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Biological Services Program

FWS/OBS-82/27
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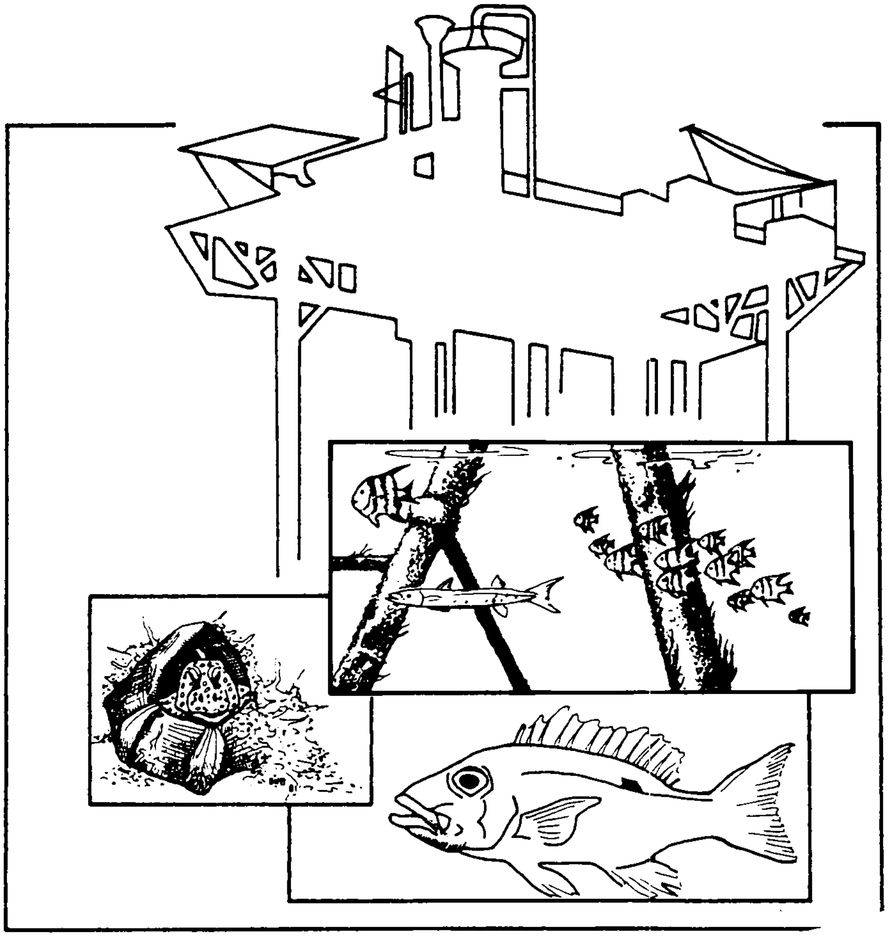
Gulf of Mexico OCS Regional Office

Bureau of Land Management
Open File Report 82-03

THE ECOLOGY OF PETROLEUM PLATFORMS IN THE NORTHWESTERN GULF OF MEXICO:
A Community Profile



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U.S. Department of the Interior

Bureau of Land Management
Fish and Wildlife Service

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.
- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.
- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

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THE ECOLOGY OF PETROLEUM PLATFORMS IN THE NORTHWESTERN GULF OF MEXICO: A COMMUNITY PROFILE

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John L. Rankin
Acting Minerals Manager
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DISCLAIMER

The findings in this report are not to be construed as an official U.S. Department of the Interior position unless so designated by other authorized documents.

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PREFACE

This community profile of petroleum platforms is part of a series of coastal habitat profiles. Its purpose is to describe the structure and ecological function of petroleum platforms in the northwestern Gulf of Mexico. The information in the profile will be useful to environmental managers, resource planners, coastal ecologists, marine science students, and interested laymen who wish to learn about the petroleum platform reef community and its role in the northwestern Gulf of Mexico. The format, style, and level of presentation should make this report adaptable to a diversity of needs, from the preparation of environmental assessment reports to supplementary reading material in college marine science courses.

This profile proceeds from an introductory section describing the history of platform installation, structural properties, and their distribution in the northwestern Gulf of Mexico, to characterizations of the composition and biology of some of the major faunal groups on or around the platforms, to descriptions of structural attributes of petroleum platform communities, to observations of successional patterns and growth of the communities, to discussions of the ecosystem dynamics of the communities in terms of trophic linkage and biomass and carbon flows. In each of these sections, the effects of discharges from the active structures on the communities are described. The effects of the petroleum platform community on the surrounding soft-bottom communities are implicitly described throughout the profile, and explicitly addressed under the section describing the ecosystem dynamics. We then briefly summarize some of the values of production platform communities to man, and, in the final section of the text make an appeal that specific steps be taken to preserve an endangered biological resource: production platform communities. By regulation, offshore petroleum platforms must be removed from the Gulf of Mexico once they are obsolete in terms of producing oil and gas.

Any questions or comments about this publication or requests for it should be directed to :

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Public Records Section
Minerals Management Service
Gulf of Mexico OCS Regional Office
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Metairie, Louisiana 70010
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ACKNOWLEDGEMENTS

Most research describing platform communities in the northwestern Gulf of Mexico has been performed by a few diving scientists, most of whom work for private research organizations and the government. Some of these scientists have spent long and arduous hours under the water actually performing the research; yet, given the nature of private industry, they either seldom find the results of their efforts in any but the gray literature or, if the material is published, they find themselves commonly classified as one of the et al.'s. We would like to particularly acknowledge the major contributions of some individuals in this category including Larry R. Martin, Randall L. Howard, Gregory S. Boland, and George D. Dennis III (LGL Ecological Research Associates, Inc.); Greg Gitschlag and Ian Workman (National Marine Fisheries Service); and Marion F. Johnson (Shell Oil Company).

Most of the photo credits belong to Gregory Boland; however, Larry Martin, Lew Halderson and Randall Howard are responsible for some of the pictures appearing in the photographic plates.

We also thank Nick Fotheringham and Ivan Show, who generously responded to our information requests. Dave Schmidt is thanked for his review of the manuscript. Bonnie Bower (drafting) and Jean Erwin (word processing) helped with the physical preparation of the manuscript.

We thank the Bureau of Land Management, New Orleans OCS Office, for printing this document with color plates which increase the scientific usefulness of the report with regard to species identification.

We thank the Project Officer, Ken Adams, for his administration of the project and Larry Handley and Villere Reggio for their technical overview and suggestions on the document. The authors assume full responsibility for factual errors and/or faulty conclusios.

CHAPTER 1

PROFILE OBJECTIVES AND BACKGROUND

1.1 INTRODUCTION

The primary objective of this community profile is to consolidate the ecological information pertaining to the interaction between petroleum platforms in the northwestern Gulf of Mexico and the resident biota. Offshore petroleum platforms represent a relatively new (and perhaps short-lived) biological habitat in the northwestern Gulf which is characterized by distinctive faunal assemblages and species associations.

When petroleum platforms are installed in marine waters, they are rapidly colonized by a diverse array of microorganisms, algae, and sessile invertebrates including shelled forms (barnacles, oysters, mussels, etc.), as well as soft (bryozoans, hydroids, sponges, and octocorals) and hard (corals) encrusting, colonial forms. The organisms which attach and grow on the structures provide habitat and/or food for many motile invertebrates and fishes, particularly brittle stars, amphipods, small crabs and shrimps, and blennies. Collectively, the sessile forms in conjunction with the dependent motile forms comprise the biofouling community.

It is not, however, the biofouling community which presents the most distinctive visual image of the production platform community, but rather the diverse assemblages of large pelagic and demersal fishes which are intimately associated with the structures. These fishes are often represented by tremendous numbers of individuals. The available data and information about these characteristic fish assemblages seem to indicate that they are more dictated by the physical factor of substrate than by biological interrelationships. If this is true, the fish assemblages associated with petroleum platforms are not true biological communities, but rather only flexible confederations of species loosely allied by a similar environmental requirement or preference, i.e., the presence of structures.

Following the introductory information about the history of the installation and distribution of platforms in the northwestern Gulf of Mexico, characterizations of the total area and nature of petroleum platform habitats, and a review of pertinent biological literature, the biological assemblages associated with these structures are described in terms of their composition and community attributes. Some of the values of these biological resource units to people are then summarized. Finally, some of the management implications of the value judgements are then summarized, and recommendations for preservation of the production platform resource are provided.

1.2 PLATFORM INSTALLATION AND DISTRIBUTION

Although the first offshore well in the Gulf of Mexico was drilled in March 1938 (Creole Field, 2.4 km from the coastline of Louisiana), substantial offshore exploration did not occur until November 1947 when the Ship Shoal Block 32 field was discovered some 19 km off the Louisiana coast (Bedinger et al. 1981). Despite this evidence that significant petroleum reserves existed on the continental shelf of the northwestern Gulf of Mexico, it was not until after 1953 that offshore development accelerated. During 1953, ownership and jurisdiction over the resources of the outer continental shelf (OCS) were defined legally by the Submerged Lands Act and the Outer Continental Shelf Lands Act. These acts enabled industry to obtain large tracts of acreage from a single owner, which in combination with the higher success (producing wells) ratio of exploratory wells drilled offshore as compared to onshore (26% success vs. 18%, Bedinger et al. 1981), greatly accelerated offshore development in the northwestern Gulf of Mexico. Additional stimulus for offshore development was provided by the call for "energy self-sufficiency" following the 1973 oil embargo, as well as by the ever-increasing value of petroleum products and the deregulation of natural gas. Reserves once considered either uneconomical by virtue of their small size or their location or inaccessible because of the lack of available technology are now being increasingly exploited.

Recent estimates by the Bureau of Land Management (BLM 1981) indicate a total of some 3,500 petroleum structures in the Gulf of Mexico, ranging in size and complexity from simple flare stacks (vertical pipes) to small satellite platforms, to major platforms of considerable structural complexity (Figure 1). The term "major platforms" refers herein to large, multi-well production platforms. As of 1980, there were 1,223 major platforms in the Gulf of Mexico including 1,103 in Louisiana waters (90.2%), 118 in Texas waters (9.6%) and only two in acreage associated with the other Gulf states (*Offshore* 1981). If all structures are considered, 3,100 or 88.6% of the total number of petroleum structures in the Gulf of Mexico are located in Louisiana waters.

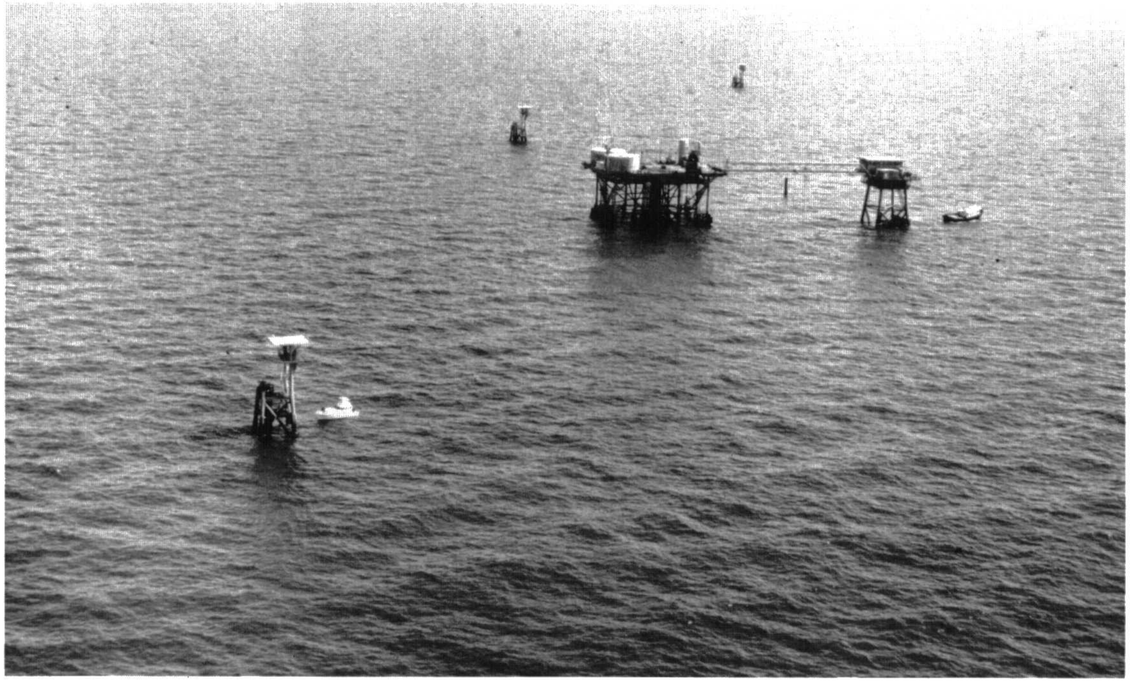


Figure 1. A multi-well production platform in the northwestern Gulf of Mexico with a connected living quarters platform. Note the three single-well, satellite structures in left foreground and in background and the flare pipe between the production and quarters platform. (Photo by Gregory S. Boland.)

The distribution of producing gas and oil fields over the Texas and Louisiana shelf is depicted in Figure 2. With the exception of a shelf-edge band extending from just west of the Mississippi trough to about the Texas-Louisiana border, drilling sites are located throughout the entire Louisiana shelf out to the 200-m depth contour. The nearshore zone along the Texas coast is characterized by relatively high densities of structures from Sabine Lake to south of Corpus Christi, but most of the southernmost nearshore areas, the central shelf, and the outer shelf areas of Texas have relatively few petroleum structures. Many of the tracts lying in these unexploited areas have been offered for lease but either have not been leased or the lease bids have been rejected. A considerable number of tracts in these areas have never been offered for lease, however. The exploration emphasis in the future may be on the medium- to deeper-water tracts off Louisiana for oil and gas, and a wider general exploration off Texas for gas reserves (*Offshore* 1981). Exploratory drilling has been somewhat limited by the availability of mobile rigs, but new rigs coming out of the yards during 1981 and 1982 are expected to alleviate this problem.

The distribution of major platforms in the Gulf of Mexico, graphed by year in which tracts were leased, is shown in Figure 3. Prior to United States Government jurisdiction in 1954, 454,382 ha (1,122,764 acres) had been leased (most in Louisiana) and 292 multi-well platforms were already in place on OCS lease blocks. Approximately 5,900,000 ha (14,600,000 acres) have since been leased by BLM from 1954-1980, with the largest areas being leased during 1962 and 1974. These tracts, along with those leased in 1960, also lead in the number of major platforms (1962 = 201 platforms; 1960 = 104 platforms; and 1974 = 101 platforms). The number of platforms on tracts obtained in 1974 will probably soon surpass the number on 1962 tracts, since a substantial number were to be set on 1974 tracts during 1981. The majority of platforms set in 1980 were installed on gas-prone tracts in High Island, West Cameron, East Cameron, and Vermilion areas (*Offshore* 1981).

Historical trends for major platform installation are chronologically depicted for 1947-1980 in Figure 4 (*Offshore* 1981). During the first decade of this period, installation of production platforms peaked in 1956. This was followed by a marked decline to relatively infrequent platform installation through 1963. From 1964-1974, production platform installation was reasonably frequent and somewhat stable. Beginning in 1975, the installation rate of major platforms increased dramatically, culminating in a record of 92 platforms placed in 1980. Platform construction in 1981 has continued at or near the record pace of 1980 with indications that the trend will continue for 2 or 3 more years before tapering off slowly (*Offshore* 1981).

1.3 TYPES AND PROPERTIES OF OFFSHORE PETROLEUM STRUCTURES

A typical offshore production area will contain all or some of five types of structures: multi-well or major production platforms, single-well platforms (often satellites of multi-well platforms), quarters platforms to house the work force, flare stacks, and pipelines. Major production platforms are large, complex structures supported by 12 or more legs and containing slots for up to 24 or more wells or well casings. Above water, major platforms have several decks on which crew members can be quartered, helicopters can land, drilling rigs can operate, petroleum products can be separated and stored, gas can be compressed, and pipelines to shore can be operated. These platforms can also be serviced by vessels which can load and offload heavy equipment and supplies by using cranes on upper platform decks. The subtidal area of platforms varies with depth since taller platforms typically have wider bases. In one gas and oil field in Texas waters about 20 m deep, major platforms provided about 3,800 m^2 of hard substrate (Gallaway 1980). Shinn (1974) estimated that a typical major platform in water 30 m deep provides about 8,173 m^2 of substrate. If the latter value is assumed to be more representative of the average major platform, and given that there are currently at least 1,223 of these platforms in the northwestern Gulf of Mexico, nearly 1,000 ha (2,471 acres) of submerged steel substrate are provided by the vertical supports of major production platforms.

In addition to the area associated with vertical supports, hard substrate is also provided by considerable amounts of discarded or lost equipment and by dislodged shelled organisms that colonize the structure. If the base of a typical major platform is assumed to measure about 50 by 75 m, an additional 460 ha (1,137 acres) of bottom area in the northwestern Gulf of Mexico are subject to substrate hardening.

Single-well and quarters platforms are considerably smaller, providing about 550 m^2 submerged hard substrate and an additional 75 m^2 of debris-covered bottom area (Gallaway 1980). If the balance of the 3,500 platforms (less the major platforms) is assumed to be represented by structures of this general size, then up to 142 additional ha (351 acres) of hard substrate can be generated in the Gulf. In total, the 3,500 petroleum structures are capable of providing some 1,602 ha (3,957 acres) of artificial reef habitat in the Gulf of Mexico.

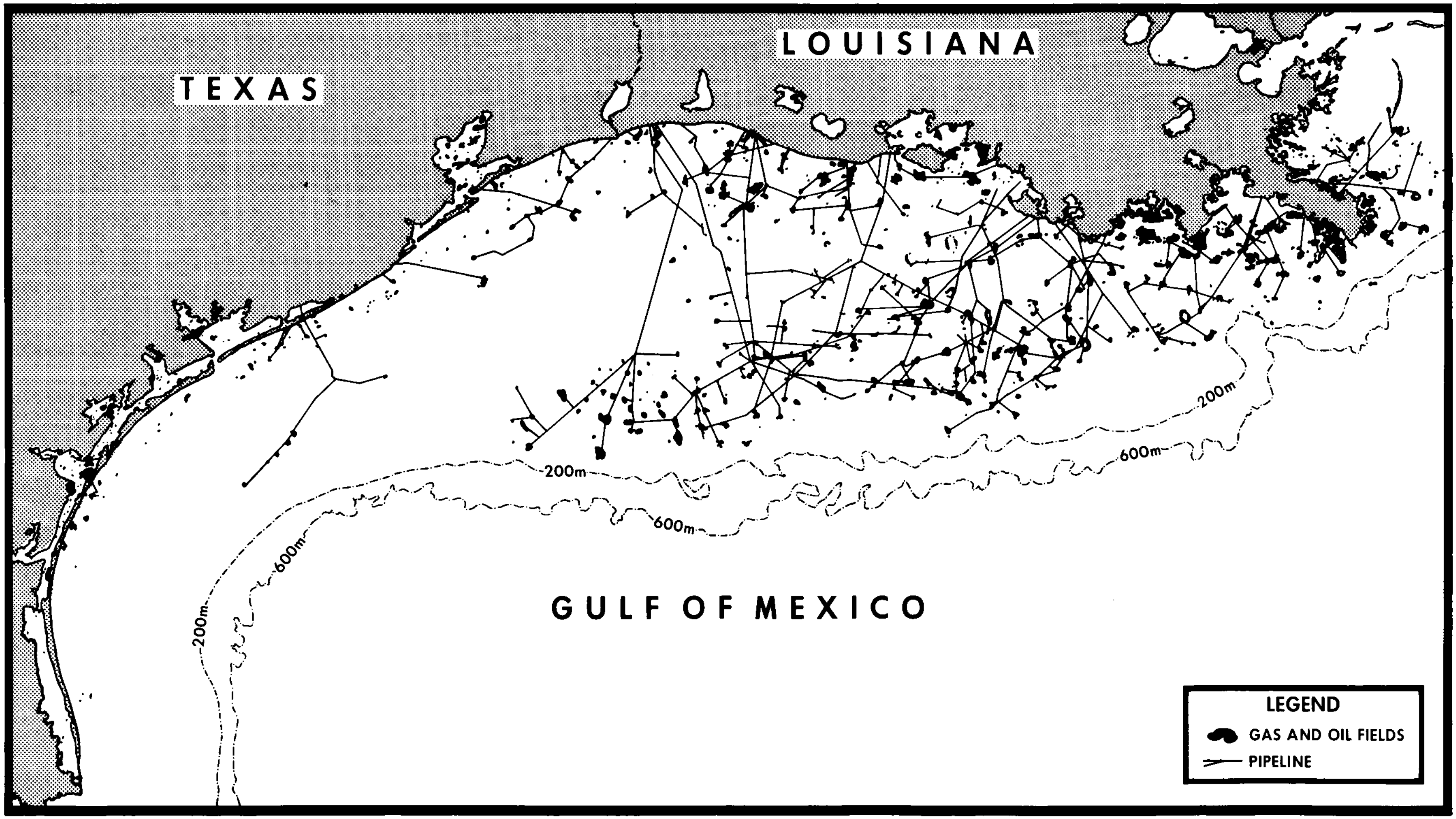


Figure 2. Distribution of gas and oil fields and pipelines on the Texas-Louisiana continental shelf. Map provided by TRANSCO Companies, Inc., 1979.

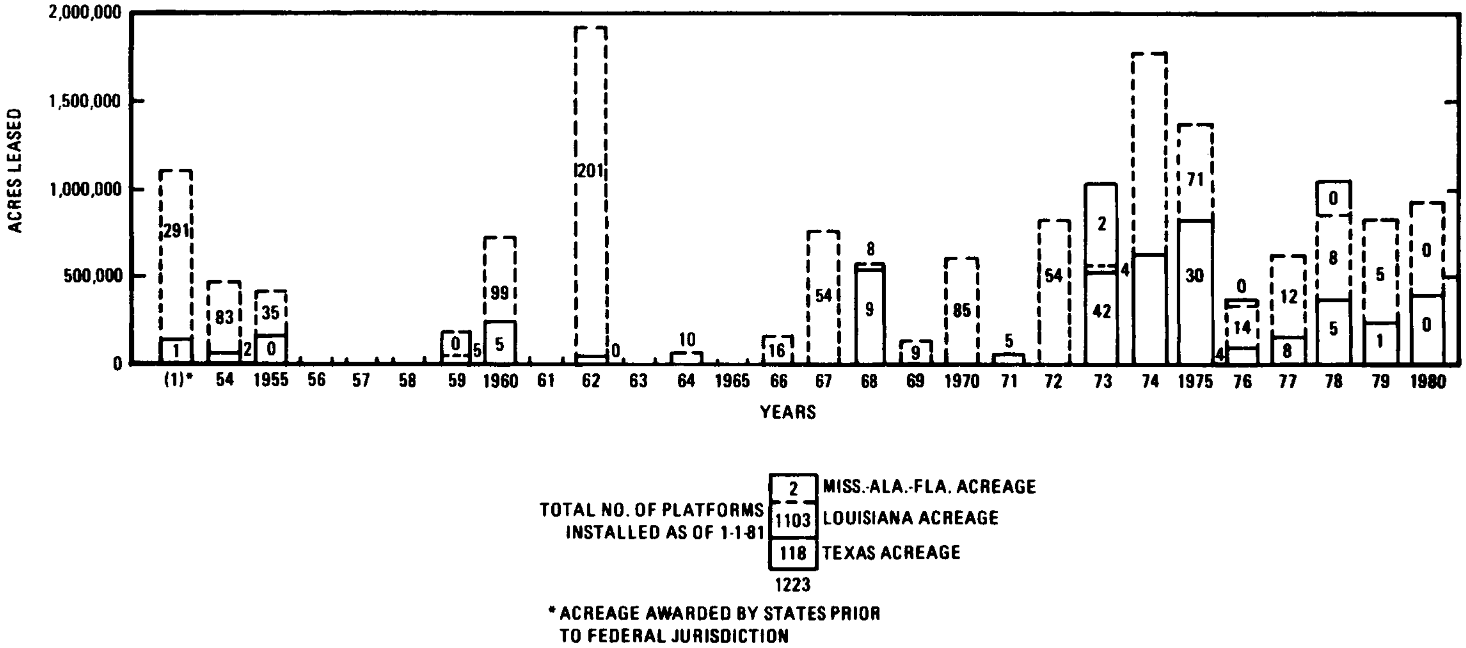


Figure 3. Amount of offshore acreage leased in the Gulf of Mexico by year and State, showing the respective number of major platforms in place.

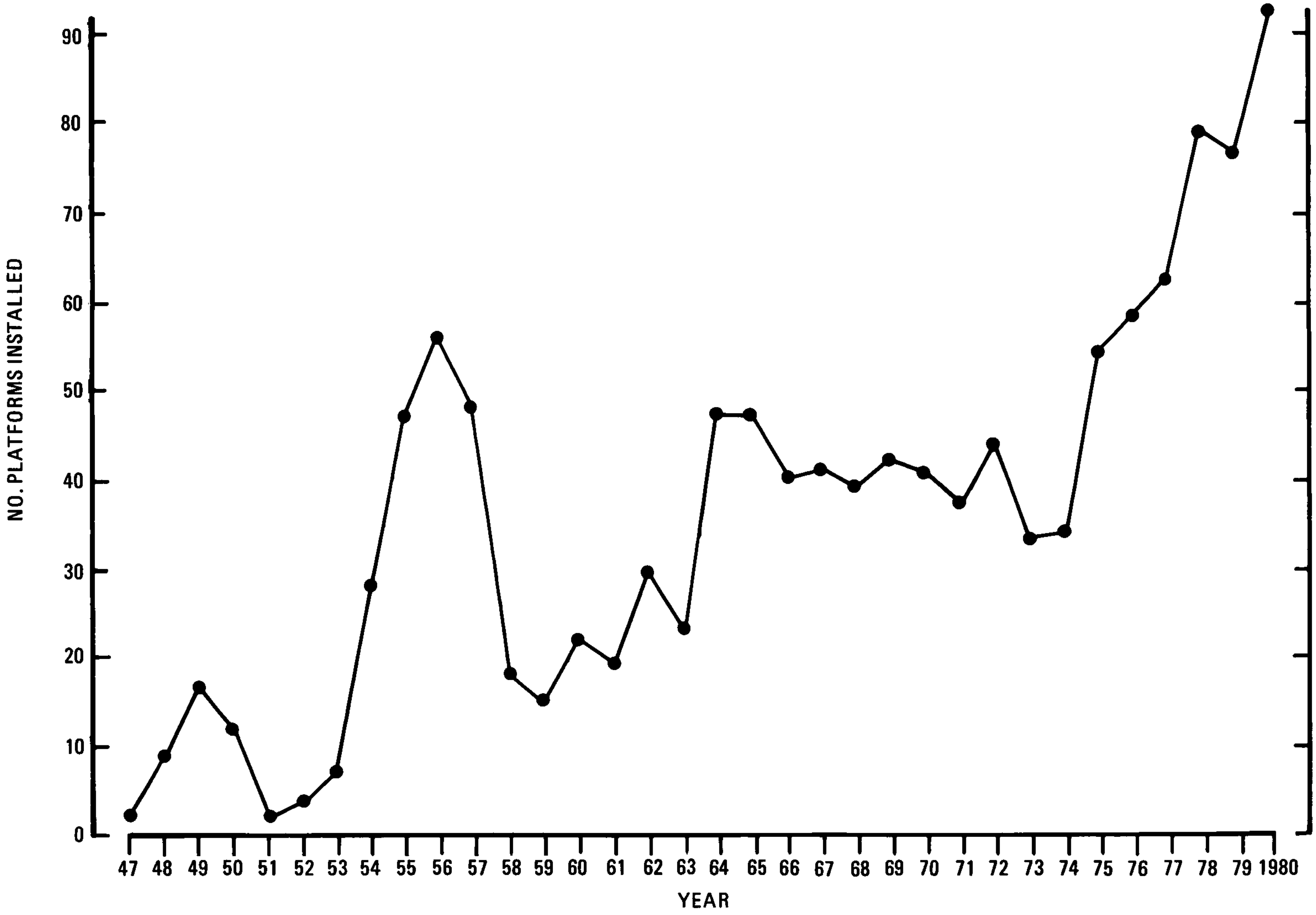


Figure 4. Number of major (multi-well) petroleum platforms installed each year in the Gulf of Mexico OCS, 1947-80. (From *Offshore* 1981.)

Typical wells require some 1 to 3 months to complete although only about 30% to 50% of the time is actually spent in drilling. As part of the drilling procedure, mud mixtures are circulated through the borehole to cool and lubricate the drilling bit and pipe, to remove cuttings from the hole, and to maintain well pressure and the integrity of the borehole. Being an integral part of the drilling procedure, muds are continuously washed from new cuttings and recycled through the system. The cuttings themselves are jettisoned overboard and sink directly to the bottom where they accumulate. In several months (as opposed to weeks or years) these discharged cuttings are either worked into benthic sediments or, as is more often the case, dispersed by bottom currents. Additional effluent associated with offshore platforms include drilling muds, produced waters, cooling waters, well-treatment fluids, deck drainage, and treated or untreated domestic wastes.

Occasionally during drilling of deeper formations, muds whose compositions differ from those which have been appropriate for shallower formations are required. Depending upon factors such as the nature of the solids control system and the composition and cost of the additives, some (or rarely, all) of the muds are discharged from the system to alter the composition of the fluids by displacement. During the life of a single well such events may occur eight to ten times, typically with 160,000-340,000 liter (l) of muds being discharged per event. The typical mud discharge during the drilling phase, however, consists of only about 8,000-32,000 l/hr. Representative discharge rates range from 4,800-160,000 l/hr. These volumes are the actual amounts of drilling fluids being discharged. Commonly, drilling fluids are diluted with seawater prior to their discharge; this results in higher total volumes of effluents with reduced concentrations of muds. The material being discharged consists of a fine particulate or solids phase, as well as a dissolved or soluble phase. The particulate materials either form flocculated clay spheroids and rapidly drift downwards to form a bottom plume, or are maintained in suspension. Along with the soluble phase, suspended particulates may form a turbid plume in the upper part of the water column. This plume is diluted at its edges by entrained seawater as it expands and is transported away from the discharge pipe. This progressively less turbid cloud often sinks until it reaches the thermocline or pycnocline. Even though the soluble phase may persist for some time, the solids phase is quickly diluted. When 39,750 l of drilling fluids were discharged at a rate of 729 l/min, background levels of suspended solids were reached within 500 m of the discharge pipe (Ayers et al. 1980).

Upon completion of drilling, the only discharge of any consequence associated with production platforms is produced ("formation") water. This briny effluent is separated from hydrocarbon products, and typically contains high concentrations of dissolved salts (up to 35,000 mg/l) including inorganic cations such as sodium, magnesium, calcium, and anions such as chloride, sulfate, carbonate, and bicarbonate. Hydrocarbons and other organic compounds are present in parts per million levels. Produced water is usually warm (30° to 40°C) and anoxic (Gallaway 1981). The volume of discharge varies considerably among formations and over time. An actively producing gas and oil production platform in the Buccaneer Gas and Oil Field (BGOF) 50 km south of Galveston, Texas, discharged an average of 160,000-223,000 l/day (Gallaway and Martin 1980), containing 382 g of alkanes and 17-23 g of a wide variety of light aromatic hydrocarbons (especially benzene, toluene, and ethylbenzene) (Middleditch and West 1980) for a total of 19% of the estimated 2 kg/day of petroleum hydrocarbons discharged from the platform. Large quantities of particulate sulfur (207 kg/day) were discharged from BGOF platforms. Sulfur is insoluble in water and has a specific gravity of about two, and thus may serve as the major transporter of oil through the water column to the sediments, if hydrocarbons can be absorbed onto sulfur particles. Oily sand is sometimes mixed with formation waters and discharged overboard, and may also transport hydrocarbons to the bottom, as may metal flakes from the platforms themselves. Contaminant levels in sediments beneath the BGOF platforms were highly variable, but typically greater than those in control areas more than 50 m away.

Operations on the major platforms in the Gulf of Mexico require workers to live on site. Living quarters are typically provided, often on an adjacent structure (see Figure 1). These quarters platforms usually have an electrical power generating unit (often fired by the natural gas being produced), a desalinization plant to provide freshwater, and a sewage treatment plant. The discharges from these activities (heated cooling water from the electrical generating plant, brines separated from seawater and treated sewage) are often combined in a single low-volume outfall. We are aware of only one estimate of the volume of such flows: 30 l/hr combined flow (Gallaway 1980).

1.4 BIOLOGICAL STUDIES OF PETROLEUM PLATFORMS

Few of the biological studies which have been conducted in the northwestern Gulf of Mexico have focused directly or indirectly upon the biological communities of petroleum platforms. Results of the first pertinent study were reported by Gunter and Geyer (1955). They described the biofouling community growing on legs of an oil platform in the northern Gulf of Mexico, and the colonization patterns on steel pipes experimentally placed at different depths around a platform. Although some work was performed on an experimental platform in the eastern Gulf of Mexico (Pequegnat and Pequegnat 1968), results of studies performed on petroleum structures in the northwestern Gulf of Mexico did not surface again until the publication of the *Offshore Ecology Investigations* (OEI), a series of comprehensive studies sponsored by industry and conducted by the Gulf Universities Research Consortium (for a review see Ward et al. 1979). As part of this effort, Bert and Humm (1979) described the composition of marine algae on platforms, George and Thomas (1979) described biofouling community dynamics and Perry (1979) compared benthic fish populations around production and drilling platforms to those in control areas.

Shinn (1974) was among the first researchers to describe the composition and vertical zonation of fishes around Louisiana offshore platforms. This study was followed by Sonnier et al. (1976), who compared fish faunas associated with natural reefs in the northern Gulf of Mexico to those around offshore petroleum structures of the region.

The Buccaneer Gas and Oil Field (BGOF) Study was administered by the National Marine Fisheries Service (NMFS) and sponsored by the Environmental Protection Agency (EPA) from 1976-1980. This study was directed solely towards determining the effects of a gas and oil field on the surrounding environment (for a review see Middleditch 1981). BGOF is located about 50 km from shore near Galveston, Texas, in water 21.5 m deep. Summarized results of specific studies on biofouling communities may be found in Fotheringham (1981) and Gallaway et al. (1981a); on platform-associated fishes in Gallaway et al. (1981a); on birds in Aumann (1981); and on ecosystem dynamics in Gallaway and Margraf (1978), Fucik and Show (1981), and Gallaway et al. (1981a).

During 1978-1979, BLM also supported investigations of petroleum production platforms in the central Gulf of Mexico west of the Mississippi River Delta (Bedinger et al. 1981). This effort was dedicated primarily to assessing the cumulative effects of contaminants from petroleum platforms at some distance away from the production facilities (as opposed to the immediate area) with regard to platform age, type of product, water depth, and bottom conditions. The Central Gulf Platform Study also included research on biofouling and platform fish communities (Gallaway et al. 1981b). The purpose of the latter program was to investigate the "artificial reef" effect of selected petroleum structures characteristic of various production types and durations. Particular attention was directed toward two nearshore platforms (water depths 12 m and 18 m; distance from shore 4.8 km and 19.3 km) and two more remote platforms (water depth 35 m and 46 m; distance from shore 42 km and 53 km).

