in the long run by offshore development. Nevertheless, the study of physical variables, such as sediment characteristics, are important in monitoring the potential effects of mineral development. For example, a beach may show less diverse community structure when compared to an earlier baseline study. The grain size and profile might also have been altered during the period of OCS development. This would indicate that the physical environment is in a state of flux or transition. Biologic changes might then be attributed to natural processes or human activities (construction of piers, etc.), rather than impacts of petroleum exploration. Though a direct cause and effect relationship for these changes may not be defined, the role of various factors may be more objectively assessed because of the available information.

Chemical aspects of sandy beaches focused mainly on hydrocarbon and trace metal levels in the sediments and animal (sand

crab) tissues. Sediment hydrocarbon data reflected both geographic and seasonal trends: mainland beaches showed higher levels than island sites. Mainland hydrocarbons were primarily derived from petroleum sources. The island beach hydrocarbons were mainly from plant compounds, indicating a predominantly biologic source. Seasonal patterns showed elevated sediment hydrocarbon levels during the winter; it was also observed that hydrocarbon content generally increased with decreasing tidal height. This is in contrast to the mussel data (in which the effect of splash was implicated) and is probably due to the fact that compounds farther from the high tide mark are less exposed to air and associated weathering processes.

The biological indicator selected for sandy beaches was the common sand crab, Emerita (Figure 7). Even though relatively few animals were analyzed compared to the number of sediment samples, their hydrocarbon uptake showed the same geographical and seasonal trends found in sediments (i.e., higher levels in the winter and on the mainland).

Sediment trace metal patterns were less clear-cut. Seasonal variation data were not consistent. This lack of uniform trends makes it difficult to discern seasonally related processes. Emerita, however, did show some trace metal patterns. Animals taken from heavily polluted harbor sites (e.g., Corona del Mar) showed high concentrations of many

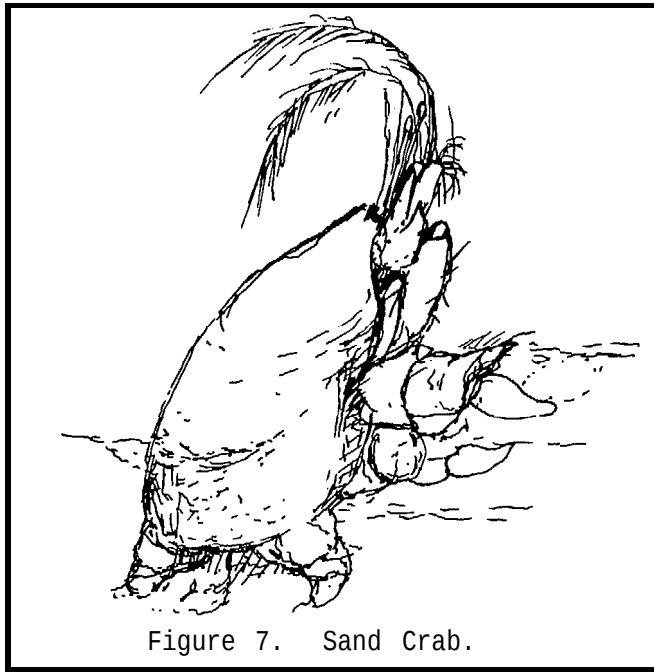


Figure 7. Sand Crab.

metals. Emerita also reflected the high levels-of cadmium on San Nicholas Island where water enriched with nutrients from upwelling is thought to be important.

No correlation appears to exist between trace metal and hydrocarbon variability. This isn't surprising, since trace metals and hydrocarbons follow different geo-chemical and bio-accumulation pathways. Trace metals tend to reflect local mineralogy conditions and are rather resistant to change. On the other hand, in areas where pollution levels are high, increased inputs are readily measured. Low levels of hydrocarbons associated with chronic pollution would be rapidly

changed due to weathering and the action of bacteria. Larger effects due to seeps or significant human input are readily manifested in organism and sediment level increases.

The Subtidal Zone

Seaward of the shore is an important region known as the subtidal. This is a submerged marine environment which is less affected by the daily tidal flux. The southern California Bight subtidal zone is characterized by extensive underwater kelp forests which provide numerous habitats for sea life. The submerged sea banks of the region also create unique habitats where shallow-water organisms exist. The Bight subtidal offers both recreational and commercial opportunities. An understanding of its natural history is particularly crucial, as there is active interest in its potential oil reserves.

The surveys of the Tanner and Cortes Banks habitats were conducted to obtain a picture of the local community structure (i.e., species association) and ambient levels of contamination. The four sites studied are considered representative of the hard-bottom communities found on the banks. The species composition in many respects is similar to other subtidal areas throughout the Bight. Some species are conspicuously absent from the banks (e.g., giant kelp; Garibaldi - a protected fish) and others are unique to this area (e.g., pink hydrocoral). The impor-

tant difference, however, is the greatly increased abundance of many species at the Tanner-Cortes sites, compared to the mainland. Some species also occur at unusual depths on the banks. These phenomena are at least partly due to the presence of unusually clear water and the absence of human activity.

