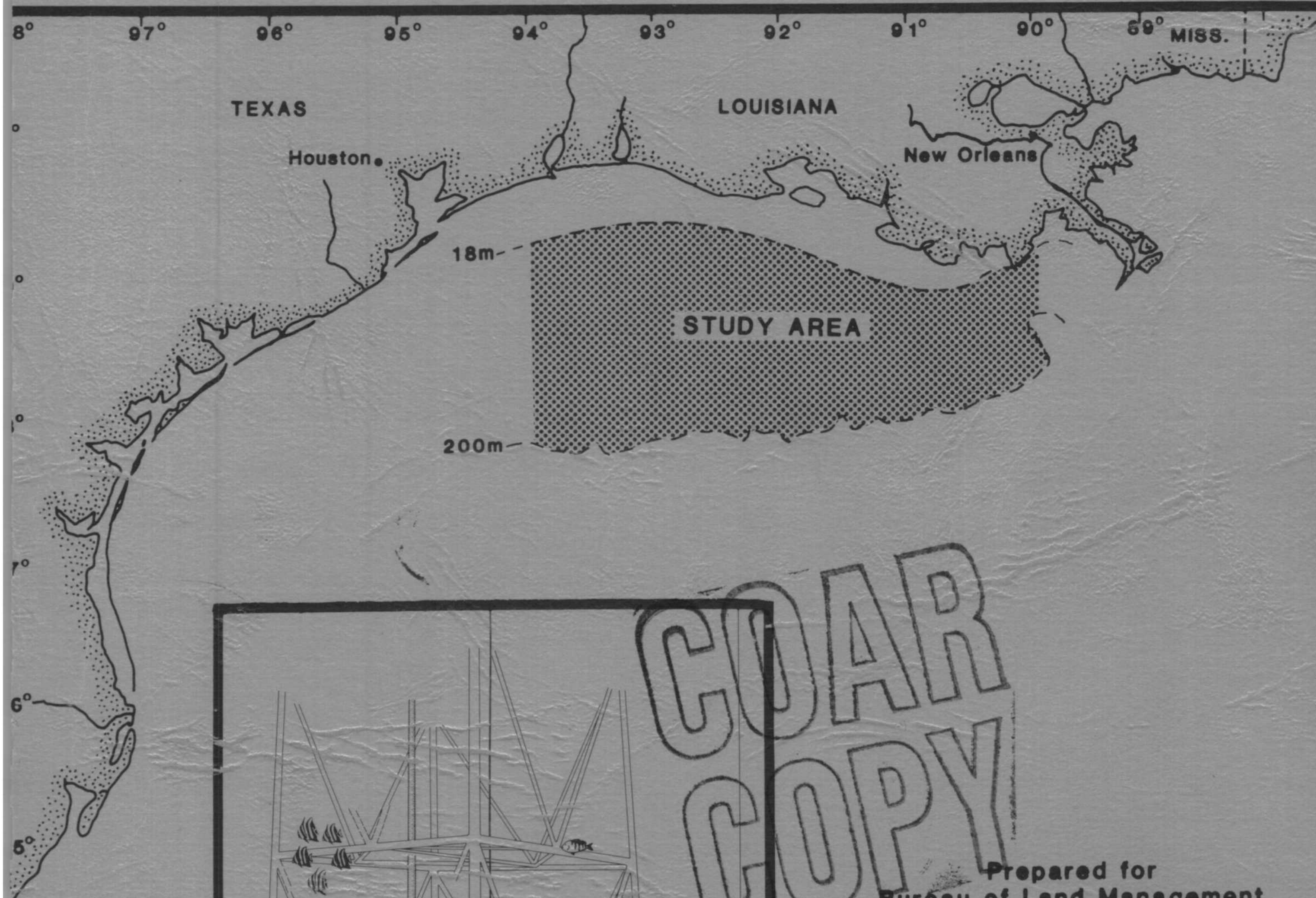
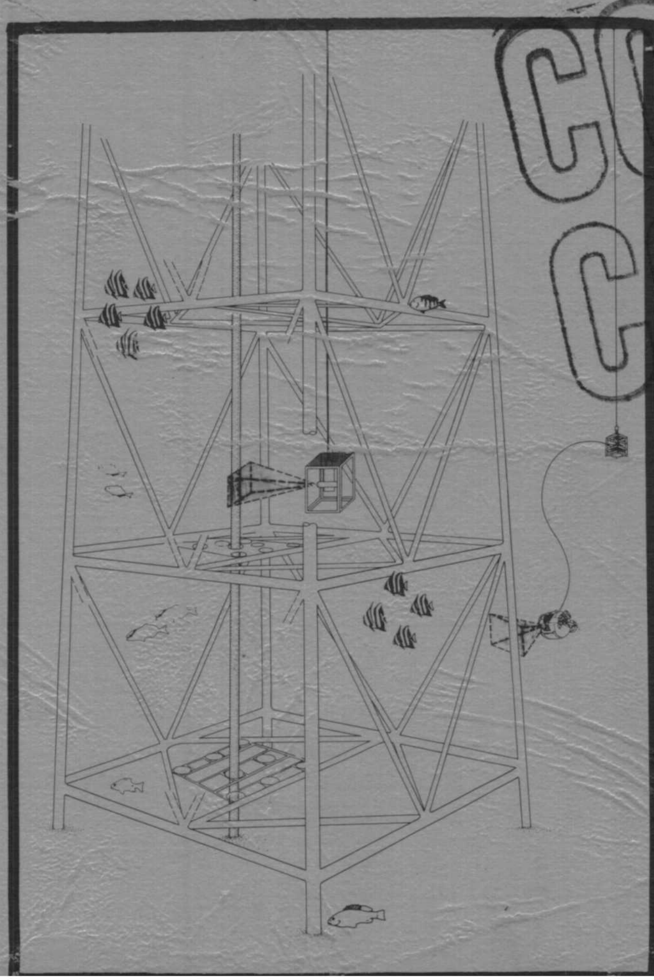
STUDY OF THE EFFECT OF OIL AND GAS ACTIVITIES ON REEF FISH POPULATIONS IN THE GULF OF MEXICO OCS AREA





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Bureau of Land Management
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Prepared by

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CSA

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April, 1982

PREPARED FOR
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ABSTRACT

The objectives of this study were 1) to compare reef fish populations associated with natural hard bottom areas with those associated with offshore oil and gas production structures and 2) to develop fish population censusing methods which were applicable in water depths beyond conventional scuba depth limits. The study was a three-phase effort with each phase designed to meet specific objectives. Planning and design for each subsequent phase depended upon the results of the preceding phase. Phase I involved an evaluation of potential study sites. Equipment and sampling methodology were evaluated during Phase II. Data for standing stock estimates of fish species associated with four oil and gas production platforms and one natural hard bottom area were collected during Phase III.

During Phase I, 25 sites were surveyed, described, and classified. Shallow water hard bottom sites (<35-m depth) consisted of relatively small, low-relief outcrop features, many of which have not been previously described. The hard substrate was generally covered by thick growths of ascidians, bryozoans, and hydroids. Atlantic spadefish, grey triggerfish, red snapper, sheepshead, and tomtate predominated.

Shallow water platforms were covered by an epibiotal assemblage numerically dominated by barnacles, bryozoans, hydroids, and encrusting sponges. The platforms supported

large populations of Atlantic spadefish, blue runner, greater amberjack, red snapper, and sheepshead.

Deep water hard bottom sites (>35-m depth) consisted of large, high-relief outcrop features rising above the nepheloid layer and typically supported coral, crustacean, fish, and sponge species with tropical affinities. The intrusion of numerous tropical fish species into typically temperate communities was the principal faunal characteristic distinguishing deep water hard bottom and platform sites from those located in shallow water.

In Phase II, two types of remotely operated vehicles (ROVs) and several visual and remote photographic fish censusing techniques were tested. The mobility offered by the tethered, free-swimming type of ROV was judged a distinct advantage over other remote censusing methods tested. Statistical analysis revealed no significant difference ($F=0.26$; $P<0.92$) in fish abundance estimates between the type of ROV employed.

Standing stock estimates of reef fish species were quantitatively assessed and compared from the remotely collected data gathered during Phase III. Fish distribution patterns were highly variable over both space and time, thus rendering accurate comparisons between platforms and hard bottom areas impossible with the short-term data collected. Twenty-five species were identified from videotapes made by the ROVs. Total standing stock and standing stock per species were correlated with total submerged platform surface area using linear regression and curve fitting equations. A high correlation between overall fish abundance and the availability of habitat area was indicated (r^2=0.79, linear; r^2=0.93, exponential). Correlations were very high for the smaller territorial reef fishes, while no correlations were found for the larger transient species. No fishes were observed more than a few metres above the hard bottom site. Offshore structures appeared to be responsible for expanding the normal hard bottom distribution of fish populations vertically in the water column.

Statistical analyses of the quantitative data from remotely controlled television systems indicated that the sampling design accurately sampled the fish populations present above the nepheloid layer. Observations of the remote sensor quantitatively corresponded with qualitative *in situ* observations and literature reports. This correspondence supports our conclusions that remote sensors and ROVs can accurately census deep water ($\geq$100 m) fish populations.

1.0 INTRODUCTION

1.1 Objectives

Discovering and quantifying the long-term effects of offshore oil and gas activities on fish populations are of paramount importance to the formulation of effective resource management policy. The proximity of these activities to numerous outer continental shelf (OCS) hard bottom areas in the northern Gulf of Mexico has stimulated considerable debate on the interaction of hard bottom fish communities with offshore oil and gas structures. This debate requires resolution through:

1) The collection of comparable quantitative data on reef fish populations associated with natural hard bottom areas and oil and gas production structures, and
2) The development of fish population sampling methods which can be applied in deep areas of the continental shelf (i.e., depths excluding or limiting direct *in situ* observations).

1.2 The Problem

Reef fish standing stocks can be studied as static or dynamic entities. For commercially valuable species it is important to know the extent of the potential resource at any static point in time. Dynamically, shifts in standing stocks or species diversity can signal ecological change. In both cases, standing stock estimates are necessary to develop meaningful management decisions for OCS fisheries resources.

To determine the effects of any activity on the biota of any continental shelf community, quantitative estimates of the natural variability within populations must be established. At present, little management related data are available on the hard bottom associated fish species of the northern Gulf of Mexico, although many of these species are of commercial importance. In 1976, fewer than 24 studies pertinent to resource management had been published on the biology of snapper and grouper (Beaumariage and Bullock, 1976). This situation has improved somewhat since that date (Tashiro, 1979; Bortone et al., 1980; Parker, 1981); however, there still remains no universally accepted standing stock estimates for these species. Virtually no standing stock data exist on haemulids (grunts) and sparids (porgies) from along the continental margins.

Within the northern Gulf of Mexico, standing stock inventories in terms of fishes per unit habitat area are complicated by the extensive oil and gas activities which are taking place. Considerable qualitative, though little quantitative, data exist which suggests strong associations between typical reef or hard bottom fish species and offshore structures (Hastings et al., 1976; Sonnier et al., 1976; Gallaway et al., 1979).

How patterns of increased species concentrations around artificial structures relate to the diversity/stability equilibrium of the ichthyofauna as a whole is a key question for the management of marine resources in the Gulf of Mexico. Quantitative, statistically valid, biogeographical data must be obtained over a long period of time (several years) before this question can be answered with any degree of accuracy.

1.3 The Study Plan

This study was a three-phase effort designed to test the feasibility of using various fish censusing techniques in conjunction with remotely operated underwater vehicles (ROVs) to inventory reef fishes in the Gulf of Mexico. Each phase was actually a study in itself, with its own specific objectives and results. Planning for each subsequent phase was dependent upon the results of the prior phase. These phases are listed below:

Phase I - Evaluation of potential study sites.

Phase II - Evaluation of equipment and methods.

Phase III - Generation and evaluation of standing stock estimates for fish species associated with natural hard bottom areas and offshore oil and gas structures.

1.4 The Study Area

The area selected for this study was the northern Gulf of Mexico OCS between 90° and 94°W longitude and the 18 and 200-m isobaths (Figure 1).