Current projects include BLM and NMFS studies of fishing activity around production platforms to assess their importance to recreational fishermen; effects of drilling and platform placement on the Flower Gardens Banks, a coral reef area approximately 200 km southeast of Galveston, Texas; industry monitoring programs of the effects of drilling and production activity in the vicinity of the Flower Gardens; and a BLM study of reef fish being conducted to assess fish populations at platforms, reefs and platforms near reefs in order to gather information on the effects of platforms on reef fish distributions. Data from these studies were not available for inclusion in this report.

CHAPTER 2

COMMUNITY DESCRIPTION

The composition of biofouling communities and fish assemblages associated with petroleum structures in the northwestern Gulf of Mexico varies considerably depending on such factors as location of the platform with respect to distance from shore, latitude, water depth, and age of the platform. Based upon biofouling and fish surveys conducted at 20 platforms in waters off Louisiana, Gallaway et al. (1981b) determined that three distinctive platform faunal groupings were represented: "Coastal," "Offshore," and "Bluewater" assemblages. Approximate boundaries for the zones characterized by these assemblages were from the beach to the 30-m depth contour (Coastal); 30- to 60-m depths (Offshore); and greater than 60 m deep (Bluewater) (Figure 5). The location and composition of these assemblages were undoubtedly influenced by a number of interrelated environmental factors including: (1) the distribution of turbid water layers; (2) seasonal extremes of temperature, salinity and dissolved oxygen; (3) primary productivity of the surrounding water column; and (4) the degree and extent to which the platforms are exposed to Caribbean water masses.

The biofouling communities of the three assemblages all have the same general structure in that they are composed of shelled forms which shape the general structure of the overall habitat, and an encrusting mat community which provides additional habitat for cryptic species. Coastal platform assemblages are typically dominated by one to several species of barnacles whose shells are covered by hydroids, bryozoans, and sponges. On Coastal platforms, the commercial oyster *(Crassostrea virginica)* is usually represented but is seldom abundant except in the protected areas of the angles and joints of the platforms. Offshore communities are highly similar but are dominated by pelecypods instead of barnacles. Offshore communities also have luxuriant growths of octocorals such as *Telesto* sp. and large masses of algae near the surface. Compared to the Coastal and Offshore biofouling communities, Bluewater biofouling assemblages are marked by low biomass. Algae and stalked barnacles are abundant at the surface, and pelecypods are abundant at greater depths. The encrusting mat only sparsely covers the platforms.

The BGOF, OEI, and two shallower Central Gulf Platform Study platforms were located within the Coastal zone, while the two deeper platforms of the Central Gulf Platform Study were in the Offshore zone. We have also examined 18 platforms in offshore Texas waters from near Galveston to a point near Brownsville. All of these have been in either the Coastal or Bluewater depth zones, and the assemblages present have been representative of the classes that would have been expected from extrapolations of the Louisiana investigations. The Bluewater assemblages seem to be virtually identical regardless of geographic location within the northwestern Gulf of Mexico. However, the Coastal biofouling communities on Texas platforms differ greatly from those in Louisiana waters, mainly in terms of the species composition of the dominant barnacles.

2.1 SELECTED BIOFOULING COMMUNITY COMPONENTS

The following section provides supplementary information on the biology of a number of fouling community groups found on or around petroleum platforms in the northern Gulf of Mexico. Emphasis is on life histories, faunal affinities, trophic interactions, reproductive patterns, and similar topics arranged by taxonomic category. This material will be most useful to readers unfamiliar with many of the animals and plants discussed in other portions of the report. The term "fouling" is hardly complimentary, accurately reflecting its original use to describe species which fouled the bottoms of ships, reducing their speed by increasing frictional drag. Many fouling organisms are well known biologically because of their economic importance to shipping and other marine industries. Petroleum platforms are also subject to drag considerations since they are designed to withstand certain maximum shear forces generated by the action of waves and currents. Fouling organisms increase those forces sufficiently to require the use of antifouling methods such as toxic paints or mechanical scraping, or, as is the case in the Gulf of Mexico, "overbuilding" each platform to take the anticipated additional drag into account. Neither approach is inexpensive; for example, in the North Sea the current "fouling allowance" requires the use of materials with an additional strength or thickness equivalent to 5 cm of steel (Hardy 1981).

Many organisms found on petroleum platforms are restricted to a particular depth range. The same organisms may occupy a more limited depth range on natural substrates, where they are commonly exposed to predators and competitors not necessarily present on the

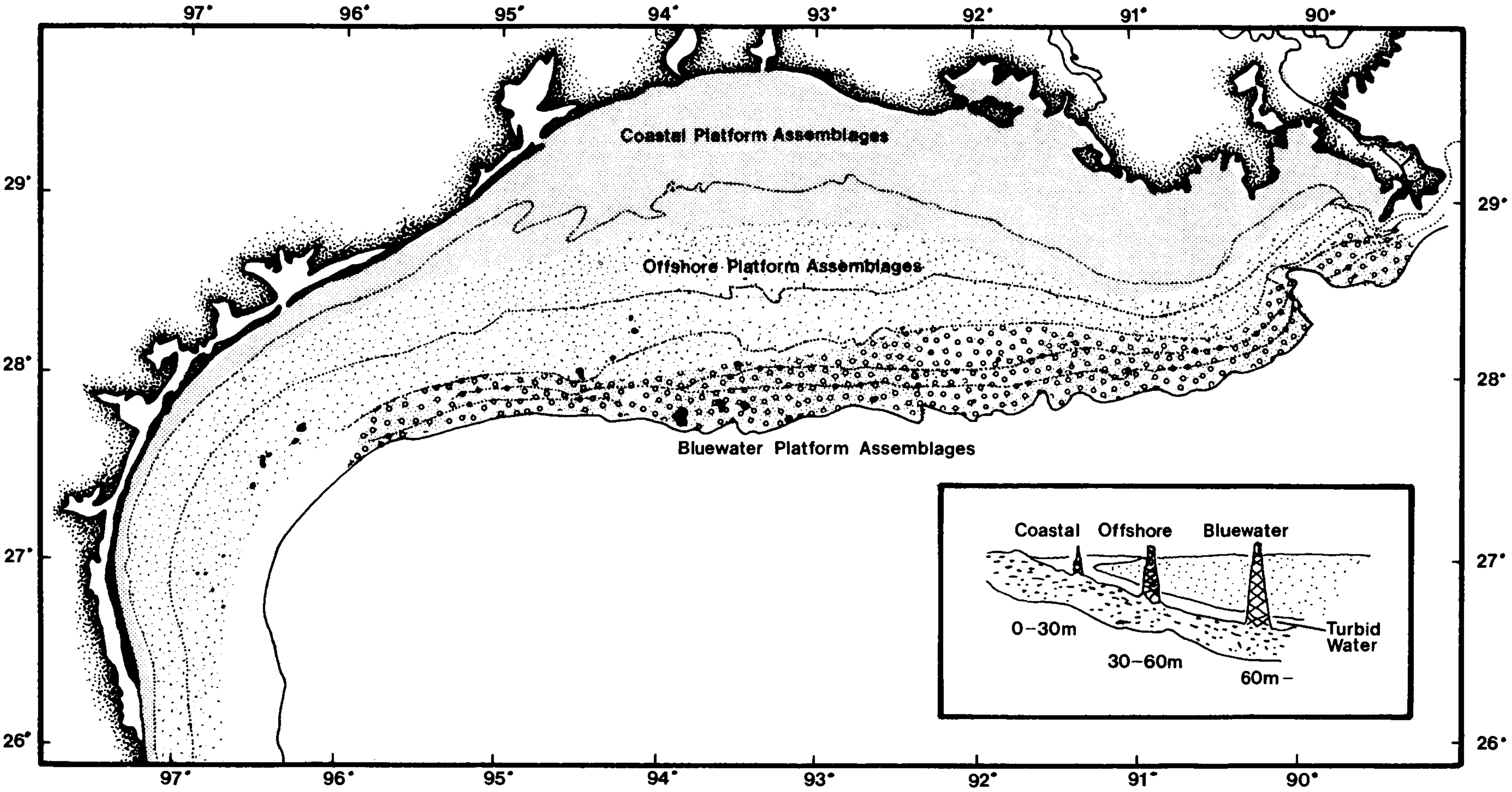


Figure 5. Distribution of characteristic production platform faunal assemblages in the northwestern Gulf of Mexico (after Gallaway 1981) showing relationship to turbid water layers (insert at bottom right following Shinn 1974).

platforms (Paine 1974, Wolfson et al. 1979, cf. Lewbel et al. 1981). The reason is that the platforms are commonly built on soft bottom, far from the nearest hard substrate. Organisms settling on platforms are not soft-bottom species; consequently, platforms represent a novel habitat (equivalent to islands) accessible only to those hard-bottom species able to drift on floating objects and to species with pelagic larvae capable of being carried to the platforms from the nearest breeding population. As a result, platforms harbor an abbreviated list of hard-bottom species compared to similarly complex natural substrates. Those species which can successfully populate the platforms often expand their depth range due to the paucity of normal predators and/or competitors.

Furthermore, the species which are not location-dependent for food (e.g., filter-feeders) are more likely to be effective platform colonists. In fact, the majority of platform fouling organisms fit this description; most feed on plankton, and many, such as barnacles and hydroids, have very wide geographic ranges indicating broad environmental tolerances. Cosmopolitan species capable of attaching to ships and withstanding environmental conditions en route to the platform areas may also be expected to have some probability of prospering once they become established. Several biogeographic provinces are represented on petroleum platforms in the northern Gulf of Mexico, including the Carolinean province (extending from the southeastern coast of the United States into Texas waters, but bypassing the more tropical Florida peninsula); the Caribbean or tropical biofouling assemblage (which includes warm-water forms primarily carried northward as larvae); and the Mexican province of nearshore species extending northward along the southern Texas coast (Gallaway et al. 1981b).

Bacteria

Marine bacteria associated with petroleum structures may be either attached to a substrate or suspended in the water column. Those attached to substrates may live on platforms and other artificial structures, on the epibiotic layer of larger organisms, or on benthic materials such as sediment grains. In any case, bacteria would be common whether or not any structures present were petroleum-related; indigenous bacteria are found in most marine environments. As a group, bacteria can tolerate a wide range of ecological conditions, persisting either because of or in spite of situations that may be unfavorable for other organisms. Bacteria reproduce relatively rapidly by cell division, thus making it possible for bacterial populations to be maintained even in areas of continual dilution by convection, as long as individuals that are removed are replaced by others at an equivalent rate.

Marine bacteria are of particular interest in petroleum-related studies for several reasons. First, bacterial activity on steel structures may cause significant corrosion due to the release of inorganic acids. This is an extremely localized effect and will not be discussed further in this report. Second, some bacteria can utilize petroleum hydrocarbons metabolically (e.g., Childers et al. 1981) and are active agents on a global scale in preventing "the accumulation of hydrocarbons in aquatic systems" (Oppenheimer et al. 1979). In other words, they can consume and degrade large quantities of petroleum, e.g. from an accidental spill. Third, oil-degrading bacteria can serve as indicators of petroleum availability or exposure (see Cretney et al. 1981 for a list of recent literature). For example, in offshore oil fields and appropriate control areas in the North Sea, the concentrations of hydrocarbons in the water column and in the sediments were directly correlated with the abundance of oil-degrading bacterial populations (Gunkel et al. 1980).

Recent large-scale research efforts to characterize marine bacteria associated with petroleum exploration and development in the northern Gulf of Mexico include the OEI, the Central Gulf Platform Study, and the BGOF Study. The OEI marine bacterial program studied forms suspended in the water column (Oppenheimer et al. 1979) while the Central Gulf Platform project considered marine bacteria in sediments (Brown et al. 1981). The BGOF study took both sediment and water-column bacteria into account (Sizemore et al. 1981). The following material summarizes and comments upon the findings of those three programs with respect to marine bacteria. Water-column studies are treated first, followed by sediment studies.

The OEI study area was near the mouth of the Mississippi River, off Timbalier Bay, Louisiana. Bacterial samples were cultured from water samples taken near production platforms and from control areas throughout the Gulf of Mexico. The authors reported that numbers of heterotrophic (i.e., non-photosynthetic) and hydrocarbon-oxidizing (i.e., oil-degrading) bacteria were not elevated in samples from platform areas vs. control areas. There was no correlation between the abundance of hydrocarbon-oxidizing bacteria and the concentration of hydrocarbons in the water samples, both of which were considered low. Samples from surface and 6-m depths were essentially the same in terms of bacterial abundance. Individual bacterial taxa were not described.

The authors interpreted their data to imply the existence of steady-state conditions in which the bacterial population in the OEI region was capable of degrading virtually all commonly found types of hydrocarbons, which were present at such low levels that Oppenheimer et al. (1979) concluded "that an adequate inoculum was naturally present to respond to oil contamination in nature."

The Central Gulf Platform Study project sites were located immediately west of the mouth of the Mississippi River, encompassing the stations previously sampled by OEI investigators. No cause-and-effect relationships were demonstrated between human activity (i.e., petroleum production) and the abundance of bacteria in sediments. Sometimes statistically significant differences existed between control sites and platform sites, while at other times no differences were noted. Seasonal changes in abundance were marked, and appeared to be a result of changing river flow and currents which altered the surficial sediments from which the sample bacteria were collected. These natural changes masked man's activity. As in the OEI study, the authors differentiated between total heterotrophs and those which could degrade oil. Mean values for the three cruises ranged from 550,000-1,100,000 aerobic heterotrophic colony-forming units (CFU) cultured on marine agar per cm^3 of sediment for control areas, compared to 84,000-3,700,000 CFU/cm^3 for primary platform study sites. Equivalent values for oil-degrading bacteria (cultured on oil agar) ranged from 6,000-2,200,000 CFU/cm^3 (Brown et al. 1981).

Average values for control sites vs. platform sites in the Central Gulf Platform Study were (based on the mean of three cruise means) 566,666 total heterotroph CFU/cm^3 of sediment and 69,000 oil-degrading CFU/cm^3 vs. 1,535,333 total heterotroph CFU/cm^3 and 1,008,666 oil-degrading CFU/cm^3 respectively. The relative proportion of oil-degrading bacteria in sediments (66%) was much higher than that found in the OEI water samples (12%). Sometimes more colonies were cultured on oil media than on standard marine agar. The authors also pointed out that previous work has suggested that the "level and proportion of hydrocarbon utilizers appear to be a sensitive index of hydrocarbons in the environment" (Brown et al. 1981, from Atlas 1981). Given the relatively high proportion of oil-oxidizing bacteria found in the Central Gulf Platform Study, the authors postulated that the entire study area had been previously exposed to hydrocarbons (a safe conclusion).

The Central Gulf Platform Study included an attempt to quantify the amount of oil that could be oxidized by bacterial activity in sediment. While there is some controversy about the best way to make this assessment, an average value of 56 μg hydrocarbon carbon/cm^3 of sediment per day was given as a realistic estimate. In addition, several bacterial metabolic activities such as sulfur oxidation and enzymatically mediated reactions were found not to be adversely affected by low levels of added petroleum.

The BGOF marine bacterial study utilized water and sediment samples collected from two platforms and a control area about 9 km away. Analyses included abundance estimates, taxonomic characterizations, assays of the ability of bacteria to tolerate components of the brine discharged from the platforms (e.g., sulfur, petroleum hydrocarbons, and biocides), and tests of oil and sulfur degradation by bacteria from the study area (Sizemore et al. 1981).

Although the numbers of bacteria in the water column and in the sediments averaged slightly higher in the control area than in the study sites during some seasons, the authors did not consider the differences between sites to be more important than those within sites at different water depths or on different dates. Parallel seasonal taxonomic changes were noted in the waterborne and sediment bacterial populations of both control and platform sites. The "general physiological profile of the bacterial population," as determined by growth on various culture media, showed no significant difference from platform to control site, with one major exception. The control site had consistently lower proportions and numbers of sulfur-oxidizing bacteria than did the BGOF platform area, which also harbored large numbers of sulfate-reducing bacteria (32% of the total population).

Brine discharges from the BGOF platforms inhibited the metabolic activity and growth of bacteria from laboratory cultures, but not of bacteria from the platform area, some of which were stimulated by addition of brine components to their growth media. Most (90%) bacteria in water samples taken from the platforms were attached to particles larger than 3μg, but the particles in the water directly below the brine discharge were apparently unsuitable for bacteria. The authors attributed this effect to either high concentrations of discharge or to some feature of the discharge itself, such as biocides.

Hydrocarbon-degrading bacteria were present in greatest abundance within 100 m of the BGOF platform bases, as were sulfur oxidizers and reducers (up to 9% oil degraders, up to 7% sulfur oxidizers, and up to 36% sulfate reducers). Little sulfur-oxidizing activity was evident in culture, due (probably) to the high proportion of non-obligate heterotrophic sulfur utilizers, which rely primarily on organic material rather than upon sulfur as an energy source. Sulfate reduction was not assayed. Hydrocarbon oxidation was quite effective; most n-alkane hydrocarbons were degraded by cultures within 7-28 days, with other components such as aromatics requiring more or less oxidation time depending on the strain of bacteria present.

In addition to these studies, Sizemore et al. (1981) investigated bacteria from diseased and healthy fish around the BGOF to determine if the observation of Gallaway et al. (1981a) of increased numbers of fish with lesions might be attributable to particular pathogens. Only one taxon known to be pathogenic (*Aeromonas hydrophilia*) was detected; this pathogen may be involved in fish diseases associated with polluted water.

The most significant findings of the three northwestern Gulf of Mexico oil platform marine bacterial programs were:

1. Numbers of bacteria associated with platforms do not differ greatly from those in control areas.
2. Proportions of oil-degrading bacteria adjacent to platforms are often somewhat higher than in control areas.
3. Oil-degrading bacteria appear to be able to reduce levels of hydrocarbons in the vicinity of platforms to near-background levels under conditions of chronic, low-concentration discharges.
4. Produced water discharges containing sulfur, hydrocarbons and biocides may engender large proportions of sulfur-reducing bacteria and hydrocarbon-oxidizing bacteria in their immediate vicinity.
5. Normal marine microbial activities are apparently not adversely affected by low levels of oil.

Algae (Plate 1a)

Marine algae in the northern Gulf of Mexico tend to be rather inconspicuous forms compared to those found on the east and west coasts of the United States, where macroalgae such as giant kelp may define entire biological communities. While solid substrate is required for the attachment of large algae, most substrates in the northern Gulf are soft sediments (Edwards 1976). Consequently, flora of petroleum platforms in the Gulf of Mexico differ from the large, luxurious algal growths previously described for platforms in temperate waters (e.g., Carlisle et al. 1964, Evans 1981, Hardy 1981, Moss et al. 1981). Bert and Humm (1979) recognized the Louisiana platforms as unique algal habitats, stating that other than platforms, virtually no "suitable solid substrate for algal attachment [existed] in this area," and that platforms thus "constitute[d] a substrate of major importance to the occurrence and distribution of marine algae."

A detailed taxonomic study of the marine algae associated with petroleum platforms and structures in the northern Gulf of Mexico was first performed during the OEI (Bert and Humm 1979). The platforms had a surprisingly rich and diverse algal assemblage. The OEI study raised the number of known marine algal species in Louisiana waters to 180, of which 120 (67%) were present on the platforms. The two platforms with the most species (76 and 63 species) were farthest from the Mississippi River mouth. A transect of three stations near the delta, going from nearshore to offshore, had 40 (the fewest seen), 50, and 53 species, respectively. Most of the algal species collected during the OEI study were either microscopic or relatively small forms a few centimeters high. Some species grow colonially into large masses, though individual plants may be fairly small (e.g., the green alga *Enteromorpha*). The OEI investigators did not provide data on algal biomass or abundance. Green algae dominated the OEI species list (35% of the number of species recorded), followed by red algae (31%), blue-green algae (18%), and brown algae (16%).

The BGOF study included the compilation of a checklist of 16 species of marine algae which were collected as part of the fouling community study (Fotheringham 1981). As in the OEI area, most of the species on the list are relatively small, though colonial forms such as *Enteromorpha* and *Chaetomorpha* were present. Most microscopic species (e.g., all of the blue-green algae) were not included in the Buccaneer list. Since no attempt was made to identify these more difficult taxa, and given the very large number of microscopic species that appeared in the OEI list, it is quite likely that the majority of species present at BGOF were omitted from the compilation.

No quantitative information was provided by Fotheringham (1981) on a species-by-species basis; most of the 16 species studied were listed as "present" in the shallower portions of the platforms, particularly in the littoral (i.e. intertidal) zone. Few species were present near the bottom of the platforms, probably as a result of low light levels due to the nepheloid layer underlying Gulf of Mexico waters (Oetking et al. 1979). Some density estimates were furnished in terms of percent cover for major groups of algae visible in quadrat photographs. Large temporal fluctuations and pronounced differences between platforms and between legs of the same platform were observed. For example, at 3 m depth on January 1, 1977, one platform leg had about 6% cover of red algae and the same of green algae, while another leg on the same platform showed 8% cover of red algae but no green. On another platform on November 1, 1976, coverage of green algae ranged from 93% at 6 m to 98% at 15 m, then dropped to zero at 18 m; red algae were not observed at any depth. On the same platform 2 months later, green algae were only recorded at 3 m (2%), and red algae were present in small amounts at 3 m and 15 m.

Recolonization studies at BGOF showed algae to be among the first species to settle and grow in experimentally scraped areas, though seasonal effects were marked. In summer, green algae on one platform occupied about 4% cover in quadrats at 15 m depth which had been scraped 56 days previously. In winter, greens accounted for 30% coverage 90 days after scraping at the same depth. Enclosing the scraped area in 3-mm mesh wire cages substantially reduced the cover of algae within the cases, suggesting that either the cages themselves inhibited algal growth (e.g., by shading or reducing water flow), or that one or more competitively dominant species formerly controlled by their predators might have prospered when protected from those predators (cf. Dayton 1971). For example, 90 days following summer scraping on quadrats at a depth of 15 m on one BGOF platform, the bryozoan *Savignyella lafonti* was present at less than 1% coverage in uncaged plots, while it exceeded 16% within the cages.

In other work at BGOF, Howard et al. (1980) investigated the taxonomic composition and biomass of an algal community which included 17 species of macroalgae contained in harvest samples. Most of the algae were collected at depths of 3 m and 8 m, although some species were restricted to shallower or deeper waters. Summer biomass for macroalgae was much higher than winter biomass (17.3 g/m^2 vs. 1.55 g/m^2, respectively, for all samples combined). Shallow water samples contained about an order of magnitude more algal material than did deeper samples. Algal biomass during the winter was higher at structures without produced water discharges, though patchiness during the summer made it impossible to discern any such pattern. The biomass dominants in summer at 3 m were (in order of abundance, by weight): (1) an unidentified green alga, (2) the red alga *Polysiphonia subtilissima*, (3) the green alga *Derbesia vaucheriaeformis*, and (4) the red alga *Callithamnion byssoides*; at 8 m, the summer dominants were (1) *C. byssoides*, (2) *Polysiphonia denudata*, and (3) the green alga *Cladophora* sp. In the winter, the biomass dominants at 3 m were (1) *C. byssoides*, (2) the brown alga *Giffordia mitchelliae*, and (3) the green alga *Bryopsis hypnoides*; at 8 m , the winter dominants were (1) *D. vaucheriaeformis*, (2) an unidentified red alga, and (3) *C. byssoides*. No surface (intertidal) samples were taken, but algal biomass has been estimated at over three times that at 3 m, and made up primarily of *Enteromorpha* and *Cladophora* (George D. Dennis III, LGL; personal communication 1981).

The Central Gulf Platform Study included a platform-by-platform survey of macroalgae taken in fouling community samples (Gallaway et al. 1981b). Taxonomic identifications were accompanied by pigment biochemistry to differentiate between microalgae and by biomass estimation. Pronounced variation between platforms was the rule. Twelve taxa were recognized from the four "primary" platforms where studies were most intense. Nine taxa were identified to the genus level (*Agardhiella, Acrochaetium, Ceramium, Derbesia, Goniotrichum, Herposiphonia, Oscillatoria, Polysiphonia,* and *Sphacelaria*). Algal cover was greatest in samples from the upper portions of platforms, and increased with increasing distance from the shore and from the turbid Mississippi River plume. With increasing water clarity, more algae were found in deeper samples.

The major conclusions which can be reached about marine algae on petroleum platforms in the northwestern Gulf of Mexico are:

1. A very large number of algal species are associated with the platforms, even in turbid nearshore conditions. Most species are relatively inconspicuous or microscopic, however, and species lists which omit these taxonomically more transient forms will be incomplete.
2. The greatest portion of algal biomass on petroleum platforms in the northern Gulf of Mexico is in the area closest to the surface, where

filamentous and/or thin tubular forms such as *Enteromorpha* predominate. Near the bottom, where a nepheloid layer may severely restrict light, algal biomass may approach zero.

3. Marine algae are important colonizers, accounting for a large share of the surface area in new or recently exposed solid substrate.

Sponges (Plates 2a and b)

Sponges are primitive animals consisting of several layers of cells supported by a matrix of organic matter, calcareous or silicious spicules, and/or proteinaceous fibers. The organization of the layers determines the size and degree of complexity of a sponge. Sponges may form simple cups or sheets, or be convoluted into massive structures several meters in diameter. Whatever the external shape of sponges, they all function similarly. Water is drawn through the outer layer of cells by an active pumping process, passes through numerous microscopic channels and chambers lined with flagella-bearing cells which produce the flow of water, and is ejected through the inner layer of cells into cavities which are connected to the outside via one or more exhalent orifices. On its passage through a sponge, water has its oxygen and organic matter removed by the sponge, and to it are added wastes to be excreted with the outflow. A large number of marine sponges harbor internal symbionts such as blue-green algae or intracellular bacteria; the biomass of *Verongia* may be up to one-third or more intracellular bacteria (Vacelet 1975, from Barnes 1980).

Sponges are extremely efficient filters; those few marine sponges which have been examined physiologically appear to feed on organic matter well below 1 micron in size, including planktonic organisms such as bacteria and colloidal material (Reiswig 1971). Pump rates are surprisingly high; for example, *Verongia lacunosa* individuals having a total volume of about 500 cm^3 pump an average of approximately 100 l/day (i.e., 200 times their own volume/day), and this value appears to be at the low end of the scale (Gerrodette 1981). Assuming that an average Gulf of Mexico petroleum platform has a surface area of about 3,800 m^2, and has an annual average of about one-third of that area covered with a layer of sponge mat approximately 1 cm thick (G.S. Boland, LGL; personal communication 1982), and if one-half that thickness is made up of sponge (rather than hydroids or algae), the average volume of sponge supported by each platform is 6.3 m^3. At a daily pumping rate of 200 times sponge volume, one might expect the sponges on a typical platform to filter about 1,300 m^3 of water per day.

Sponges reproduce both sexually and asexually. Most sponges are sequentially hermaphroditic, producing swimming larvae which metamorphose into sessile adults after settling. Many species of sponges have indeterminate growth patterns, spreading out over available substrate and assuming whatever form is dictated by environmental conditions. Small portions of the original adult may regenerate or form other adults if physically cut off.

Taxonomic problems are rife within the sponges. Classification of sponges is not based upon external appearance, since this feature is so variable, but rather upon spicule morphology. As many sponges look similar externally, most species cannot be reliably differentiated in the field by visual means. Even within the same individual of the same species, spicules may vary in size and shape, and specialists are required to properly identify most sponges. Consequently, the majority of sponges are probably undescribed. In this group, however, it seems reasonable to accept an ad hoc ecological lumping, since most sponges are very similar trophically. While this approach is not aesthetically appealing (especially to taxonomists), for all practical purposes one sponge is very much like the next sponge, viewed strictly from a trophic standpoint. Sponge species have definite habitat requirements and differ in their associated communities, their abilities to overgrow or be overgrown by adjacent species, and so forth. These comments may best be interpreted as an apology for the abysmal state of sponge classification, which forces most authors to leave sponges unidentified.

The OEI investigation of nearshore Louisiana platforms did not discuss sponges in detail, but their biomass (163 g/m^2) was second only to barnacles in samples collected on a typical platform at a depth of 2.4 m in winter (George and Thomas 1979). Below that depth, they declined rapidly to negligible values at 12.8 m. Surveys on the same platform in midsummer showed values 10%-15% of those at equivalent depths in the winter, indicating a seasonal decline occurred during the warmer months. Sponges were not found to be a significant colonizing group in test panels suspended to collect settling species in the OEI area; one unidentified sponge was listed to be present only on test panels suspended from a platform about 83 km from shore.

The Central Gulf Platform Study observed sponges to be most important on two Coastal platforms in Louisiana waters. At one platform, sponges accounted for 10% cover at 10 m, but were not common near the surface; at the other platform, sponges were dominant at the surface (45% cover) and abundant at 10 m (22% cover). Sponges did not account for significant cover at either of the two Offshore platforms, indicating a strong habitat preference for nearshore environments. The most important species was a member of the family Clionidae (Gallaway et al. 1981b).

On BGOF platforms, Fotheringham (1981) identified 13 species of sponges. Fotheringham supplied two apparently contradictory sets of data for sponges; one table entitled "Seasonal and vertical distribution of algae and invertebrates" listed sponges as "present" only in the summer. However, more detailed information on percentage cover occupied by important species on the two platforms surveyed indicated heavy winter sponge growth for several species. Several sponges spanned broad depth ranges. For example, in November sampling on one platform, *Haliclona loosanoffi* was abundant from the surface down to 21 m, with a striking increase in relative importance with depth (up to 99% coverage at 15 m), excluding the section immediately adjacent to the bottom. However, most species were more restricted in depth distribution; e.g., seven species were identified only within one 3-m band. Coverage was patchy and variable from one sampling period to the next. Two months later on the same platform, coverage of *H. loosanoffi* was nil down to 15 m, where it occupied 73% of the available space; at 18 m it had expanded from 0% coverage in November to 80% coverage in January. In contrast to the OEI study, sponges on the BGOF appeared to be important colonizing organisms on experimentally bared substrates. Species of *Haliclona* appeared to dominate both winter and summer experiments, in both caged and uncaged quadrats.

Major conclusions about sponges on platforms in the northwestern Gulf of Mexico include:

1. Sponges account for a large proportion of the mat of fouling organisms which covers the shells of barnacles and bivalves attached to platforms.
2. The sponges on nearshore Louisiana and Texas platforms show winter growth and a summer dieback. Sponges are relatively unimportant from a biomass standpoint on Bluewater platforms.
3. Sponges on platforms have broad depth tolerances, with some species preferring upper portions of platforms and shunning the areas immediately adjacent to the bottom, while other species show an inverse of this distribution.
4. Sponges are important colonizers of bare substrate at BGOF, but not in the OEI area.

Barnacles (Plates 3a and b)

Barnacles are marine crustaceans which are sessile as adults. While approximately one-third of the 900 species of barnacles are parasitic or commensal on other organisms, most species are free-living and are attached to solid objects such as ships, rocks, shells, or artificial substrates such as oil platforms (Barnes 1980). Free-living forms include stalked barnacles, which are attached by a peduncle or long neck-like structure, and stalkless barnacles. Both stalked and unstalked free-living forms are either wholly or partially protected by calcareous plates. In unstalked barnacles, five or more of the plates are typically fused into a cup-shaped shell within which the living tissue is shielded by several movable plates that can act as a cover for the cup. Free-living barnacles feed on suspended particles of organic material in the water, which they filter through specialized thoracic appendages.

Many free-living barnacles have sharply zoned intertidal or shallow subtidal distributions, but others show few restrictions and are found over a wide depth range (Hurley 1973a). Barnacles are very successful at colonizing exposed structures such as oil platforms due to several features of their life histories. When presented with suitable substrate, their ability to settle and adhere is remarkable; for example, larvae of several species can settle on objects such as vessels moving at 25 km/hr (Dalley and Crisp 1981).

Since barnacles are suspension-feeders, a wide variety of environments are suitable from the standpoint of food availability, so long as sufficient plankton is present. On the other hand, since the choice of substrate is permanent, once a larva settles, a poor location will affect adult survival and reproduction. The planktonic larvae of intertidal barnacles exhibit very specific depth and substrate preferences for settling, probably because small vertical distances in an intertidal area may result in exposure to radically different physical and biological conditions. Conversely, some subtidal barnacles show quite broad depth and substrate preferences (Hurley 1973b).

Most free-living barnacles are hermaphroditic and reproduce by cross-fertilization with adjacent individuals. Settlement is typically gregarious, favoring the development of large masses of barnacles in the same location (Knight-Jones 1953). The fecundity of those species of *Balanus* which have been examined for reproductive potential is truly impressive, ensuring a very large number of planktonic larvae that can settle on any suitable substrate. For example, *Balanus pacificus* has been estimated to produce 15,000 embryos per brood for the first year after maturity, and averages 28 broods per year, for an annual total of 420,000 nauplii (Hurley 1973a). Attainment of sexual maturity is rapid in many species of *Balanus*; e.g., *B. tintinnabulum californicus* is often sexually mature at an age of 9 to 12 weeks (Coe and Allen 1937) and *B. eburneus* is sexually mature at 8 weeks (Moore and Frue 1959).

The biomass dominants in the Coastal zone of Louisiana are unstalked barnacles of the genus *Balanus*. George and Thomas (1979) reported that in the OEI study, a shallow platform (2.4-3 m water depth) in Timbalier Bay harbored 60,402 barnacles/m^2. On several other deeper water platforms, barnacle densities ranged from 900-12,250/m^2 in water less than 9.1 m deep, below which densities dropped rapidly. The two Coastal platforms included in the Central Gulf Platform Study averaged 6,751 barnacles/m^2 (Gallaway et al. 1981b).

Of particular interest is the observation by George and Thomas (1979) that the most abundant species of barnacle, *Balanus reticulatus*, had not been recorded in the Gulf of Mexico before the OEI study. In light of current shipping traffic between oil ports, transport of this barnacle by vessels and recent introduction seem intriguing possibilities. *Balanus reticulatus* has been re-identified as a subspecies of *Balanus amphitrite*, *B. amphitrite niveus* (Gallaway et al. 1981b). *Balanus amphitrite* is a cosmopolitan species known to be a biomass dominant in shallow water (to 3 m on offshore petroleum platforms in the Gulf of Arabia, Basson et al. 1977). The numerous subspecies of *B. amphitrite* have varying ranges of salinity tolerance (Henry 1959).

Balanus amphitrite niveus is a widespread subspecies somewhat restricted to warmer seas. *Balanus amphitrite niveus* was found at all depths and stations in the OEI study. It settled seasonally from May to December, but was rare in January and during the spring (George and Thomas 1979). It has been reported not to be tolerant of low salinities and not to occur commonly in estuaries (Moore and Frue 1959). *Balanus amphitrite niveus* does range into fairly shallow water, as it was the most common inshore fouling organism (over 60,000 individuals/m^2) on a platform examined by the OEI in less than 3 m of water in Timbalier Bay, Louisiana, where salinity ranged from 20-28 ppt typically (George and Thomas 1979). In the Central Gulf Platform Study, Gallaway et al. (1981b) commented that *B. amphitrite niveus* was "predominantly an inshore species, although it did occur offshore where it was mostly restricted to the surface."