Diving surveys of the banks sites revealed two primary community types. Shallow-water areas are characterized by what is termed a "ridge-top" community. Here, the dominant aspect is a canopy-forming brown seaweed (Eisenia) (Figure 8) and its associated community. The other community dominated in deeper waters (25 m). This "crust" community was characterized by encrusting algae and masses of brittle starfish (Figure 9). Underwater topography plays a role in the distribution of ridge and crust habitats. Community structure and diversity are also directly related to differences in depth. This pattern is probably attributable to the amount of light filtering down through the water. That is, the clear water allows the palm kelp (Eisenia) to flourish at unusual depths, but below a certain level, even on the banks, the light becomes too dim for photosynthesis. In the absence of Eisenia the species protected by the canopy are not found. Except for the deepest station at South Tanner, no community pattern was found to be related to geographic position on the banks. Virtually no Eisenia occurs at South Tanner. The results of this study may be extended

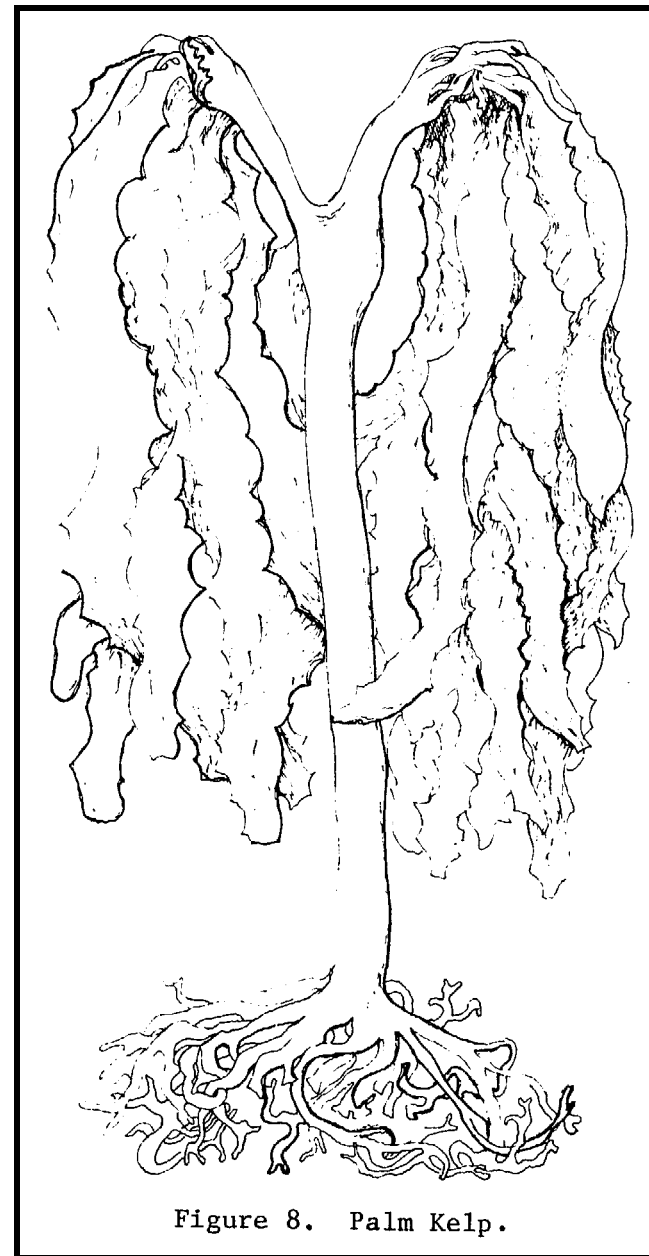


Figure 8. Palm Kelp.

to areas of similar depth and topography. SAI scientists suggest that future studies cover broader geographic areas (perhaps by underwater video cameras).

Three Banks subtidal species (starfish and kelp) were used to monitor hydrocarbon and trace metal levels. In general, it appears that tissue hydrocarbon levels are considerably lower here than in other areas and consist primarily of biologic sources. Unfortunately, water samples were not collected at the same time (i.e., synoptically) so that no direct correlation between the environ-