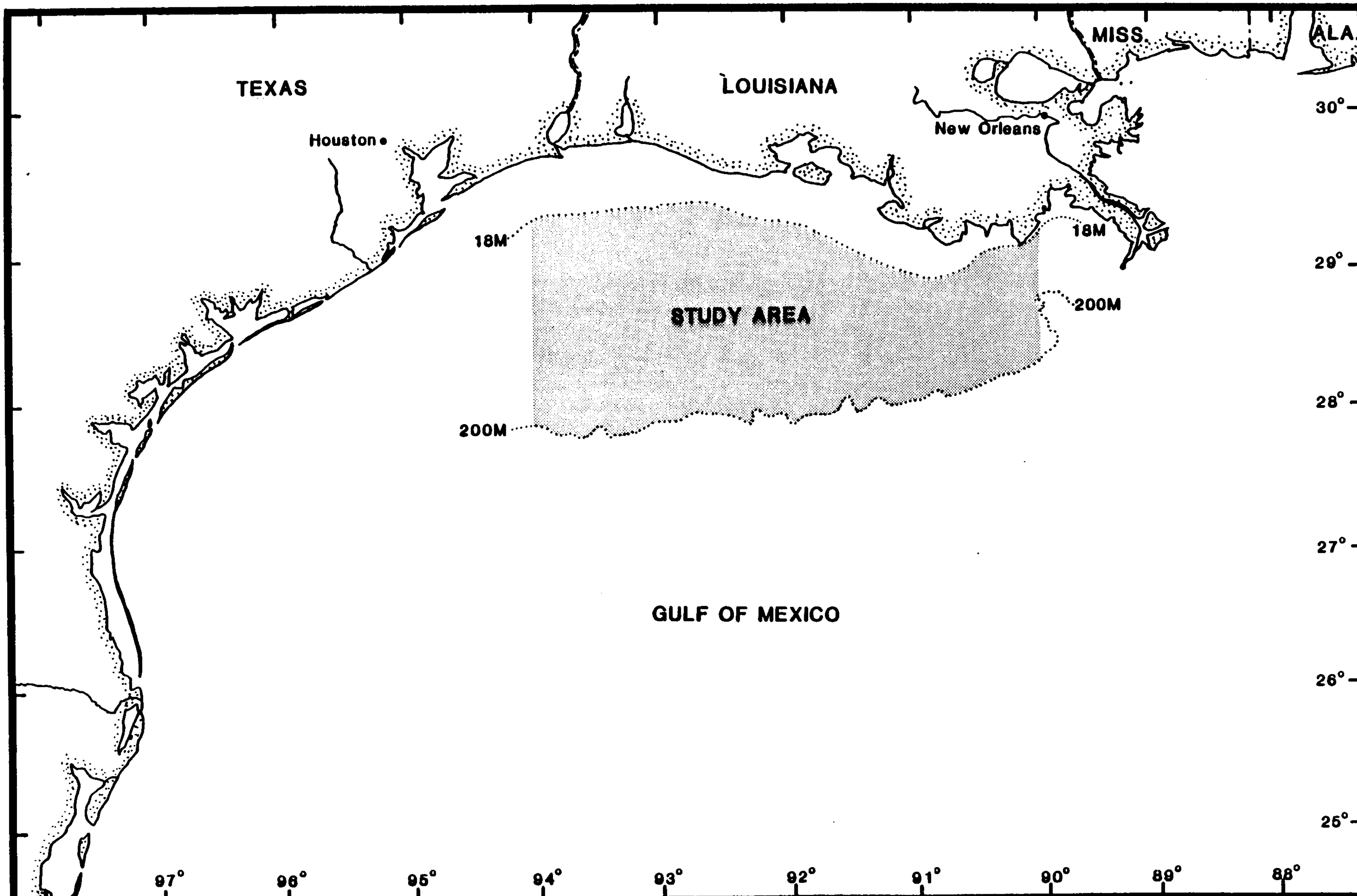


FIGURE 1. GEOGRAPHIC AREA OF STUDY.

There are numerous hard bottom areas, described as "natural reefs", within this area. The large offshore reefs, the snapper banks, and the topographic highs which occur on the outer continental shelf of the northwestern Gulf of Mexico are generally well known. The Bureau of Land Management has conducted biological and geological assessments including submersible reconnaissance of most of these features (Bright et al., 1976; Bright and Rezak, 1978a,b, 1981). The presence of small hard bottom features on the middle and inner shelf has been known predominantly by local commercial fishermen. Although some of the locations of these features may have been recorded in the Sea Grant SNAG data (Graham, 1980), these areas have not been well mapped and generally have not been studied by the scientific community. As a result, very little is known of the fauna occupying these mid-shelf natural hard bottoms.

The major factors influencing the composition of the biotal assemblages inhabiting the hard bottom areas are their distance from shore and their relief. Temperatures at the Flower Garden Banks and other topographic highs remain sufficiently warm to allow corals and tropical coral reef fishes to survive. Severe temperature changes in shallow nearshore areas restrict tropical species which may enter the area during warmer months. Temperature fluctuations are reduced at the deep offshore sites. A band of very turbid water (nepheloid layer) is typically encountered near the sea floor in the northwestern Gulf of Mexico. Due to the greatly increased sediment load and the resulting low light penetration, the nepheloid layer significantly influences the distribution of epifaunal forms (Bright and Rezak, 1978a; Gallaway et al., 1979). Hard bottom features with sufficient relief to extend above the nepheloid layer support biotal populations that differ from those associated with low-relief features.

Extensive OCS oil and gas development activities have taken place near natural reefs. Reef communities present on petroleum platforms offshore of Louisiana have been discussed by George and Thomas (1979), Shinn (1974), Sonnier et al. (1976), Gallaway (1981), Gallaway and Martin (1980), and Gallaway et al. (1979). Gallaway et al. (1979) described three major platform assemblages: a coastal assemblage, an offshore assemblage, and a blue water or tropical assemblage.

The coastal platform assemblage occurs in nearshore waters with depths shallower than approximately 27 m. The biomass of the sessile epifauna is dominated from the surface to about the eight-metre depth by the small acorn barnacles *Balanus amphitrite* and *B. improvisus*. In turn, the barnacles are covered by a mat of bryozoans, hydroids, macroalgae, and encrusting sponges. The macroalgal component of the mat is restricted to zones near the surface (from one to six metres deep) where growths may be luxuriant or sparse, depending largely upon turbidity and season. Oysters are usually present but seldom abundant. Hydroids dominate the near-bottom areas and a few dead barnacles and serpulid worm tubes are usually present. The sessile epifauna of the coastal platform assemblage provides a low-relief habitat which influences the composition of the associated cryptic macrofauna. Although xanthid crabs and blennies are present, the motile fauna consists mostly of small crustacean species, particularly amphipods (e.g., Corophium sp., Stenothoe sp., and Caprella sp.).

The offshore platform assemblage occurs in water from 27 to 64 m deep. The near-surface areas are characterized by luxuriant growths of red and green algae in which the tree oyster Isognomon bicolor is often present in high densities. Although the bivalve Chama macerophylla and oysters (Ostreacea) are the typical biomass dominants to a depth of approximately 20 m, the octocorals Telesto sp., solitary hard corals Astrangia sp. and Phyllangia sp., and various hydroids and bryozoans also occur. Below 20-m depths, colonial forms such as anemones (Zoanthidae), ascidians (Ascidiacea), and encrusting sponges (Homocoelidae) predominate. There appears to be a marked drop in biomass levels of sessile epifauna between 20 and 30-m depths. Biomass in the upper 20 m of the water column ranges from 8 to 11 $kg.m^{-2}$, and usually around 2 $kg.m^{-2}$ below 20-m levels. The sessile epifauna of the offshore platform assemblage is of high relief and supports a diverse cryptic fauna. Not only are microcrustaceans species well represented, but arrow crabs, relatively large blennies, oyster drills, sea urchins, and stone crabs are also abundant.

The blue water, or tropical platform assemblage, occurs in water deeper than 64 m. The distinguishing characteristic of this assemblage is the dominance of the fish community by tropical reef forms. Creole-fish, creole wrasse, and Spanish hogfish are possibly the dominant platform associated fishes, while Atlantic spadefish and sheepshead are typically absent. Tropical invertebrates, such as the spiny lobster *Panulirus argus*, are also members of the platform associated fauna.

1.5 Available Techniques

Before long-term studies can be undertaken, reliable field techniques must be established for the comparison of reef fish asssemblages. Relatively few methods are available for quantifying fish populations, although these techniques may be applied in a variety of ways.

State-of-the-art fish censusing allows for the collection of data via two general approaches: 1) destructive sampling, and 2) non-destructive sampling. Accuracy using either of these approaches is highly sensitive to extraneous environmental factors.

1.5.1 Destructive Sampling

For the purpose of this report, destructive sampling is defined as any sampling technique which permanently removes the subject organism from the environment. In terms of quantitative fish censusing, destructive sampling methods include 1) ichthyocides, 2) explosives, 3) fish traps, 4) netting, and 5) tagging-recapture. Even using these drastic techniques, quantitative data on hard bottom fish communities are difficult to obtain.

1.5.1.1 Ichthyocides

Some workers have achieved a measure of success in quantitatively sampling coral reef fish populations using ichthyocides (e.g., rotenone) (Randall, 1963; Wass, 1967; Emery, 1973; Smith, 1973). This technique seems to work well if applied on a limited basis; however it often yields biased results because not all fish species are affected identically by ichthyocides. Large, water column dwelling species tend to be able to escape the poison by swimming away. Bottom dwellers and cryptic species are overcome in great numbers because they delay longer before abandoning their territory or hiding place. These types of species-specific behavior patterns significantly bias the collected samples.

1.5.1.2 Explosives

Explosives have an advantage over ichthyocides in that their effects are instantaneous. Aside from their obvious detrimental effects on the sampling site, explosives also have many of the drawbacks of poisons in that not all species are affected in the same way. The samples are biased because of such variables as behavior patterns and preferred habitats. With explosives, samples tend to be dominated by pelagic or water column dwelling species (Talbot and Goldman, 1973).

1.5.1.3 Fish Traps

To obtain reliable population structure data with fish traps, a variety of species specific traps and considerable fishing effort are required. Trap sensitivity indexes are required for the specific trap design and population curves must be generated for statistical analysis (Ricker, 1975).

1.5.1.4 Netting

Seines, trawls, and gill nets can be used to obtain quantitative data on fish populations in certain areas. These techniques are extremely biased toward certain species and are relatively ineffective in hard bottom areas.

1.5.1.5 Tagging-Recapture

Seines, trawls, gill nets, and fish traps are also used in conjunction with tagging-recapture methods. Tagging-recapture techniques have been utilized extensively in estimating standing stocks of various commercially important species (DeLury, 1951; Chapman, 1952, 1954; Cormack, 1969). Over the past century, estimates of four principal types of population parameters have been attempted using tagging-recapture techniques: 1) exploitation, 2) size,

3) survival rate from season to season, and 4) recruitment rate. Tagging-recapture studies are designed based upon which type of estimate is desired.

Tagging-recapture studies have almost universally been designed to obtain species specific results (i.e., to evaluate the fishing pressure or resource availability of a commercially or recreationally important fish species). Despite the fact that the statistical analysis procedures and sample confidence levels are fairly well established for this type of work (Ricker, 1975), large discrepancies can still occur between the population estimates and the actual populations observed (Parker, 1981).

1.5.2 Non-Destructive Techniques

With the advent of acoustic and diving technologies, investigators began to develop non-destructive methods to assess fish populations (Brock, 1954; Risk, 1972; Key, 1973; McCain and Peck, 1973; Smith and Tyler, 1973; Hobson, 1974; Chave and Eckert, 1974; Itzkowitz, 1974; Jones and Chase, 1975). Underwater motion pictures, closed circuit television systems, minisubmersibles, and ROVs have provided an extension of non-destructive fish censusing techniques (Ebeling et al., 1971; Alevizon and Brooks, 1975; Putt, manuscript).

Non-destructive techniques have their own set of biases just as do destructive sampling methods. By their very nature they tend to sample the larger, more visible species more effectively than the cryptic species. They also induce sampling error by the fact that some species actively avoid the diver or observation equipment while others are attracted to them.

1.5.2.1 Diver Observations

All *in situ* visual observations have essentially the same major problem, that is, "determining some method of establishing order on or control over the apparent visual randomness of the subject population" (Jones and Thompson, 1978). Order can be imposed on underwater observations only through methods that define and limit those observations. Researchers often utilize an established transect line or reference point to enumerate fishes within a specific distance from the fixed position. Many of the photographic techniques include fixed reference points and known volumes of water to quantify their samples (Putt, manuscript). Other investigators use some time-dependent variable (e.g., the length of a super-eight film cartridge) to limit their observations (Alevison and Brooks, 1975). Jones and Thompson (1978) utilized time as a limiting factor and scored, rather than counted, fish species encountered. This technique does not yield actual numbers of individuals but does provide a species abundance ranking index which can be utilized to compare one fish assemblage with another (Jones and Thompson, 1978; Thompson and Schmidt, 1977).

Recent comparisons between the transect method (Brock, 1954) and the time-dependent, random count technique (Jones and Thompson, 1978) indicate that while repeatability is high for both techniques, more observer bias is introduced in the random count technique (Sanderson et al., 1980).

1.5.2.2 Acoustical Observations

Considerable time and effort have gone into research on acoustical methods of enumerating fish species, however, results have been unsatisfactory to date. Acoustical detection/display systems are unable to differentiate fishes in varying orientations toward the sensor and thus, generate several different signatures for the same fish or species of fish (Hocutt and Stauffer, 1980).

1.5.2.3 Submersible and/or ROV Observations

Transects have been utilized to evaluate variations between visual fish counts obtained by a diver swimming the transect and an observer following the transect line in a submersible. Population estimates based on diver counts were 33% higher than those based on submersible counts (Parker, 1981). Some of the variation results from differences in the field of view of the diver (360°) and that of the submersible observer (180°).

The importance of observer viewing geometry in evaluating population estimates generated by visual techniques is particularly important when investigating fish populations in deep water. Divers cannot sample in deep areas of the continental shelf, therefore, some type of remotely operated vehicle or submersible must be utilized if visual fish counts are desired. Submersible designs determine the observer's angle of view. Closed circuit television systems (CCTVs) that are operated from ROVs restrict the field of view to the peripheral limits of the camera system.