The second most common species of *Balanus* on the two Coastal platforms of the Central Gulf Platform Study was *Balanus improvisus*, a finding which concurs with the OEI work off Timbalier Bay. George and Thomas (1979) reported that *B. improvisus* was "present at all stations, but restricted to the upper 9.1 m on the pilings." George and Thomas (1979) noticed that *B. improvisus* was nearly always found on the shells of *B. amphitrite niveus* rather than on the platform surfaces themselves. They hypothesized that it was competitively inferior to *Balanus amphitrite niveus*. *Balanus improvisus* settled and grew as a dominant in January and March notwithstanding evidence that breeding was year-round, thus implying successful settlement might be restricted by competition with *B. amphitrite niveus* in other months (recall that *B. amphitrite niveus* settles between May and December). Gallaway et al. (1981b) categorized *B. improvisus* as "basically an inshore species," although it has wide thermal and osmotic tolerance (Moore and Frue 1959, Bousfield 1973). The distributions of both *B. amphitrite niveus* and *B. improvisus* are basically quite similar.

Two other species of *Balanus*, *B. eburneus* and *B. tintinnabulum*, were uncommon on platforms in the OEI study area, and were also sparse (as was an additional species, *B. calidus*) at the nearshore Central Gulf Platform Study sites. On a world-wide basis, however, *Balanus tintinnabulum* is broadly distributed in warmer waters. For instance, it is the biomass dominant on petroleum platforms in the Gulf of Arabia (Basson et al. 1977).

Barnacles were "the most abundant perennial inhabitants" of the BGOF platforms in Texas waters (Fotheringham 1981). *Balanus tintinnabulum* was "the most conspicuous structural feature of the Buccaneer Field fouling community" (Gallaway et al. 1981a). *Balanus tintinnabulum* was previously considered an incidental species on Texas offshore oil field structures (Gunter and Geyer 1955), but it occupied as much as 77% of the original substrate on BGOF structures, forming a layer 10-15 cm thick (Fotheringham 1981).

Competitive interactions (either direct or indirect) may play an important role in community dynamics of barnacles. Despite the clear dominance of *Balanus tintinnabulum* as a competitor on the BGOF platforms, its success may not be due to superior settlement characteristics. Fotheringham (1981) observed that in experimentally scraped quadrats, *Balanus improvisus* and *Balanus* (*amphitrite* complex) were the most important barnacle colonists, but that barnacle larvae in the plankton and colonists in scraped areas were uncommon, implying an unpredictable annual set. Gallaway (1980) reported that *B. tintinnabulum* could settle upon and overgrow smaller barnacles due to a combination of rapid growth and large eventual size. A similar role has been demonstrated for *Balanus balanoides*, which can smother, undercut, or crush the barnacle *Chthamalus* (Connell 1961). The introduction of non-local species may have drastic results; e.g., importing the barnacle *Elminius modestus* to European coasts resulted in the nearreplacement of the native form, *Balanus improvisus*, in some habitats (Bishop 1951, Kaestner 1959, Boland 1980).

General conclusions which can be reached about barnacles on platforms in the northwestern Gulf of Mexico include:

1. On Coastal platforms in Louisiana, the dominant biofouling organisms are *Balanus amphitrite niveus* (=*B. reticulatus*) (a species which has recently increased in abundance in the Gulf of Mexico) and *B. improvisus.* These two species accounted for most biomass all the way down platform legs to near the bottom. *Balanus improvisus* settles on the shells of *B. amphitrite niveus,* and was most successful as a colonist in winter and early spring, after which *B. amphitrite niveus* was a more successful settler.
2. On Coastal platforms in Texas, *Balanus tintinnabulum* is the biomass dominant, growing rapidly and over a long period of time, thus, outcompeting other barnacles such as *B. improvisus* which settle more readily but are overgrown by *B. tintinnabulum*.
3. Barnacles are relatively unimportant on Offshore or Bluewater platforms.

Bivalves (Plates 4a and b)

Bivalves are a large group (20,000 species) of two-shelled molluscs comprising a number of unattached forms such as burrowing clams which live in soft sediment or in holes bored in rock or wood; surface-dwelling species such as scallops which live on sandy or muddy bottoms; and various sessile species which frequently attach to petroleum platforms (Barnes 1980). Attached forms such as oysters and mussels which live on solid substrates are anchored either by cementing one shell ("valve") to the substrate or by using adhesive threads. Sessile species filter the surrounding water through their gills for plankton. Most bivalves reproduce by releasing gametes, which fuse and develop into planktonic larvae that drift until they find a suitable location for attachment.

Attached bivalves have been particularly useful for studies of the effects of pollutants on marine organisms due to their relatively long lifespan (often a number of years), economic value (e.g., oysters), broad geographic distribution, and sessile life habit which requires them either to tolerate a toxicant or to die since they cannot migrate away (Cunningham 1979). Since bivalves filter large volumes of water to extract food, respire, and eliminate metabolic wastes, low concentrations of pollutants in the water may become concentrated within bivalve tissues; e.g., one *Crassostrea virginica* may filter 30-40 l of seawater/hr or 26-34 m^3/yr.

In some coastal waters, bivalves are the overwhelming biomass dominant on platforms. For example, on a platform in California, Wolfson et al. (1979) found mussels (*Mytilus californianus* and *M. edulis*) up to 25 cm long at densities which averaged 0.13 m^3 of mussels per m^2 of platform surface.

The OEI investigators did not report significant bivalve biomass on the platforms near Timbalier Bay. The oysters *Crassostrea virginica* and *Ostrea equestris* were described as rare, primarily located from 0-3 m and 7.6-10.7 m depth, respectively, on two platforms. Citing earlier work by Gunter and Geyer (1955), George and Thomas (1979) affirmed that all molluscs in the fouling assemblages appeared to be rare.

In direct contrast to this conclusion, Gallaway et al. (1981b) noted that bivalves were common on the deeper portions of the Coastal platforms of Louisiana. The most abundant bivalves were three species of oysters (Ostracea), whose densities ranged from 496-576/m^2 at a depth of 10 m on two platforms. Oysters were the dominant taxon on one platform leg adjacent to a discharge of produced water, indicating a tolerance to some pollutants. The oysters collected in the Central Gulf Platform Study included a complex of four species which were not possible to identify separately with any certainty in the field due to the use of photographic techniques and taxonomic difficulties in the group: *Crassostrea virginica, Ostrea equestris, Lopha frons* (= *L. folium*), and *Hyotissa thomasi*. Discrete collections did permit a qualitative determination of relative proportions of each species at the platforms, however. The most abundant species on the nearshore platforms were *Crassostrea virginica* and *Ostrea equestris. Crassostrea virginica,* the common commercial oyster of the east coast of North America, is not ordinarily abundant seaward of the coastal bays, but was found at the Coastal platforms in sizes up to 10 cm in length. *Ostrea equestris*, the horse oyster, is a normal inhabitant of shallow Gulf of Mexico waters and occasionally invades bays. Larger individuals (to 2.5 cm long) were seen on the platforms than are commonly found in bays. Another common bivalve was *Chama macerophylla*, the leafy jewel box, a Gulf of Mexico and Caribbean species commonly reported from depths of 1-30 m (Abbott 1968).

In the BGOF study of platforms in Texas waters, Fotheringham (1981) observed that *Ostrea equestris* occupied 32% of the available space in photographs taken on one platform at a depth of 6 m in November 1976, but was absent from other samples taken at the same time. Oddly, January 1977 samples showed no significant space taken by oysters at any depth, though *Ostrea equestris* was described as "common" in summer samples. Since these bivalves are large and their shells would be expected to persist even when the occupant had died, the seasonal differences probably were due to sampling variability rather than to an actual change in abundance of visible shells. Other bivalves described by Fotheringham as "common" or "abundant" at BGOF included the arc shell *Anadara transversa*, depth 3-12 m; *Chama macerophylla* and the pholad boring clam *Diplothyra smithyi*, depth 21.5 m; and the bicolored tree oyster, *Isognomon bicolor*, from the surface to a depth of 12 m. *Isognomon bicolor* is a warm tropical species found in the Gulf of Mexico and Caribbean (Abbott 1968, Andrews 1977). Andrews reported that *Isognomon* occurs in "clusters on rocks in inlet-influenced areas."

On the two Offshore platforms investigated by Gallaway et al. (1981b) in the Central Gulf Platform Study, bivalves replaced barnacles (the inshore dominant) as the most important group of organisms in terms of biomass. Bivalves were responsible for between 65% and >99% of the wet weight biomass down to a depth of 30 m, the greatest sampling depth. *Isognomon* dominated the 1 m sample biomass (wet weight 3,168 g/m^2) on the shallower of the two platforms and was replaced by oysters in 10 m and 20 m samples (wet weights 3,067 g/m^2 and 17,695 g/m^2, respectively). *Hyotissa thomasi* was the most abundant, largest oyster (over 10 cm) and was previously reported in the western Gulf of Mexico only from reefs at the margin of the continental shelf. *Chama macerophylla* was also important on that platform, ranging in wet weight from 608-1,093 g/m^2 at depths of 1-20 m. On the other platform, *Chama* was the most important organism at all depths, decreasing in wet weight from 4,357 g/m^2 at 1 m to 167 g/m^2 at 30 m. The mossy arc shell, *Arca imbricata*, was also common in shallow samples collected at 1-10 m (53-1,168 g/m^2). *Arca* is a common clam in moderately shallow water ranging from North Carolina to the Gulf of Mexico and the Caribbean (Abbott 1968, Andrews 1977). It requires a firm substrate for attachment and has been referred to as a "byssate epifaunal nester" (Andrews 1977).

Major conclusions which can be reached about bivalves on platforms in the northwestern Gulf include:

1. Coastal platforms in Louisiana waters do not harbor high bivalve biomass at shallow depths, but deeper portions of platforms may shelter large numbers of oysters.
2. Oysters and other bivalves are common on Coastal platforms in Texas waters.
3. On Offshore Louisiana platforms, bivalves (especially tree oysters and leafy jewel boxes) replace barnacles as the biomass dominant.
4. At least four species of oysters are found on Gulf of Mexico platforms.

Hydroids (Plate 1b)

Hydroids are small organisms having a polyp-like body consisting of a hollow tube and a combination mouth and anus surrounded by tentacles. The tentacles are armed with stinging cells capable of entangling and injecting enzymes and toxins into prey. Hydroids do not filter water, but selectively remove small suspended or planktonic organisms which come in contact with the tentacles. Hydroids may be either solitary (resembling anemones) or colonial, growing into large, fluffy masses of the interconnected polyps.

Hydroids are common components of biofouling communities and often support their own associated flora and fauna. For example, the ostrich-plume hydroid, *Aglaophenia pinquis*, forms a habitat for the caprellid amphiod *Caprella equilibra*, offering shelter and food such as microscopic plants which grow on the hydroid. In turn, the caprellids keep the hydroids from becoming overgrown by their own fouling species (Dundon 1973). Hydroids have complicated reproductive cycles, and can spread by division and colony growth as well as by settling as larvae on exposed surfaces. Although some hydroids do form thin external support structures ("thecae"), the amount of material invested in construction of these structures is small relative to that produced by a barnacle or bivalve. As a result, hydroids are capable of rapid, striking changes in biomass as they "bloom" and die back, leaving little evidence of their former abundance.

Hydroids were an important component of the fouling mat on the inshore Louisiana OEI platforms. Most of the biomass was comprised of barnacles and hydroids. Although the absolute abundance of hydroids decreased with depth, their relative importance increased as other species dropped out. The shallower samples had large numbers of the hydroid *Syncorne*, while deeper samples included the hydroid *Bougainvillia tennella*. The investigators found that "hydroids dominate the outer covering of the barnacles below 7.5 m. . . [and] the fouling fauna is completely dominated by hydroids from 12.2 m to the bottom" (George and Thomas 1979).

Hydroids were patchy but extremely abundant in some spots on the four Louisiana platforms investigated quantitatively in the Central Gulf Platform Study (Gallaway et al. 1981b). Twelve species were reported. The hydroids on the two Coastal platforms occupied about 23%-43% cover (based on colonial forms only) in samples from the surface to a depth of 10 m. On one of the two Offshore platforms farther from shore, hydroid distribution was bimodal, with cover exceeding 90% at the surface and at 30 m, and a lower value (11%) at an intermediate depth, 20 m. On the other Offshore platform hydroids were relatively less abundant, ranging from 3% at 30 m to 25% at the surface. The species composition varied greatly from one platform to the next, and at different depths within platforms. Common taxa included *Obelia dichotoma, Turritopsis nutricula, Eudendrium carneum, Sertularia turbinata,* and *Clytia* spp.

In the Texas Coastal zone, hydroids were an important component of the mat of sponges, bryozoans, and plants which covered barnacles at BGOF (Fotheringham 1981). Nine species of hydroids were identified. Their abundance was quite variable in time and space. For example, hydroids as a group accounted for 93%-98% cover at depths of 6-9 m and were absent below those depths in photographic samples taken on one platform in November 1976. Two months later, hydroids had spread downward to the bottom of the platform; percentage cover over the entire depth range was not less than 65%. Temporal changes were also quite evident at the species level. *Syncorne eximia* was described as "abundant" at both platforms in the winter in the littoral zone but absent from other depths, and absent at any depth in the summer. Two species of *Obelia* were common only on one platform in the littoral zone and during both seasons. *Turritopsis nutricula* was abundant or common over the depth range from the surface to the bottom on both platforms, but only in the summer. *Tubularia crocea* was common only on one platform, where it bloomed in the littoral and 6-9 m depth ranges in the winter (Fotheringham 1981). Gallaway (1980) also described a winter bloom and summer reduction of *Tubularia crocea* at BGOF, and noted that hydroid stalks were an important food for Atlantic spadefish during the spring decay.

Hydroids made effective use of experimentally bared substrate in the BGOF study, settling early and overgrowing other settlers such as sponges (Fotheringham 1981). Variability in percentage cover between quadrats was high. Quadrats which were caged to exclude predators at the time of scraping typically had lower percentages of hyrdoid cover.

General conclusions about hydroids on northwestern Gulf of Mexico platforms include:

1. Hydroids are patchy but extremely abundant in spots on Coastal and Offshore Louisiana and Texas platforms. They are the dominant species in many near-bottom samples but are often most abundant (on a weight basis) near the surface as components of the mat community.
2. Hydroids are effective, rapid colonizers of bared substrate and are capable of overgrowing competitors.

Anemones, Stony Corals and Octocorals (Plates 5a, b, c, and d)

Anemones, stony corals and octocorals are members of the same phylum (Cnidaria) as hydroids and share many of the same characteristics such as a hollow polyp-like body, tentacles armed with stinging cells, and either solitary or colonial growth patterns.

Anemones may grow as solitary individuals or in clusters, but, unlike stony corals or octocorals, are not interconnected internally if found in groups. Anemones reproduce both sexually and asexually, either releasing planktonic larvae, dividing by fission, or budding to form two or more new individuals. Consequently, large masses of identical anemones often develop; individuals within these masses, or clones, are genetically the same if formed asexually (Francis 1973). Anemones may move into an area by settlement and growth of larvae, or by fission or budding and cluster expansion, or by physically creeping along the substrate.

Living anemones, stony corals, and octocorals have a mucus-covered epidermis that inhibits the growth of epifauna on their surfaces, though crevices or other spaces between living tissue may harbor small motile epifauna. A sheet of anemones may, therefore, be considered (from a biomass standpoint) to be almost exclusively anemones.

Stony corals secrete solid skeletons of fused calcium carbonate crystals. The group includes those colonial, hermatypic species whose skeletons make up massive coral reefs, as well as numerous smaller ahermatypic species whose skeletons are usually only a few centimeters in size. Hermatypic corals in shallow water (i.e., less than 100 m deep) typically shelter symbiotic unicellular algae (zooxanthellae) which give the living tissue a brownish-green color. The zooxanthellae utilize sunlight and the waste products of the animal portion of the coral to photosynthesize metabolic compounds which are in turn used by the coral for its growth and to aid in the rate of skeleton formation. Hermatypic corals usually grow best, therefore, in clear water where light levels are high, and are, by and large, a fully tropical group of organisms. The only active coral reefs in the northern Gulf of Mexico are those on the offshore banks in shallow, warm blue water (Bright and Pequegnat 1974). Ahermatypic corals which do not typically have zooxanthellae rarely form massive reefs, and often are found in deep water at lower temperatures (e.g., Gerrodette 1981).

Octocorals do not usually secrete fused skeletons, but contain large numbers of unfused, small calcareous spicules in their tissues. They differ from stony corals and anemones largely in having eight pinnate tentacles around the mouth of each polyp. The group includes the familiar sea fans, which have a supporting, flexible skeleton of proteinaceous material; the spectacular soft corals of the Indo-Pacific, which form colorful, enormous colonies several meters high; the soft, fleshy sea pens and sea pansies found in unconsolidated sediment; and a variety of smaller colonial forms.

Both corals and octocorals reproduce asexually by formation of new polyps at colony margins, and sexually, releasing either gametes or brooded larvae into the water. Larval dispersal in the field has been described for only a few corals, and may be very restricted (Ostarello 1973, Gerrodette 1981). Consequently, since those species present on platforms may be assumed to have travelled for some time and distance from the nearest breeding adults, inhabitants would be expected to be rather cosmopolitan species with widespread larvae.

As a group, anemones, stony corals, and octocorals tend to be difficult to identify on the basis of external characters. Although spicule morphology is diagnostic in octocorals, spicules vary in size and shape within individual colonies and from one geographic area to the next. Anemones have no spicules, and must be sectioned for study of internal septa and/or nematocysts for definitive identification. Stony corals are identified by skeletal structure, which requires dissolving the living tissue; variation is rife within species growing in different environments of light, depth, or geographic area. Consequently, identification of animals within these three groups is frequently tentative, with subsequent name changes not at all uncommon (e.g., Lang 1973). Comparisons of studies of petroleum platforms have been hampered by such problems.

On the Coastal Louisiana platforms studied in the OEI by George and Thomas (1979), anemones dominated the mat community from a depth of about 2-6 m. Densities sometimes exceeded 5,000 individuals/m^2. Neither stony corals nor octocorals were reported. Anemones were a component of the settling community that colonized experimental test panels, accounting for up to about 10% of the total biomass on some panels, and were most abundant on panels suspended below a depth of 5.5 m. In previous work, Gunter and Geyer (1955) also described two species of anemones as "abundant" off the Louisiana coast (from George and Thomas 1979): *Anthopleura krebsi* and *Aiptasia pallida*, specifying an optimum depth for *Aiptasia* of 0.6-5.2 m and for *Anthopleura* of 9.5-14 m. Gunter and Geyer also noted the presence of a stony ahermatypic coral, *Astrangia asteriformis*, at an optimum depth of 9.1 m.

The Central Gulf Platform Study grouped all anemones together (Gallaway et al. 1981b). They were an important community component, especially on one of the two Coastal platforms, where they accounted for 58%-81% of the total number of individuals/m^2. On one of the two Offshore platforms, they were most common at a depth of 10 m (57% of the total individuals), while they were most abundant at 30 m on the other platform (12% of the total individuals).

One octocoral was recognized in the Central Gulf Platform Study, the rather primitive form *Telesto* sp. (probably *T. riisei*), a low-profile encrusting species found primarily on horizontal members at 20 m on the Offshore platforms. *Telesto* is a member of a small group of octocorals (only three genera) with only one species (*T. riisei*) described as a significant member of fouling communities (Bayer 1961). They are commonly found in various water depths; *T. riisei* is widespread throughout the Caribbean from Florida to Brazil and to a depth of about 60 m.

Several species of small ahermatypic stony corals were found occasionally on platforms in the Central Gulf Platform Study, including *Astrangia* sp., *Phyllangia americana*, and *Oculina diffusa*. More recent taxonomic analysis has suggested, however, that *Astrangia* and *O. diffusa* collected on the platforms may be the same species (*O. diffusa*), implying that the coral identified by George and Thomas (1979) as *A. asteriformis* may also be *O. diffusa* (G.D. Dennis, III, LGL; personal communication 1981).

The BGOF study identified anemones only to family; three families were recognized, as was one stony coral (*Astrangia* sp.) and a single octocoral (*Leptogorgia virgulata*). The octocoral is a very widely distributed species of gorgonian sea whip found from the New York area south all the way to Brazil (Bayer 1961). Although it appeared in the species list at several depths, it was described as "rare" and was not common enough to account for any significant cover or biomass. The coral was found occasionally only near the bottom of the platforms (Fotheringham 1981).

Anemones were not included in Fotheringham's (1981) tables of fouling species in undisturbed photographic quadrats of either BGOF platform or mentioned in the descriptions of organisms which settled on experimentally bared surfaces, suggesting that they were unimportant from a numerical or biomass standpoint. However, Gallaway et al. (1979) reported high abundances (to 6,628 individuals/m^2) at BGOF for one unidentified species of anemone in winter 1978. Most anemones were seen near the bottom (18 m). The same species was also a common colonizer in scraped samples though it was not possible to determine whether colonization occurred by larval settlement or by anemones from adjacent areas moving into the scraped zones.

The following are general conclusions about anemones, stony corals, and octocorals on platforms in the northwestern Gulf of Mexico:

1. Anemones are important organisms, especially on coastal Louisiana and Texas platforms. They tend to form distinct bands or zones at specific depths, especially toward the bottom. They are capable of rapid settlement on bared substrate.
2. Stony corals and octocorals are conspicuous but numerically unimportant on Gulf of Mexico platforms.

Bryozoans (Plates 6a and b)

Bryozoans, also known as ectoprocts, are sessile colonial animals which produce elaborate external skeletons to house the small individuals making up a colony. Most of the 4,000 species of bryozoans are found in shallow marine environments attached to solid substrates, plants, or other animals (Barnes 1980). Their usual growth forms are either encrusting (forming thin sheets) or erect (forming somewhat flexibile bush-like growths). They are filter-feeders, relying on suspended material such as plankton for nutrition. Most marine bryozoans are hermaphroditic and brood their eggs. Hermaphroditism is common in sexually-reproducing fouling organisms which rely upon rapid reproduction to propagate before the arrival of other colonists or superior competitors.

Bryozoans were present but apparently not particularly abundant on Louisiana Coastal platforms during the OEI and earlier studies (Gunter and Geyer 1955, George and Thomas 1979). Densities given by George and Thomas (1979) ranged from 1.1-20 g/m^2, and only three species (*Bugula neritina, Membranipora* sp., and *Acanthodesia* sp.) were identified. However, bryozoans were common on settling plates suspended in the water to collect fouling organisms; after 60 days' exposure, *Bugula neritina* occupied an average of 20% of the available space.

The Central Gulf Platform Study found bryozoans to be quite important on Louisiana platforms (Gallaway et al. 1981b). Twenty-three species of bryozoans were recognized from the four platforms in the study. Four of the nine most abundant colonial taxa were bryozoans. *Bugula neritina* was most common on Offshore platforms, but also did well adjacent to produced water discharges. *Aeverillia setigera* and *Parasmittina spathulata* were primarily inshore species, while *Crisia eburnea* was most abundant farther offshore. On the two Coastal platforms, bryozoans accounted for 32%-78% of available cover. On the two Offshore platforms, bryozoans varied markedly from one sample to the next, but coverage was highest in the 10-20 m depth range (58%-88%).

Nine species of bryozoans were identified at BGOF (Fotheringham 1981). Pronounced differences between platforms were evident, with one platform evidently much more suitable as bryozoan habitat than the other. Nearly all of the species were most abundant in the summer, e.g., *Bugula neritina, B. rylandi, Savingnvella lafonti, Schizoporella errata,* and *Aetea anguina.* This observation is in direct contrast with findings of Gallaway (1980) that bryozoans (and, in particular, *Bugula neritina*) bloomed in the winter, declined in the spring, and were at low levels in summer and fall.

General conclusions about bryozoans on northwestern Gulf of Mexico Platforms are:

1. Bryozoans are patchy in appearance from one location and from one sampling period to the next on Coastal and Offshore Louisiana platforms. When present, they are often extremely abundant.
2. Bryozoans are common on Coastal Texas platforms during late fall and early winter, but are subject to a considerable dieback in warmer months. The timing of this dieback may vary annually, since present data are contradictory.

Motile Epifaunal Invertebrates (Plates 7a, b, c, and d)

The sessile components of the fouling community provide shelter for many small, motile or semi-motile animals living on or within the surfaces of other organisms, or in crevices and similar refuges. The motile species depend upon the sessile species for protection from predators, refuge from water motion, support for tubes and other dwelling places, locations for detritus and other food to settle, and for other nutritional requirements. The invertebrates utilizing the fouling community range in size from microscopic unicellular organisms to large worms, amphipods, crabs and other crustaceans. Space does not permit a detailed treatment of each group. Several selected taxa are discussed herein. Readers are referred to Barnes (1980) for general descriptions of each group.

In studies of the Louisiana Coastal platforms, Gunter and Geyer (1955, from George and Thomas 1979) described only one species of motile invertebrate as "abundant": the amphipod *Corophium. Corophium* is a crustacean which constructs tubes made of sediment and other particulate material cemented together by glandular secretions. Most Corophiids eat detritus by scraping it from the substrate with long antennae (Bousfield 1973).

High densities (e.g., 35,880/m^2) were reported for amphipods on Louisiana Coastal platforms by the OEI investigators; highest densities were reported for samples near the surface (George and Thomas 1979). Several species of amphipods dominated the motile epifauna samples: *Corophium acherusicum, Stenothoe* sp. and *Caprella* sp. *Stenothoe* is a member of a family known for associations with hydroids (Gosner 1971), and the relationship between *Caprella* and hydroids has been described earlier. *Corophium* and *Stenothoe* dominated in summer, but were replaced by *Caprella* and others in the winter. *Corophium acherusicum* is "virtually cosmopolitan in warm temperate coastal waters . . . in shallows, in protected and estuarine situations, in somewhat reduced salinities" (Bousfield 1973). George and Thomas (1979) observed the highest densities of *Corophium* in the upper 3 m, declining with depth; *Caprella* sp. showed an inverse of that pattern. Although George and Thomas (1979) believed the two species were therefore competitors for either food or habitat, it is equally likely that the depth-related predominance of caprellids, which scrape surfaces for detritus, may have been due to the great abundance of hydroids. Without knowing which species of caprellid was represented, such comments are speculative; however, they do illustrate the importance of understanding community dynamics (as opposed to community structure) among fouling organisms.

Motile epifauna deemed important at BGOF by Fotheringham (1981) included tube-building amphipods (*Erichthonius brasiliensis, Jassa falcata*) in caged, experimentally cleared quadrats. Their tubes apparently did not account for any significant coverage in undisturbed quadrats at any depth on either platform, despite their being described as "common" between 6 m and 18 m on both platforms. Fotheringham (1981) also considered a number of other amphipods common or abundant, including *Caprella equilibra*, and *Stenothoe gallensis.* Other crustaceans of note included a pycnogonid (*Tanystylum obiculare*), and the tanaíd *Tanais* sp. and the isopod *Dynamene perforata* (two groups related to amphipods).

The Central Gulf Platform Study included a detailed treatment of amphipods on Louisiana platforms (Gallaway et al. 1981b). Coastal platforms were dominated by amphipods at 1 m, where they accounted for 25%-84% of the dominant discrete (i.e., countable) organisms. Most of the amphipods on the two Coastal platforms were *Stenothoe* sp., either *S. gallensis* or *S. minuta. Stenothoe minuta* is an estuarine species (Bousfield 1973), while *S. gallensis* has been collected from coral reefs in offshore Mexican waters (McKinney 1977). A mixture of *S. gallensis* and *S. minuta* in a ratio of 25:1 was noted at one of the two Offshore platforms studied by Gallaway et al. (1981b). The greatest proportions of amphipods were found in deep water (20-30 m), where the tube-dwelling corophiid amphipod *Erichthonius brasiliensis* achieved densities up to 10,987/m^2, accounting for up to 97% of the discrete organisms counted.

Caprellids are elongated amphipods which brood their young, having no pelagic or swimming larvae. Despite this apparent limitation to dispersal, many species have world-wide distributions, probably due to very broad substrate affinities and the ability to "raft" on floating detritus, algae, wood, etc. Caprellids as a group are opportunistic feeders, consuming whatever organic material is most readily available (Dundon 1973). *Caprella equilibra* has a range which spans the Atlantic Ocean, Pacific Ocean, Black Sea, and the Mediterranean Sea. Caprellids are commonly associated with colonial epifaunal species such as hydroids and bryozoans. Caprellids can achieve impressive densities: Dundon reported abundances for *C. equilibra* on hydroids of up to 77,000/m^2 of hydroid; a related epifaunal species (*Caprella gorgonia*) was observed at densities up to 151 individuals/gram wet weight of host (Lewbel 1978). Gallaway et al. (1981b) collected large numbers of caprellid amphipods from both Coastal and Offshore platforms studied in the Central Gulf Platform program. *Caprella equilibra* was the most common form, and was found in large numbers (up to 30,666/m^2) at all depths from the surface down to 30 m.

Polychaetes are segmented marine worms closely related to the familiar terrestrial earthworm. They are extremely diverse and abundant in the ocean, virtually dominating many communities, especially soft bottoms. They are often divided for convenience into two groups: "sedentary polychaetes," which are semi-motile and typically live in tubes that they build, and "errant polychaetes" which roam freely in search of prey. Many of the tube-dwellers are filterfeeders or eat detritus that settles within reach, while most of the errant polychaetes are carnivorous or omnivorous, eating things they encounter on the bottom. Errant polychaetes are common components of fouling communities, living in spaces between barnacle and bivalve shells. Sedentary ploychaetes which build small tubes also frequently cover surfaces in fouling communities. The tubes may be rigid, calcareous structures which in turn provide habitat for other fouling species, or softer, more membranous sheaths. Large numbers of polychaete worms were seen at all depths on the OEI platforms (e.g., range from 200-325/m^2 on one platform in July), though shallower samples had somewhat more worms (George and Thomas 1979). George and Thomas (1979) did not indicate which type of polychaete was present on OEI platforms, but observed 56,781/m^2 on settling plates in Timbalier Bay. Gunter and Geyer (1955) reported that *Eupomatus*, a serpulid polychaete also known as *Hydroides*, was found on the bottom of Louisiana platforms, and it is possible that the same species was present on the OEI platforms. Serpulids secrete calcareous tubes and feed on suspended particles.

Twelve species of polychaetes were collected at BGOF by Fotheringham (1981). The most common forms included *Neanthes succinea, Haplosyllis spongicola*, and *Trypanosyllis gemmipara.*

Twenty-seven species of polychaete worms were collected in the Central Gulf Platform Study by Gallaway et al. (1981b) on the Louisiana platforms. The most common species were members of the family Syllidae, a group of small carnivorous and parasitic worms found associated with sponges, hydroids, and other invertebrates (Gosner 1971). Dominant taxa included *Brania* sp., *Typosillis* sp., *Haplosyllis spongicola, Odontosyllis* sp., and *Eusyllis* sp. Densities for individual species ranged as high as 13,733/m^2, and were generally greatest in water depths from 1-10 m.

Pycnogonids are marine animals called sea spiders, whose closest relatives are the scorpions, spiders and horseshoe crabs. They tend to be small (1-10 mm), and look physically rather like slow-moving spiders. Many pycnogonids are epibiotic on bryozoans, anemones, hydroids and sponges, feeding either on their hosts or on microorganisms growing on the substrate. Pycnogonids brood their young, which are carried by the male until the young leave to complete metamorphosis on the substrate (Barnes 1980). This group was mentioned as being present within the shallow fouling mat in the OEI studies (George and Thomas 1979). Gallaway et al. (1981b) also reported having collected large numbers of pycnogonids (up to 5,733/m^2) at a depth of 1 m from both Coastal and Offshore Louisiana platforms in the Central Gulf Platform Study.

Nemerteans are small, elongated animals known as ribbon worms or proboscis worms. Although some form mucus-lined burrows or tubes, most are free-ranging hunters. All nemerteans are carnivorous, capturing prey with an eversible proboscis that is sometimes armed with a poison-injecting stylet. They feed on a wide variety of prey, including polychaetes, crustaceans, molluscs, and other small animals. They present taxonomic difficulties even when collected, as preservation usually induces fragmentation or contraction into an unrecognizable ball of mucus-covered tissue. Consequently, identification to the phylum level is often the best non-specialists can do. Nemerteans were common on Louisiana Coastal and Offshore platforms investigated by Gallaway et al. (1981b). They tended to be most abundant from 1-10 m, where they attained densities up to 11,066/m^2.

Ophiuroids, also called brittle or serpent stars, are closely related to the familiar sea star or starfish. They usually have five very flexible arms. A number of species are commensal with sponges, living on or within them. Many ophiuroids release pelagic free-swimming larvae, although others brood their young and release crawling juveniles. Ophiuroids often feed by the use of tube feet and mucus, capturing suspended particles and transporting them to the mouth, enabling the animals to remain within their burrows or holes. Ophiuroids were present on the Coastal and Offshore Louisiana platforms of the Central Gulf Platform Study in very high densities near the surface (*Ophiactis savignyi*, to 92,400/m^2) (Gallaway et al. 1981b). These ophiuroids were embedded in the mat with their arms extended.

Other common motile forms on the OEI Louisiana platforms were described by George and Thomas (1979) and included small xanthid crabs (*Neopanope texana*) and flatworms. *Neopanope* was most abundant at intermediate depths (2.4-9.1 m), where its density on one platform reached a maximum of 325 crabs/m^2. Flatworms are primitive carnivorous or omnivorous worms belonging to a group with many parasitic and symbiotic members. Large numbers (20,747/m^2) of the flatworm *Leptoplana* sp. were collected on settling panels in Timbalier Bay.

While seldom numerically dominant, shrimp, lobsters and large crabs are sometimes well represented on northwestern Gulf of Mexico structures. Representative and common examples of these forms include pistol shrimp (*Synalpheus* spp.), arrow crabs (*Stenorhynchus seticornis*), xanthid crabs (Xanthidae), and on platforms in deep water, spiny lobster, mainly *Panulirus argus*. Spiny lobsters shelter under crevices, caves, ledges, or debris during the day, and scavenge about the bottom at night. Most of the lobsters we have seen were between large funnel-like collars around vertical drill casings in the upper 30 m of the water column.

General conclusions about motile epifaunal invertebrates on northwestern Gulf of Mexico platforms are:

1. An extremely diverse assemblage of small and large motile invertebrates utilize the shelter and food provided by sessile members of the epifaunal community.
2. The most abundant amphipods are tube-dwelling forms such as corophiids, stenothoids, and caprellids which are typically symbiotic with hydroids and other mat organisms.
3. The most commonly reported polychaetes are syllids, a group often associated with hydroids and sponges.
4. Pycnogonids, another epibiotic group, are frequently found on the fouling mat.
5. Nemerteans are common predators on the other epifaunal invertebrates on platforms.
6. Ophiuroids may be present in very high densities embedded in the fouling mat.
7. Large, conspicuous invertebrates such as lobsters and crabs may be found in low densities around and beneath platforms.