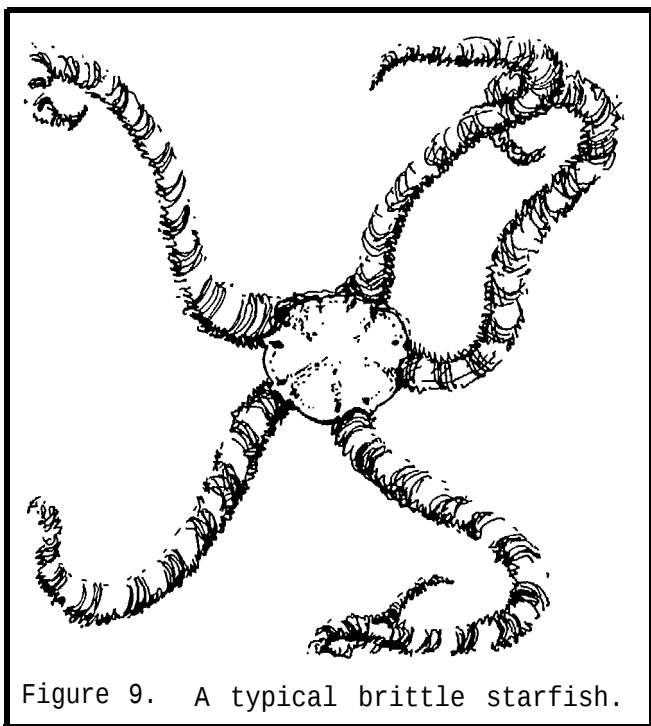


Figure 9. A typical brittle starfish.

ment and the animals tested could be made. Some seasonal patterns were observed in the levels of hydrocarbons. Tissue hydrocarbon levels were generally higher in the winter.

An interesting observation from trace metal tissue assays is an increase in barium and lead levels in the Banks over other areas of the Bight. These metals are components of drilling muds, and may reflect the fact that those operations were underway at the time of the survey. Further investigations are needed to clarify some of these more ambiguous findings. No other significant between-site, or seasonal pattern of trace metal distributions, was evident.

Large areas of the Southern California Bight subtidal coastline are dominated by a different and complex marine ecosystem. Here, the giant kelp Macrocystis (Figure 10) resembles vast underwater forests. Their rapid and lengthy growth creates an extensive, resilient habitat for many marine organisms. Reports have indicated that 128 plant species and over 700 animal species may live in this habitat. Though the Bight kelp beds have been the subject of numerous studies, conclusive data are still lacking on regional trends which may effect their distribution.

SAI has now completed two years of quarterly, aerial surveys. The giant kelp was given primary attention because it is the dominant plant species everywhere it occurs. Its range therefore determines

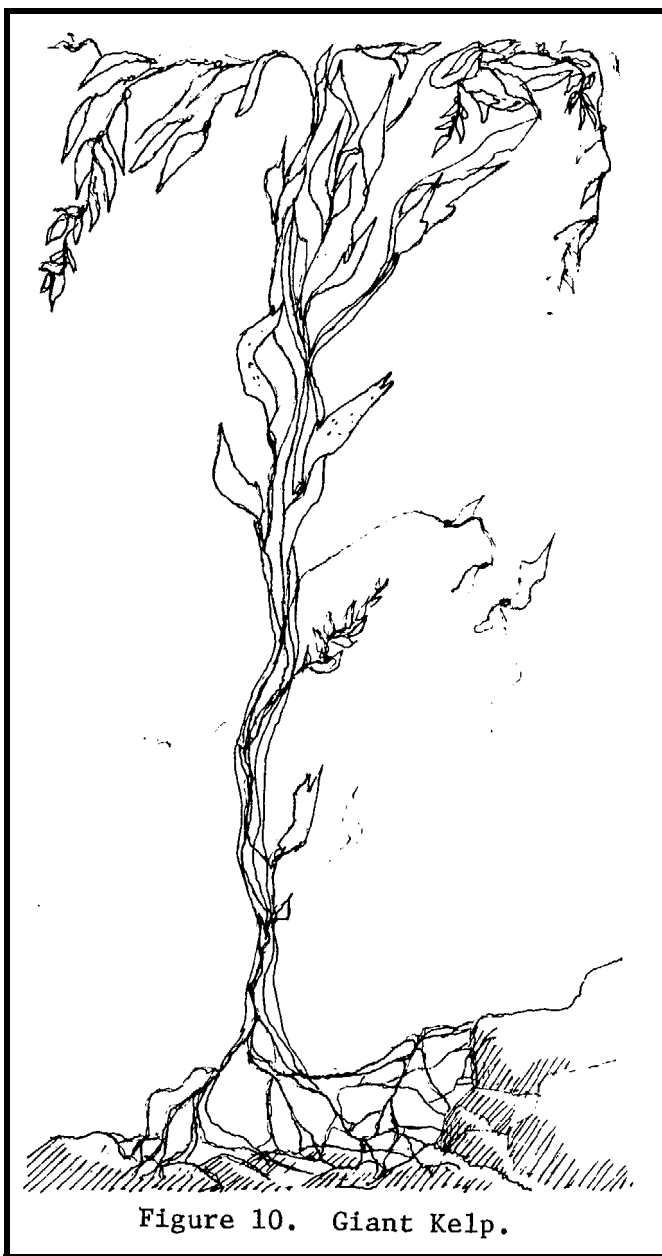


Figure 10. Giant Kelp.

the distribution of the other associated organisms. The growth form of an extended canopy floating at the water's surface enables it to be surveyed by aerial photographic methods.