To date, no comparative studies utilizing submersibles and ROVs for fish community description and quantification have been attempted. Based on previous diver versus submersible comparisons, reductions in population estimates generated from ROV observations can be expected (Parker, 1981).

1.5.2.3.1 Potential of the ROV

ROVs have not been utilized in scientific studies to the extent of manned submersibles. Research tasks which have employed ROVs fall into the inspection and survey categories, the classic example being the utilization of the CURV III to inspect offshore radioactive waste dump sites (USEPA, 1975). Survey work has involved visual bottom reconnaissance, sample collection, and photography. In virtually all survey applications, ROVs were utilized only to confirm interpretations or to supplement details for conclusions drawn from data collected by conventional means (Busby Associates, 1979). Eden et al.

(1977) have reported that, in most instances, ROVs are capable of achieving results equivalent to manned vehicles at significantly lower cost. Although manned submersibles (direct observation) employed in biological surveys tend to record greater numbers of species than do remote sampling devices such as the video systems on ROVs (Lissner, 1979), their cost is prohibitive for most researchers. Manned submersible time currently costs from 6,000 to 14,000 dollars per day depending upon the system, while ROVs can be leased for 3,000 to 5,000 dollars per day (Reed, 1982).

ROV development is a very dynamic field in terms of marine technology. To date, most developmental engineering has occurred on a day-to-day basis as operators struggle to meet the changing and unpredictable demands of their clients. As a consequence, there are no clearly defined design goals or specific development programs formulated to test the capabilities of ROVs as research tools.

Because of the economic advantage in using ROVs for scientific research, Busby Associates (1979) recommended to the National Oceanographic and Atmospheric Administration (NOAA) that comparative tests between ROVs and manned submersibles be employed in scientific investigations during similar programs and under the same field conditions. ROVs should be evaluated on considerations unique to the scientific user. Some of the specific aspects recommended for evaluation were data quality, viewing quality (resolution/range), three-dimensional viewing (depth and scale perception), natural visibility limits, navigation/positioning, vehicle effects on organism behavior, manipulation/sampling effectiveness, and the observer's endurance limits.

1.5.2.3.2 Types of ROVs

ROVs have been evolving over the last 27 years as tools for undersea research and development. The first ROV was a cable-controlled, free-swimming device called POODLE, which was a direct modification of a diver transport vehicle called PEGASUS designed by Dimitri Ribikoff. POODLE was built in 1953 and over the next 22 years only 19 additional ROVs were constructed. These were operated almost exclusively by government and/or research institutions.

The thrust in ROV development began in 1976 with the acceleration in offshore oil and gas activities. Between 1975 and 1980 a total of 116 ROVs has been added to the world inventory. This reflects the direct effects of the expanding offshore market. Private industry accounted for only 15% of the 1974 world market, but by 1979, 90% of the world's ROVs were being employed by the private sector.

Vadus and Busby (1979) identified four classes of ROVs in their review of remotely operated vehicles. For purposes of continuity, those classifications will be maintained here.

1.5.2.3.2.1 <u>Tethered, Free-Swimming Vehicles</u>

Tethered, free-swimming vehicles are powered and controlled through a surface-connected cable. They are self-propelled and are capable of maneuvering along the bottom or through the water column. Generally, they offer remote viewing capabilities through closed circuit television and many offer movie and still frame photographic documentation as well. Most vehicles are rectangular in shape and consist of open metallic frameworks that enclose the components. Existing models vary from 0.17 to 4.8 m in length. Most models use propellers for propulsion, however, a very few use water jets. Maximum depth capabilities range from 100 to 6000 m, however, most routine ROV operations take place in less than 1000 m. Generally, the length of their umbilical cable limits ROVs of this type from achieving their maximum operational depth. Speed at operating depths for this classification of ROV is generally about 82 cm sec^{-1} (about 1.6 knots), but this is not the most important consideration in employing a tethered, free-swimming vehicle. The ability to stay on the job and to maneuver in the presence of strong currents is the prime factor controlling the feasibility of a particular tethered ROV for a given project.

1.5.2.3.2.2 <u>Bottom-Crawling Vehicles</u>

Bottom-crawling vehicles are also powered and controlled through surface-connected cables.

Vehicles in this category are primarily designed to perform specific work tasks. They are almost entirely industrial in design and their orientation is primarily toward the offshore oil and gas market. The number of vehicles in this class is relatively small and the vehicles are universally operated by the companies responsible for their construction.

1.5.2.3.2.3 Towed Vehicles

Towed vehicles are powered and controlled from a surface support ship. They have very limited maneuvering capabilities and generally provide remote viewing through CCTV. Towed vehicles are primarily used for bottom reconnaissance. An industrial example of their function is manganese nodule assessment in depths of 6000 m. In line with the reconnaissance/mapping function of this class of vehicles, their equipment often includes motion and still cameras, side scan sonar, as well as CCTV.

1.5.2.3.2.4 Untethered Vehicles

Untethered vehicles are self-propelled, self-contained vehicles which maneuver throughout the entire three-dimensional environment and are controlled either by acoustic commands or by computer programs. Although untethered vehicles have been successfully tested, technology in this field must be considered as emerging. Several major technological innovations will be required before untethered ROVs achieve wide acceptance in scientific and/or industrial applications.

Major among these required technological advances is the development of a system for real-time, through-water, television signal transmission for remote viewing capability and feedback control systems.

1.5.2.3.3 <u>Problems with ROVs</u>

ROVs suffer from a number of recurrent problems which are inherent in the design of the vehicles due to present technological levels. The histogram in Figure 2 illustrates in descending order the ten most common problems encountered and their percentages of occurrence by user/operators of tethered, free-swimming ROVs, such as those proposed for this study. By far, the vast majority of problems encountered by those attempting to employ ROVs in the field involves the surface-attached umbilical cord. At best, an entangled umbilical cord results in hours of delay. In some cases, entanglement has actually forced abandonment of the vehicle (Vadus and Busby, 1979). Most experienced operators are very reluctant to take their vehicles into situations where the risk of cable entanglement is high.

There are several environmental factors that can affect the use of ROVs. Rough seas and/or swell surge can have a crippling effect on ROV use in shallow water. During deep operations, strong currents and excessive turbidity restrict the effectiveness of ROVs.

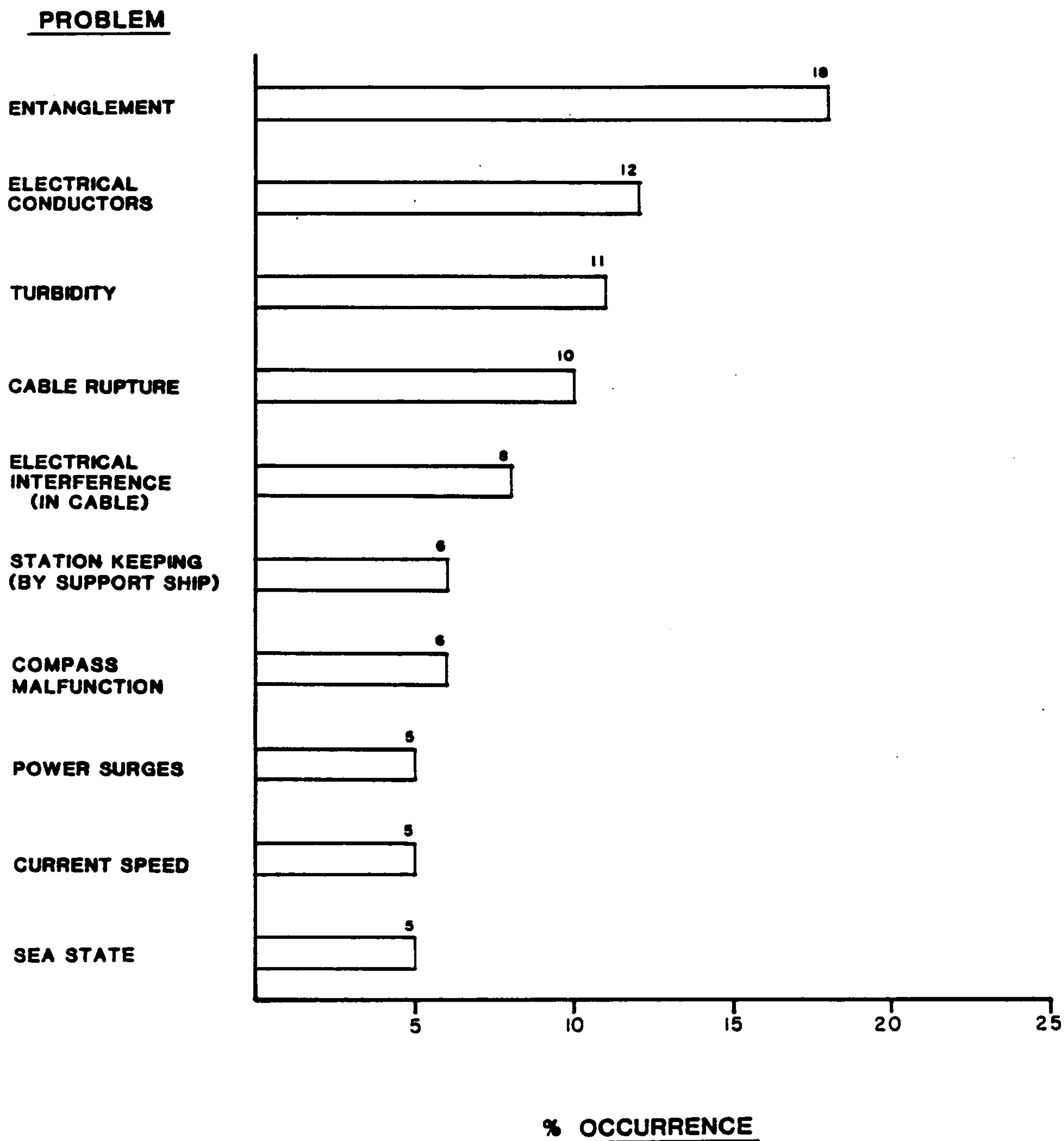


FIGURE 2. TEN MOST COMMONLY ENCOUNTERED PROBLEMS AND THEIR PERCENT OCCURRENCE IN ROV OPERATION. (AFTER VADUS AND BUSBY, 1979)

1.5.2.3.4 Trends in ROV Design

Trends in the design of ROVs seem to be toward increasing specialization of the vehicles. This reflects the growing industrial market where specific tasks must be performed repeatedly. Unfortunately, these increasing improvements in specialized vehicles generally do not improve the capabilities of ROVs for scientific work. To be applicable and cost effective in most scientific studies, ROVs need to perform several tasks well. Nevertheless, it is generally believed that ROVs do offer improved cost effectiveness for several types of offshore scientific work.

2.0 PHASE I - SITE CHARACTERIZATION

2.1 Objectives

The objectives addressed during Phase I were 1) to develop a list of potential hard bottom and platform study sites within the northern Gulf of Mexico OCS in an area bounded on the east and west by 90° and 94°W longitude and on the north and south by the 18 and 200-m isobaths, respectively (Figures 1 and 3); and 2) to evaluate the tentatively selected study sites in terms of adequacy and appropriateness for subsequent phases of this study. The selected potential study sites were to include three natural reefs distant (≥6 km) from oilfield platforms, three oilfield platforms distant (≥6 km) from natural reefs, and one to three oilfield platforms adjacent (≤2 km) to natural reefs. During this initial phase, the habitat at each potential site was to be generally characterized in terms of areal extent, vertical relief, complexity, epibenthic cover, and fish populations.

2.2 Preliminary Site Selection

Following discussions with various persons (i.e., commercial snapper fishermen, dive boat operators, charter fishing captains, scientists, etc.) knowledgeable of fish and epifaunal populations associated with platforms and hard bottom sites in the study area, 25 potential study sites were selected (Figure 3).