Fishes (Plates 8a, b, c, d, e, f, g, h, i, j, k, l, m, and n)

Petroleum platforms in the northwestern Gulf of Mexico serve as aggregation points for huge members of fish representing many species. The cause of this attraction and the degree of permanence at particular structures vary depending upon the ecological role of the species in question, as well as environmental conditions. In the most general sense, the fishes can be classified as either transients or residents. Within the resident category, two general groupings can be made: (1) species directly dependent upon the biofouling community for food and/or cover, and (2) those which appear to be attracted to the structures mainly for cover alone, exhibiting little or no trophic dependence on the biofouling community. Surprisingly, fish which are tropically independent of platforms often are responsible for most fish biomass around production platforms (e.g., the Atlantic spadefish, *Chaetodipterus* faber). In the northwestern Gulf of Mexico, small juveniles of the Atlantic spadefish first appear in the surf zone of barrier islands in late May and

June, and remain common to abundant in nearshore habitats through the summer. In nearshore habitats, they occur in schools, generally aggregating around jetties, wrecks, pilings and bridges (Gallaway et al. 1981a). Few fish exceeding 450 g are taken in nearshore habitats.

Recruitment of large juvenile spadefish (approximately 150 mm long) to petroleum platforms begins in spring, is high during summer, and is completed during fall. Results of mark-recapture studies have shown that this species is exceedingly "habitat faithful" once recruited to an offshore structure and that population levels around platforms are directly proportional to the size of the structure. Typical densities range from 0.15-0.20 fish/m^3 of water under the platform (Gallaway et al. 1979). Population levels are highest during fall and winter when both large (up to 9 kg) and small, recently recruited fish are present, and lowest during spring and summer, particularly during spring when the largest fish are generally absent and the recruitment rate is low. In conjunction with the presence of juveniles in the surf during late spring and the scarcity of larval spadefish around petroleum platforms during all seasons (Finucane et al. 1979), these data suggest that the large fish may move to nearshore areas during spring for spawning. Around one major Coastal Texas platform at BGOF, seasonal population estimates and 95% confidence intervals for summer, fall, winter, and spring were 6,554 (4,482-10,501), 7,791 (5,332-12,494), 8,783 (6,220-13,388) and 6,379 (4,563-9,526), respectively (Gallaway and Martin 1980).

In-situ observations and index of fullness values indicate that Atlantic spadefish actively feed in the upper part of the water column around the periphery of platforms during the warm seasons, utilizing mostly macrozooplankton such as pteropods as food (up to 75% of weight of stomach contents) (Gallaway et al. 1979). During cold seasons, the fish typically appeared to reside in the lower water column or at the bottom, and fed at much reduced rates (e.g., index of fullness values during fall and winter periods were 5 or less as compared to values in excess of 20 during spring and summer). What little food was ingested during the cold periods appeared to consist of biofouling organisms (sponges, hydroids and bryozoans). During winter, the condition of Atlantic spadefish was at a seasonal low, population levels were highest, and disease epidemics were common (see Gallaway et al. 1981a). As the water warmed during spring, colonies of a winter-blooming hydroid, *Tubularia crocea*, were sloughed from the platform and gorged upon as suspended material by Atlantic spadefish (Gallaway et al. 1979). We have seldom seen Atlantic spadefish browsing directly on the fouling community, except for a few individual fish during winter. This fact, in conjunction with other observations, indicates that these fish are primarily sight-feeders, preying upon macrozooplankton and suspended particulate matter, especially barnacle molts. Other species having a similar trophic niche probably include the lookdown (*Selene vomer*), Atlantic moonfish (*Vomer setapinnis*), and the creolefish (*Paranthias furcifer*).

Resident benthic species around production platforms which also appear to be mainly trophically independent of the biofouling community include fish such as the red snapper (*Lutjanus campechanus*) (Gallaway et al. 1981b). Red snapper are recruited to petroleum platforms and other reefs from the demersal nekton near the end of their first year of life, when they are about 200 mm long (Bradley and Bryan 1976). These fish are extremely habitat-faithful, and population levels around major platforms have been observed as high as 7,000 individuals (Gallaway and Martin 1980). This species is trophically linked to the surrounding soft-bottom motile epifauna, preying mainly upon shrimps, swimming crabs and fish (Moseley 1966, Bradley and Bryan 1976, Gallaway et al. 1981a). Red snapper apparently feed at night over soft bottoms away from the platforms, returning to the reef during the day for cover (Hastings et al. 1976, Gulf of Mexico Fishery Management Council 1980). Other species perhaps having a similar trophic mode include large tomtate (*Haemulon aurolineatum*) and some groupers.

Resident species which appear trophically dependent upon the biofouling community for food and/or cover include small cryptic forms such as the blennies (Blenniidae), as well as large grazers (e.g., sheepshead, *Archosargus probatocephalus*) and small grazers (e.g., butterflyfishes, Chaetodontidae). Blennies, as a group, appear dependent upon empty barnacle shells for the conduct of their life history. Adults live in the shells which offer protection from most predators. Eggs are also deposited in empty shells, and the usual presence of an adult along with eggs and recently hatched young indicates some degree of rearing. Thus, the type and size of the dominant barnacle in the biofouling community can be viewed as a structural feature which directly controls the density of blennies as well as many other large cryptic species. Shells have a high profile which is further enhanced by clumping, resulting in a markedly irregular surface, and providing large cracks and crevices which can be utilized for cover by large cryptic species such as pistol shrimp, xanthid crabs, and polychaete worms. The nature of the encrusting mat community also apparently controls the composition and density of small cryptic species (primarily microcrustaceans) as well as some large species (e.g., brittle stars). Habitat limitation appears to be far more important in the regulation of most platform community populations than are any trophic-related limits.

Trophic studies of the crested blenny (*Hypleurochilus geminatus*) at BGOF indicated that this species fed actively throughout the year and relied almost entirely upon the biofouling community for food (Gallaway and Martin 1980). Based upon the identifiable food contents in stomachs obtained during 1978-1979, hydroids and barnacle molts were the dominant food items of blennies during summer and fall; amphipods and algae were important during winter; and amphipods, hydroids, and algae were the dominant forms during spring. Barnacles not only provide critical habitat for blennies, but also serve as food, mainly through the process of molting and through the work of large grazers who leave bits of barnacle flesh in the crushed shells as a result of their feeding. We suspect that small reef fishes such as butterflyfishes and angelfishes have food habits similar to blennies, and observations of their pecking feeding behavior suggest that they may ingest colonial mat organisms as they take discrete, cryptic species (e.g., microcrustaceans and polychaetes).

Sheepshead in the BGOF were extremely habitat-faithful, with population levels proportional to the submerged area of structure; they were recruited to platforms only as adults about 22-50 cm long (Gallaway and Martin 1980). This recruitment occurred during a brief spawning aggregation during April, when the population was some 17- to 19-fold higher than observed during other seasons and consisted of many running-ripe adults exhibiting courtship behavior. During the previous summer (1978), one small structure which had been harvested of all but about 10 of the resident sheepshead did not recolonize until the spring 1978 aggregation, after which the population returned to pre-harvest levels. Normal density of sheepshead was estimated to be about 0.3 fish/m^2 of submerged platform substrate. For a major platform, total population of sheepshead averaged around 1,000-1,500 individuals, whereas small platforms supported populations of about 150 fish. During the observed spawning aggregation, population levels at a major and a small platform in the BGOF were estimated to have been 16,969 and 3,055 individuals, respectively.

Sheepshead were trophically dependent upon the biofouling community at BGOF and fed actively throughout the year. During summer periods when the biofouling biomass levels were lowest, portunid crabs comprised about 67% of the sheepshead diet by weight, and the fish were also observed to feed on rafts of sargassum floating by the platforms. These foods were supplemented by the biofouling community. During the remainder of the year, the diet consisted almost entirely of biofouling materials. Gray triggerfish (*Balistes capriscus*) and other balistid fishes are similar to sheepshead in terms of trophic dependencies.

With the probable exceptions of barracuda (*Sphyraena barracuda*), almaco jack (*Seriola rivoliana*), hammerhead sharks (*Sphryna* spp.), and cobia (*Rachycentron canadum*), most of the large predators around petroleum platforms do not appear to be residents, but rather are believed highly transient. The above listed exceptions along with the bluefish (*Pomatomus saltatrix*) are either known or expected to feed upon other resident platform species, and probably have a longer residence time at platforms than do the other large predators such as various mackerels (Scombridae), jacks (*Caranx* spp.), and the little tunny, *Euthynnus alletteratus*. The latter species come and go to platforms for periods of a few hours to a few days as they follow large schools of prey species such as scads (e.g., *Decapterus punctatus*) and sardines (e.g., *Sardinella anchovia*). Both the pelagic prey and predator species are attracted to structures per se (Klima and Wickham 1971, Wickham et al. 1973), but with different schools constantly moving into and away from the structures. Large variations in the daily number of pelagic species are normal; the results of the above experimental studies showed as many as 10,000 fish were observed around small, floating structures one day after they had been positioned. We do not believe that the mackerels, jacks, and tuna feed upon resident platform species to any major degree.

With the exception of the bluefish, large predators which do feed on platform residents are not numerous, typically ranging in orders of magnitude from 1 to 10. Around a given structure, bluefish are usually present in schools of up to about 5,000 individuals. It seems obvious that bluefish do not feed much on the resident platform species, given the slow recruitment of most of the resident species and their relative seasonal constancy in terms of population levels. Gallaway and Martin (1980) showed that bluefish around petroleum platforms were heavily dependent upon demersal fish and macrocrustacean communities of the surrounding soft bottoms, and, to some degree, upon the transient pelagic prey species mentioned above.

Other Vertebrates

We are unaware of studies showing any behavorial response to structures by marine mammals or reptiles. During our studies in the BGOF, an unidentified sea turtle was occasionally observed and was believed to have been the same individual. Porpoises were sometimes sighted moving through platform areas with no particular attention paid to the platform.

Aumann (1981) studied the effects of petroleum structures on migratory and local marine birds. He concluded that the effects of the structures on birds ranged from insignificant to beneficial during non-migratory seasons (summer and winter). Species such as black tern (*Chlidonias niger*) and snow goose (*Chen caerulescens*) passed through the area but were not influenced by the presence of the structures. Terrestrial passerine birds were observed on the platforms and were all representative of winter residents along the coast. The presence of the structures was considered beneficial to gulls (particularly the laughing gull, *Larus atricilla*) and the royal tern (*Sterna maxima*) which made extensive use of the structures and surrounding waters for resting and feeding areas. No detrimental effects of structures on fall migratory birds were postulated, but possible benefits were suggested. Insect-feeding birds, in particular, foraged considerably on the diverse and ample supply of insects that inhabit platforms. The birds appeared to be in excellent physical condition, and departure time from the platforms was suggested to have had little or no effect on the southward trans-Gulf flight.

Numerous dead spring-migrating birds were observed on the platforms; death appeared to have been a result of exhaustion and lack of food and water as opposed to collision with the structures or contamination by petrochemical substances. In the absence of the platforms, an additional hour of flight time would have put the birds on land where resources would be available. Aumann (1981) concluded that "mortality from predators and other factors on land also contribute quite heavily to mortality of spring migrants" and that "dead birds on the platform are readily apparent, whereas dead birds on land quite often go undetected."

2.2 HABITAT STRUCTURE AND ZONATION

Extending from the bottom to above the water's surface, petroleum platforms provide the basal substrate for development of a high-profile reef. This basic habitat structure is greatly modified by development of biofouling communities, which enhance habitat quality for other reef community components by providing either food and/or cover. While this section emphasizes vertical or bathymetric zonation, the horizontal zonation of communities as indicated by the presence of characteristic assemblages at different distances offshore and latitudes is also presented, primarily by the organization of this section.

Coastal Platforms

Structural and zonational patterns within the Coastal group of platforms differ (1) between platforms located in Louisiana waters and in Texas waters, and (2) between those closer to shore and those farther offshore, at least off Louisiana. The Louisiana-Texas difference corresponds to some degree with Parker's (1960) designations of faunal provinces based upon benthic macroinvertebrates obtained from soft bottom grab samples. He showed the zone west of the Mississippi River Delta to be a faunal assemblage (West Louisiana Province) distinct from those along the coast of Texas (he divided Texas into three provinces). The West Louisiana Province generally corresponded with the delineation of a Humid Zone extending from the delta to near Galveston, Texas, which is separated from sub-humid and semi-arid conditions farther west and south along the Texas coast.

The major structural feature of Coastal platforms is the domination of the biofouling community by barnacles throughout the water column. In Louisiana, the dominant species of barnacles is usually either *Balanus amphitrite niveus* and/or *B. improvisus* (George and Thomas 1979, Gallaway et al. 1981b), both of which are small acorn barnacles that provide only low relief. George and Thomas (1979) found that the total wet weight of the biofouling community decreased with depth on a typical platform in summer samples (e.g., 5.2, 2.9, and 0.5 kg/m^2 at respective depths of 2.4, 9.1, and 12.8 m). Winter biomass was slightly higher in samples near the surface, and lower in deeper samples. Barnacles were responsible for 79%-97% of the total at all depths during both summer and winter. Anemones, sponges, bryozoans, and hydroids were the only other major contributors to total biomass, and at no time did the weight of any of them exceed 11%.

George and Thomas (1979) provided a generalized account of vertical zonation on a Coastal Louisiana platform located about 22 km offshore, in water 18 m deep. In this account, *Balanus amphitrite niveus* was called *B. reticulatus*. The authors found a thick concentration of the green alga *Enteromorpha* covering the fouling mat at and just below the surface, with interspersed hydroids (*Syncoryne*), xanthid crabs (*Neopanope* *texana*), amphipods (*Corophium*), and pycnogonids. The fouling mat was attached to *Balanus reticulatus* and *B. improvisus* in approximately equal numbers. Below a depth of 2.4-6 m, sea anemones (*Aiptasia*) replaced algae and hydroids on the barnacles, which were somewhat larger than at the surface and which were now mostly *B. reticulatus* (70%). *Balanus eburneus* was found occasionally, also. Several amphipods (*Corophium*, *Stenothoe*, and *Caprella*), xanthid crabs, and the blenny *Hypleurochilus* were common. Below 7.5 m, nearly all the barnacles were *B. reticulatus*, covered with hydroids; *B. tintinnabulum* and *B. improvisus* were present but rare. No living barnacles were found below a depth of 12.2 m, where hydroids dominated the community down to the bottom.

Results of the Central Gulf Platform Study investigations of two Coastal platforms in Louisiana waters during summer 1978 (Gallaway et al. 1981b) were, in general, similar to results obtained from the 1974 surveys reported by George and Thomas (1979). However, there were some notable differences, as well as observations of other community components not covered in the previous surveys. Barnacles and other shelled organisms were cleaned of encrusting materials to obtain the weights of the barnacles and pelecypods per se.

Total biomass levels of the biofouling community on the shallower Coastal platform (water depth 12 m) averaged lower at the surface (9.5 kg/m^2) than near the bottom (13.5 kg/m^2). Water was turbid at all depths, as represented diagrammatically in Figure 6. The biomass dominants at 1 m and 10 m were barnacles, which respectively comprised 65% and 58% of the total biomass and 92% and 87% of the biomass of all discrete (as opposed to colonial) biofouling species. The estimated biomass of barnacles plus the encrusting organisms growing on them at each depth represented some 94% and 92% of the total biomass at each depth, respectively. *Balanus amphitrite niveus* outnumbered *Balanus improvisus* 6:1 at 1 m, and 3:1 at 10 m. Aside from the colonial species forming the mat community (which represented 29%-34% of the total biomass), the only other major contributors to biomass were anemones and oysters, neither of which exceeded 6% of the total biomass at either depth. The mat community at 1 m comprised 29% (2.8 kg/m^2) of the total biomass, and was dominated by the green alga *Derbesia* sp. (27% of the coverage provided by the mat), a boring sponge (Clionidae, 28% of the cover), a bryozoan (*Aeverillia setigera*, 20% of the cover) and the hydroid *Obelia dichotoma*, which provided about 12% of the total cover. At 10 m, the mat community represented 34% of the total biomass (4.6 kg/m^2) and contained no macroalgae, being dominated by the same species of the bryozoan (38% of the total cover), hydroid (33%) and boring sponge (20%) that were dominant at 1 m. Results of pigment analyses showed microalgae (diatoms, green flagellates and blue greens) were represented at both depths. Overall productivity was about three times higher at 1 m than at 10 m.

Small, motile, cryptic species, while contributing little to biomass, were numerically abundant on the shallower Coastal platform. The amphipod *Stenothoe* sp. was very common from the surface to the bottom (27,733-28,133 individuals/m^2), whereas the caprellid *Caprella equilibra* and an unidentified nemertean were present only at 1 m (7,466 and 11,066 individuals/m^2, respectively). Large, motile cryptic species were represented only by blennies and very small specimens of the stone crab, *Menippe mercenaria*. Blennies were found only near the surface where densities ranged from 8-16 fish/m^2. The stone crab was represented at both depths, but was more abundant at 10 m (139 crabs/m^2) than at 1 m (48 crabs/m^2).

Zonation of fishes other than the cryptic blennies at the shallower platform was not evident, but observations were hampered by poor visibility. Dominant fishes were the sheepshead (very high numbers of very small specimens concentrated around the vertical supports), and the Atlantic spadefish (observed in small schools). Also glimpsed in schools around the platform were bluefish and blue runner (*Caranx crysos*). Individual specimens of lookdown and Atlantic moonfish, which are normally seen in schools, were also observed. Although not very abundant, other reef-associated species were observed at this platform: whitespotted soapfish (*Rypticus maculatus*), gray triggerfish, an unidentified butterfly fish (Chaetodontidae), lane snapper (*Lutjanus synagris*), and two species of grouper (*Epinephelus nigritus* and *Mycteroperca rubra*).

The water column around the deeper Coastal platform was characterized by a turbid layer from the surface to a depth of about 3 m, a clear zone between 3 m and 12 m and another turbid layer from 12 m to the bottom at 18 m (Gallaway et al. 1981b). In terms of location, depth, and water conditions, this platform was most similar to those investigated in the OEI by George and Thomas (1979). Although there was no sampling below 10 m, there was a sharp break in biomass associated with the turbid layer. The biofouling growth in this turbid zone consisted almost entirely of hydroids, interspersed with an occasional hard coral thought to be *Oculina diffusa*.

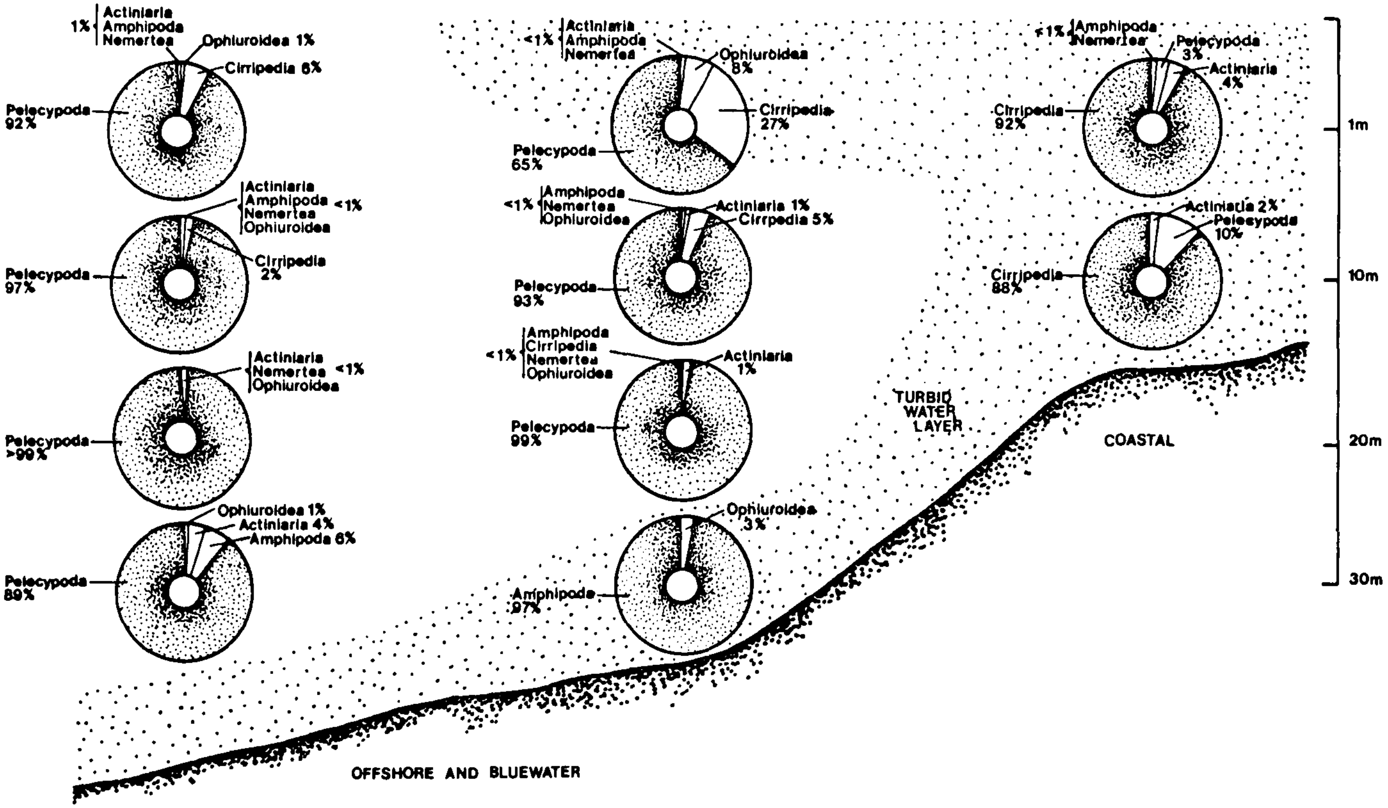


Figure 6. Observed vertical zonation of discrete faunal fouling biomass on representative platform communities of the northwestern Gulf of Mexico (after Gallaway et al. 1981b).

At the deeper Coastal platform, total biomass levels near the surface (5.4 kg/m^2) were remarkably similar to those observed by George and Thomas (1979), but at 10 m, biomass levels were determined to be 9.6 kg/m^2 (Gallaway et al. 1981b) compared to only 2.9 kg/m^2 observed at 9.1 m by the previous investigators. Common to both studies, small acorn barnacles (primarily *Balanus amphitrite niveus*) dominated at each depth above 12 m. In the Central Gulf Platform Study, barnacle biomass was 3.8 and 4.9 kg/m^2, or 71% and 50% of the total at 1 m and 10 m, respectively. When the encrusting mat growing on the barnacles was included in calculations, the combination of mat plus barnacles comprised 98% of the total biomass at 1 m and 78% of the biofouling biomass at 10 m. At 1 m, the remaining 2% of the biomass was somewhat evenly spread over 14 species; at 10 m, oysters (Ostreacea) represented 1.6 kg biomass/m^2, 17% of the total, while the balance of the biomass spread over 32 species.

The mat community of the deeper Coastal platform was characterized by a scarcity of macroalgae (*Derbesia* sp. was represented in the 1-m deep samples) and dominance by hydroids and bryozoans. Microalgae were represented at both depths. The dominant colonial faunal forms at 1 m were the hydroid *Clytia* sp. and the stolonate bryozoan *Aeverillia setigera*. The latter species and the hydroid *Turritopsis nutricula* dominated the mat collections at 10 m.

Numerical densities of small, motile cryptic species at the deeper Coastal platform were high, particularly at 1 m where the amphipod *Stenothoe* sp. was represented by 52,800 individuals/m^2 (62% of all discrete organisms, including barnacles) and another amphipod, *Corophium* sp., was represented by 14,667 individuals/m^2 (18%). At 10 m, discrete organisms were represented by a total density of 21,104 individuals/m^2 spread somewhat evenly over 37 species. Relatively large, motile, cryptic species were represented at 1 m by blennies (8-16 fish/m^2) and the xanthid crab *Eurypanopeus depressus* (5/m^2). At 10 m, blennies were not encountered, but other cryptic forms were abundant. The polychaete *Brania* sp. was represented by 3,200 individuals/m^2, the pistol shrimp *Synalpheus fritzmuelleri* by 32 individuals/m^2, and small xanthid crabs by 362 individuals/m^2.

Most of the fish observed at the deeper Coastal platform appeared to be concentrated in the clear zone in the middle of the water column. The dominant fishes observed were, in order of abundance, (1) mixed schools of moonfish and lookdown (formed vertical "walls" in the water column). (2) sheepshead, (3) spadefish, (4) gray triggerfish and (5) mixed schools of bluefish (mostly) and blue runner. In the last group, two to three schools each consisting of 30 to 40 individuals were believed present. Sheepshead were considered particularly abundant; both they and gray triggerfish were observed grazing on fouling macroepifauna. Considerable evidence of their grazing was evident. Incidental pelagic fish observed included crevalle jack (*Caranx hippos*), greater amberjack (*Seriola dumerili*), and, at the surface, needlefish (*Strongylura* sp.).

In addition to sheepshead and triggerfish, several structure- or reef-associated species of fishes and invertebrates were represented at this site. Reef fishes observed included belted sandfish (*Serranus subligarius*), rock hind (*Epinephelus adscensionis*), flamefish (*Apogon maculatus*), sergeant major (*Abudefduf saxatilis*), and juvenile cocoa damselfish (*Pomacentrus variabilis*). The snapper-grouper component of the ichthyofauna did not appear to be major. A few gray snapper (*Lutjanus griseus*) and a few small groupers (some believed to have been warsaw grouper *Epinephelus nigritus*, but the scamp, *Mycteroperca phenax*, may have also been seen) were observed on nearly every dive.

According to Shinn (1974), the vertical zonation of fishes around nearshore Louisiana platforms is characterized by spadefish, barracuda, lookdown, and sheepshead in the upper part of the water column; red snapper and large groupers typically near the bottom, but often in mid-water; and, on the bottom, species such as speckled trout (*Cynoscion nebulosus*), sand trout (*Cynoscion arenarius*), and flounders (*Paralichthys* sp.). To the bottom group we would add the Atlantic croaker (*Micropogon undulatus*) and note that we have not observed speckled trout at Coastal platforms, although they may be present, particularly at platforms near the beach. Schools of bluefish and some jackfishes like blue runner appear to be quite abundant around Coastal platforms at all depths. In the upper and middle part of the water column, Atlantic moonfish are typically abundant at Coastal platforms in Louisiana waters as are an occasional gray snapper. At Coastal platforms more distant from shore, it is not unusual to encounter large schools of baitfish such as round scad, Spanish sardine, and scaled sardine (*Harengula pensacolae*) in the upper part of the water column. Klima and Wickham (1971) have shown that structures per se attract these fish and their predators, the jacks, but that the congregations are transient in nature.

Several Coastal platforms have been investigated in Texas waters, but quantitative studies have been conducted only at BGOF (Middleditch 1981). As in Louisiana the biofouling community was diverse and abundant. Fotheringham (1977) identified 16 algal and 101 invertebrate species. The most immediate and striking difference between the Texas and Louisiana Coastal biofouling communities was the dominance of the Mediterranean barnacle (*Balanus tintinnabulum*) on Texas platforms. In contrast to the small acorn barnacles characteristic of Louisiana Coastal platforms, the Mediterranean barnacle attained basal diameters of 6-8 cm and equivalent heights. Additionally, it grew in clusters, forming a high-relief habitat. The density of these barnacles was sometimes higher immediately at the surface, but varied little with depth except in the zone of the persistent bottom turbid layer, which characteristically extended from the sediment-water interface upwards for 2-3 m. Few live barnacles occupied this zone, though some empty shells were encountered.

One of the structures in the BGOF was sampled seasonally (Gallaway et al. 1979, Howard et al. 1980). Winter biomass was about twice that in summer, and biomass decreased near the bottom (Figure 7). Winter increases were attributed to changes in the mat thickness, which was thin at all depths in the summer. The mat was dominated near the surface by algae and encrusting sponges; at mid-depth by encrusting sponges, hydroids, and bryozoans; and near the bottom by encrusting sponges and hydroids. Changes were not as pronounced near the bottom, where the mat remained thin year-round and hydroid and sponge growth did not appear to vary seasonally. Occasional colonies of the coral *Oculina diffusa* grew near the bottom. Representative winter values for total biomass for the surface, 8-9 m, and at the bottom (18-19 m) were 19.8, 23.1, and 3.0 kg/m^2, respectively. Just above the turbid bottom layer, biomass increased dramatically to values slightly lower than those at 8-9 m, indicating a sharp discontinuity in community structure at the upper limit of the turbid water.

The most striking difference in appearance (and biomass) between the summer and winter mat communities on the BGOF structures was the extensive winter development of the branching bryozoan *Bugula neritina* and the colonial hydroid *Tubularia crocea* in the upper water column. This development began in fall (October-November), peaked during winter (January-February), and declined during early spring (March-April). The decline of the hydroid colonies was due to sloughing of macro-particulate matter into the water column, which subsequently became an important spring food for pelagic fishes such as spadefish (Gallaway et al. 1979). The hydroid and bryozoan development on BGOF structures during winter resulted in a high-profile, bushy cover which allowed for, or was associated with, a bloom of microcryptic organisms.

In contrast to the Louisiana Coastal platform sited at a similar depth (18 m) and described above, the abundance and composition of microcryptic species at BGOF during summer was low (overall density of 22,535 individuals/m^2 compared to 52,027/m^2 in Louisiana). The surface collections at BGOF were dominated by nematodes (8,472/m^2), a polychaete (*Synsyllis longilaris*, 6,388/m^2) and a tanaid (*Tanais* sp., 6,458/m^2). At mid-depths only the nematodes (3,194/m^2) and *Synsyllis longilaris* (2,847/m^2) were well represented. These two taxa also occurred at the bottom in densities exceeding 3,000/m^2, but the polychaete *Haplosyllis spongicola* was dominant (11,736 individuals/m^2).

Total density of microcryptic species on the same BGOF structure during winter 1978 was approximately 219,000 individuals/m^2. The dominant groups during winter were largely microcrustaceans (*Caprella equilibra*, 60,116/m^2; *Jassa falcata*, 57,116/m^2; and *Erichthonius brasiliensis*, 56,326/m^2) although the groups which were dominant during summer remained well represented (e.g., overall nematode density during winter was 7,097/m^2, and *Haplosyllis spongicola* was represented by 3,512 individuals/m^2).

The macrocryptic fauna on the Texas plaforms, however, was much more abundant on the BGOF structures than on the Louisiana platforms, presumably because of the greater relief provided by the larger dominant barnacle. Based upon sampling performed at 3- and 8-m depths during summer 1978, blenny density ranged from 30-40 fish/m^2 (up to 50/m^2 on some platforms); pistol shrimp from 107-336/m^2; brittle stars from 7,675-34,331/m^2; and stone crab from 16-64/m^2.

The composition and vertical zonation of pelagic fishes around the BGOF structures were similar to those observed at Coastal platforms in Louisiana waters. Spadefish (dominant), sheepshead, and barracuda were characteristic of the upper water column; red snapper and groupers were common to the bottom and often seen at mid-depths; and schools of bluefish, blue runner, and baitfish were common. The fish fauna at BGOF structures differed notably from those in Louisiana in that large schools of lookdown were never observed over the 4 years of investigation, and by the high abundance of the tomtate. The sciaenid fishes listed by

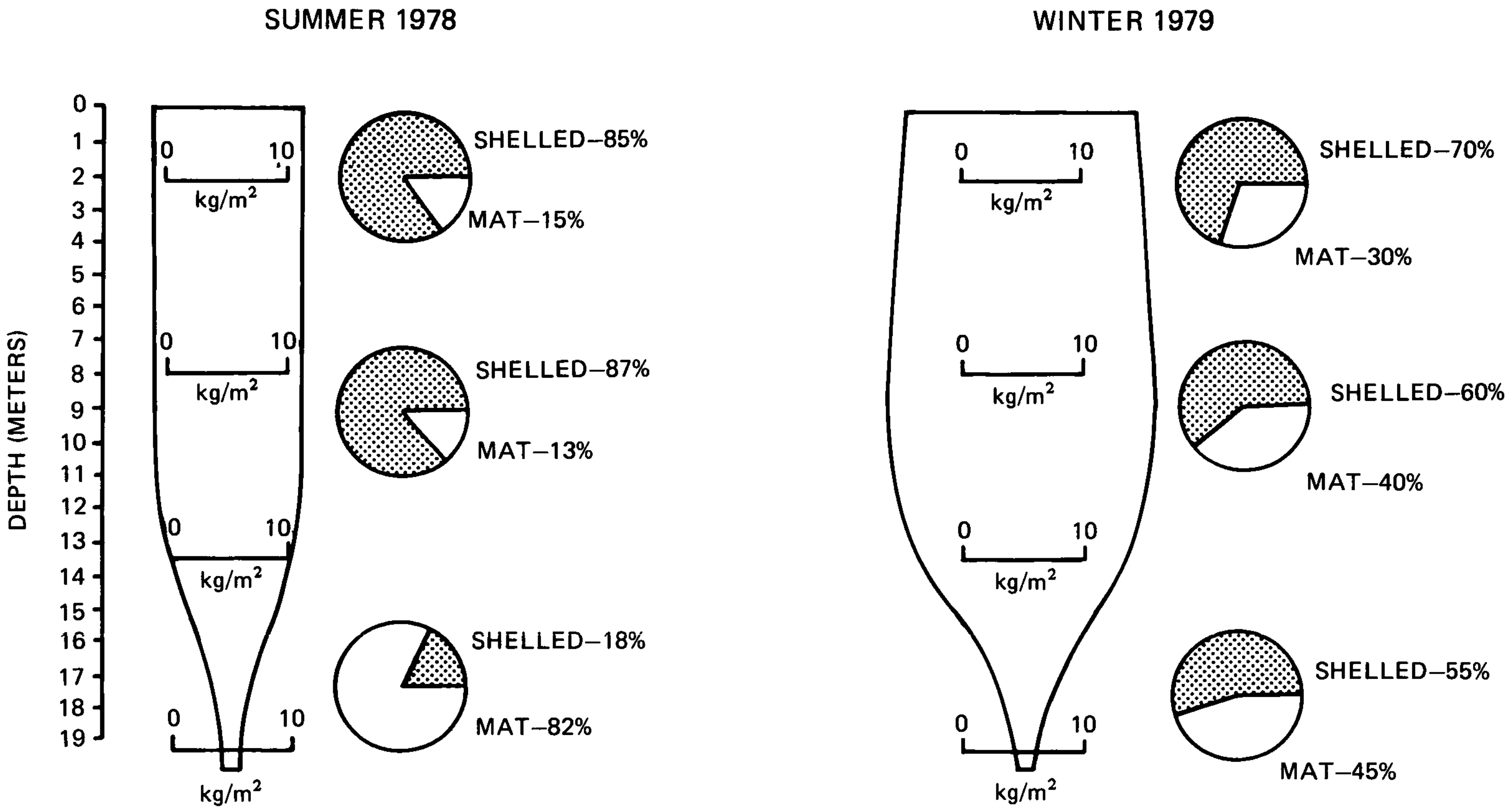


Figure 7. Seasonal levels of biofouling biomass and gross composition on a BGOF structure (After Gallaway et al. 1981a).