The results of these surveys reveal widespread changes in canopy area. However, the observed changes in individual bed areas were small in comparison to the variations over the past 60 years. This longer period has seen shrinkage of the kelp beds in virtually all regions where data are available.

The combination of higher water temperatures and storm activity are two factors which limit kelp growth. A general framework in natural control of kelp density has been suggested by these studies. Factors such as protection by islands from storm and wave action, denuding during winter storms, maximum growth during early summer, followed by thinning of the canopy during late summer (due to higher water temperatures) interact variably, depending on the particular location.

FUTURE

Not all the findings are understood at this stage, especially as they might relate to fundamental processes. We still lack a complete understanding, for example, of what governs the fate of chemical pollution and its effects on biological community structure.

Knowledge of this and other questions will be further enhanced by the results of the third year (1977-78) intertidal study. Complete elucidation of potential impacts will require predictive (experimental) studies, which should follow this baseline work.

It should be noted that the radical change in weather experienced in the third year (1977-78) may force reassessment of some patterns and conclusions. Two years of drought were followed by a year of heavy rains and storms. Despite some contradictory results, we have still reached a point where research on basic environmental processes is now more clearly defined. The purpose of future investigations would be to generate predictive models using indicators. These models would help in the management of specific regions of the Southern California Bight.

CONCLUSIONS:

The principal advances and findings from the second year study of the southern California Bight are:

General

- Improved methodology in sampling techniques and recording procedures
- Improved laboratory and data analysis procedures

- " Development of a unique oil pollution index for hydrocarbons
- Improved resolution of trace metals

Rocky Intertidal

- There is a north-south geographic pattern in community structure.
- Government Point is a unique site which harbors uncommon assemblages of cold and warm water species.
- Island rocky intertidal sites generally are more lush than their mainland counterparts.
- Mussel-bed communities occurring in a three dimensional micro-environment are distinguishable in type and relative abundance from bed to bed and from site to site.
- Fast-growing, opportunistic or weed-like organisms rapidly reestablish themselves
- Immature communities present at naturally disturbed sites recover rapidly
- Flora recover more rapidly than fauna
- The lower intertidal region recovers before the upper

- Reestablishment by new species is more likely than encroachment by organisms from undisturbed areas.
- Animal tissues and sediments from sites influenced by natural oil seepage and man-made input show correspondingly higher hydrocarbon levels compared to those from more pristine sites.
- Trace-metal burdens in mussels were related more to regional mineralogy, than to petrogenic sources.
- Physical and geologic disturbances appear to have a greater influence on the biotic communities than low-level hydrocarbons.

Sandy Beaches and Sloughs

- The role of physical variables is noted to be important in future monitoring of the potential effects of OCS mineral development.
- Biologic communities found in sandy beaches can be predicted by considering physiographic factors
- The annual salinity range is a major force determining community composition in sloughs.
- Protected beaches such as Twin Harbors show a more consistent presence of the same species from year to year.

- Sediment and sand crab tissues from the mainland showed higher petroleum hydrocarbon content than those from the islands.
- Mainland hydrocarbons were predominantly of petrogenic origin whereas island sources were largely biogenic. Hydrocarbon levels were higher during the winter and generally increased with decreasing tidal height.
- Sand crabs taken from heavily polluted harbor sites showed higher concentrations of many metals. High levels of cadmium in animals taken on San Nicolas Island were attributed to upwelling.

Subtidal

- Pristine conditions (clear water) at Tanner and Cortes Banks are primarily responsible for the abundance of many species and the presence of unique species (such as pink hydrocoral) compared to the mainland.
- Community structure and diversity appear to be related to depth, probably as a function of the amount of light filtering down through the water.
- In general, tissue hydrocarbon levels are lower in the Banks than in other areas, are primarily of

biogenic origin and are higher in winter.

- Relatively high barium and lead contamination in tissues may reflect the presence of drilling muds in the Banks region during the sampling.
- Density fluctuation measurements of kelp beds by aerial photographs during the two years of the study were small in comparison to the much greater shrinkage over the past sixty years.
- Higher water temperatures, storms and wave action tend to limit kelp bed area.

Future

- Many questions remain to be answered, particularly the factors which govern the fate of chemical pollution and its effect on biological communities.
- The third year study which is in progress may provide some contrary results since it represents a significant change from two years of drought to a year of heavy rains and storms.
- Future studies should be of a predictive design following this baseline work. The use of physical, chemical and biological indicators is recommended.

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