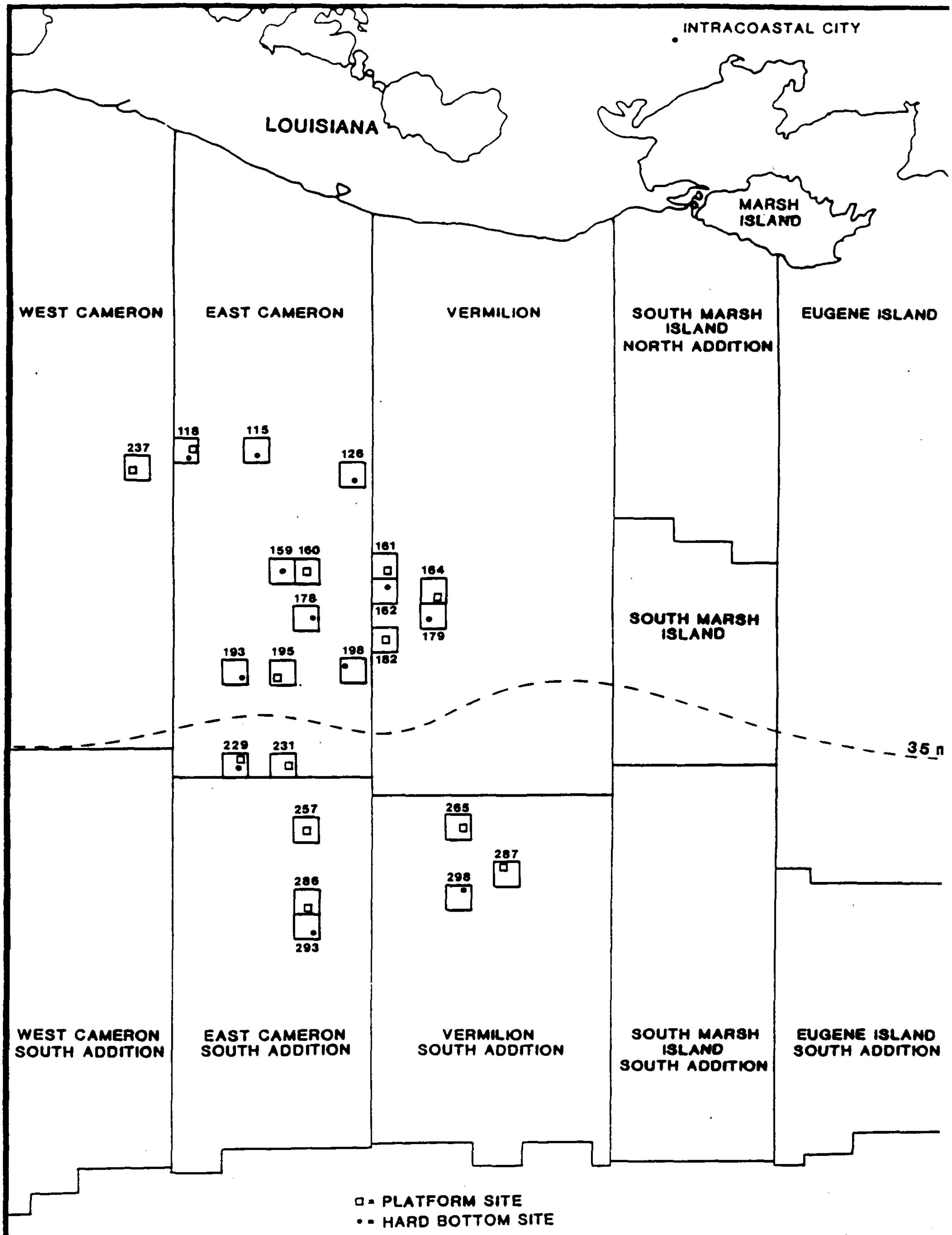


FIGURE 3. GEOGRAPHIC LOCATIONS OF SITES SURVEYED DURING PHASE 1.

2.3 Field Operations

The M/V SOUTHERN CLIPPER was used during Phase I primarily because of the knowledge possessed by its owner/captain of the hard bottom sites and platforms within the study area, and because of the increased speed of this vessel over traditional offshore survey vessels. Scuba diver reconnaissance, underwater television, and still cameras were used to describe and to assess each potential site.

Real-time, video footage of natural hard bottom and platform-associated biota was recorded using a diver-held Hydro Products Model TC-125 black and white underwater television camera coupled with a Model SC-303 television system control unit and a Sony Model AV-3650 videotape recorder. The camera employed a f/1.4 lens. All operating functions of the camera were automatic, with the exception of the lens focusing which was remotely controlled. The control unit contained the television camera power supply, television monitor, and all required operating controls. In addition to the video data, audio data were recorded on Sony V-32 38-mm (1.5-inch), 60-minute videotapes. Whenever possible, observations at hard bottom sites were recorded along two perpendicular transects crossing the feature. Platform observations covered in most cases the entire vertical relief of the structure as well as its major structural components (i.e., well guides, crossmembers, legs, etc.). Observations were confined to depths of less than 30 m as no-decompression diving schedules were followed.

Further documentation of tentative study site characteristics was accomplished using in situ photography. Diver-held Nikonos II and III underwater 35mm cameras with Subsea 100 and Sea and Sea 50 underwater strobes were used to take close-up and wide-angle photographs of the epibenthos and fish populations.

Divers collected qualitative samples of the epibenthos for positive species identifications. All samples were placed in rigid containers with identifying labels and were preserved in either 10% buffered formalin or 70% ethyl alcohol, depending upon the taxon collected.

All observations and subjective opinions concerning hydrographic (e.g., water clarity, temperature, etc.), structural (e.g., depth, size, area, relief, etc.), and biotal characteristics of the site were recorded on audiotape and in field notebooks during debriefing sessions following each dive. The same team members who recorded the television data also narrated these observations during the debriefing sessions.

2.4 Laboratory Procedures

Television videotapes and still photographs were examined and the epibenthos and fishes identified. In most cases, the epibiota could not be specifically identified from the videotapes, but a general description was made of the community type and amount of biomass present. Audiotapes and field logs from debriefings were cross-referenced via their station numbers. These logs and tapes were reviewed in conjunction with the videotapes.

All biological samples were sorted to major taxa, stored in 70% ethyl alcohol, if they were not originally preserved in this solution, and subsequently identified to the lowest possible taxonomic level allowed by contract time frames. Due to the qualitative nature of the Phase I data, no measures of community structure, such as species diversity or evenness indices, were calculated.

2.5 Results

Since most of the hard bottom areas are known locally by several names, hard bottom features are herein referred to by their OCS lease area and block locations unless previously designated names are widely accepted. Fish species are referred to within the text by their common names (after Robins et al., 1980). Appendix A alphabetically lists the common and corresponding scientific names of all fish species observed during the study.

The locations of the 25 tentatively selected study sites surveyed during the Phase I cruise are given in Figure 3. Table 1 contains detailed characteristics (i.e., OCS lease block, water depth, distance from shore, LORAN C coordinates, latitude, and longitude) for each study site. The selected hard bottom sites consisted of relatively small low-relief

TABLE 1. LISTING OF SURVEYED HARD BOTTOM AND PLATFORM STUDY SITES AND PERTINENT CHARACTERISTICS.

Feature	Depth (m)	Distance from Shore (km)	LORAN C Coordinates	Latitude	Longitude
Shallow Water Hard Bottom Sites					
East Cameron Area, Block 115, Hard Bottom (EC115HB)	18-21	53	11118.2 26791.6 46886.3	28°08'64"N	92°53'04"W
East Cameron Area, Block 118, Hard Bottom (EC118HB)	17-20	58	11112.0 26699.8 46884.0	29°07'09"N	93°01'83"W
East Cameron Area, Block 126, Hard Bottom (EC126HB)	18-22	54	11138.4 26872.9 46875.8	29°05'52"N	92°42'76"W
East Cameron Area, Block 159, Hard Bottom (EC159HB)	22	73	11149.6 26736.6 46852.1	28°55'96"N	92°51'82"W
East Cameron Area, Block 178, Hard Bottom (EC178HB)	27	81	11172.5 26756.7 46833.5	28°49'67"N	92°46'66"W
East Cameron Area, Block 193, Hard Bottom (EC193HB)	27-29	92	11166.6 26620.4 46824.7	28°45'17"N	92°58'30"W
East Cameron Area, Block 198, Leg Wreck (EC198HB)	21-32	88	11187.7 26785.7 46823.6	28°46'62"N	92°41'96"W
Vermilion Area, Block 162, Hard Bottom (VR162HB)	25-28	72	11174.7 26865.5 46843.6	28°54'26"N	92°37'67"W

TABLE 1. (CONTINUED).

Feature	Depth (m)	Distance from Shore (km)	LORAN C Coordinates	Latitude	Longitude
Vermilion Area, Block 179, Hard Bottom (VR179HB)	26-29	77	11191.1 26912.4 46835.1	28°51'84"N	92°31'73"W
Deep Water Hard Bottom Sites					
East Cameron Area, Block 229, Hard Bottom, Jackaman's Hole (EC229HB)	18-43	109	11193.7 26595.5 46797.5	28°35'56"N	92°55'73"W
East Cameron Area, Block 293, Hard Bottom, 29 Fathom Place (EC293HB)	30-61	138	11253.9 26628.5 46748.1	28°19'72"N	92°44'19"W
Vermilion Area, Block 298, Hard Bottom, Sonnier Bank (VR298HB)	18-61+	126	11286.2 26970.6 46741.4	28°30'27"N	92°28'32"W
Shallow Water Platform Sites					
West Cameron Area, Block 237, Platform "A" (WC237PB)	20	68	11108.4 26629.0 46881.5	29°05'61"N	93°08'42"W
East Cameron Area, Block 118, Platform "B" (EC118PB)	20	57	11111.1 26706.5 46885.6	29°07'74"N	93°01'34"W
East Cameron Area, Block 160, Platform "A" (EC160PA)	26	72	11156.8 26780.8 46850.0	28°56'80"N	92°45'20"W

TABLE 1. (CONTINUED).

Feature	Depth (m)	Distance from Shore (km)	LORAN C Coordinates	Latitude	Longitude
East Cameron Area, Block 195, Platform "A" (EC195PA)	31	92	11179.5 26694.5 46821.2	28°44'84"N	92°50'04"W
Vermilion Area, Block 161, Platform "A" (VR161PA)	28	70	11171.1 26869.9 46847.3	28°55'58"N	92°37'45"W
Vermilion Area, Block 164, Platform "A" (VR164PA)	29	73	11190.1 26922.2 46837.2	28°53'64"N	92°29'53"W
Vermilion Area, Block 182, Platform "A" (VR182PA)	31	82	11190.2 26831.4 46826.5	28°48'09"N	92°38'04"W
Deep Water Platform Sites					
East Cameron Area, Block 229, Platform "A" (EC229PA)	37	111	11191.0 26603.8 46800.9	28°36'83"N	92°55'47"W
East Cameron Area, Block 231, Platform "A" (EC231PA)	37	109	11202.1 26659.9 46797.2	28°36'28"N	92°49'36"W
East Cameron Area, Block 257, Platform "A" (EC257PA)	49	124	11228.8 26651.8 46772.9	28°28'12"N	92°45'98"W
East Cameron Area, Block 286, Platform "A" (EC286PA)	57	135	11248.7 26627.0 46752.4	28°21'08"N	92°45'07"W

TABLE 1. (CONTINUED).

Feature	Depth (m)	Distance from Shore (km)	LORAN C Coordinates	Latitude	Longitude
Vermilion Area, Block 265, Platform "A" (VR265PA)	49	115	11257.2 26838.2 46771.8	28°30'27"N	92°28'32"W
Vermilion Area, Block 287, Platform "A" (VR287PA)	55	121	No Data	28°26'14"N	92°22'07"W

areas inshore of the 35-m isobath and large high-relief features deeper than the 35-m isobath. In the following text, study sites in depths shallower than 35 m are termed "shallow water sites" and those in greater depths are termed "deep water sites". Appendix B gives a phylogenetic listing of the identified taxa from visual observations and collected specimens at each site surveyed during this phase. Qualitative characterizations of the tentatively selected hard bottom and platform study sites are given in the following sections.

2.5.1 Shallow Water Hard Bottom Sites

The shallow water hard bottom sites discussed below include those natural reefs that occur inshore of the 35-m isobath.

2.5.1.1 East Cameron Area, Block 115, Hard Bottom (EC115HB)

A relatively small (approximately 19 m^2) area of emergent hard bottom was identified within East Cameron Block 115 in 20 m of water. The site was greater than nine kilometres from any platform, but only 1.85 km from a shipwreck. Divers identified a strong temperature and salinity gradient at ten metres. Visibility within the bottom nepheloid layer was reduced to approximately 1.5 m. Hard substrate consisted of sheer rock outcrops rising two to three metres from the sea floor.

Much of the hard substrate was covered with ascidians (*Distaplia bermudensis*) and colonial anemones. In addition, arrow crabs, bryozoans, corals, hydroids, and sponges were typical residents of the hard bottom (Appendix B).

Seven fish species were identified during observations at the site (Appendix B). These included Atlantic spadefish, belted sandfish, blue runner, gray triggerfish, red snapper, sheepshead, and tomtate. Red snapper was by far the most abundant species.

2.5.1.2 East Cameron Area, Block 118, Hard Bottom (EC118HB)

This hard bottom site within East Cameron Block 118 was located in approximately 20 m of water and was 1.8 km south of the production platforms in the East Cameron Block 118 Field. The rocky bottom appeared to consist of a rather narrow ($\leq$3 m wide) band running east-west for a distance of at least 76 m. The hard bottom consisted of silt covered rock outcrops, with up to three metres of relief. Very turbid bottom water (visibility <3 m) and a strong thermocline were encountered at the 11-m depth. Several gas seeps were observed bubbling intermittently from the sea floor.

Observed epibiota consisted of arrow crabs, ascidians, bryozoans, corals, bushy hydroids, and sponges (Appendix B).

Fishes observed near these rock outcrops included

Atlantic spadefish, cocoa damselfish, mangrove snapper, red snapper, and sheepshead (Appendix B).