Shinn (1974) were not common to the bottom at BGOF structures, but the cubbyu (*Equetus umbrosus*) and, sometimes, the bigeye (*Priacanthus arenatus*) were common. Reef fish components at the BGOF were basically similar to those observed at Louisiana platforms, including as the most common inhabitants, belted sandfish, cocoa damselfish, sergeant major, night sergeant, grey triggerfish, and an occasional butterfly fish.

During summer 1981, LGL Ecological Research Associates, Inc. (under the auspices of the BLM) conducted qualitative surveys of three platforms offshore of south Texas. Two of these were near shore, one off Mustang Island in the vicinity of Corpus Christi, Texas, and one off South Padre Island north of Brownsville. In nearly all respects, the platform off Matagorda Island in water about 19 m deep was similar to BGOF structures. The biofouling biomass was dominated from the surface to near-bottom areas by the Mediterranean barnacle. Near the bottom, growth consisted mainly of hydroids and patches of the coral *Oculina diffusa*. The mat community in the shallower zones was dominated by an interspersed assemblage of sponges, hydroids and bryozoans. At least superficially, fish and cryptic faunal assemblages appeared the same as those characteristic of BGOF structures. The major difference, however, was the profuse growth of the biofouling mat, which was more similar to BGOF winter than summer levels.

The more southerly platform, even though close to shore, was in water about 22 m deep and had characteristics of both Coastal and Offshore assemblages. In this regard it seemed to be representative of an ecotone between these two zones, and will be described under the *Offshore Platforms* section which follows.

Offshore Platforms

Although the octocoral *Telesto* sp. is never a biomass dominant, we consider its presence a good indicator for the Offshore faunal assemblage associated with petroleum platforms in the northwestern Gulf of Mexico. Additionally, even though barnacles may be well represented in near-surface zones, the major differences between the Offshore and the Coastal assemblages are that pelecypods, as opposed to barnacles, dominate the biofouling biomass, and that there is a sharp break in biomass between 20- and 30-m depths, which does not necessarily relate to the proximity or presence of the bottom turbid layer. Gallaway et al. (1981b) reported results of quantitative summer sampling for two platforms in Louisiana waters (one considered as ecotonal between the Coastal and Offshore assemblages) and have recently made qualitative surveys of two Offshore platforms in south Texas waters, one of which was also considered as ecotonal. In each case, the relative abundance of barnacles at the surface and the rather sparse growths of *Telesto* sp. were the primary features leading the authors to classify these more nearshore structures in the Offshore zone as ecotonal in nature.

The ecotonal platform in the Offshore zone of Louisiana was located at a distance of 42 km from shore, in water 35 m deep. It was sampled from the surface down to a depth of 30 m (Gallaway et al. 1981b). Total biofouling biomass from 1-20 m ranged from 8.5-11 kg/m^2, but dropped to a low of about 2 kg/m^2 at 30 m. Discrete fauna, mostly shelled forms, comprised 56%-73% of the total biomass from 1-20 m, indicating extensive development of the mat community. At 30 m, discrete fauna only comprised 1% of the total biomass. Of the discrete fauna, pelecypods comprised 65%, 93% and 99% of the biomass of discrete organisms at depths of 1, 10 and 20 m, but were not represented at 30 m, where the fouling mat constituted 99% of the total sample biomass (see Figure 6). The Mediterranean barnacle was codominant (27% of the total biomass) along with pelecypods at the 1-m sampling depth. The dominant pelecypod at the surface was the tree oyster (*Isognomon bicolor*), representing 48% of the total biomass contributed by discrete organisms. From 10-20 m, the Ostrecea (probably mostly *Hyotissa thomasi*) and the leafy jewel box (*Chama macerophylla*) dominated in terms of biomass of discrete organisms.

Macroalgae (particularly reds and greens) were an important component of the biofouling mat to a depth of 10 m on the Offshore ecotonal platform in Louisiana, but were absent in samples taken at greater depths. Microalgae (diatoms and blue-greens) were represented down to 30 m; patches of coralline algae were seen by divers in some areas greater than 10 m deep, but were not represented in any of the samples. Complementing the algae at 1 m were heavy growths of the hydroid *Obelia dichotoma*; from 10-20 m, the branching bryozoans *Bugula neritina* and *Crisia eburnea* were dominant. At 30 m, the hydroid *Eudendrium carneum* was the dominant in two of the three sample replicates, but the third replicate was dominated by a colonial zoanthid anemone.

This ecotonal platform was characterized by a rich and abundant cryptic fauna. Total numerical densities of discrete organisms (including shelled forms) at 1 m, 10 m, 20 m, and 30 m were, respectively, 150,352/m^2, 53,547/m^2, 39,221/m^2, and 44,309/m^2. At 1 m, the brittle star *Ophiactis savignyi* was dominant (92,400/m^2); the amphipods *Stenothoe* sp. (7,200/m^2) and

Erichthonias brasiliensis (10,987/m^2) respectively dominated at 10- and 20-m depths; and the caprellid *Paracaprella pusilla* was represented in the growths of hydroids found at 30 m by an estimated 31,787 individuals/m^2. Associated with barnacles in the near-surface zone, blennies had a density of 8-12 fish/m^2. The sea urchin *Arbacia* sp. was found both near the surface and at 8-9 m in densities of 4 individuals/m^2. At 8-9 m, xanthid crabs, brittle stars and pistol shrimp were represented by 64, 4 and 4 individuals/m^2 respectively.

The dominant fishes observed at the ecotonal Louisiana Offshore platform during the summer sampling period were bluefish, spadefish, and mixed schools of moonfish and lookdowns. Blue runner and other jacks (Crevalle jack, *Caranx hippos*; greater amberjack, *Seriola dumerili*; almaco jack) were common. Sheepshead and grey triggerfish were present but not abundant, and large predators were represented by barracuda, cobia, and a nurse shark (*Ginglymostoma cirratum*). Reef fish were neither diverse nor abundant. Forms encountered included cocoa damselfish, cubbyu, whitespotted soapfish, bigeye, and bermuda chub, *Kyphosus sectatrix.* The snapper-grouper assemblage, however, was a major component of the ichthyofauna, being represented by large schools of gray snapper supplemented by medium to large schools of red and lane snapper (*Lutjanus synagris*). A small species of mycteropercid grouper, perhaps the scamp (*Mycteroperca phenax*), was also abundant. Based upon videotapes taken at 1-, 14-, and 23-m depths, spadefish, lookdown, and gray snapper dominated near the surface, and spadefish, blue runner and gray snapper were most abundant at mid-depth. At 23 m, snapper were most common in the video observations. Large Atlantic croaker were caught by angling at the bottom.

The biofouling community on the ecotonal Offshore platform off South Padre Island was similar to the ecotonal Louisiana platform in that the tree oyster and Mediterranean barnacle were the dominant shelled forms in near-surface areas, with pelecypods becoming increasingly dominant with depth; the mat community development was extensive; and a few scattered clumps of *Telesto* sp. were present. It differed mainly by the species of anemone represented, which was an exceedingly abundant, large, showy species that even competed with blennies for space inside empty barnacle shells on the south Texas platform.

The Louisiana platform located 53 km from shore in water 46 m deep studied by Gallaway et al. (1981b) was considered representative of a distinct Offshore faunal assemblage. At this platform, all species of barnacles comprised only 1.6% of the total sample biomass of discrete organisms as compared to 86% contributed by bivalves. The octocoral *Telesto* sp. was the visual dominant, being most dense on the horizontal cross members of the platforms–supports which were not quantitatively sampled as part of the program. Total biofouling biomass from the shallowest to deepest sampling areas on the vertical supports was 5.8, 11.4, 5.3, and 0.2 kg/m^2 at depths of 1 m, 10 m, 20 m, and 30 m, respectively. Of these amounts, discrete forms comprised 69%, 73%, 55%, and 12% of the total, again showing extensive development of the mat community. The dominant bivalve at each depth was *Chama macerophylla*, supplemented by equivalent biomass of Ostracea (again probably mostly *Hyotissa thomasi*) at 10 m.

Macroalgae (mainly greens and reds) were abundant at 1- and 10-m depths on the Louisiana Offshore platform, along with an encrusting calcareous sponge at 1 m and the stalked bryozoan *Bugula neritina* at 10 m. At 20-m depths, the latter species was the most abundant colonial form, although zoanthid anemones and the encrusting bryozoan *Cleidochasma contractum* were well represented. At the deepest area sampled, demosponges, colonial anemones and ascidians comprised most of the biomass.

Both large and small cryptic species were abundant on the Offshore platform. Total numerical densities of discrete forms decreased monotonically with depth from 100,464/m^2 at the surface to 23,541/m^2 at 30 m. The brittle star *Ophiactis savignyi*, the amphipod *Caprella equilibra*, and polychaetes (particularly *Brania* sp.) were dominant at 1 m; *O. savignyi, C. equilibra* and *Stenothoe* sp. were most abundant at 10 m; the amphipod *Erichthonias brasiliensis* was dominant at 20 m; and *C. equilibra* and *E. brasiliensis* were dominant at 30 m. Results of sampling in near-surface zones indicated blennies were represented by densities up to 60 fish/m^2 along with gastropods (4/m^2) and nudibranchs (4/m^2). At depths of 8-9 m, blenny density ranged from 4-12 fish/m^2, xanthid crabs were abundant (56/m^2) and pistol shrimp were represented by about 4 shrimp/m^2.

Although the spadefish was the dominant pelagic species at the Offshore Louisiana platform and most of the other species characteristic of the Coastal fish assemblages were also well represented and abundant (e.g., lookdown, moonfish, blue runner, sheepshead, grey triggerfish), the fish assemblage differed by the marked abundance of gray and red snapper and the richness of tropical species. Tropical species such as cocoa damselfish, blue and French angelfish, sergeant major, brown chromis, filefishes (Monacanthidae), tangs (Acanthuridae), flamefish (*Apogon maculatus*), and the creole fish were all well represented, as were the almaco jacks, greater amberjack, bar jack (*Caranx ruber*), and rainbow runner (*Elagates bipinnulta*). Other large predators included barracuda, crevalle jack, cobia, and hammerhead shark.

Bluewater Platforms

To our knowledge, quantitative biofouling samples have not been taken from Bluewater platforms in the northwestern Gulf of Mexico. Our in-situ observations indicate that biofouling biomass is low, probably in the range of 1-5 kg/m^2. Algal mats and stalked barnacles predominate at the surface and, at depth, hydroids and pelecypods appear to dominate. Invertebrates characteristic of the shelf-edge banks, e.g., the spiny lobster (*Panulirus* sp.) and the sea urchin *Eucidaris tribuloides*, are common on Bluewater structures. The most notable difference, however, between the Bluewater and the other platform assemblages is reflected by the fish fauna.

At Bluewater platforms, the huge pelagic schools of spadefish, lookdowns, and bluefish are absent, seemingly replaced by numerous creole fish and almaco jacks along with the ubiquitous blue runner. The grazing sheepshead is replaced by the gray triggerfish and a host of tropical species. In the upper part of the water column down to 30-m depths, mycteropercid groupers and hinds (e.g., *Epinephelus adscensionis*) are common to abundant. The vertical members of Bluewater platforms are surrounded by swarms of wrasses (particularly the creole wrass, *Clepticus parrai*, and Spanish hogfish, *Bodianus refus*) and other tropical species including damselfishes, angelfishes, tangs, rock beauty (*Holocanthus tricolor*), red spotted hawkfish (*Amblycirrhitus pinos*), and red hogfish (*Decodon puellaris*). The most abundant large predator, at least within safe diving depths (30 m), is the barracuda; hammerhead sharks are also common.

Except for the presence of hermatypic corals and species either dependent upon or associated with these corals (e.g., the parrotfishes), the faunal assemblages on Bluewater platforms greatly resemble those of some of the shelf-edge banks.

Effects of Discharges (Plates 9a, b, c, d, and e)

Concentrations of drilling fluids in the environment resulting from overboard discharges seldom attain toxic levels, except within the immediate vicinity of the discharge. Within this area, community structure can be altered (e.g., Benech et al. 1980), but the primary impact from the discharge of drilling muds appear to be the limited effect of direct smothering by the non-toxic cuttings. Zingula (1975) observed crabs and gastropoda digging in a cuttings pile as well as groupers and snappers "nosing in the pile, undisturbed by chips still falling through the water." We have also observed fish using areas with accumulations of drill cuttings as habitat and, unless completely smothered, invertebrates such as anemones continuing life in the midst of cuttings.

Produced water discharges also affect community structure, with microcrustaceans and barnacles being the most susceptible of the biofouling organisms (Gallaway et al. 1981a). Again, however, the impact appears restricted to within a few meters of the point of discharge due to rapid dilution of a relatively non-toxic fluid. The 48-h LC50 for larval brown shrimp, the most sensitive organism tested in the BGOF studies, was 9,500 ppm; for barnacles the 96-h LC50 was 83,000 ppm (Middleditch 1981). The 96-h LC50 for the crested blenny was determined to be 269,000 ppm.

2.3 GROWTH AND SUCCESSION

The most common approaches to determining growth (or production) and successional patterns of the biofouling community on northwestern Gulf of Mexico structures have been either to suspend substrates and retrieve them at later dates (Gunter and Geyer 1955, George and Thomas 1979) or to denude platform substrate with subsequent sampling following periods of recolonization (Gallaway et al. 1979, Howard et al. 1980, Fotheringham 1981). These studies show that growth, or production rates, and compositional aspects vary considerably with season and depth, as well as with location with respect to distance offshore. Further, George and Thomas (1979), comparing their study results with those previously reported (Gunter and Geyer 1955) for the same area, indicated that a true climax community may not develop; i.e., the system may be characterized by dynamic change as opposed to reaching a static end-point, at least within the time period under consideration.

Fouling organisms were allowed to colonize for an unspecified 60-day period on test panels (174 cm^2). These panels were placed at seven depths (surface to 8.5 m) beneath a nearshore platform in Louisiana waters (George and Thomas 1979). Total biomass on these plates at retrieval ranged from 4,150 g/m^2 at the surface to 1,740 g/m^2 at the bottom, indicating net average production rates of 69 to 29 g/m^2/day. At the surface, barnacles, bryozoans, and algae were the dominants, and barnacles comprised 40% of the biomass. At depths of 1.8 and 3.7 m, barnacles comprised in excess of 60% of the biomass and the next most abundant form was xanthid crabs. From 5.5 m to the bottom, bryozoans and hydroids were the most abundant organisms on the plates and most of the barnacles collected were dead.

Fotheringham (1981) reported the relative composition of the early colonizers of protected and unprotected denuded areas at various depths on BGOF structures during 1976-1977. These experiments were conducted for summer-fall periods (56 days, July-September 1976), fall-winter (90 days, September 1976-January 1977), fall-spring (156 days, September 1976-March 1977) and winter-spring (46 days, January-March 1977). Following the 56-day colonization period at a 15-m depth during summer-fall, sponges, hydroids, and the erect bryozoan *Savignyella lafonti* covered most of the sample quadrats, although some 18% of the quadrat remained uncolonized. Following 90 days of colonization after the substrates were cleaned in September 1976, green algae, hydroids, and sponges were the visual dominants on the unprotected quadrats, of which only 4% of the originally cleaned area remained uncolonized by any macroscopic form. In contrast, some 38% of the protected (caged) quadrats remained bare after this 90-day period with only an ascidian (40%) and *Savignyella lafonti* (16%) appearing very successful. Small barnacles were represented, but not abundant (maximum coverage was about 7% of the sample area).

Quadrats cleaned in September and allowed to colonize for 156 days were similar to those allowed to colonize for 90 days. These quadrats, however, were characterized by an increased abundance of red algae on the uncaged quadrats and of the encrusting bryozoan *Parasmittina trispinosa* at 15-m depths in both caged and uncaged quadrats (Fotheringham 1981).

Cleaned quadrats were allowed to colonize for 46 days during January to March 1977 and had little development. Bare substrate, or uncolonized area, comprised from 42% to 93% of the sample quadrats. Green algae and hydroids were the most successful of the early colonizers.

Recolonization studies were continued in the BGOF during 1977-1978 (Gallaway et al. 1979) and 1978-1979 (Howard et al. 1980), but the emphasis was on net production and growth. In Gallaway et al.'s (1979) investigations, substrates near the surface were cleaned at two separate structures during summer 1977 and then allowed to colonize for 90 days (summer to fall) and 180 days (summer to winter). The substrate cleaned during summer and harvested in fall was again harvested in winter. The net production rate for summer-to-fall was 77 $g/m^2/day$; summer-to-winter production was 62 $g/m^2/day$, and fall to winter production was 16 $g/m^2/day$. Except for the fall-to-winter rate, most of the production (about 90%) was contributed by the barnacle *Balanus amphitrite*. For the fall-to-winter period, the mat component was estimated to have contributed 75% of the total net production.

Gross production based upon seasonal changes in standing stock biomass on a BGOF structure was estimated at three depths (Gallaway et al. 1979). Using these data, we estimated that net production ranged from 29 to 39 $g/m^2/day$ at the surface, 36 to 85 $g/m^2/$ day at mid-depths (about 9 m) and 4 $g/m^2/$ day at the bottom (18 m). These data indicate that production estimates based upon recolonization of cleaned substrates probably overestimate production which occurs once initial colonization has been established.

Recolonization studies were continued in the BGOF during 1978-1979, with production rates estimated for various structures at depths of near-surface, 3 m, 5 m, and 8 m (Howard et al. 1980). Seasonal production rates at the surface for four 90-day periods starting in spring were about 40, 65, 10 and 1 $g/m^2/day$, compared to about 10, 40, 1 and 1 $g/m^2/day$ at 3 m; 2, 15, 8 and 9 $g/m^2/day$ at 5 m; and 5, 12, 2, and 1 $g/m^2/day$ at 8 m depths. For substrate near the surface allowed to colonize for about 180 days, the estimated production rates were 100 $g/m^2/day$ for summer-to-winter and 5 $g/m^2/$ day for winter-to-summer. Most of the observed production was attributable to barnacles except during cold seasons when the mat community flourished. As mentioned above, it was commonly observed that the small acorn barnacle *Balanus amphitrite* set first, but was typically overgrown by the later-setting large barnacle, *Balanas tintinnabulum*, which was the dominant barnacle on BGOF structures.

Howard et al. (1980) also reported winter-spring production estimates by selected mat components: the hydroid *Tubularia crocea* and the bryozoan *Bugula neritina*. For the hydroid, regrowth of an average stalk clipped to simulate grazing was estimated 1.6×10^{-4} g/day whereas an undamaged stalked increased biomass at a rate of 4.2×10^{-4}g/day. A typical colony consisted of about 500 stalks. The bryozoan investigated increased in colonial biomass at a rate of 2.4 $g/m^2/day$. If all the above is considered, one can conclude that a new platform placed in the Coastal zone can attain climax levels of total biofouling biomass in 180 days, or less, depending upon the time of year the structure is initially placed down.

The effects of produced water discharges on production rates and successional patterns have been reported by Gallaway et al. (1979), Howard et al. (1980), Gallaway et al. (1981a, b), and Gallaway (1981). Produced water apparently retards production (particularly of barnacles), but the detrimental effects appear limited to an area within a few cubic meters of the discharge (Gallaway et al. (1981a). Additional evidence in these studies indicate that outside the immediate area of detrimental impact, production rates of the biofouling community beneath such discharges were markedly higher than rates observed at similar depths on control structures.

2.4 CONCEPTUAL MODELS AND SYSTEM PROCESSES

Conceptual models of platform communities in the northwestern Gulf of Mexico have been presented by Gallaway et al. (1976), Gallaway and Margraf (1978), Fucik and Show (1981), and Gallaway et al. (1981a), all emerging from the BGOF studies. Drawing upon these studies and additional personal observations of platform assemblages made thereafter, a generalized conceptual model has been developed (Figure 8). In this treatment, the system has been partitioned into 10 compartments, organized into three interconnected, major components; namely the fouling, benthic, and pelagic communities. For the most part, the model depicted in Figure 8 shows energy and/or material flows (solid arrows), but it also takes into account the major physical or habitat-regulatory features of the system (dashed lines with check-valve symbols).

The fouling community includes primary producers (micro- and macroalgae); attached fauna which may be either colonial (e.g., sponges, hydroids, bryozoans) or discrete (e.g., barnacles, molluscs) forms, but all are characterized by a filter or suspension feeding mode; and by species which are trophically dependent upon attached floral and faunal organisms. The latter category ranges from small (e.g., polychaetes, amphipods, pistol shrimp, arrow crabs, tropical reef fishes, blennies) to large (e.g., stone crabs, triggerfishes, sheepshead, chubs) grazing and predatory species. Each of the fouling community compartments is regulated to some degree by the amount of platform substrate available for habitation including space per se and water quality factors associated with liquid discharges from the platform. In a similar fashion, the nature of the faunal component which develops (e.g., large versus small barnacle dominant, barnacle versus mollusc dominant) greatly influences the degree and type of development of the flora (mainly by providing more space for development) and fouling feeders (e.g., high relief communities provide more habitat for cryptic species such as blennies than low relief habitats). Further examples of the latter relationship would include high amphipod densities associated with pronounced hydroid and bryozoan development in contrast to high brittle star densities usually associated with marked sponge dominance.

Aside from in situ production, the fouling flora and fauna are recruited from outside the system, mainly from planktonic larval stages. These forms exit the system as particulates when they are sloughed from the substratum into the water column where they begin sinking as they are transported away from the platforms by currents.

The fouling feeders exhibit varying degrees of residency and many move into and out of the system seasonally. For example, sheepshead are generally permanent residents at a particular structure, each habitat typically colonized at or near carrying capacity early in the spring. Depending upon natural fishing mortality, the sheepshead population declines until the next spring, when large numbers of spawning adults aggregate around the platforms. After spawning, the available habitat is filled, and the balance of migratory spawners leave the system.

Other grazers on the fouling community, including many of the colorful tropical species, occupy platforms sited in temperate climatic zones during the summer season, but desert these habitats (or perish) at the onset of colder seasons. Still others, like the blennies, spend their entire life cycle on a given structure, reproducing and brooding their young in the recesses provided by the shelled forms of the attached fauna.

The shelled forms which are sloughed from platform substrate fall almost directly to the bottom, greatly influencing the nature of the substrate and thus regulating the nature of the benthic community which develops immediately below and around the platforms (Figure 8). The benthos compartment includes infaunal (polychaetes, amphipods, etc.) as well as epifaunal (shrimps, crabs, small fishes) forms. These communities are also regulated to some degree by habitat alterations induced by the platform per se (drilling cuttings, metal debris, etc.). The majority of the benthic biomass is represented by transitory epifaunal forms and the more permanent infauna is characterized by low biomass levels.

Benthic predators include resident forms such as red snapper as well as seasonally abundant forms such as flounders and sciaenids (Atlantic croaker, silver seatrout, sand seatrout, etc.). Many of these forms appear

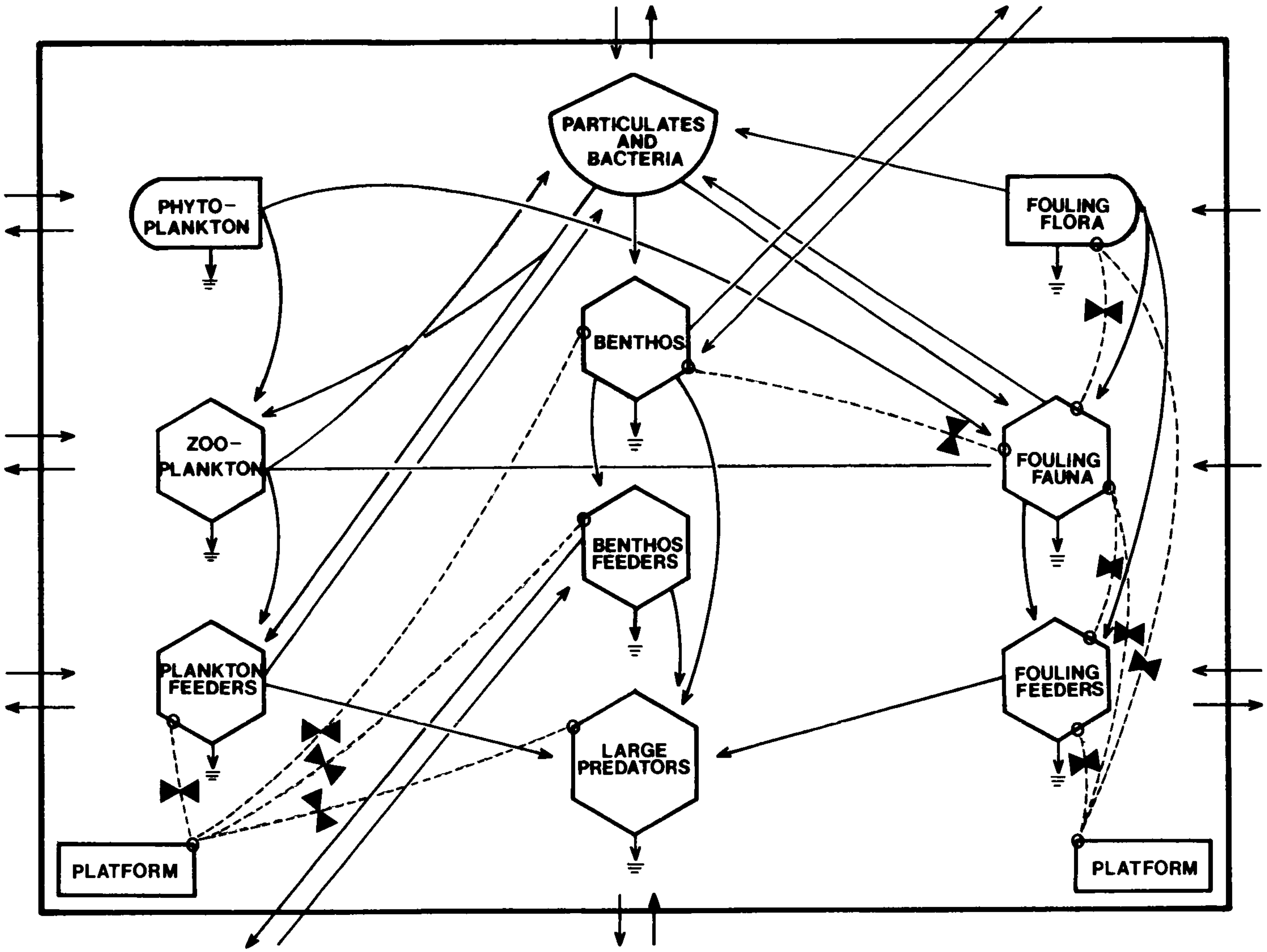


Figure 8. A generalized conceptual model of the petroleum platform biological system.

to be attracted by the habitat afforded by the structure where they spend much of the daily cycle in a resting or low activity mode, then forage out away from these habitats during feeding periods. Most of the recruitment to the benthic-feeding component comes from outside the system, and marked out-of-the-system migrations are common.

Most of the energy requirements of the filter-feeding fouling fauna are provided by the continual transport of phytoplankton, zooplankton, and particulate carbon through the system by currents (Figure 8). However, this harvest of suspended materials by the fouling community is offset to varying degrees by their contributions, particularly by sloughed particulates and by the production of meroplankton. The structures also serve to attract and concentrate planktivores. For some species, (e.g., scads and sardines) the attraction is only transitory, but for others such as Atlantic spadefish, the attraction is more or less permanent. Because of the huge numbers of planktivores aggregated around the structures, their contribution to the particulate compartment is not small. On occasion, the entire bottom around production platforms has been observed to have been littered with partially digested pteropods transported to the bottom in spadefish fecal material.

The last compartment associated with the platform system is represented by the large predators. This category includes both transient and resident species, many of which are attracted by the presence of structure per se as well as by the aggregation of prey species. The most transitory of the large predators are the pelagic predators such as the mackerels and tunas, followed in degree of permanency by seasonal predators like bluefish groupers and hammerhead sharks, to permanent predators as exemplified by the barracuda. Along with the benthic-feeding red snapper, the large predators represent the prime target species for most recreational fishermen.

A mathematical version of the conceptual platform community model described above, and in Figure 8, was initially developed by Gallaway and Margraf (1978) and later modified and improved by Fucik and Show (1981). Both mathematical models indicated high exchanges of materials with surrounding environment (obvious) in addition to an extremely high cycling efficiency. Results of the flow analysis of the Fucik and Show (1981) model, which more closely approximates Figure 8 than the Gallaway and Margraf (1978) version, indicated that carbon entered the system through the phytoplankton, zooplankton, plankton feeders, fouling flora and fouling fauna compartments and the other compartments serve to export carbon. The flow dynamics of the fouling community were of considerable interest, in that the largest carbon flow into this compartment was from the fouling flora, followed in magnitude by particulates and bacteria, zooplankton and phytoplankton, in that order (see figure 5 in Fucik and Show 1981). Flouling flora also provided carbon to fouling feeders and to particulates and bacteria, which flowed through zooplankton to plankton feeders, as well as to fouling fauna and benthos. As a result, carbon derived from fouling flora was represented in the pelagic and benthic communities of the system as well as being transferred throughout the fouling community.

Most of the carbon flow from the fouling flora to the fouling fauna is likely to go via small, herbivorous grazers as opposed to sessile filter-feeding froms. The carbon flow to the fouling fauna from particulates and bacteria in the model exceeded that from phytoplankton and zooplankton. Hydrocarbon profiles of barnacles indicated that they were mainly dependent upon both phytoplankton and detritus (Middleditch and West 1980). However, some 70% to 80% of the carbon stored in the particulates, zooplankton, plankton feeders, benthos and benthic feeders was estimated to have been of phytoplankton origin. By contrast, some 18% to 35% of the carbon stored in the fouling fauna and fouling feeders compartments was indicated to have been of phytoplankton origin. Ratios of carbon (percent), which is stored in large predators during each of four seasons and which originated in the phytoplankton versus fouling flora compartments, were 55:33; 69:26; 46:43; and 71:21.

Net imports and exports of carbon from the various compartments of the BGOF model system are shown by Figure 9. Although the producers of the system represented a source of carbon, the net import-export was nil, as the input from production was balanced by grazing. The plankton feeders such as Atlantic spadefish were indicated to have imported by far the greatest amount of carbon to the system from external sources. Additional carbon imports came from zooplankton production, and recruitment and production of the fouling fauna. The amount of carbon input provided by the plankton feeders suggests that the fish in this category are recruited from outside the system to platforms, where they remain and grow at a rate faster than that at which they are lost by out migration or to other external sources, such as man. By contrast, during all but the spring-summer period of heaviest recruitment, benthic-feeding fishes coming to the platforms from the external environment (namely red snapper) provided a net carbon flow out of the system, indicating that losses

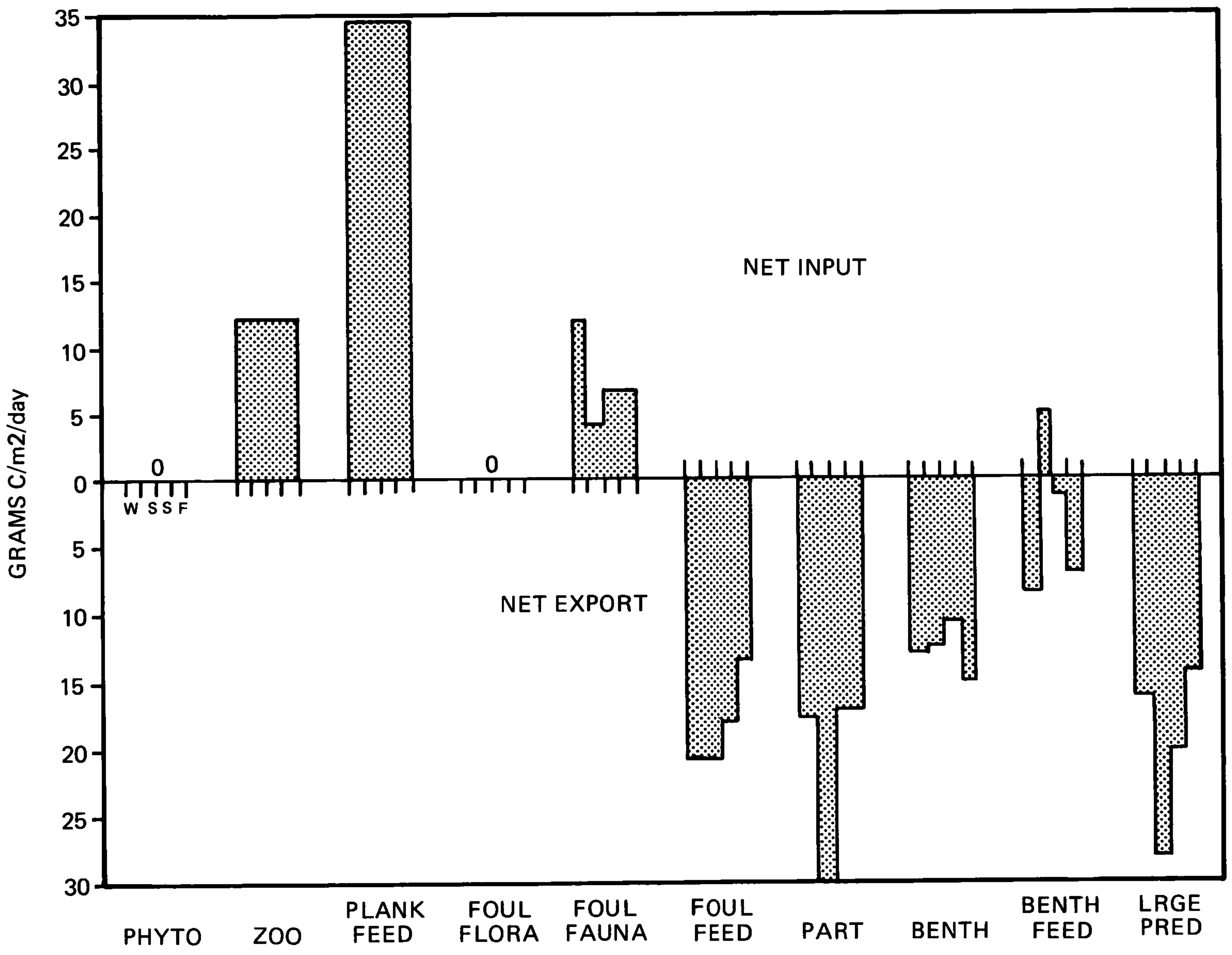


Figure 9. Seasonal variations in the net inputs and exports of carbon in the BGOF system (Fucik and Show 1981).

to external sources exceeded attraction rates and growth. Studies of the platform-associated, benthic-feeding red snapper showed that the flow of this carbon was primarily to humans, the result of fishing pressure on the species (Gallaway et al. 1981a). Export of carbon from the system attributable to benthos was probably also related to fishing pressure from the shrimp-trawl fishery, which was active in the vicinity, as well as to migration of animals through the system. Losses of carbon from the system through fouling feeders (particularly the tropical fish component) and large predators (e.g., bluefish) probably reflected seasonal migration as well as fishing pressure on some species (e.g., sheepshead, barracuda, and mackerel). At least 95% or more of the materials in all compartments of the stored material exported from the BGOF system exited through large predators (Fucik and Show 1981).

Particulate material was also indicated to be a major exporter of carbon from the BGOF system (Figure 9). In the current model structure, most of the within-system flow to particulates came from plankton feeders and zooplankton, supplemented by lesser amounts of materials from the fouling community and phytoplankton. Even though the flows of particulate carbon out of the system were high and mainly of a non-cellular or nonliving nature, waters sourrounding platforms were not characterized by relative increases in non-cellular particulate organic carbon attributable to the BGOF system. This could have been due to rapid dilution of such materials by advection and mixing processes, but a more likely explanation is that the majority of the non-cellular particulates were transported directly to the bottom sediment. This premise is supported by direct observation of Atlantic spadefish fecal material which is seasonally abundant in benthic grab samples, decreasing gradients of sediment organics away from the platforms attributable to platform community productivity (Brooks et al. 1981), and by results of other studies (e.g., Parker et al. 1971).

Particulates in the water column derived from the fouling flora and fauna compartments would be living cells indistinguishable from bacteria, phytoplankton, or zooplankton in the adenosine triphosphate (ATP) analysis used in the BGOF field studies. Most of this material is probably trapped and/or taken up almost immediately by system components (cryptic species, fouling feeders and plankton feeders). Thus, its residence time in the water column is short, as is the distance that the material is transported, indicating a high cycling efficiency for the system (Gallaway and Margraf 1978, Fucik and Show 1981).

The major contribution of the Fucik and Show (1981) model of a platform ecosystem was the determination of the importance of the fouling flora with respect to carbon flows in a platform ecosystem. Their results also indicate a high degree of internal cycling of materials in the system as Gallaway and Margraf (1978) suggested. The 1981 model of Fucik and Show indicated that slightly more carbon was contributed to the external environment than was taken from surrounding areas, suggesting that platforms result in an increase in productivity of a region.

Based upon results of field studies as well as simulations from both of the models, uptake of contaminants from platform discharges appears limited, in large part, to the fouling community (e.g., fouling mat, barnacles, blennies, and sheepshead). Even within these organisms, levels of contamination were low, with no evidence of any bioaccumulation by any species (Gallaway et al. 1981a).

COLOR PLATES

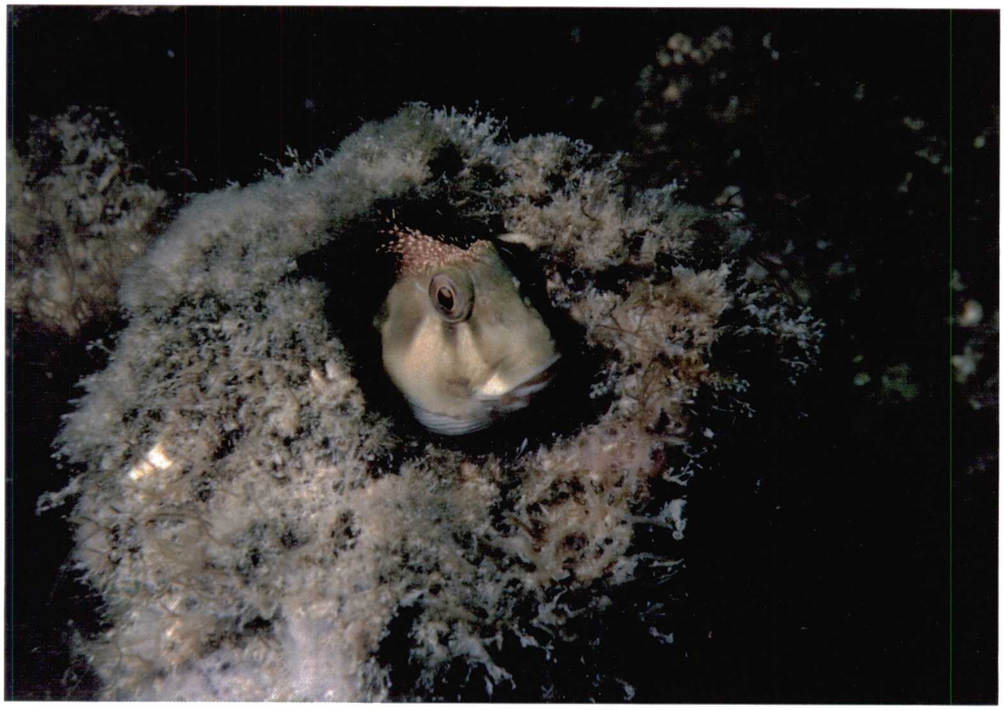
KEY TO PLATFORMS REPRESENTED IN COLOR PLATES

Habitat zone	Operator	Structure	Water depth (m)	Distance from shore (km)
Coastal	Chevron	BM-3KN	12	5
	Shell	WD-32A	16	19
	Oxy Petroleum	MU-749L-1	20	8
	Gulf	WC-333-A	21	79
	Shell	GA-296-B	22	50
	Shell	GS-288-A	22	50
	Shell	GA-296-6	22	50
	Mobil	SPI-1048L	23	13
Offshore	Gulf	ST-128A	30	37
	Amoco	ST-161A	45	48
Bluewater	Transco	NPI-A42-A	67	61
	Union	EHI-334-B	68	171
	Mobil	HI-A595-D	120	173
	Mobil	HI-573-A	102	171

Plate 1a

ALGAE

Algal mat primarily, *Derbesia*. Photo taken at 1m water depth. ST-128A

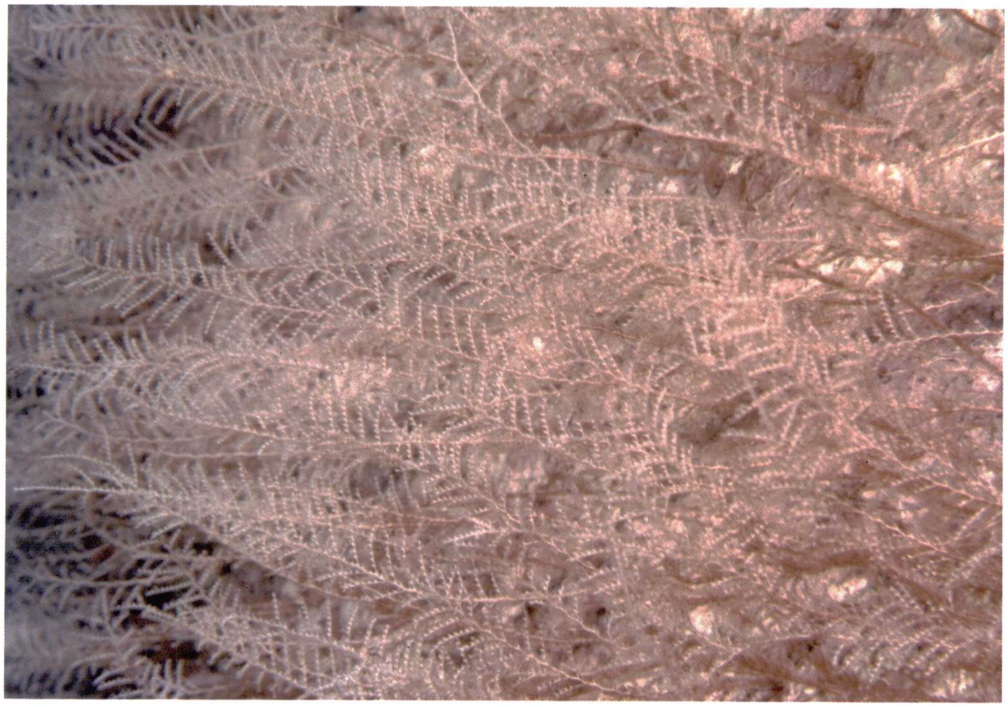


Filamentous green algae on barnacle shell. Primarily *Enteromorpha* sp. and *Cladophora* sp. Photo taken at 1m water depth. WC-333-A

HYDROIDS

Dense stalks of hydroid *Tubularia crocea* (February). Photo taken at 2m water depth.

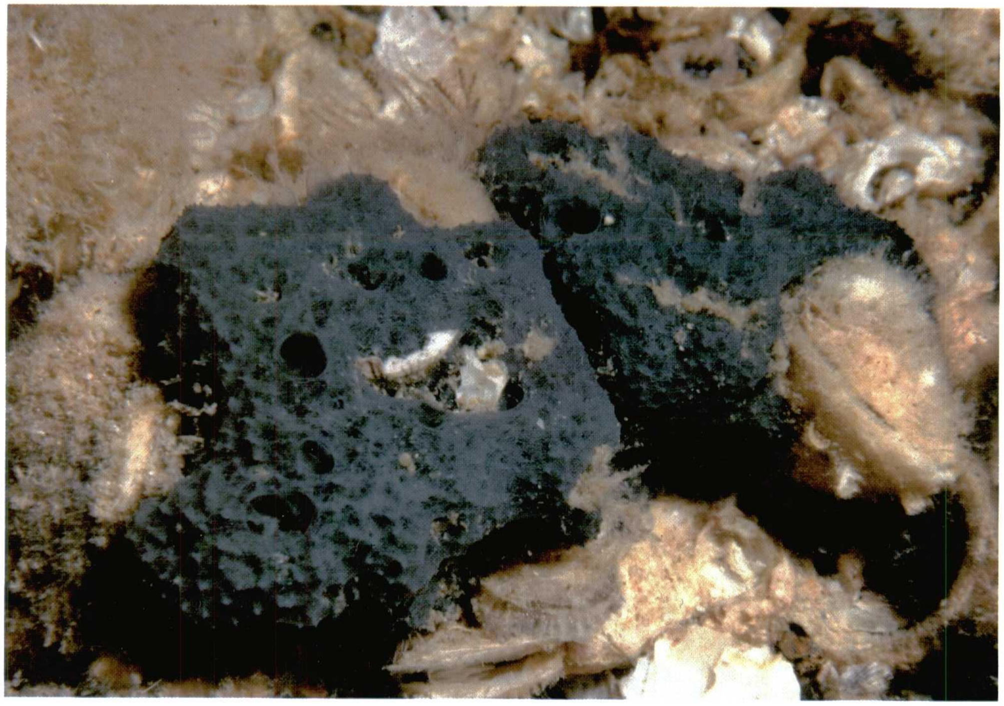
GA-296-B



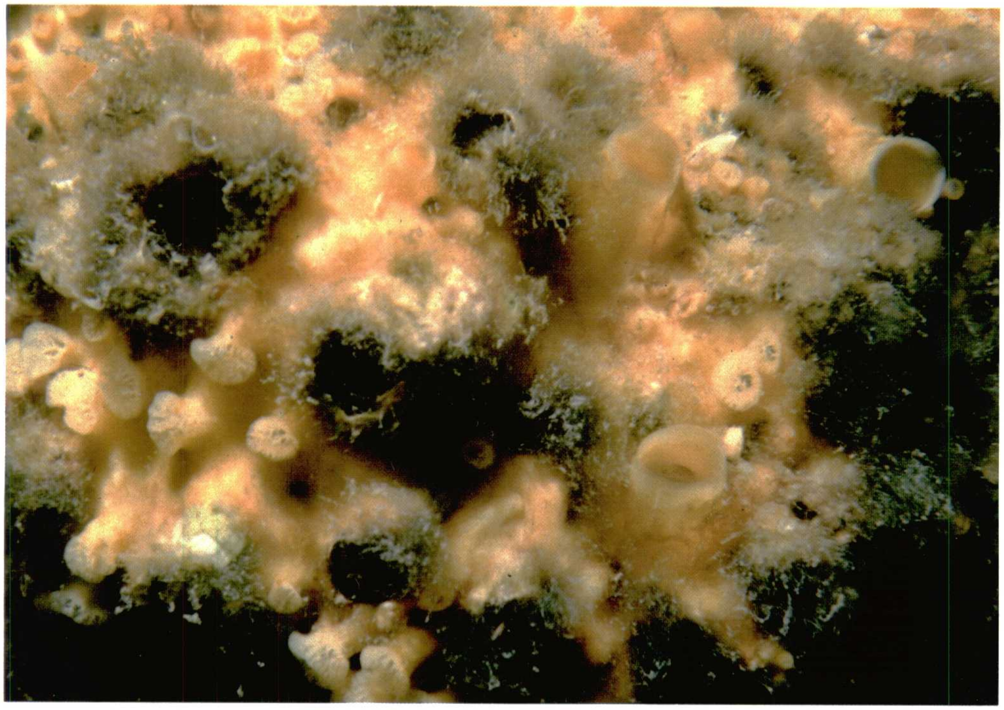
Unidentified feather hydroid near surface. Photo taken at 1m water depth.

HI-A595-D

SPONGES



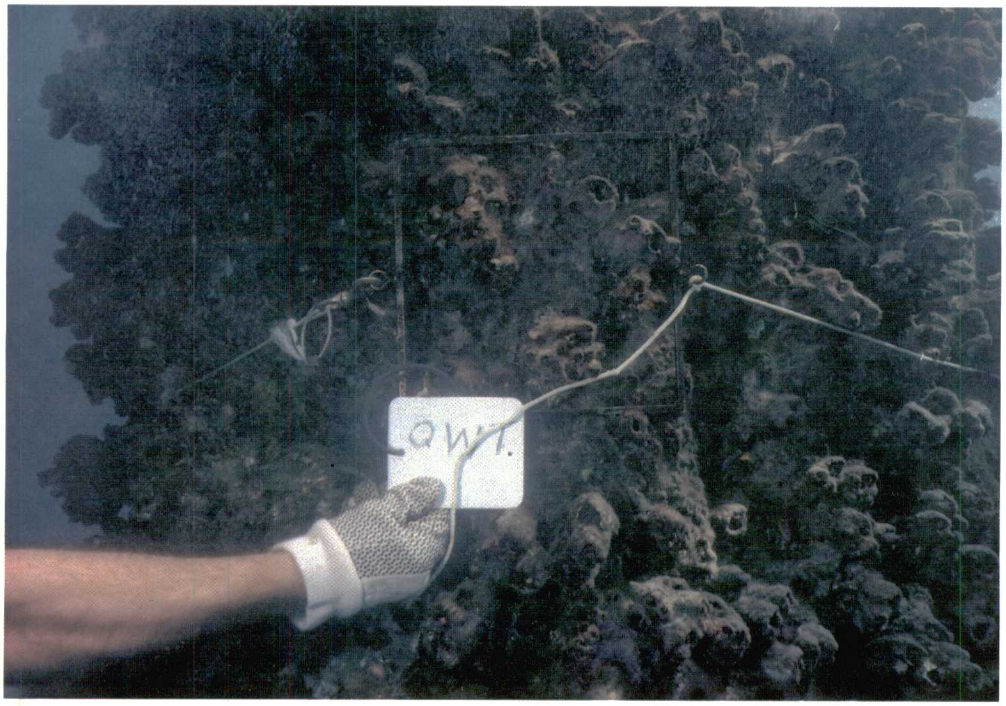
Massive sponge, probably *Ircinia* sp. Photo taken at 5m water depth. GA-296-B



Unidentified encrusting yellow sponge with filamentous green algae. Photo taken at 3m water depth. SPI-1048L

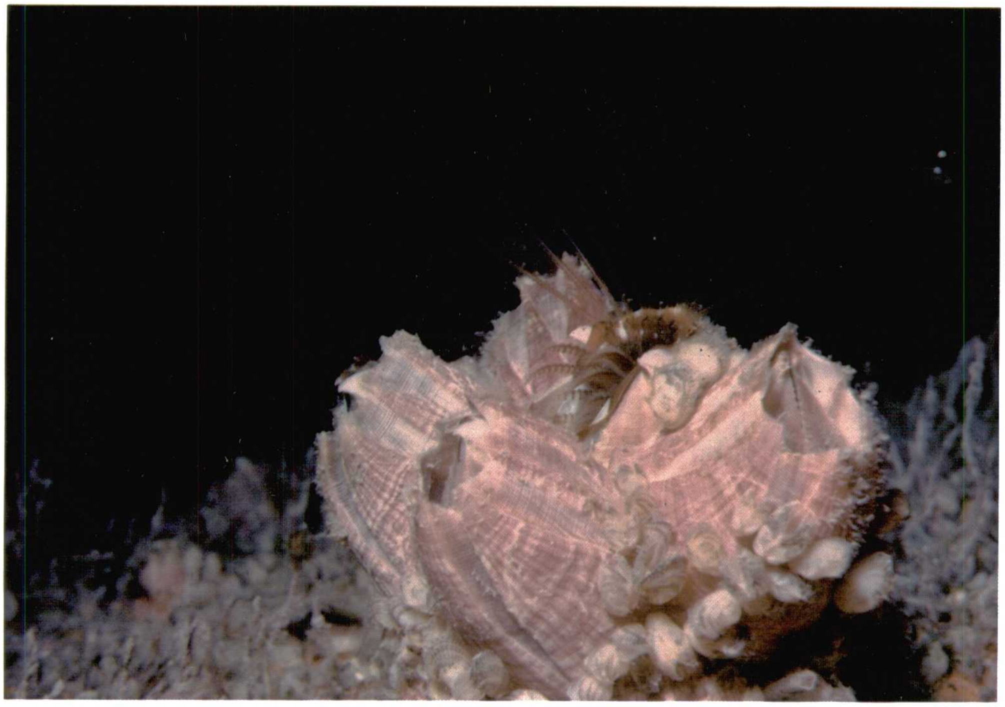
SPONGES

BARNACLES



High relief community of primarily *Balanus tintinnabulum* barnacle clusters. Photo taken at 1m water depth.

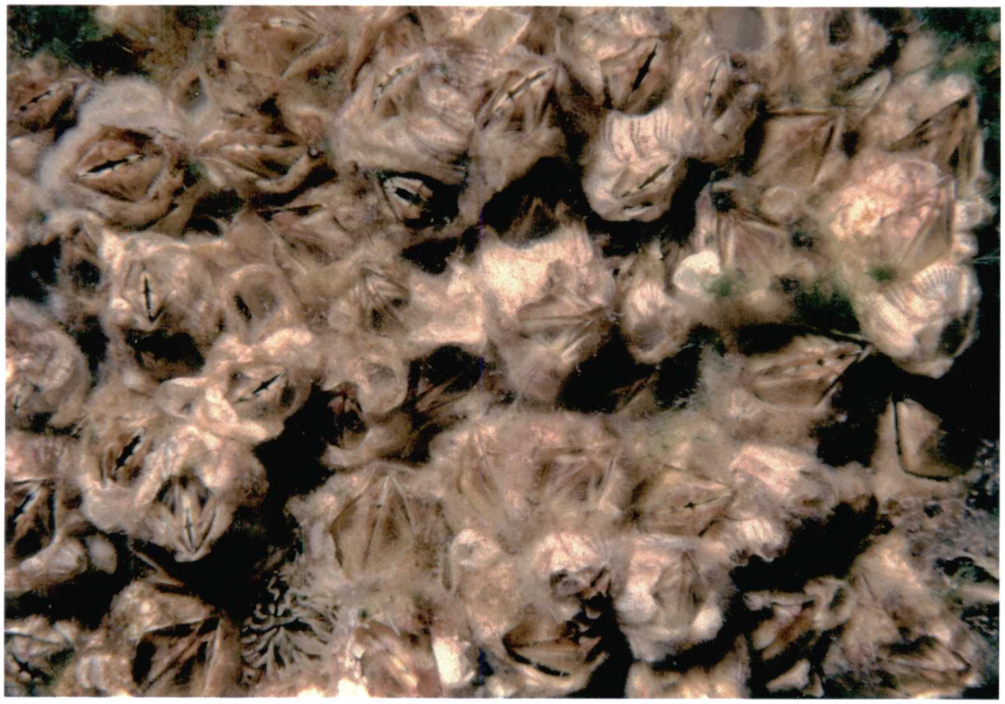
GA-296-B



Cluster of *Balanus tintinnabulum* barnacles with legs extended for feeding. Photo taken at 2m water depth.

NPI-A42-A

BARNACLES



The acorn barnacle *Balanus amphitrite niveus.* Photo taken at 5m water depth.

WC-333-A

Sparse *Balanus* barnacles on bluewater platform. Photo taken at 2m water depth.

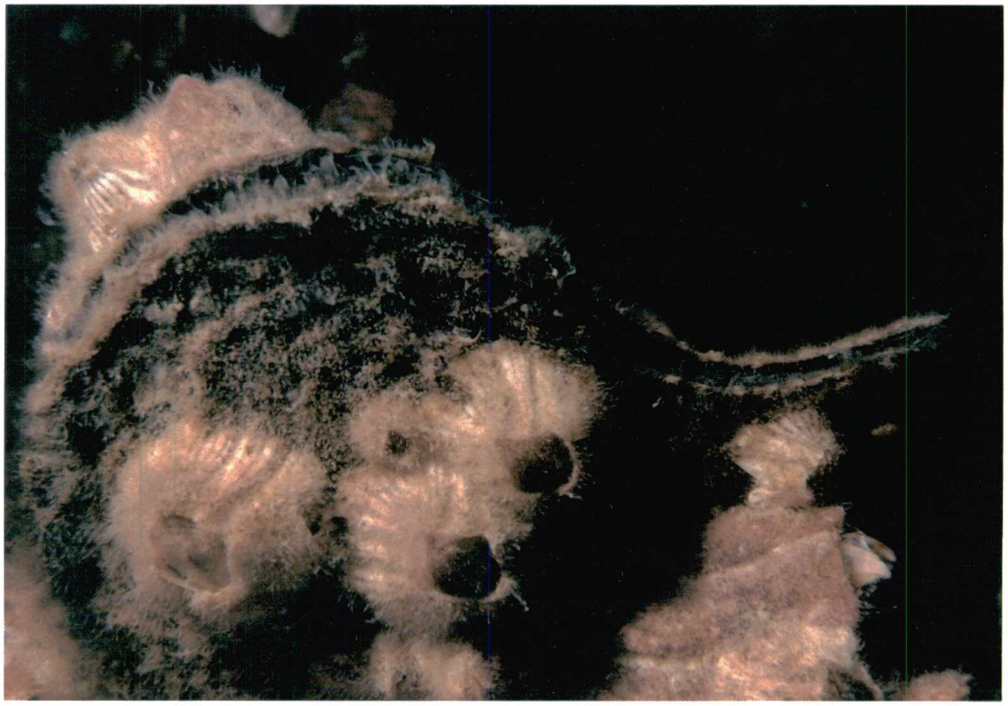
NPI-A42-A

BIVALVES

Small oyster, probably *Lopha frons*. Photo taken at 10m water depth. NPI-A42-A

Tree oysters, *Isognomon bicolor* between *Balanus* barnacles. Photo taken at 1m water depth. GA-296-B

BIVALVES



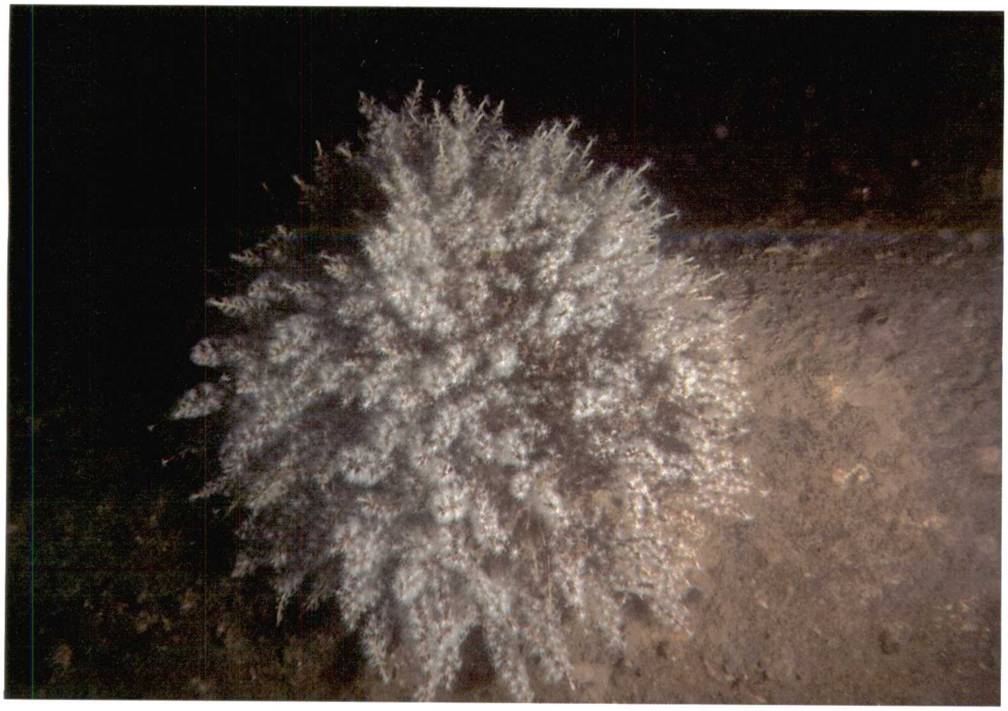
Atlantic winged oyster, *Pteria colymbus*, encrusted with *Balanus* barnacles. Photo taken at 5m water depth.

GA-296-B

Pen shells, *Pinna carnea*. Photo taken at 1m water depth.

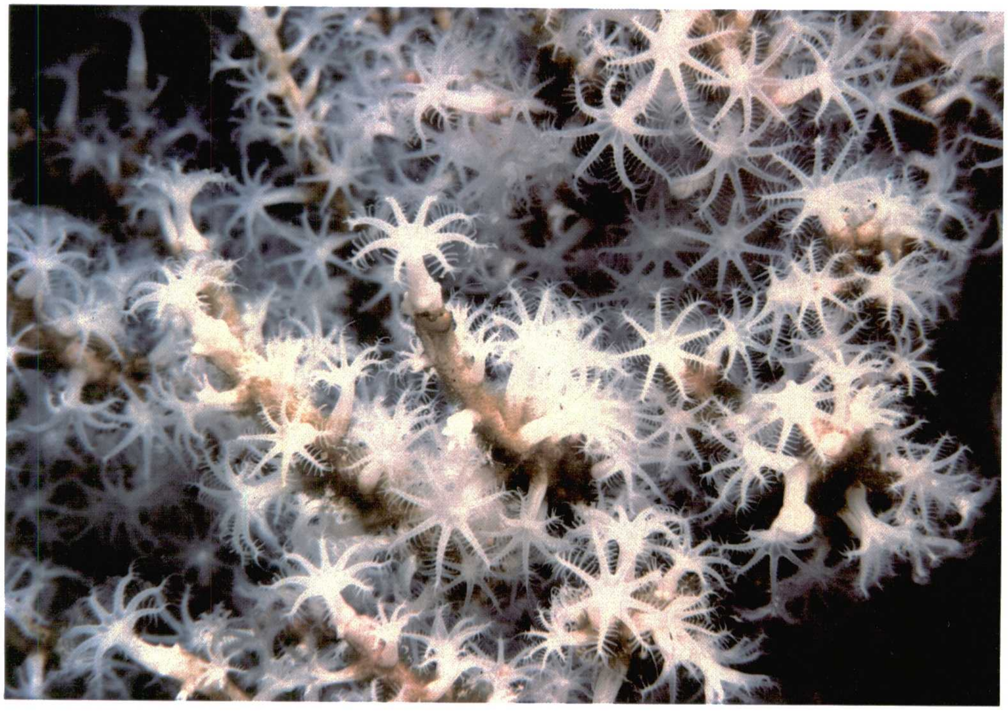
HI-A595-D

OCTOCORALS



Large colony of *Telesto riisei* on horizontal cross member. Photo taken at 18m water depth.

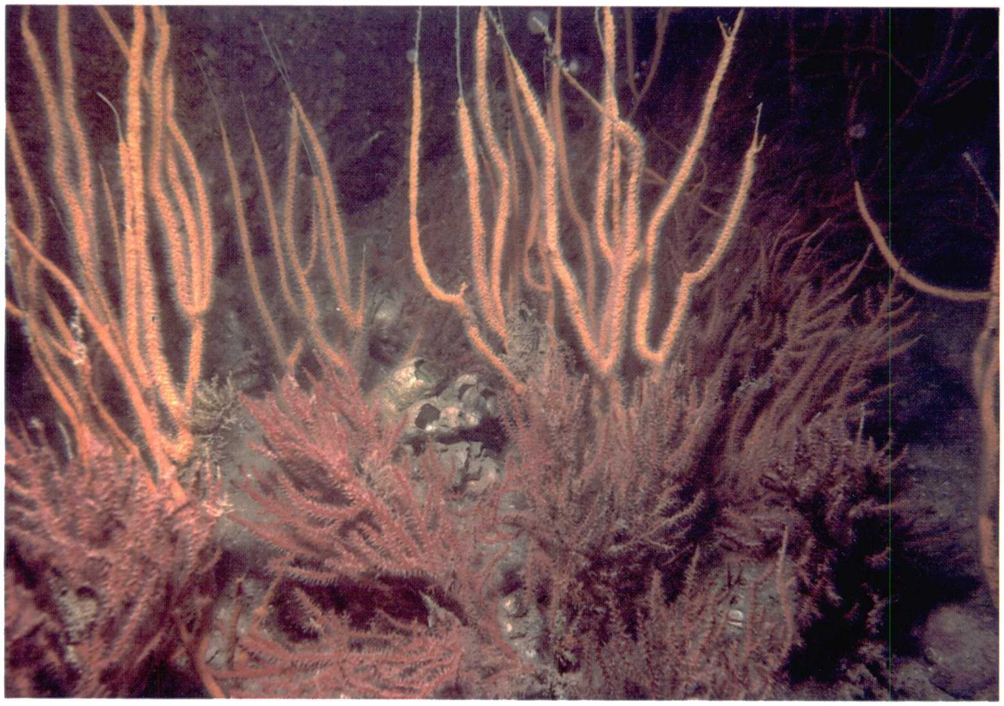
SPI-1048L



Close-up of *Telesto riisei.* Photo taken at 18m water depth.

SPI-1048L

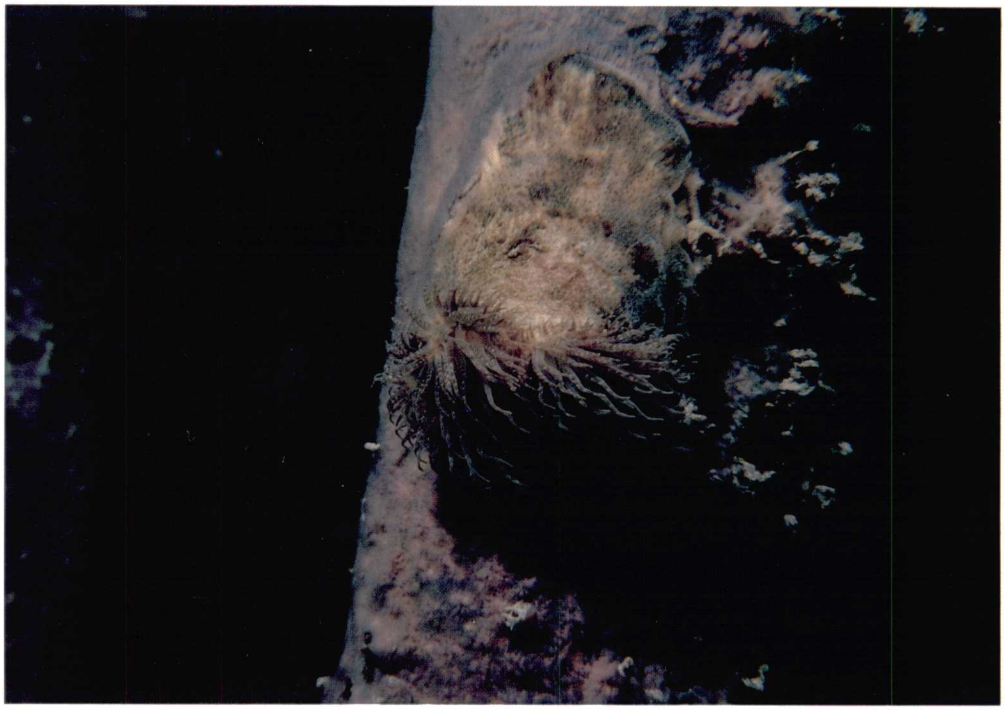
OCTOCORALS



Two species of gorgonian octocoral *Leptogorgia virgulata* and the smaller red *Lophogorgia hebes*. Photo taken at 18m water depth.

SPI-1048L

ANEMONES



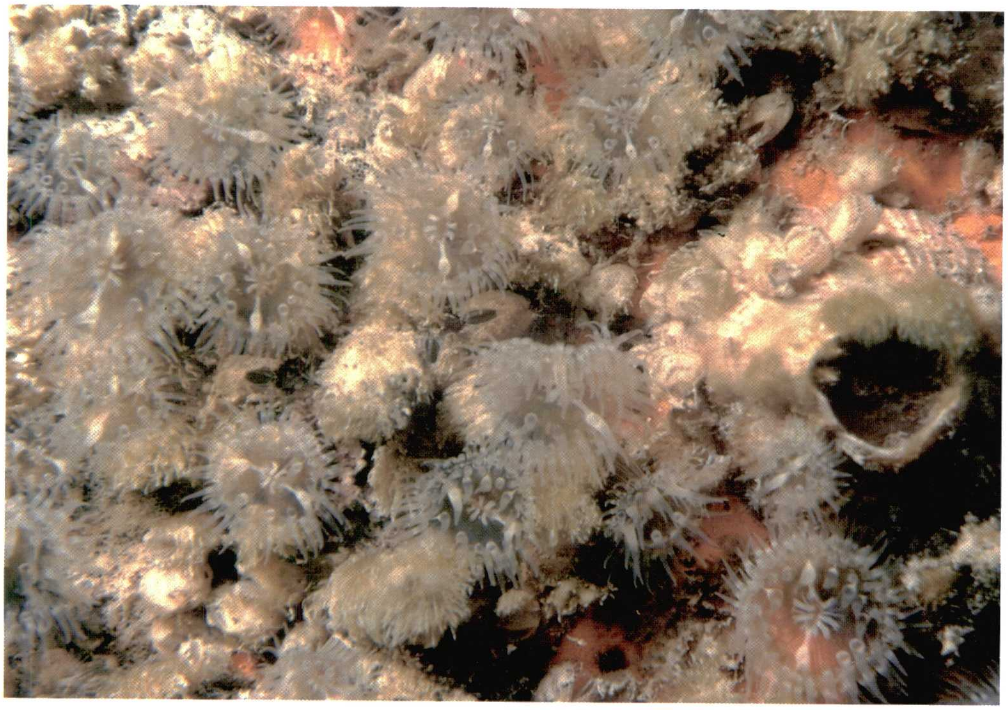
Unidentified pair of anemones on vertical leg. Photo taken at 10m water depth.