2.5.1.3 East Cameron Area, Block 126, Hard Bottom (EC126HB)

A small (30-m diameter) area of sediment covered rock outcrops rising two to three metres out of a soft mud-silt sea floor at a depth of 22 m comprised the hard bottom seen in this lease block. Horizontal visibility at the bottom was approximately one metre.

Epibiotal populations consisted of colonial anemones, ascidians, bryozoans, corals, scattered gorgonians, and hydroids (Appendix B). Numerous arrow crabs and urchins (*Arbacia* sp.) covered the emergent hard bottom.

Fish species observed near the outcrops included Atlantic spadefish, cubbyu, gray triggerfish, and red snapper (Appendix B). Extremely turbid water prevented adequate visual assessment of the fish populations associated with the hard bottom.

2.5.1.4 East Cameron Area, Block 159, Hard Bottom (EC159HB)

An area of uneven sea floor, believed to be scattered hard bottom, was identified within East Cameron Block 159. The feature was located approximately nine kilometres from the nearest platform. Diver observations at the site revealed only sandy bottom, with no occurrences of hard bottom.

The seafloor at the 22-m depth supported various anemones and tube worms but no commercially important fish species.

2.5.1.5 East Cameron Area, Block 178, Hard Bottom (EC178HB)

Low-relief (1 to 1.5 m) rock outcrops on sandy bottom in 27 m of water were identified approximately 0.86 km south of the nearest platforms in East Cameron Block 178 and 9.73 km south of the nearest platforms in East Cameron Block 160. Several gas seeps were noted in East Cameron Block 178.

The scattered rock patches supported relatively large numbers of corals (*Oculina* sp. and *Phyllangia* sp.), sea whips (*Leptogorgia setacea* and *L. hebes*), and sponges (*Ircinia*). Several samples of epibiota were collected by divers for identification (Appendix B). The scattered nature of the hard substrate and the low visibility (1.5 m) prevented divers from identifying any particularly predominant reef feature.

Nine species of fishes were identified by divers (Appendix B). Blue runner, red snapper, rock hind, and tomtate appeared to be the most abundant, while belted sandfish, cubbyu, and whitespotted soapfish were common near rock outcrops.

2.5.1.6 East Cameron Area, Block 193, Hard Bottom (EC193HB)

An area of uneven sea floor located within East Cameron Block 193 was investigated using bathymetric traces. This area was approximately 200 m in diameter and had a maximum relief of less than two metres in a water depth of 29 m. This potentially hard bottom site was located approximately nine kilometres west of the nearest platform in East Cameron Block 195.

Due to the site's depth, low relief, and anticipated poor visibility due to the nepheloid layer present, it was decided that this area was not suitable for this study. No visual observations were attempted.

2.5.1.7 East Cameron Area, Block 198, Hard Bottom, Leg Wreck (EC198HB)

An unusual artificial reef in East Cameron Block 198 was included as one of the potential study sites. This artificial reef consisted of an approximately 122-m long triangular leg lost from the jack-up drilling rig PENROD 53 in 1976. The leg wreck artificial reef was located 6.84 km and 6.71 km from platforms within East Cameron Blocks 182 and 201, respectively. Lying on its side on the sea floor, the leg formed an extended pyramid, rising nine metres off the bottom to within approximately 21 m of the surface. A nepheloid layer covered the structure and the layer was observed rising to a depth of 18 m. Horizontal visibility at the top of the structure was approximately five metres and decreased with depth.

Epibiota on the wreck was relatively sparse. A few scattered barnacles, corals (*Oculina* sp.), gorgonians (*Leptogorgia virgulata*), and urchins were noted (Appendix B).

Numerous red snapper were observed at the upper limits of the nepheloid layer, as well as near the leg. In addition, Atlantic spadefish, blue runner, gray triggerfish, greater amberjack, and vermilion snapper were observed (Appendix B).

2.5.1.8 Vermilion Area, Block 162, Hard Bottom (VR162HB)

The hard bottom within Vermilion Block 162 occurred as a series of rock outcrops rising from a soft mud sea floor at a depth of 28 m. The greatest relief recorded at the site was 3.5 m. A nepheloid layer occurred at a depth of approximately 20 m and totally covered the hard bottom outcrops. Visibility at the hard bottom was approximately 1.5 m. A thermocline was recorded at a depth of 15 m. Numerous natural gas seeps were observed bubbling intermittently from fissures in the outcrops.

Rock substrate was covered with a thick mat of bryozoans (*Hippopetraliella marginata*) and hydroids. Small colonies of corals (*Oculina* sp.), numerous crabs (*Stenorhynchus seticornis*), and gastropods (*Vermicularia knorri*) were also observed (Appendix B).

Only four species of fishes (i.e., Atlantic spadefish, gray triggerfish, red snapper, and tomtate) were identified at the site (Appendix B). Red snapper was the most abundant.

2.5.1.9 Vermilion Area, Block 179, Hard Bottom (VR179HB)

An area of broken bottom with rock outcrops of up to 2.5 m relief was identified running east-west within Vermilion Block 179. The site was located approximately four kilometres southwest of the Vermilion 164 Field. This field included three four-pile well jackets (Vermilion 164, Platform "A"; Vermilion 164, Platform "B"; and Vermilion 178, Platform "A"), an eight-pile production platform (Vermilion 179, Platform "B"), and a one-pile caisson structure (Vermilion 178, Platform "B"). Hard bottom observed by divers consisted of outcrops rising only 1 to 1.5 m from the sea floor at a depth of 29 m. Rock outcrops were quite similar to those observed within Vermilion Block 162. The outcrops were entirely enveloped by the turbid nepheloid layer which extended from about the 21-m depth to the bottom and reduced bottom visibility to approximately 1.5 m. These rocks were laced with cracks and fissures, and numerous gas seeps were observed.

Rock surrounding the point of gas escape was usually covered with an unidentified white material (possibly the filamentous alga _Chaetomorpha_ or a sulfur bacteria). Other hard substrate surfaces were covered by bryozoans, scattered hard corals (_Oculina_ sp. and _Phyllangia_ sp.), and thick growths of hydroids (_Sertularella_ sp.). The epibenthic community also included numerous arrow crabs (_Stenorhynchus_ sp.), gorgonians (_Leptogorgia_ sp.), octocorals (_Telesto_ sp.), and urchins (_Arbacia punctulata_) (Appendix B).

Fishes observed included belted sandfish, gray triggerfish, red snapper, and tomtate (Appendix B).

2.5.2 Deep Water Hard Bottom Sites

The deep water hard bottom sites discussed below include those natural reefs that occur offshore of the 35-m isobath.

2.5.2.1 East Cameron Area, Block 229, Hard Bottom, Jackaman's Hole (EC229HB)

Jackaman's Hole, located 2.39 km south from Platform "A" in East Cameron Block 229, consisted of a large rock outcrop feature and a depression on an otherwise flat bottom at a depth of 37 m. The water depth within the "Hole" was approximately 43 m, while the peak of the hard bottom feature was within approximately 18 m of the surface. Rock outcrops were in the form of ridges and hummocks atop this feature, with reliefs of from three to five metres (Figure 4). The underwater visibility at this site during Phase I was excellent (≥9 m) for the northwestern Gulf of Mexico. No thermocline or significant currents were noted.

Epibiota included bryozoans, hard (*Oculina* cf. *diffusa* and *Siderastrea radians*) and soft (*Telesto riisei*) corals, gastropods (*Conus erminieus*), hydroids, and urchins (*Diadema antillarum* and *Arbacia punctulata*) (Appendix B).

Although 20 species of fishes were identified at this site, their abundance was low (Appendix B). Many of the species (e.g., blue angelfish, French angelfish, queen angelfish, spotfin butterflyfish, Spanish hogfish, etc.) are considered tropical forms and probably are not year-round

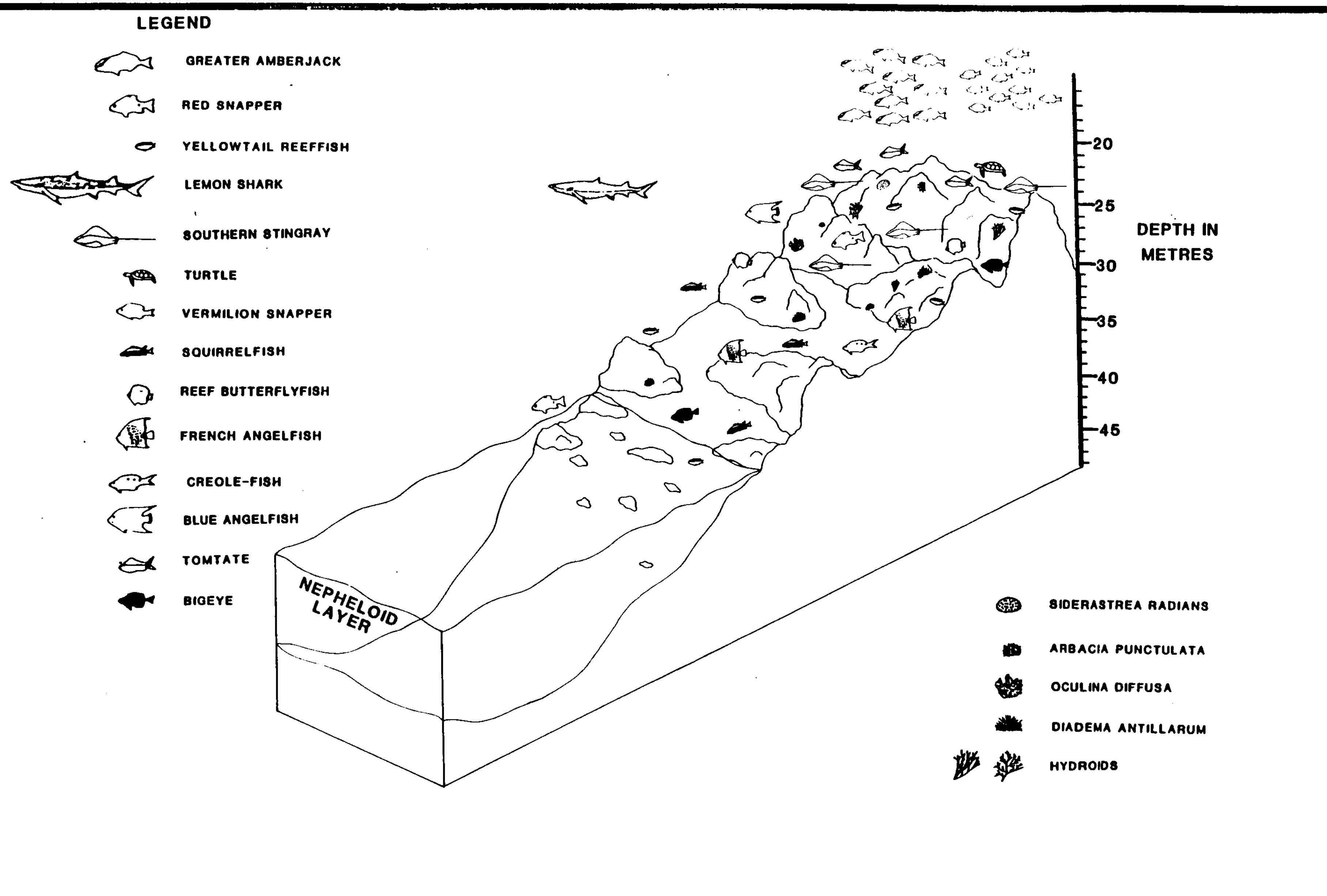


FIGURE 4. DIAGRAMMATIC REPRESENTATION OF EAST CAMERON AREA, BLOCK 229, HARD BOTTOM, JACKAMAN'S HOLE.

residents. Vermilion snapper was the only commercially valuable fish observed and few (10 to 30) individuals were noted.

2.5.2.2 East Cameron Area, Block 293, Hard Bottom, 29 Fathom Place (EC293HB)

This hard bottom feature was located within East Cameron Block 293 and three kilometres from the platform in East Cameron Block 286. The feature consisted of a rock outcrop rising from a depth of 57 m. The approximately 23-m diameter crest area above a depth of 37 m was surveyed by divers. The crest consisted of very rugged rock surfaces and included a two to four-metre diameter pinnacle rising from approximately 36 m to a water depth of 30 m. The feature is not presently included in bathymetric maps of the area or within lists of OCS topographic highs.

Rock surfaces supported large areas of fire coral (*Millepora* sp.) and sponges (*Agelas* sp., *Ircinia* sp., and *Neofibularia* sp.) (Appendix B). Spiral sea whips (*Cirrhipathes* sp.) and other antipatharians were also observed at what might be considered a surprisingly shallow depth for these organisms in the northwestern Gulf of Mexico. Warm water fauna was also represented by coral colonies (*Porites* sp.) and the spiny lobster (*Panulirus argus*).

Twenty species of fishes were recorded during the brief observations at the feature including large numbers (40 to 100) of creole-fish, greater amberjack, vermilion snapper, and yellowtail reeffish (Appendix B). Tropical species included blackbar soldierfish, queen angelfish, reef butterflyfish, Spanish hogfish, spotfin butterflyfish, and spotfin hogfish.