NPI-A42-A

ANEMONES

Unidentified anemones in and around dead barnacle shell. Photo taken at 9m water depth.

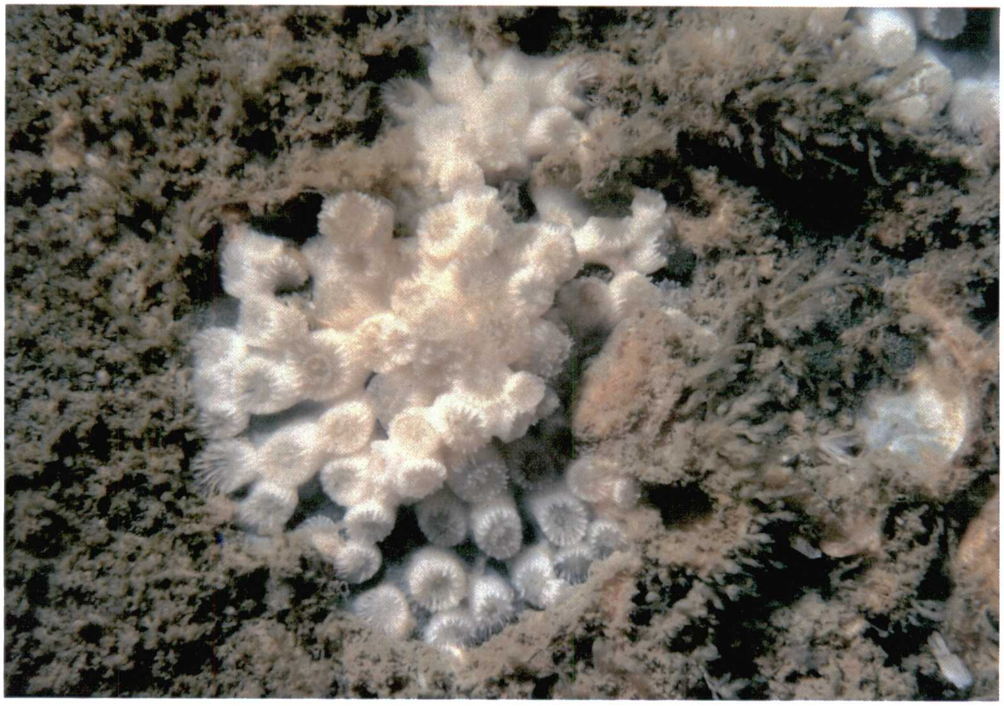
SPI-1048L



Group of unidentified actinarian anemones. Photo taken at 2m water depth.

NPI-A42-A

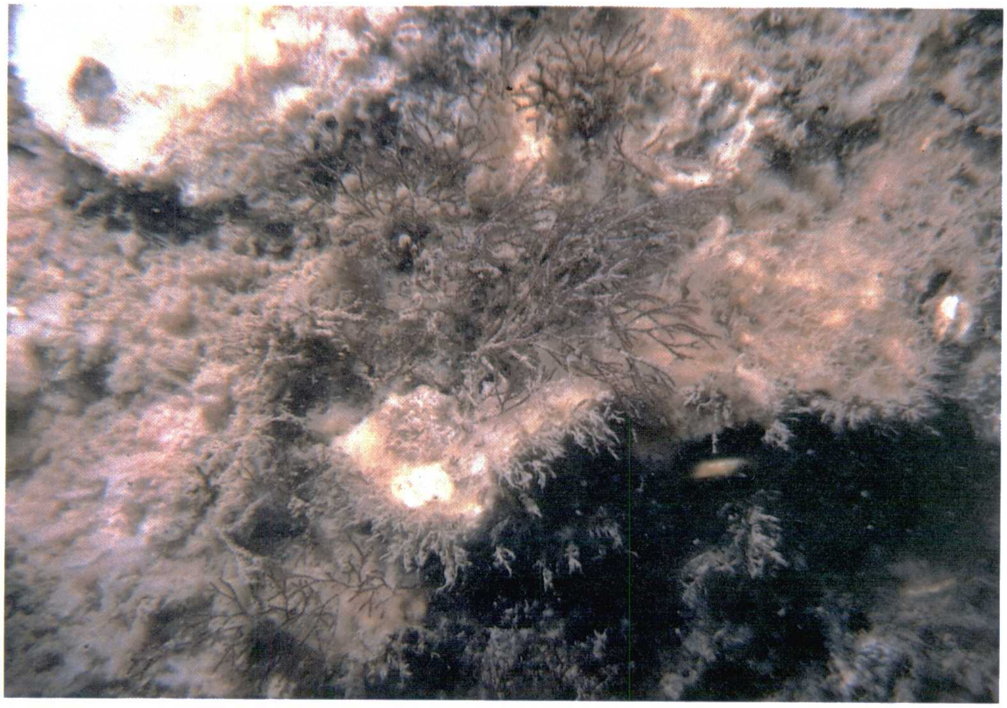
STONY CORALS



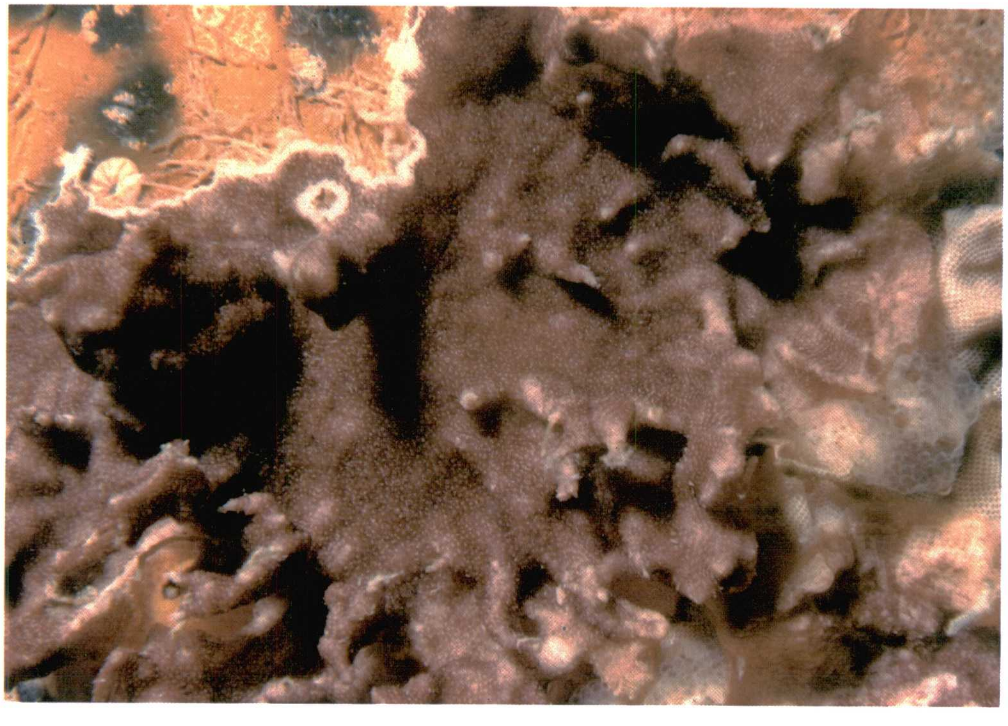
Ivory bush coral, *Oculina diffusa*, near bottom on horizontal cross members. Photo taken at 21m water depth. GA-296-B

Phyllangia americana on vertical leg. Photo taken at 20m water depth. GA-296-B

BRYOZOANS



Branching bryozoan, *Bugula neritina*. Photo taken at 12m water depth. MU-749L-1



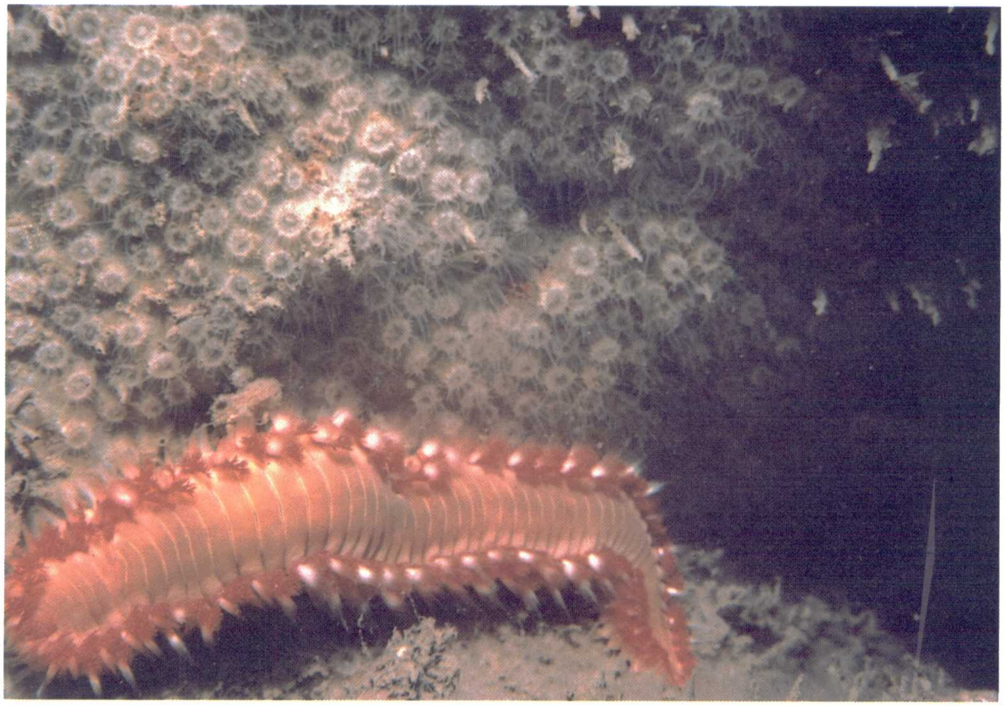
Unidentified red encrusting bryozoan. Photo taken at 2m water depth. NPI-A42-A

BRYOZOANS

Unidentified foliaceous bryozoan. Photo taken at 1m water depth. HI-A595-D

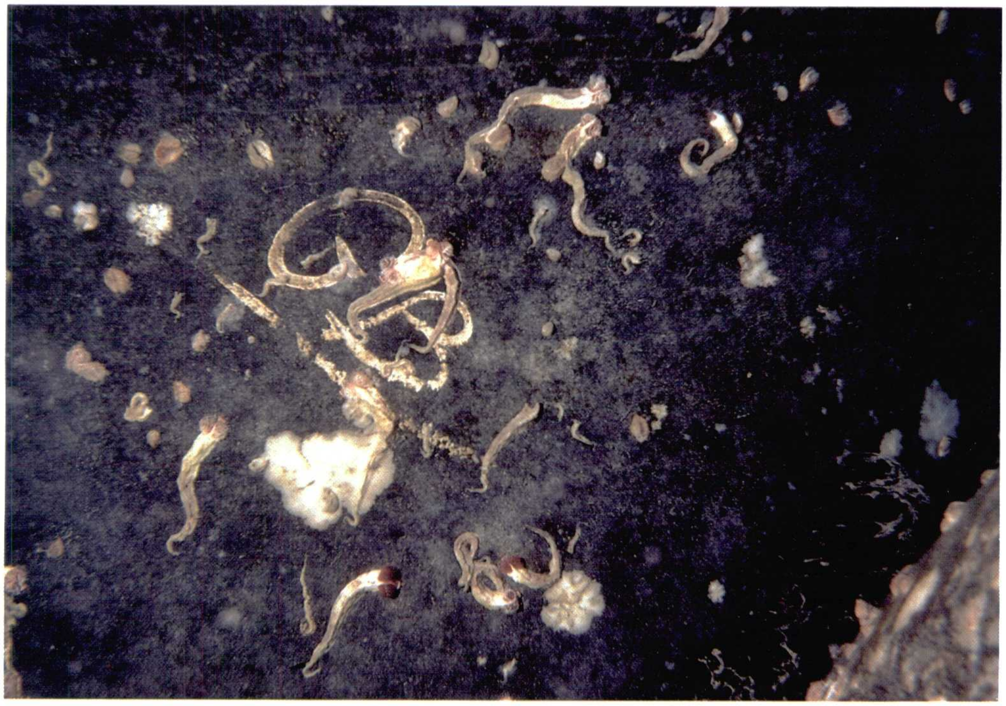
Foliaceous bryozoan with drill cuttings deposited on surface. Photo taken at 11m water depth. NPI-A42-A

MOTILE EPIFAUNAL INVERTEBRATES



Fireworm, *Hermodice carunculata*, on colonial anemones. Photo taken at 9m water depth.

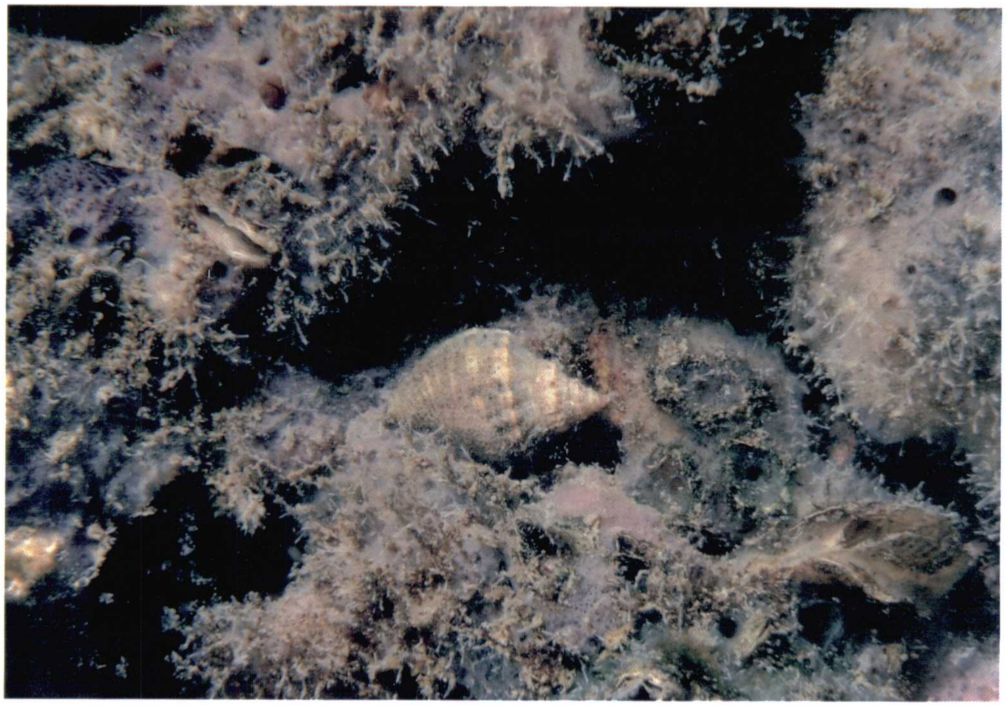
ST-128A



Feather duster worms and tubes, *Spirobranchus giganteus.* Photo taken at 20m water depth. (Non-motile but common polychaete)

EHI-334-B

MOTILE EPIFAUNAL INVERTEBRATES

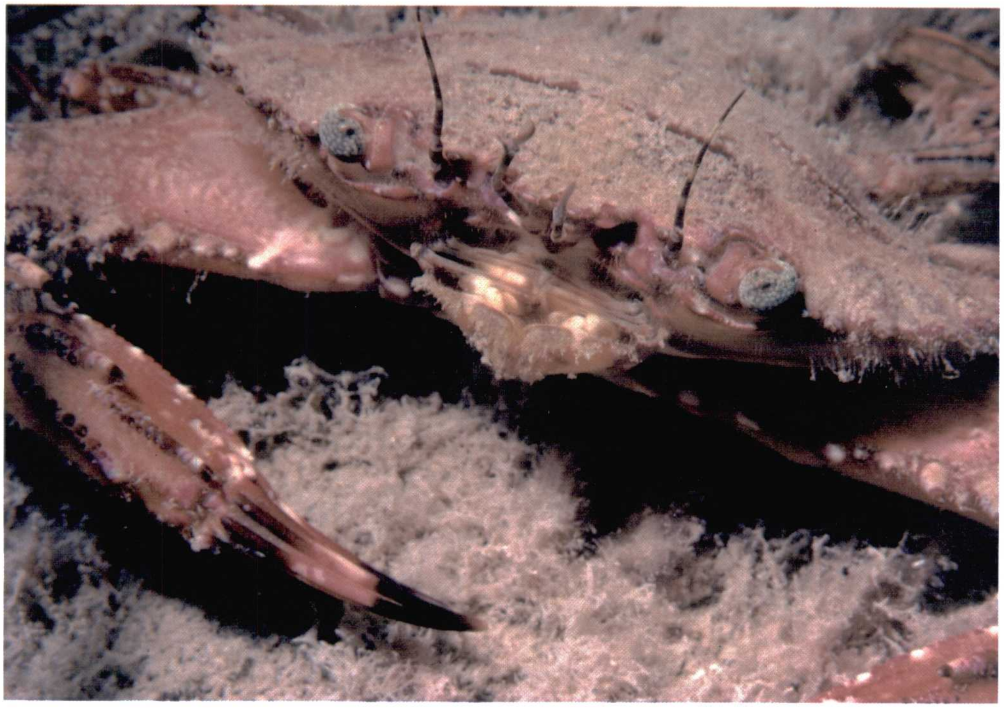


Rock shell, *Thais haemastoma*. Photo taken at 2m water depth. WC-333-A

Unidentified nudibranchs. LGL file photo. ST-128A

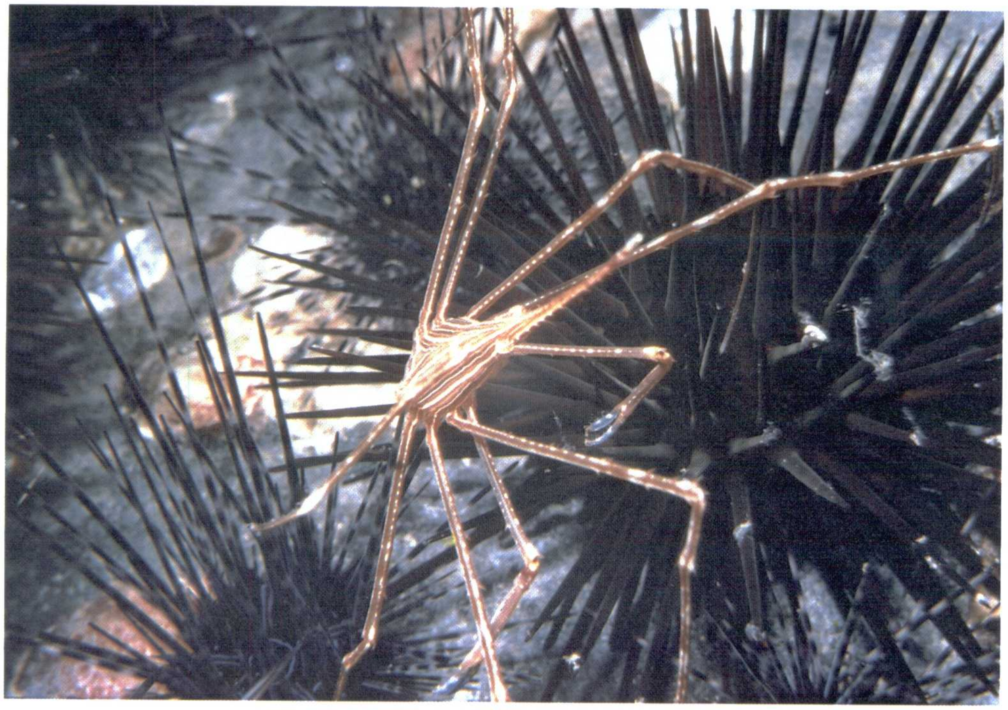
MOTILE EPIFAUNAL INVERTEBRATES

Stone crab, *Menippe mercenaria.* Photo taken at 6m water depth. GA-296-B



Swimming crab, probably *Portunus ordwayi*. Photo taken at 9m water depth. HI-A595-D

MOTILE EPIFAUNAL INVERTEBRATES



Arrow crab, *Stenorhynchus seticornis*. Photo taken at 9m water depth.

HI-A595-D

Arms of brittle stars in sponge mat. *Ophiothrix* or *Ophiactis* sp. Photo taken at 2m water depth. LGL file photo.

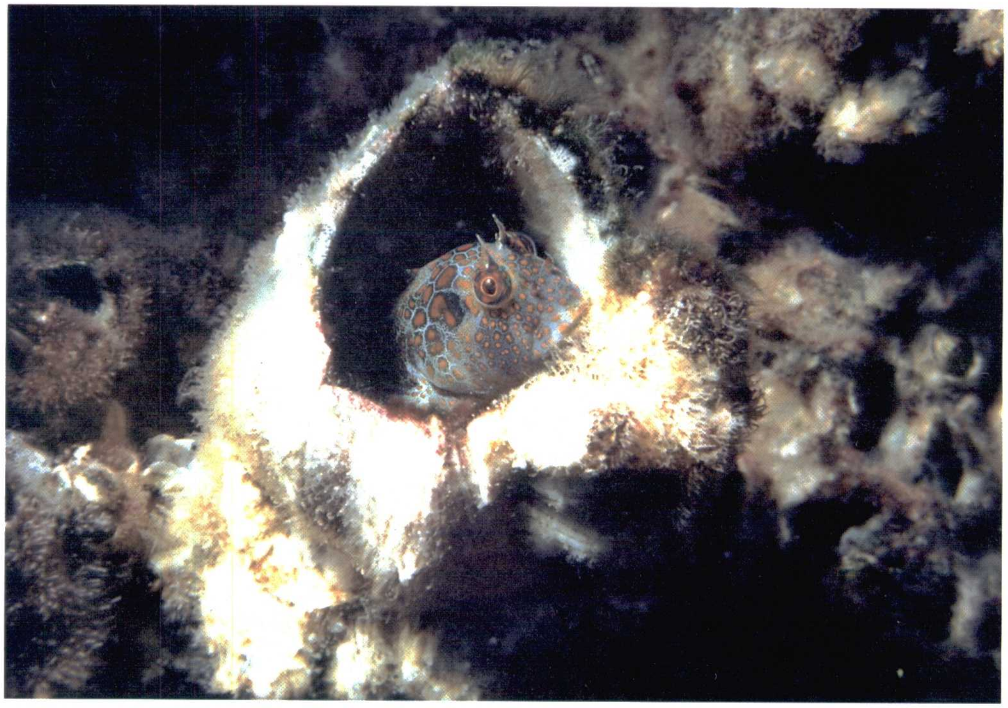
ST-128A

BLENNIES

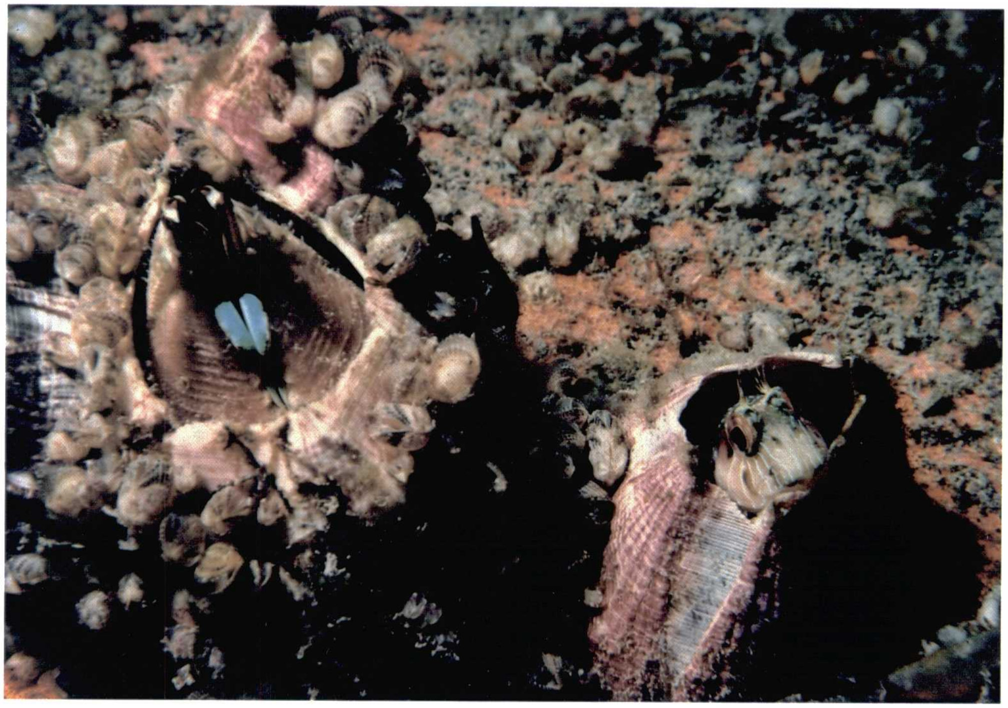
Molly Miller, *Blennius cristatus*. Photo taken at 1m water depth. GA-296-B

Crested blenny, *Hypleurochilus geminatus*. Photo taken at 2m water depth. WC-333-A

BLENNIES

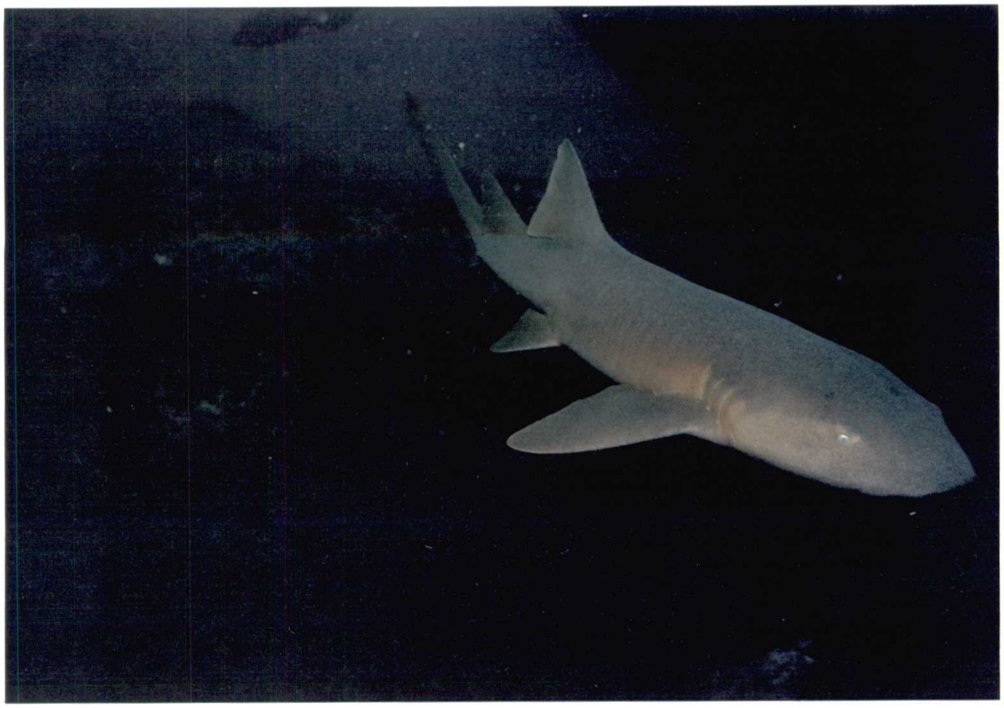


Orangespotted blenny, *Hypsoblennius invemar*. Photo taken at 2m water depth. WC-333-A



Seaweed blenny, *Blennius marmoreus*. Photo taken at 2m water depth. NPI-A42-A

FISHES



Nurse shark, *Ginglymostoma cirratum*. Photo taken at 14m water depth. ST-128A

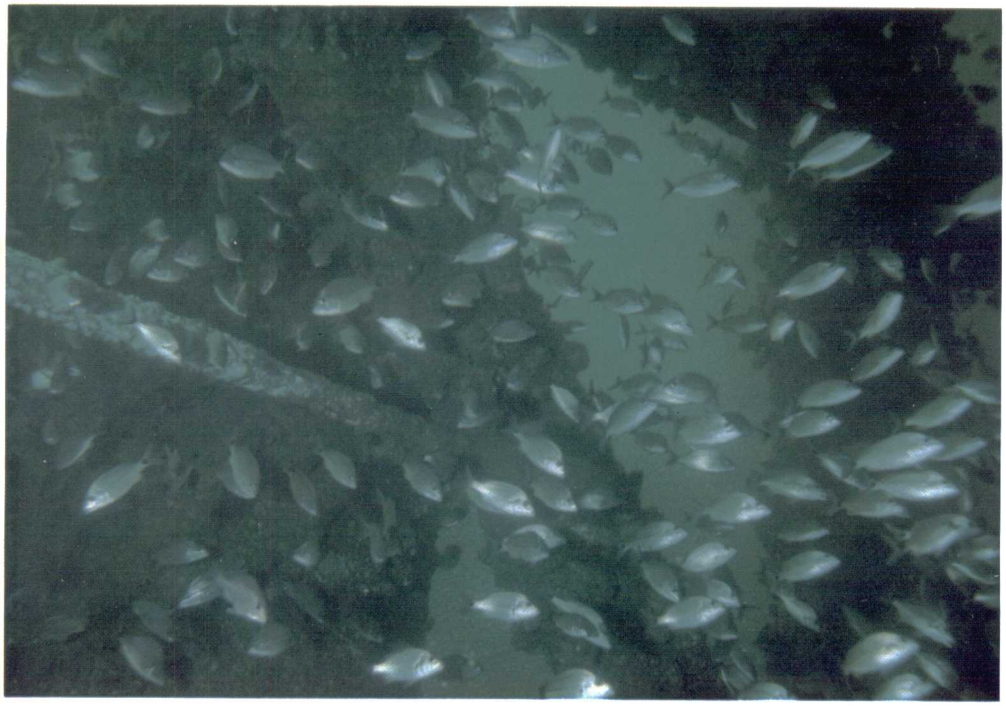
Greater amberjack, *Seriola dumerili*. Photo taken at 20m water depth. EHI-334-B

FISHES

Blue runner, *Caranx crysos*. Photo taken at 10m water depth. HI-595-D

Lookdown, *Selene vomer*. Photo taken at 15m water depth. ST-128A

FISHES



School of primarily tomtate, *Haemulon aurolineatum* GA-296-6

Bigeye *Priacanthus arenatus* SPI-1048L

FISHES

Scalloped hammerhead, *Sphyrna lewini*. Photo taken at 5m water depth. GA-296-B

Almaco jack, *Seriola rivoliana*. Photo taken at 20m water depth. EHI-334-B

FISHES

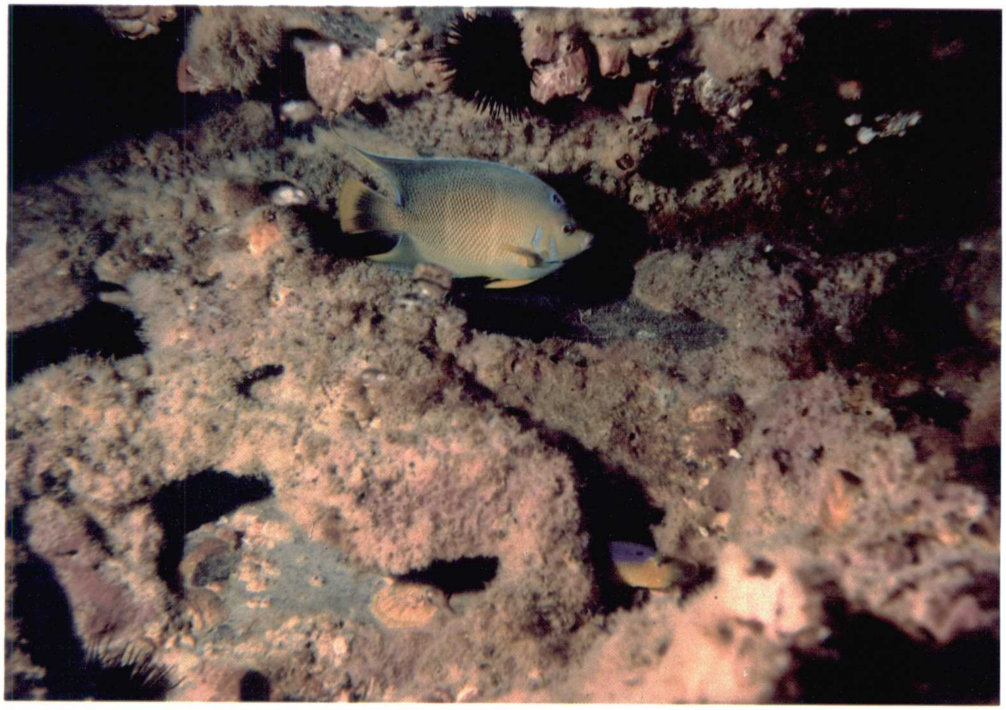
Bluefish, *Pomatomus saltatrix*. Photo taken at 10m water depth. ST-128A

Great barracuda, *Sphyraena barracuda*, and spadefish, *Chaetodipterus faber*. Photo taken at 2m water depth. ST-161A

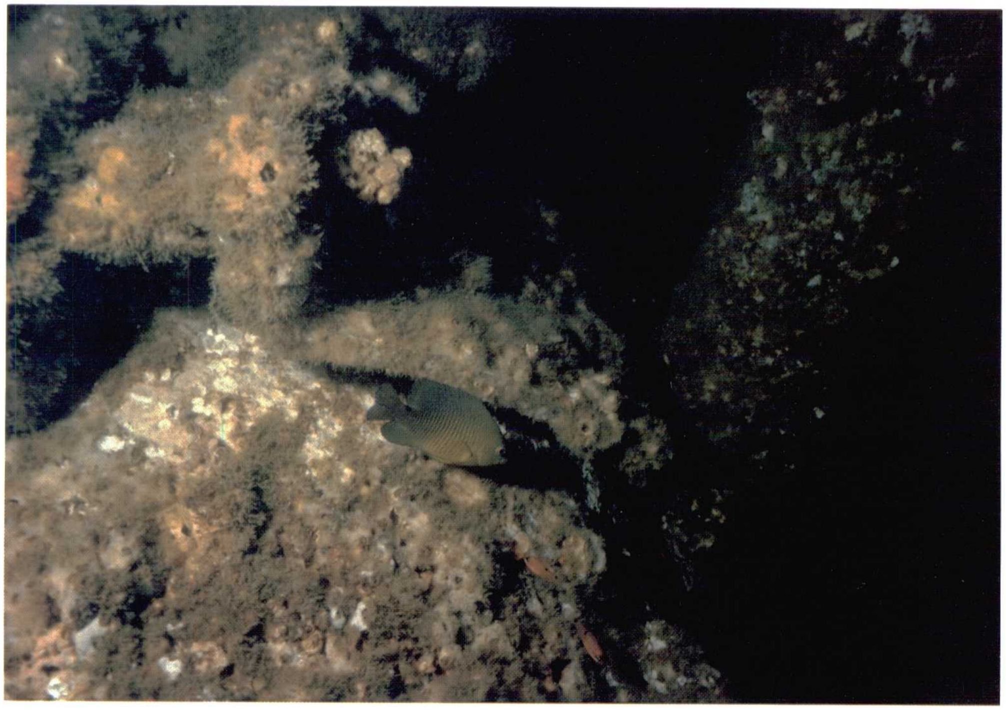
Red snapper, *Lutjanus campechanus*. Photo taken at 20m water depth. GA-296B

Grey snapper, *Lutjanus griseus*. Photo taken at 5m water depth. ST-161A

FISHES



Queen angelfish, *Holacanthus ciliaris*. Photo taken at 10m water depth. WC-333-A

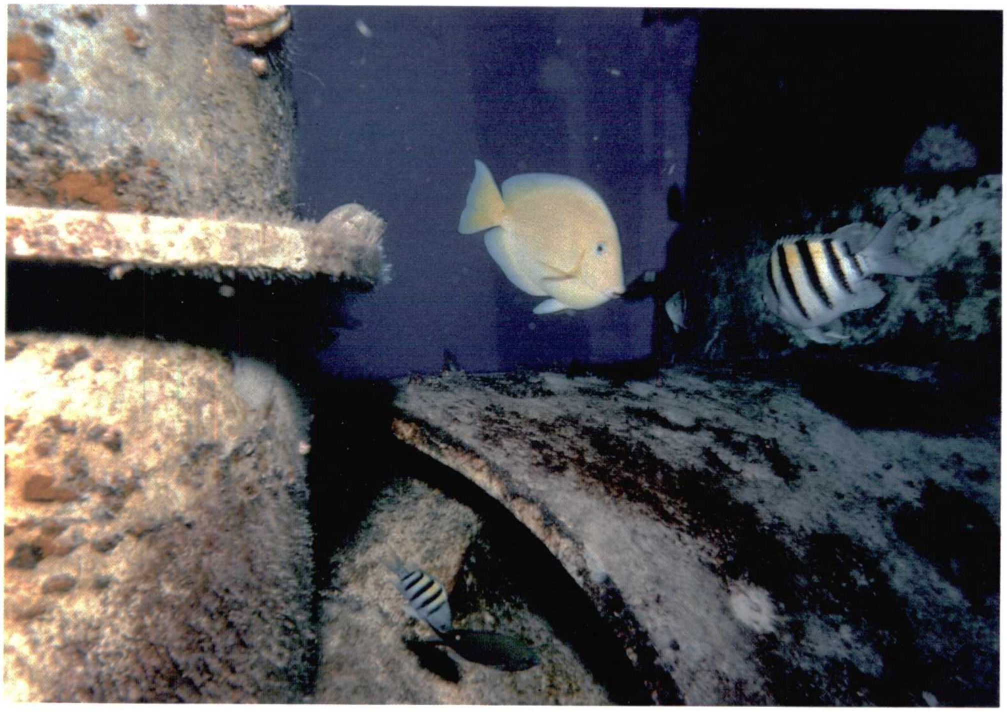


Cocoa damsel, *Pomacentrus variabilis*. Photo taken at 3m water depth. WD-32A

FISHES

Spotfin butterflyfish, *Chaetodon ocellatus*. Photo taken at 5m water depth.