2.5.2.3 Vermilion Area, Block 298, Hard Bottom, Sonnier Bank (VR298HB)

Sonnier Bank, previously known as "Three Hickey Rock", was a relatively large feature composed of siltstone outcrops extending from 17 m to at least 58 m deep. This bank has been surveyed by a research submersible and has been described by Bright and Rezak (1978a). The shallowest of the five peaks that comprise the bank was surveyed above 26 m during Phase I. Water clarity at the bank crest was excellent, exceeding 18 m. Strong currents were found flowing toward the west (260°) at the surface and toward the east (80°) at the bottom. No readily observable gradients in temperature or salinity were noted.

The surveyed area was covered with encrusting fire coral (Millepora sp.) and sponges (Ircinia sp. and Neofibularia nolitangere). Thorny oysters (Spondylus americanus), flame scallops (Lima scabra), bristle worms (Hermodice carunculata), and serpulid worms (Spirobranchus giganteus) were observed to be common members of the bank crest community. Several spiny lobsters (Panulirus argus) were also observed during the survey (Appendix B).

The bank supported large numbers of fishes. Thirty-two species were identified by divers during the initial assessment survey (Appendix B). Particularly large numbers of angelfishes, blue runner, creole-fish, and creole wrasse were present. The crest of the bank was marked by a large school of blue runner feeding at the surface. During calm sea conditions, the location of such schools is routinely used by fishermen and divers to pinpoint the shallowest point on the bank (Sonnier, 1981).

2.5.3 Shallow Water Platform Sites

Shallow water platform sites discussed below include those structures that occur inshore of the 35-m isobath.

2.5.3.1 West Cameron Area, Block 237, Platform "A" (WC237PA)

This platform was a four-pile platform installed in 1978. It was located approximately 68 km from shore in 20 m of water. Visibility at the surface was estimated to be six metres, but deeper than 15 m it rapidly decreased to no more than one to two metres at the bottom.

Above the nine-metre water depth, platform surfaces were heavily fouled by barnacles, bryozoans, and hydroids (Appendix B). Hard corals (*Phyllangia* sp.), encrusting sponges, and urchins (*Arbacia* sp.) were also common. Below approximately 18 m, epifauna was reduced to only scattered barnacles.

The platform supported an abundance of fishes (Appendix B). Large schools, consisting of hundreds of Atlantic moonfish, Atlantic spadefish, and blue runner were observed beneath the platform. Gray triggerfish, red snapper, and sheepshead were also quite common, especially in the lower half of the water column. Blennies, cocoa damselfish, scamp, and sergeant major were commonly observed close to platform surfaces and at the horizontal supports. They were especially common at the seven-metre water depth.

2.5.3.2 East Cameron Area, Block 118, Platform "B" (EC118PB)

The structure consisted of a small four-pile well-jacket platform installed in 1973 and located approximately 57 km from the Louisiana coast. Water depth at the platform was 20 m. Platform "B" was within 1.8 km of another well-jacket (East Cameron 118, Platform "A"). During the survey of this platform, a salinity gradient was observed from the surface to about the 11-m depth. Horizontal visibility was limited to five to six metres and decreased rapidly below 15 m.

Above the nine-metre depth, the fouling community was dominated by algae, barnacles, and hydroids. From 9 to 15 m, bivalves, bryozoans, and gastropods became more evident. Seven species of bivalves were identified from collected samples (Appendix B). Epibiota was greatly reduced below 15 m, where platform surfaces were buried by fine sediment.

Schools of Atlantic spadefish, bluefish, blue runner, and sheepshead were observed beneath the platform (Appendix B). Blue runner appeared to be the most abundant species.

Gray triggerfish, greater amberjack, and red snapper were seen in smaller numbers. Cocoa damselfish and sergeant major were observed close to the platform surface where protective holes and crevices were present.

2.5.3.3 East Cameron Area, Block 160, Platform "A" (EC160PA)

This eight-pile platform was installed in 1957 in 26 m of water and had six wells. Epibiotal and ichthyofaunal observations were concentrated near horizontal supports at 7, 14, and 23-m depths. Water clarity at the structure was influenced by a strong salinity gradient which occurred from eight to ten-metre depths and a nepheloid layer which began at a depth of approximately 20 m.

At the seven-metre level, approximately 95% of the surface was covered with various epibiota including barnacles, bryozoans, hydroids, and red algae. Epibiota at 14 m was similar in composition, with the addition of the octocoral *Telesto riisei* and the urchin *Arbacia punctulata*. The 23-m depth showed a marked reduction in epibiota, with only about 50% coverage. Once again, barnacles, bryozoans, and hydroids were found, in addition to a few specimens of the gorgonian *Leptogorgia virgulata*. Identified epibiotal specimens are listed in Appendix B.

Atlantic spadefish, greater amberjack, red snapper, and sheepshead were observed at all levels (Appendix B). Blue runner was the most abundant species near the surface, and red snapper was numerically dominant at the lower levels. Other fishes observed at the rig were blennies, cobia, cocoa damselfish, gray triggerfish, scamp, sergeant major, spotfin butterflyfish, and vermilion snapper.

2.5.3.4 East Cameron Area, Block 195, Platform "A" (EC195PA)

The structures within Block 195 consisted of two four-pile platforms connected by an elevated walkway. These platforms were greater than nine kilometres from any known hard bottom areas or other platforms, and approximately 92 km from the Louisiana coast in 31 m of water. Platform "A" was installed in 1969 and supported eight production wells. The connecting Platform "B" was installed in 1970 to support pipeline operations. No wells were associated with it. During Phase I, observations were recorded only beneath Platform "A". Water clarity from the surface to the nepheloid layer, at 23 m, was excellent (>20 m). Evidence of a salinity gradient was visible as a subsurface refractive layer between six and ten metres.

Epibiotal cover at this platform was greatly reduced, compared to previously surveyed structures (Appendix B). Barnacles covered 70 to 80% of the platform's surfaces above a depth of nine metres and were overgrown by bryozoans, hydroids, and filamentous red algae. Below nine metres, epibiota became increasingly sparse and covered an estimated 30% of available surfaces to a depth of 18 m. An epibiotal community consisting of widely scattered barnacles, corals (*Oculina* sp.), crabs (*Stenorhynchus* sp.), and urchins (*Arbacia punctulata*) was observed to the maximum depth surveyed (25 m).

Fishes included Atlantic spadefish, blue runner, gray triggerfish, greater amberjack, sheepshead, and vermilion snapper (Appendix B). Warm water species observed included blue angelfish, doctorfish, sergeant major, and spotfin butterflyfish. In addition, an approximately 31-kg Warsaw grouper was speared at the structure during the survey.

2.5.3.5 Vermilion Area, Block 161, Platform "A" (VR161PA)

This platform was a four-pile, well-jacket structure located 70 km from the Louisiana coast in 28 m of water. The platform was installed in 1965 and was located within four kilometres of the Vermilion Block 162 hard bottom area (VR162HB; Section 2.5.1.8) and two other platforms (Vermilion 161, Platform "B" and Vermilion 162, Platform "B"). During the observation dives, visibility was less than seven metres from the surface to the top of the nepheloid layer, which began at a depth of 20 m. Visibility within the nepheloid layer immediately dropped to about three metres and decreased with increasing depth to the bottom. A strong thermocline was noted at a depth of 15 m.

The epibiotal community on the structure was visually identical to previously described platforms, with thick

(8 to 13 cm) barnacle growths and associated algal, bryozoan, and hydroid populations from the surface down to depths of 18 to 20 m (Appendix B). Below this level, fewer large barnacles were evident, and a low-relief fouling mat of hydroids and sponges was found. Scattered corals (*Oculina* sp.) and gorgonians were the more visible members of the sediment laden epifaunal communities below 20 m.

Fishes observed at the platform included, in order of abundance, Atlantic spadefish, sheepshead, blue runner, Atlantic moonfish, red snapper, gray triggerfish, and great barracuda (Appendix B).

2.5.3.6 Vermilion Area, Block 164, Platform "A" (VR164PA)

This platform was a four-pile, well-jacket structure installed in 1957 in a water depth of 29 m. It was one of five structures making up the Vermilion 164 Field located 73 km from the Louisiana coast. The nearest platforms are 1.16 km northwest and 0.74 km southeast of the structure. An area of hard bottom was surveyed approximately four kilometres southwest of the platform (VR179HB; Section 2.5.1.9). During observational dives at the platform, reduced visibility was noted within a strong salinity gradient which occurred at a depth of approximately six metres. Visibility was approximately nine metres from a depth of six metres to the nepheloid layer, which was encountered at a depth of about 21 m. Below 21 m, the water became increasingly turbid. The bottom directly beneath Platform "A" was covered with a large mound of rocks rising about three metres above the surrounding sea floor.

Epibiota on the rocks was sparse, consisting predominantly of colonies of the hard coral Oculina sp. and encrusting sponges (Appendix B). Epibiotal growth on platform members within the nepheloid layer was also limited; widely scattered barnacles, hydroids, and encrusting yellow sponges were present. Epibiota above 20 m formed thick (several centimetres) layers. Substrate provided by barnacles was utilized by cryptic fauna (e.g., blennies, crustaceans, etc.) and was covered by mats of bryozoans and hydroids.

Large schools of blue runner, consisting of 30 to 50 individuals, dominated the fish population above the nepheloid layer (Appendix B). Schools of Atlantic spadefish, bluefish, greater amberjack, and scattered gray triggerfish and red snapper were observed in generally uniform numbers throughout the upper water column. Cocoa damselfish was present near protected areas formed at junctions of horizontal and diagonal leg supports. Several scamps were seen. Atlantic spadefish, red snapper, sheepshead, and tomtate were observed near the base of the platform within the nepheloid layer. Red snapper and sheepshead were most abundant.

2.5.3.7 Vermilion Area, Block 182, Platform "A" (VR182PA)

Platform "A" was installed in 1971 and consisted of an eight-pile production platform bearing ten wells. It was connected by an elevated walkway to a four-pile auxiliary platform. Platform "A" was located approximately 82 km from the Louisiana coast in a 32-m water depth and 2.8 km from the nearest neighboring platform. From the surface to about 18 m, visibility was very good ($\geq$20 m). The nepheloid layer was encountered at 21 m and visibility was restricted to approximately five metres, becoming increasingly reduced with depth.

Barnacles, bryozoans, corals (*Oculina* sp. and *Phyllangia americana*), hydroids, and the octocoral (*Telesto riisei*) covered practically all exposed surfaces (Appendix B).

Blue runner and gray triggerfish constituted the numerically dominant fishes observed (Appendix B). Blue runner was particularly abundant. Schools of this species moved in and out of the structure almost continuously. Small schools of greater amberjack and small numbers of Atlantic spadefish, cocoa damselfish, scamp, sergeant major, and sheepshead were seen. Few red snappers were observed beneath the platform.

2.5.4 Deep Water Platform Sites

The deep water platform sites discussed below include those structures that occur offshore of the 35-m isobath.

2.5.4.1 East Cameron Area, Block 229, Platform "A" (EC229PA)

This platform was a large four-pile structure installed in 1962 in 37 m of water. The platform was more than nine kilometres from any other platform and 2.39 km from the hard bottom feature, Jackaman's Hole (EC229HB; Section 2.5.2.1). Water clarity at the platform was approximately nine metres. No near-surface thermocline was observed.

Epibiota observed above nine metres included, in order of abundance, barnacles, bivalves, urchins, algae, gastropods, octocorals, hydroids, and bryozoans (Appendix B). Barnacles and bivalves, which blanketed approximately 90% of the platform surfaces, were encrusted by algae, hydroids, and sponges. Apparently, grazing by urchins (*Arbacia punctulata*) and gastropods had denuded patches of substrate in several locations of all encrusting biota except for scattered barnacles. Platform surfaces from depths of about 9 to 26 m were almost entirely covered by 11 to 25-cm thick growths of the octocoral *Telesto riisei*. Scattered bivalves, bryozoans, hydroids, and urchins were noted living within openings in the octocoral cover. Observations were not recorded below approximately 27 m.

Seventeen species of fishes were identified (Appendix B). Blue runner, greater amberjack, and vermilion snapper were the most abundant. Large numbers (50-100) of tomtate and vermilion snapper, as well as blue angelfish, scamp, sergeant major, Spanish hogfish, and white spotted soapfish were found near the junction of the horizontals, well casings, and well guides at depths of 20 m. Schools of greater amberjack and blue runner were observed throughout the surveyed water column. No diver observations were made within the bottom water layer due to the depth and bottom time restrictions.

2.5.4.2 East Cameron Area, Block 231, Platform "A" (EC231PA)

The structure consisted of an eight-pile production platform installed in 1975 in a water depth of 37 m. During the survey of this platform, a stratified water column was evident. A less saline surface layer was optically identified by a visible gradient between depths of six to ten metres. A turbid nepheloid layer was observed at an approximate depth of 26 m. Above the nepheloid layer, horizontal visibility was estimated to be six metres. No observations were made below 27 m.

Species identified at the platform during the survey are listed in Appendix B. Epibiota consisted predominately of barnacles, hydroids, and encrusting sponges which covered the platform from the surface to a depth of approximately nine metres. Urchins (*Diadema antillarum*) and scattered patches of the octocoral *Telesto riisei* were also observed on the upper sections of the platform. Below approximately nine metres, and especially on horizontal supports, thick (15 to 23 cm) growths of the octocoral *Telesto riisei* dominated the epibiotal growth. Bryozoans, hard corals (*Phyllangia* sp.), crabs (*Stenorhynchus* sp.), hydroids, oysters, encrusting sponges, and urchins (*Arbacia punctulata*) were also well represented in the epibiotal assemblage observed between 9 and 25-m depths. At a depth of 27 m (within the nepheloid layer), the biomass of epibiota was greatly reduced. Approximately 50% of the available platform surface was covered by epibiota, in comparison to 95% coverage at shallower depths. Thin patches of *Telesto* sp. were observed on horizontals, while vertical sections were predominately bare except for scattered barnacles, encrusting sponges, and urchins.

Pelagic fish populations swimming around and through the platform consisted of blue runner, cobia, and greater amberjack (Appendix B). Demersal species included angelfishes (*Holacanthus* sp.), creole-fish, scamp, groupers, sergeant major, spotfin butterflyfish, squirrelfish, and vermilion snapper. Cocoa damselfish was especially prominent at the junctions of wells and horizontal supports. Red snapper was not observed at the platform during the survey.

2.5.4.3 East Cameron Area, Block 257, Platform "A" (EC257PA)

Platform "A", installed in 1971, was an eight-pile structure supporting nine wells. The platform stood in 49 m of water approximately 121 km from the

Louisiana coast. It was greater than nine kilometres from other platforms or hard bottom features. A visually apparent salinity gradient was present at a depth of four to nine metres. Visibility within the surface water mass was estimated to be ten metres and improved significantly below the salinity gradient.

The structure was heavily fouled by bryozoans, hydroids, oysters (*Pinctada imbricata*), and sponges (Appendix B). Bivalves (*Spondylus americanus*), hard corals (*Phyllangia* sp.), octocorals (*Telesto riisei*), and urchins (*Arbacia punctulata*) were scattered throughout the depths surveyed.

Numerous Atlantic spadefish, blue runner, gray triggerfish, greater amberjack, and vermilion snapper were observed throughout the water column (Appendix B). More tropical forms such as Bermuda chub, blue angelfish, creole-fish, French angelfish, great barracuda, queen angelfish, sergeant major, and Spanish hogfish were observed near horizontal supports and well casings.

2.5.4.4 East Cameron Area, Block 286, Platform "A" (EC286PA)

This platform was located approximately 135 km from shore in a depth of 57 m. The structure, installed in 1971, was an eight-pile platform supporting seven wells. The platform was greater than five kilometres from other platforms, and three kilometres northwest of the high-relief hard bottom feature studied in East Cameron Block 293 (EC293HB; Section 2.5.2.2). During the survey of the platform, water clarity was excellent. Divers estimated horizontal visibility to be greater than 18 m. The near-surface salinity gradient observed at other sites was not found at this location. Observations were concentrated near the horizontal supports at depths of 6 and 17 m.

The epibiotal assemblage appeared quite diverse and was dominated by bivalves, bryozoans, and hydroids. Nine species of bivalve were identified from the collections taken by divers (Appendix B). Three species of sea urchin (*Arbacia punctulata*, *Diadema antillarum*, and *Eucidaris tribuloides*) were noted at the platform. Bivalves and scattered barnacles were covered by bryozoans, hydroids, and encrusting sponges. Octocorals (*Telesto* sp.) and hard corals (*Phyllangia americanus*) were present on the platform in small, widely scattered colonies.

The fish populations were also quite diverse. Twenty-one species of fishes were identified during the survey (Appendix B). Tropical, or blue water, species were especially evident. These included the angelfishes (*Pomacanthus* spp.), Bermuda chub, blue tang, brown chromis, creole-fish, and doctorfish. As at other platforms, these species were observed congregated near platform crossmembers and well guides. Crevalle jack, great barracuda, and greater amberjack constituted the largest predatory species observed.

2.5.4.5 Vermilion Area, Block 265, Platform "A" (VR265PA)

The platform consisted of a large eight-pile structure which was attached to an adjacent eight-pile platform by an elevated walkway. The two structures were located more than five kilometres from any other platforms and approximately 114 km from shore. Water depth beneath the structures was 49 m. VR265PA was installed in 1971, supporting 18 wells.

Extensive epibiotal populations covered the structure (Appendix B). Barnacles covered with algae, bryozoans, and hydroids dominated above the nine-metre depth. From 9 to below 23 m, the greatest observation depth, bivalves (Arca zebra, Chama congregata, Pinctada imbricata, and Spondylus americanus), octocorals (Telesto sp.), and encrusting sponges became more abundant. As in the case of most of the platforms surveyed, arrow crabs (Stenorhynchus seticornis), hard corals (Phyllangia americana), and sea urchins (Arbacia punctulata) were common on the platform throughout much of the depths surveyed.

A diverse assemblage of fishes was present beneath the platform (Appendix B). Vermilion snapper was the most abundant. Other schooling species included Atlantic spadefish, blue runner, greater amberjack, and lookdown.

Blue angelfish, blue tang, cocoa damselfish, creole-fish, doctorfish, French angelfish, scamp, sergeant major, spotfin butterflyfish, and squirrelfish were observed only in close association with platform members.

2.5.4.6 Vermilion Area, Block 287, Platform "A" (VR287PA)

Platform "A" within Vermilion Area, Block 287 was a four-pile structure installed in 1977 in a water depth of 55 m. The platform was located approximately 124 km from the Louisiana coast and about six kilometres from the closest neighboring platform. During the survey, a westward flowing, relatively turbid, near-surface water mass was observed. Below the turbid surface layer (i.e., 17 m), only a very slight current was found.

Epibiota was very sparse, covering only 20 to 30% of the available surface area (Appendix B). This paucity of epibiota may have resulted from the age of this platform (only three years) or there may have been biological factors present. Barnacles and bivalves, most of which were dead, appeared to be the initial colonizers. Bivalves (Isognomon bicolor, Pteria colymbus, and Spondylus americanus), gastropods (Thais haemastoma canaliculata), hydroids, octocorals (Telesto riisei), and encrusting sponges were thinly scattered across metal surfaces. Sea urchins (Arbacia sp.) were especially prominent members of the fouling assemblage and may have contributed to reducing the growth of some epibiota.

Small schools (5 to 20 individuals) of blue runner, gray triggerfish, and greater amberjack, and individual blennies and doctorfish were the only fishes observed beneath the structure (Appendix B). The platform supported the lowest epibiotal biomass and numbers of fishes of any platform surveyed during Phase I.

2.6 Conclusions

A list of 25 potential hard bottom and platform study sites within the defined study area was developed and each site surveyed during Phase I operations. The 25 evaluated sites can be classified into shallow water (inshore of the 35-m isobath) and deep water (offshore of the 35-m isobath) hard bottom features and platforms.

Figure 5 diagrammatically illustrates the characteristics of the shallow water hard bottom areas. The shallow water hard bottom sites consisted of relatively small, low-relief, outcrop features. Naturally occurring gas seeps were frequently observed. Hard substrate was normally covered by thick growths of ascidians, bryozoans, and hydroids. Observations of reef fish populations during the first field efforts were difficult due to the total coverage of the sites by the nepheloid layer. Significant populations of Atlantic spadefish, gray triggerfish, red snapper, sheepshead, and tomtate were present at the shallow hard bottom sites.

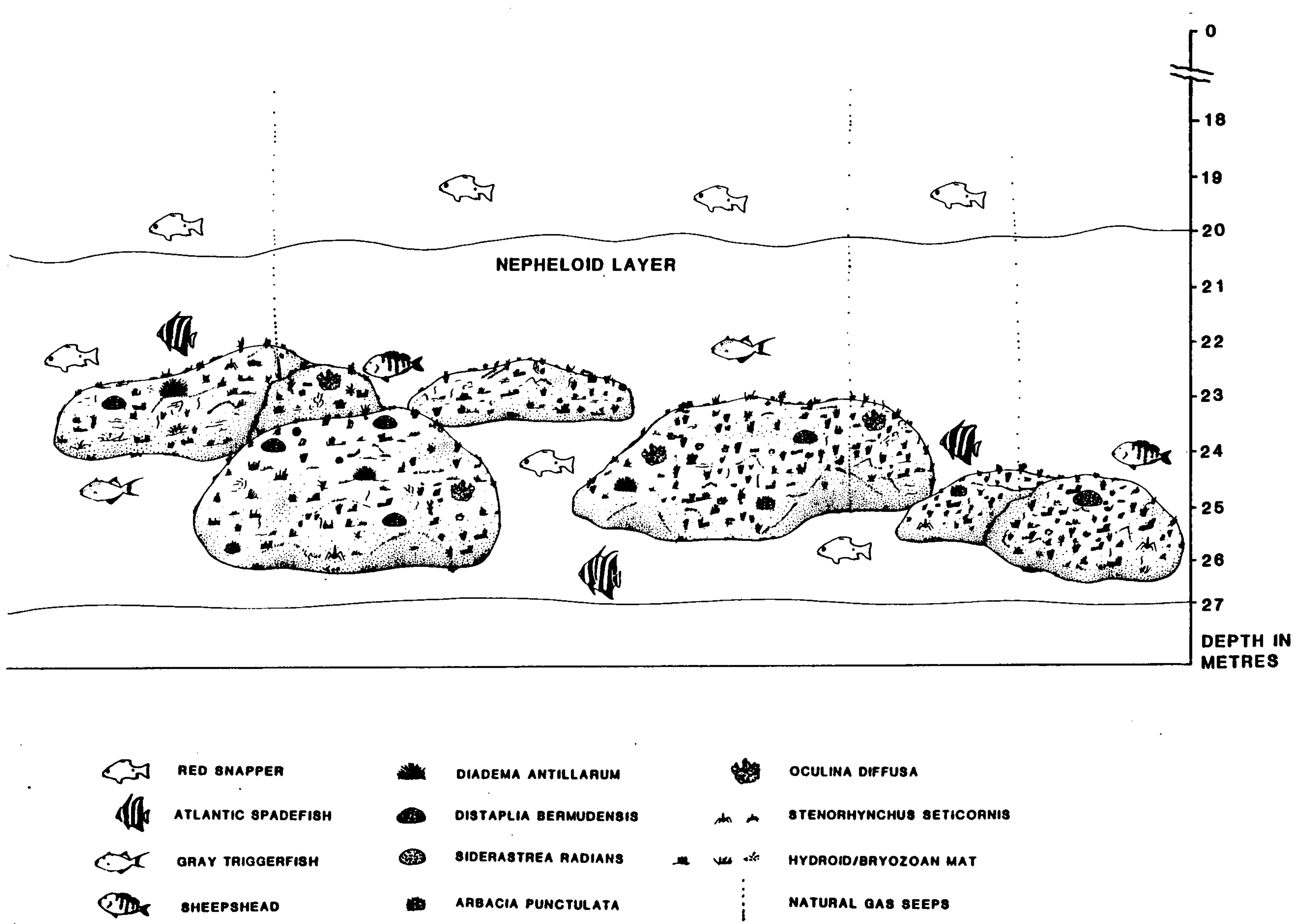


FIGURE 5. DIAGRAMMATIC REPRESENTATION OF A TYPICAL SHALLOW WATER HARD BOTTOM AREA.

Deep water hard bottom sites consisted of large, high-relief features rising above the nepheloid layer into clear water. The tops of these features supported warm water species of corals, crustaceans, sponges, and fishes.

Shallow water platforms were covered by an epibiotal assemblage dominated by barnacles, bryozoans, hydroids, and encrusting sponges. The platforms supported large fish populations composed primarily of Atlantic spadefish, blue runner, greater amberjack, red snapper, and sheepshead. Deep water platforms supported greater amounts of bivalves and octocorals (*Telesto* sp.) than did shallow water structures. Qualitative observations of platform epibiotal populations during this study corresponded well with biological assemblages described by Gallaway et al. (1979) for offshore (27 to 64-m depth) and blue water (>64-m depth) areas.

The principal faunal characteristic distinguishing both deep water hard bottom and platform sites from shallow water sites was the occurrence of large numbers of tropical reef fishes at the deep water sites. Creole-fish, creole wrasse, and various species of angelfishes and butterflyfishes were common members of the deep water zone fauna while common shallow water species such as Atlantic spadefish and sheepshead were typically absent from deep water sites.

Following the site characterization surveys, two sites were to be selected for the Phase II equipment and methods evaluations and nine sites were to be selected for subsequent

Phase III assessments of fish population standing stocks. Site requirements for Phases II and III were not identical. Characteristics of the hard bottom and platform study sites that were considered "ideal" for Phase II objectives included the following:

1) Water clarity adequate for visual observation techniques;
2) Abundant and diverse assemblage of fishes;
3) Close proximity to each other, thus reducing travel time; and
4) A platform large enough to allow relatively unrestricted movement of equipment within the confines of its structure.

The East Cameron Area, Block 229, Hard Bottom (EC229HB; Section 2.5.2.1) known as Jackaman's Hole and the nearby East Cameron Area, Block 229, Platform "A" (EC229PA; Section 2.5.4.1) appeared to meet the test site requirements. These sites were accordingly selected as the study area for Phase II.