GA-296-B

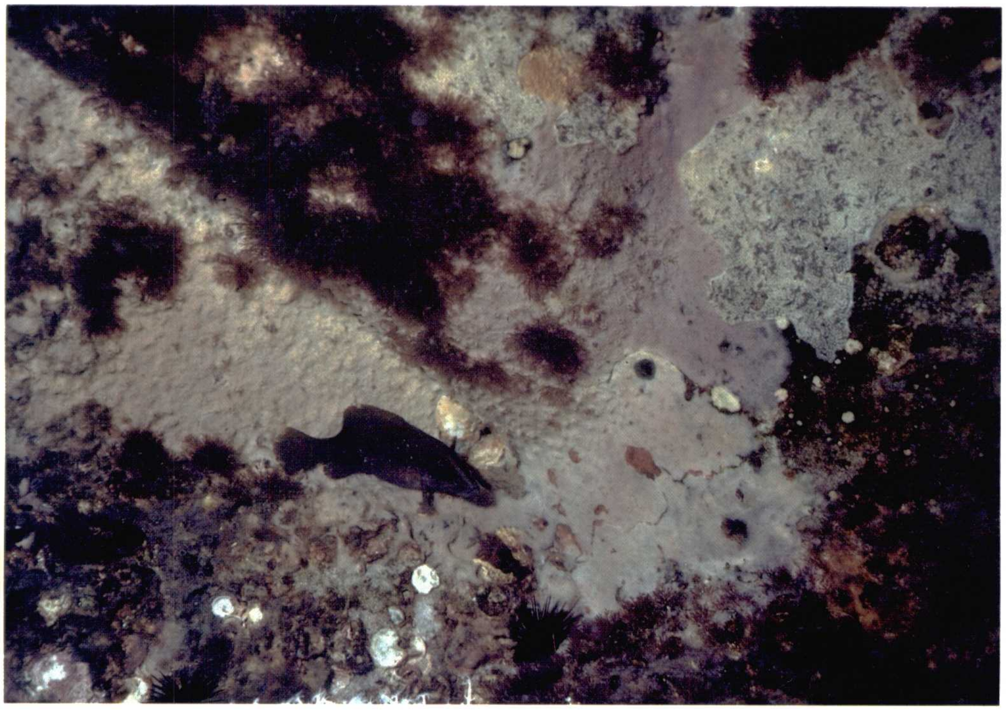


Blue tang, *Acanthurus coeruleus*, and sergeant major, *Abudefduf saxatilis*. Photo taken at 1m water depth.

HI-A595-D

FISHES

Flamefish, *Apogon maculatus*. Photo taken at 10m water depth. WD-32A



Whitespotted soapfish, *Rypticus maculatus*. Photo taken at 5m water depth. ST-161A

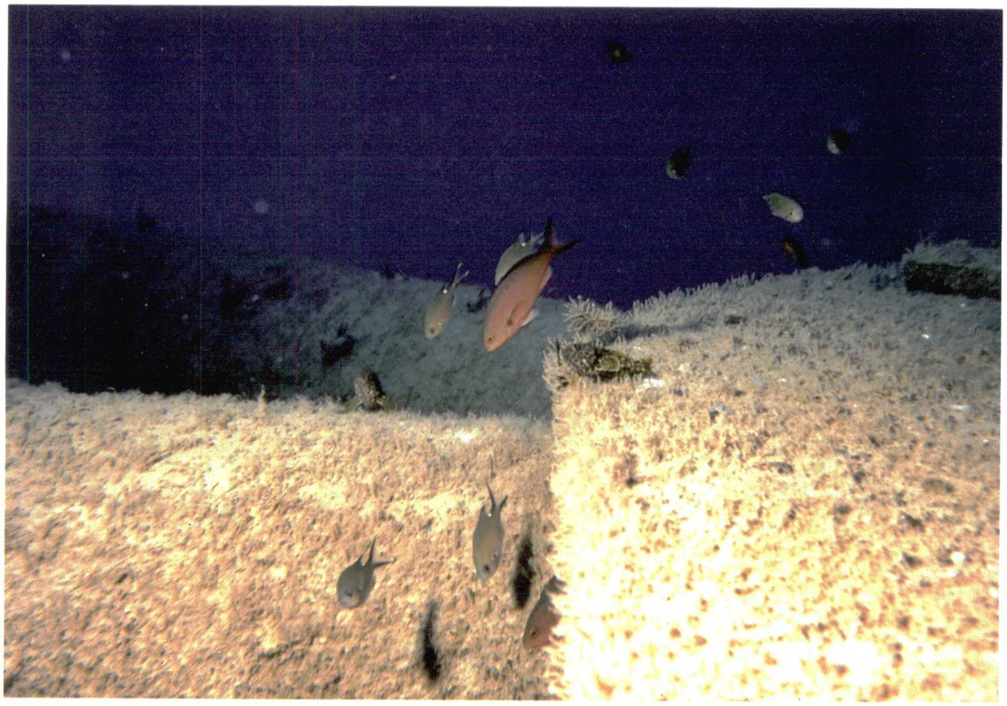
FISHES

Sheepshead, *Archosargus probatocephalus*. Photo taken at 20m water depth. ST-161A

Chub, *Kyphosus* sp. Photo taken at 2m water depth. GA-296-B

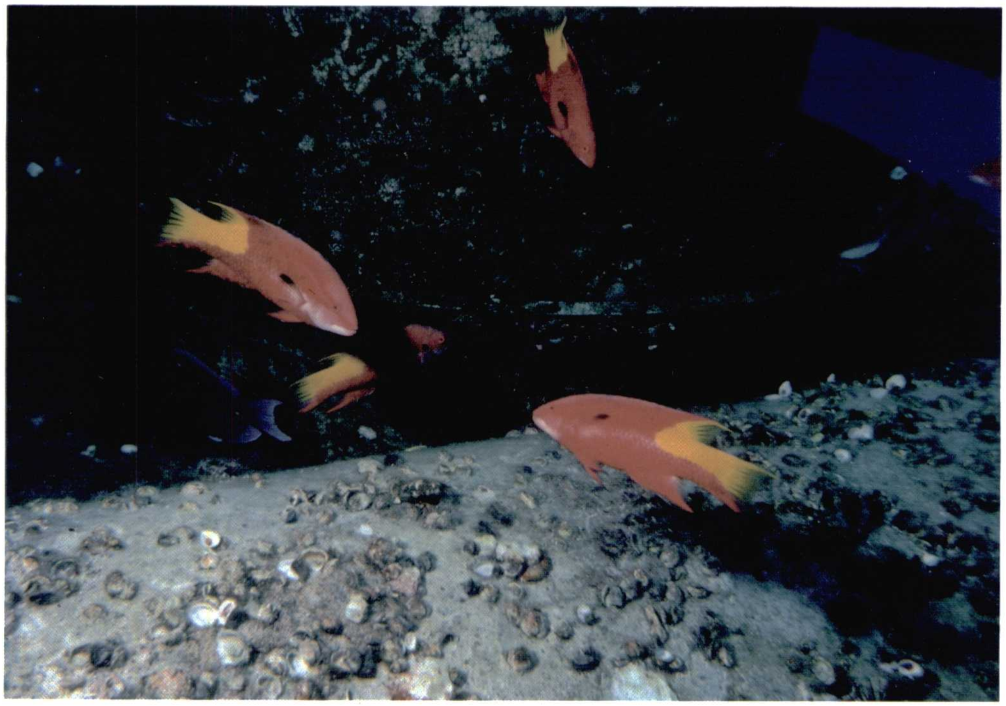
FISHES

Grey triggerfish, *Balistes capriscus*. Photo taken at 10m water depth. HI-A595-D



Creole fish, *Paranthias furcifer*, and brown chromis, *Chromis multilineatus*. Photo taken at 10m water depth. HI-A595-D

FISHES



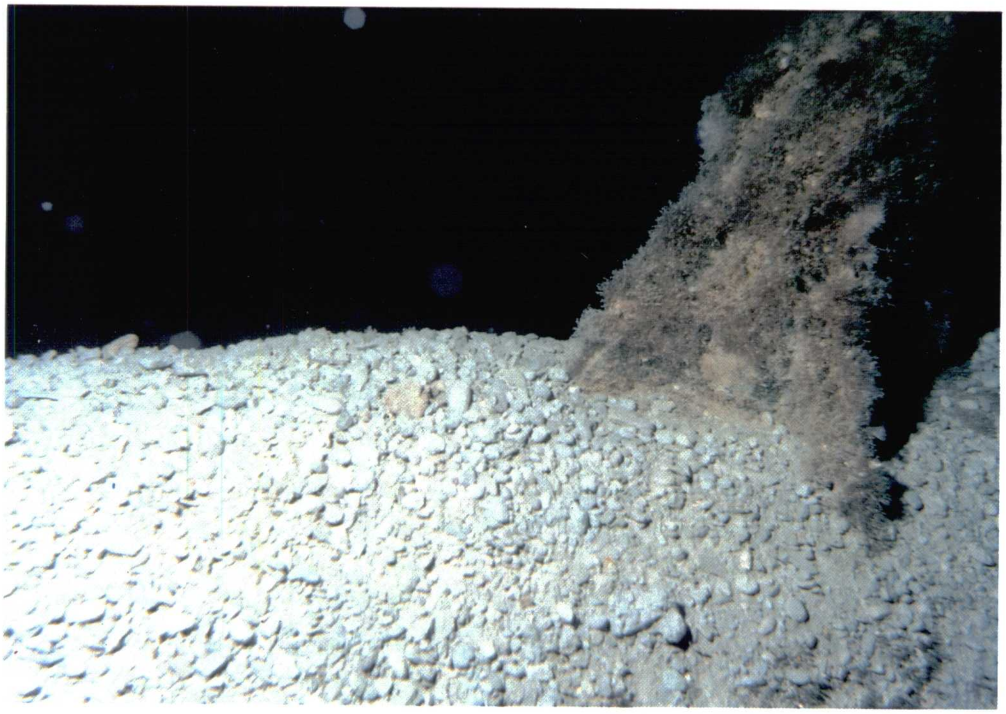
Spotfin hogfish, *Bodianus pulchellus*. Photo taken at 10m water depth. HI-573-A

Comb grouper, *Mycteroperca rubra*. Photo taken at 10m water depth. BM-3KN

DRILL CUTTINGS

Drill cuttings deposited on horizontal cross-members. Photo taken at 11m water depth.

NPI-A42-A

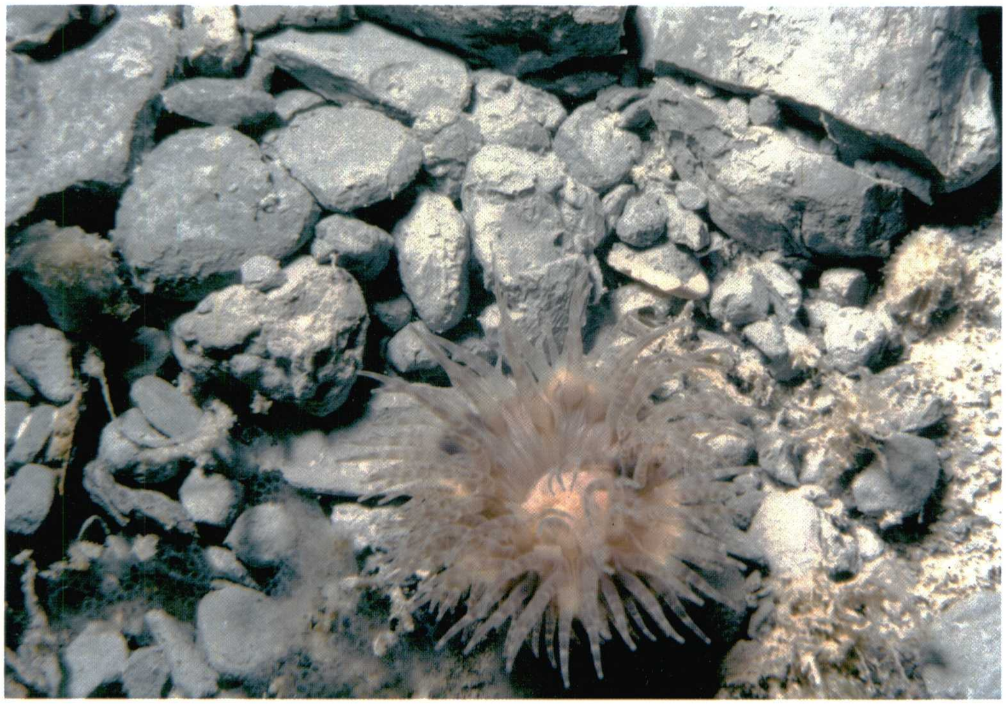


Drill cuttings on individual horizontal cross member. Photo taken at 11m water depth.

NPI-A42-A

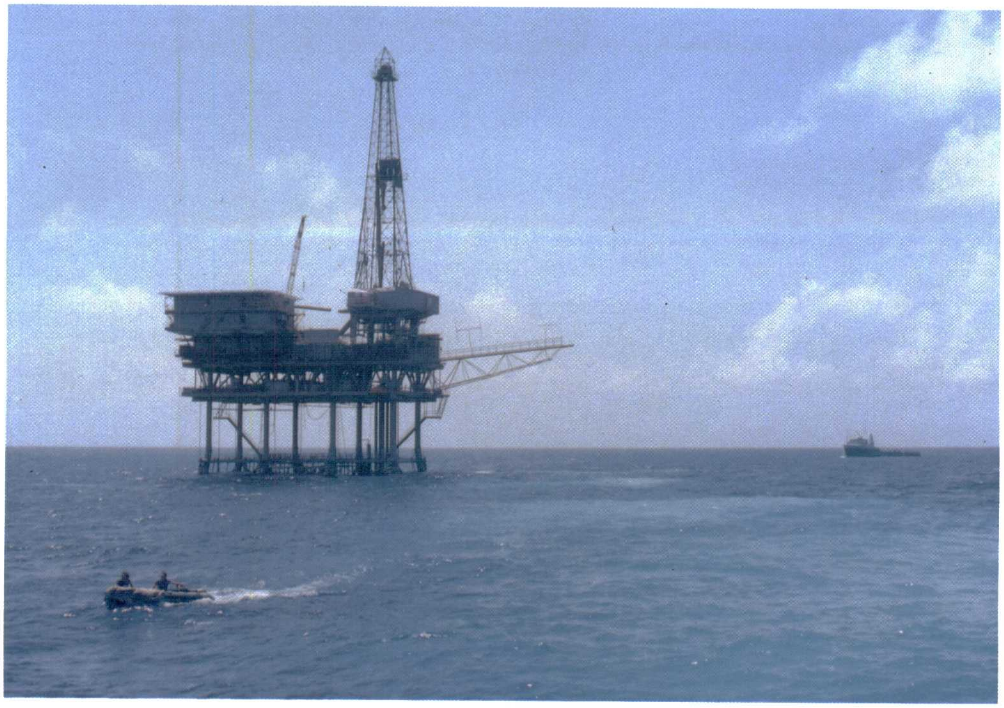
DRILL CUTTINGS

Drill cuttings utilized for habitat by whitespotted soapfish and rock hinds. Photo taken at 11m water depth. NPI-A42-A

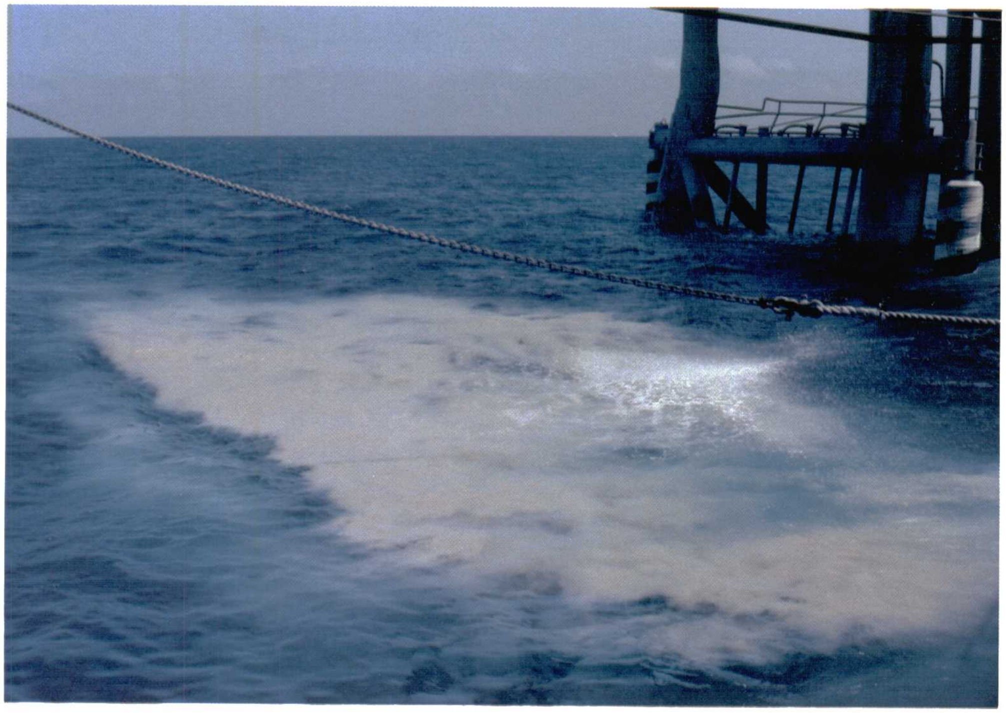


Anemone living at edge of drill cutting pile. Photo taken at 11m water depth. NPI-A42-A

MUD DISCHARGES



Periodic above-water mud discharges moving with current. HI-A595-D

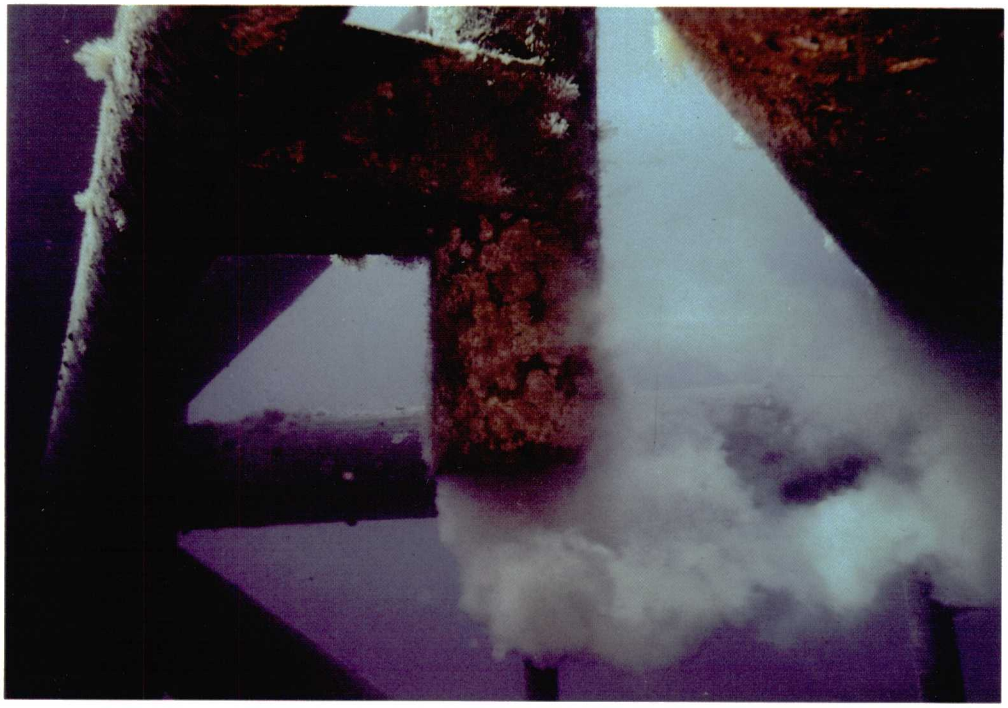


Mud discharge contacting surface near platform. HI-A595-D

Plate 9d

MUD DISCHARGES

View of previous mud discharge from underwater. Photo taken at 2m water depth. HI-A595-D



Small subsurface mud discharge. Photo taken at 2m water depth. HI-A595-D

PRODUCED WATER DISCHARGE

Produced water discharge just above surface.

GA-296-B

Affected area of biofouling community immediately below produced water discharge (seen in upper left). Photo taken at 1m water depth.

GS-288-A

CHAPTER 3

VALUE OF PLATFORM ECOSYSTEMS TO MAN

Petroleum platforms in the northern Gulf of Mexico (and in most other locations) constitute unusual environments compared to the surrounding waters and soft bottoms into which they are often embedded. They may be considered "islands" with varying degrees of insularity depending upon their size and distance from other "islands." If surrounded by soft bottom, they may alter the abundance of local fauna within their immediate vicinity; but given the ratio between the area which might be affected and the relatively undisturbed benthos lying some distance from them, this alteration must be considered minor. Thus, much soft bottom is probably unaffected by platforms. On the other hand, platforms provide habitat for species which would not normally be there were it not for the solid substrate offered by the platforms. Some of these species are of direct economic and recreational interest.

3.1 FISHERIES

When one thinks of platforms, fishing immediately comes to mind. Platforms act as nuclei for commercial and sport fishermen who return frequently because fishing is better there than over soft bottom. Platform personnel frequently fish during off-duty hours. Many species of fish linger near platforms including those without trophic dependence upon them. This effect has been exploited in many other areas of the world, where artificial reefs or floating rafts have been installed specifically to enhance fishing (see Steimle and Stone 1973). The north central Gulf of Mexico has not had the stimulus to install such structures since platforms serve this function admirably. The platforms are fished by anglers and spear fishermen alike. Typical species caught at the platforms include resident fish as well as those pelagic forms temporarily attracted to them.

Fish populations around platforms in the northern Gulf have been described in several studies (e.g., Shinn 1974, Sonnier et al. 1976, Hastings et al. 1976, Jackson et al. 1978, and Gallaway and Martin 1980). Many species are found only around petroleum platforms and natural reefs in the northern Gulf and include several groupers and other fish of economic value. For species such as these, availability of natural habitat may be a limiting factor, with artificial reefs allowing for population expansion and a larger fishery.

The aggregation of fishes at production platforms increases exploitation rates, conceivably to the point of overexploitation, given the rate of increases of recreational fishing. The Gulf of Mexico Fishery Management Council (1980) suggested that red snapper stocks were overfished in some areas, a condition directly attributable to the recreational fishery as opposed to commercial fishery. Preliminary analyses of catch-effort data for red snapper led us to suspect that this might also have been the case in the northwestern Gulf of Mexico (Gallaway et al. 1981a). We now believe, however, from new evidence that the commercial declines in red snapper fisheries are probably unrelated to recreational overharvest of pre-adult fish at oil platforms. We suspect that the high levels of small fish at Texas and Louisiana production platforms which are heavily fished result from a currently unexploited and perhaps stable stock of adults occurring over soft bottoms.

3.2 RECREATION

The platforms in the northern Gulf of Mexico provide recreation to fishermen and scuba divers. Their use for diving is largely for spearfishing as there are few other sites of interest to divers within easy reach of the shore. This use must be considered minor, however, since the advent of low-cost airfares to Caribbean destinations has removed much of the appeal of platform diving. Results of recreational fisheries surveys by Ditton and Graefe (1978) in the northwestern Gulf of Mexico's Houston-Galveston area indicated that only one-third of the boating population was saltwater fishermen and only 5% fished offshore. However, oil and gas structures attracted more fishing than any other structure, natural or artificial (87% of the boats and 50% of all offshore recreational fishing effort were directly associated with oil and gas platforms). Offshore fishermen were estimated to have contributed over five million dollars to the local economy.

Between 1955 and 1975, participation in saltwater sport fishing in the United States increased 3.5 times and related expenditures grew sevenfold (Texas A&M University 1980). Increases in offshore recreational fishing have occurred since that period and this increase was attributed to the establishment of offshore drilling platforms.

3.3 OTHER USES

Platforms in the northern Gulf of Mexico may have scientific uses which have barely begun to be realized.

Much research is currently underway by biologists interested in the practical applications of island theory, the body of knowledge dealing with populations isolated from one another by geographic barriers. One reason for this interest is that the natural habitats of many rare or endangered species are rapidly being modified by human activities. When a canal, for example, divides a forest into sections, those species unable to cross the canal are suddenly isolated into separate populations. If the population in any one section of the forest is incapable of breeding due to a shortage of males or females, or because of small population size, that population may become extinct. The smaller the island or the greater the isolation, the higher the extinction rate (MacArthur and Wilson 1967). Conversely, islands can favor the flow of organisms from one location to another, acting as stepping stones. Since early colonization patterns seem subject to chance factors, and because early settlers may monopolize space (founders' effect), differences between platforms and parts of platforms offer unparalleled opportunities for studying this situation in marine systems. Petroleum platforms act as stepping stones, serving as refuges for planktonic larvae and other settling species which otherwise might not be able to establish themselves in the Gulf of Mexico. The Mediterranean barnacle became prominent only in recent years because of increased suitable substrate provided by platforms. The planktonic larvae of many species have limited amounts of time to remain in the water column, after which they must settle and metamorphose. Finding appropriate habitat is crucial for those organisms. The abundance of platforms in the Gulf of Mexico provides orders of magnitude more opportunity for larval settlement than is naturally available due to the paucity of hard substrate in the northern Gulf. The investigation of these island effects may increase scientists' understanding of semi-isolated populations and colonizers.

In addition to the study of island theory and genetics of founding populations, platforms are a practical environment for conducting marine science. They are located in a wide variety of places where ships would normally sample; they often have complete living facilities, but do not have some of the obvious disadvantages of ships: limited electrical power, cramped quarters, insufficient deck space, seasickness, and rocking. Planktonic sampling with nets or pumps, for example, may be done simply by hanging gear from the side whenever there is a current. Benthic sampling can be performed in shallow water during good weather from small boats launched from the platforms. The opportunities are limited only by imagination and funding.

3.4 FATE OF PLATFORM ECOSYSTEMS

Now the offshore petroleum industry is mandated by regulation to remove platforms once production has ceased. Not only is a valuable biological resource thus lost by this practice, but the cost of removal may run into millions of dollars. The ultimate environmental and economic impacts of removing all or most of these structures or platforms from the Gulf of Mexico are unknown, but can easily be envisioned as being strongly detrimental.

At some point, refurbishing of platforms might be economical for industry, but now it is more economical to desert offshore structures, allowing them to be used for other purposes. In at least one instance, industry donated an offshore platform to a State government for use as an artificial reef. There is considerable evidence that industry would cooperate with responsible proposals from groups willing to assume ownership and the responsibility of maintaining offshore structures.

CHAPTER 4

MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Assuming that hydrocarbon production from a given platform averages about 40 years and that this period will not be much extended due to exploiting deeper reserves, the entirety of the presently estimated 3,100 offshore petroleum platforms would be removed by the year 2020, with as many as 300 to 400 removed by the mid- to late 1980's. Although without expensive maintenance petroleum structures can rapidly deteriorate to an unsafe condition as well as become more of a navigational hazard, they do represent insular, reef ecosystems which in all likelihood increase the productivity of a given region. These structures aggregate species which serve as the basis for a recreational fishery that is rapidly expanding and has an ever-increasing economic value. The value of the petroleum platform resource in the northwestern Gulf of Mexico should be recognized, and legal restrictions (e.g., removal) that may prevent the continued use of the structure as reefs should be closely examined. At the minimum, a clear understanding of the ecological, social, and economic ramifications of large-scale platform removals should be determined.

As indicated in the introductory literature review section, two studies are in progress which, when completed, will document present recreational and commercial use levels of the petroleum platform reef resource considering such factors as location, distance from shore, depth and type of biological assemblage represented. Historically, the emphasis with regard to placement of artificial reefs (or in this case preservation) has been primarily based upon social considerations, i.e., to maximize utilization and harvest of the associated biological resources. In the future, ecological considerations should receive equal emphasis because the two are strongly related in supply-demand fashion. Designated preservation of a patchwork of groups of platforms located at different depths across the northwestern Gulf of Mexico, with each group having an assigned type of use which could also be regulated by seasonal openings and closures, might be an appropriate first step toward management of this resource. This would be particularly effective if monitoring studies were designed to evaluate the effectiveness of different management strategies.

Regardless of the management approach which might be chosen, the public, and/or government, should accept the responsibility of maintaining and preserving this resource—a cost which has been borne to date by industry at no direct cost to either the primary users or others who economically benefit from this resource. Studies and research should be initiated to determine the location and number of platforms which should be preserved to optimize utilization of the petroleum reef resource, considering both fisheries management and economic factors. A standard procedure should be developed allowing the transfer of liability for the structures from industry to government, thus enabling timely conversion of obsolete oil and gas production platforms to artificial reefs.

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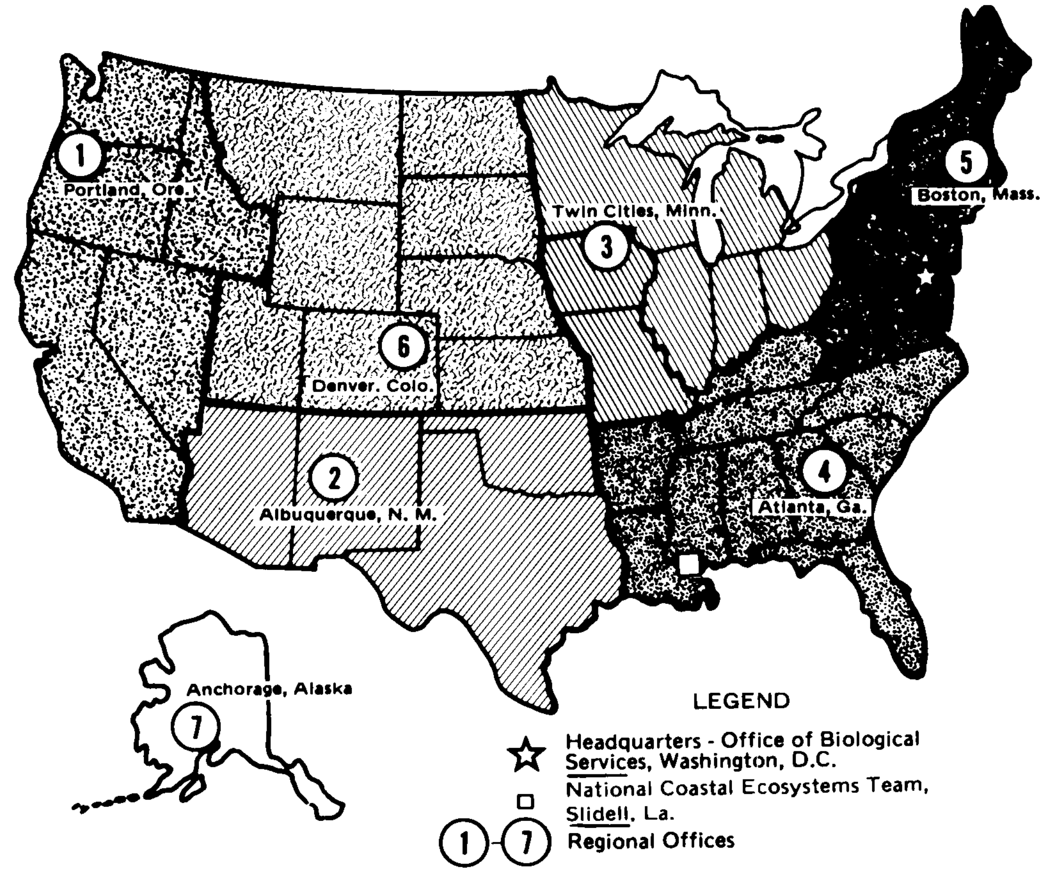

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