Numerous variables must be considered in order to quantify the effect of oil and gas activities on reef fishes in the northwestern Gulf of Mexico. Factors such as water depth, platform age, size of platform and hard bottom feature, number of nearby structures, relief, and distances between features may significantly affect fish populations. Assessment of a number of similar sites is required to determine natural variations between habitats and the influence each factor has on fish populations. Population studies over extended periods of time are required to evaluate naturally occurring temporal variability. Within the limited time frame available for Phase III, study sites were required which would reduce as much as possible the number of these variables.

It was believed that selection of shallow water sites would reduce the number of variables and increase the number of possible sites; however, shallow water hard bottom areas are usually in turbid water and are not presently considered sensitive biological areas by the Bureau of Land Management. Only two suitable combination hard bottom and platform sites (EC229PA-EC229HB and EC286PA-EC293HB) and one isolated hard bottom area (VR298HB) were available in deep water. We felt that study of a deep water bank would provide baseline data on the assessment methodology (number of stations, variability, etc.) suitable for future studies of the deep water bank systems. Following the Phase I survey, we felt that the shallow hard bottom areas offered the best available sites in similar depths and with sufficiently small geographic areas to be evaluated for the effect of OCS oil and gas activities on reef fish populations. Table 2 lists the nine sites tentatively selected for evaluation of fish population standing stocks during Phase III. In addition, Sonnier Bank (VR298HB; Section 2.5.2.3) was selected as a solitary deep water bank for assessment should field time allow.

TABLE 2. STUDY SITES SELECTED FOR FISH STANDING STOCK ESTIMATES DURING PHASE III.

Hard Bottom Sites

East Cameron Block 115, Hard Bottom

East Cameron Block 126, Hard Bottom

East Cameron Block 178, Hard Bottom

Isolated Platform Sites

East Cameron Block 160, Platform "A"

East Cameron Block 195, Platform "A"

Vermilion Block 201, Platform "A"

Combination (Hard Bottom/Platform Sites)

Vermilion Block 162, Hard Bottom/Vermilion Block 161, Platform "A"

Vermilion Block 179, Hard Bottom/Vermilion Block 164, Platform "A"

East Cameron 118, Hard Bottom/East Cameron 118, Platform "A"

3.0 PHASE II - EQUIPMENT AND METHODS EVALUATIONS

3.1 Objectives

The objectives of Phase II were 1) to evaluate selected equipment and methods for efficacy in determining standing stocks of selected species of reef fishes near oil and gas platforms and natural hard bottoms; and 2) to select the equipment and methods most applicable to surveying the deep waters of the continental shelf.

Each piece of equipment and each assessment technique were judged in relation to a hypothetical ideal fish assessment system. Such a system would 1) collect quantitative data of fish assemblages at both species and total community levels; 2) incorporate only non-destructive sampling; 3) allow replicate assessments over short terms; 4) have no impact on fish behavior (i.e., frighten or attract fishes); 5) accurately assess the patchiness and spatial variability present in reef fish populations; 6) be operated easily in strong currents and high seas; 7) require few operating personnel; and 8) be deployed, moved, and recovered rapidly.

Evaluations of complex systems, such as ROVs which incorporated more than one operational unit (i.e., low-light level television and remote vehicle), were directed to each unit's performance as well as the combined system's characteristics.

Television systems were expected to be affected by the two problems common to all remote visual assessment methods:

1) how to view an area large enough to ascertain the spatial distributions of fish stocks; and 2) how to quantify the water volume viewed. The various methods or operational modes in which each system was used were attempts to compare solutions of these basic problems.

3.2 Testing and Evaluation Plan

During Phase II field operations, equipment and methods were evaluated at Jackaman's Hole and at East Cameron Area, Block 229, Platform "A" (Figure 6). The production platform was approximately 2.4 km north of the hard bottom site. Both these locations are described in detail in Section 2.0 (EC229HB; Section 2.5.2.1 and EC229PA; Section 2.5.4.1).

3.3 Geographic Area of Study

Within the context of this study, the term "site" is used to refer to the specific feature (e.g., East Cameron Area, Block 229, Platform "A") under study. The term "station" refers to the exact area or portion of a site (e.g., the northwest platform leg at 30-m depth) observed at any one time. Figure 7 illustrates a top view of the various stations around the platform site at which tests were conducted.

3.4 Survey Equipment and Methodology

3.4.1 Field Observations

Field observations were conducted from the M/V JIM LYTAL, a 30-m long Gulf of Mexico supply vessel.

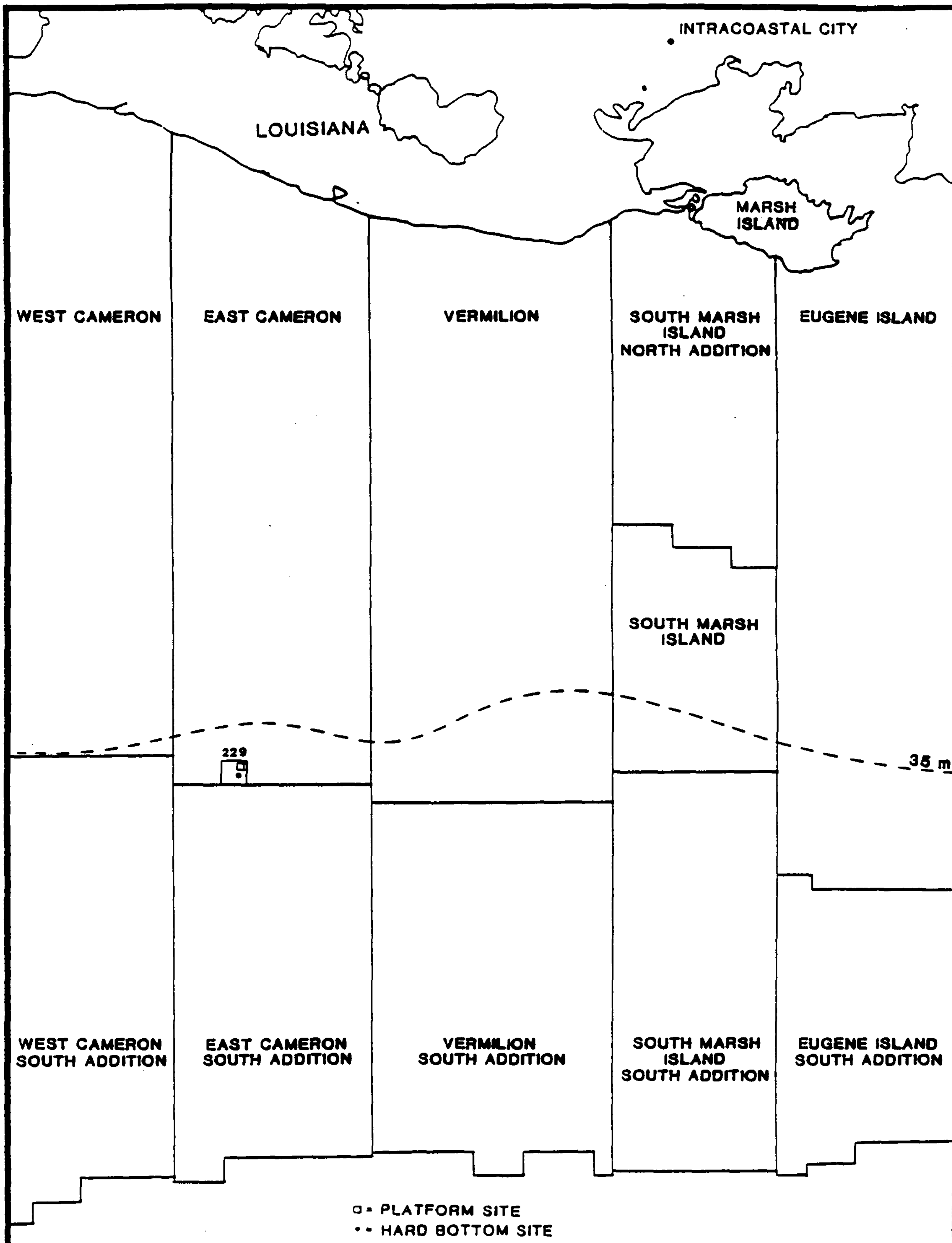


FIGURE 6. GEOGRAPHIC LOCATIONS OF TEST SITES FOR EQUIPMENT AND METHODS EVALUATIONS CONDUCTED DURING PHASE II.

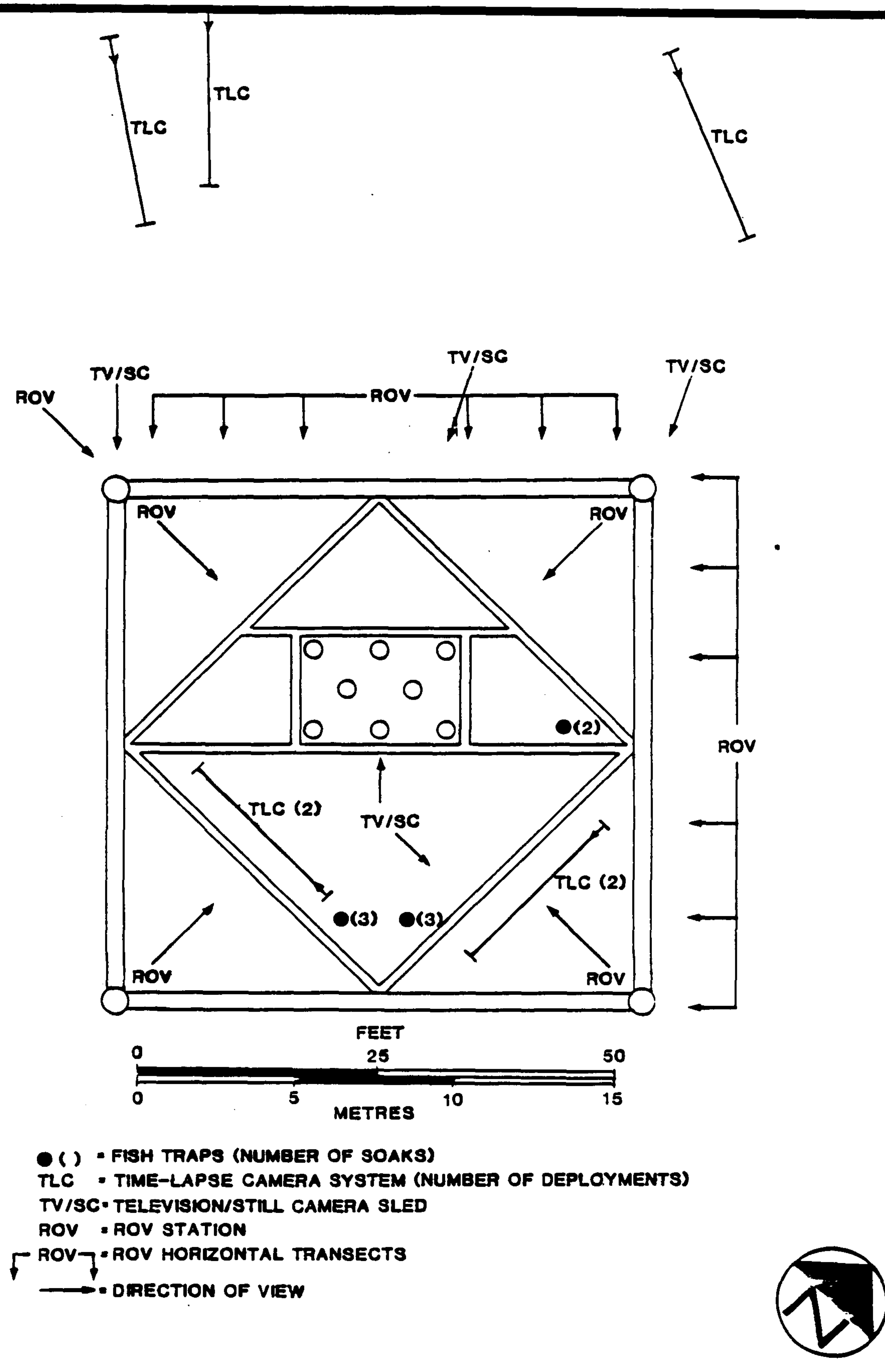


FIGURE 7. TOP VIEW OF STATIONS AROUND EAST CAMERON AREA, BLOCK 229, PLATFORM "A" AT WHICH TESTS WERE CONDUCTED.

3.4.1.1 Diver Observations

Observations by divers using scuba were made at both the hard bottom site and at the platform. Thirty-five-millimetre photographs of equipment, epifauna, and fish populations were made using Nikonos underwater cameras.

From previous experience with platform-associated reef fish populations, spatial zonation of the fishes at the structure was anticipated. Diver observations were considered the most accurate qualitative method of determining fish population characteristics in regard to spatial zonation and movement patterns. Data from various remote methods were compared to the conclusions drawn from diver observations.

3.4.1.2 Remotely Operated Vehicle (RCV-225)

Underwater television observations were recorded using a Hydro Products RCV-225 Remote Controlled Vehicle System. The system consisted of a Hydro Products Model TC-125-SIT underwater television camera mounted within the remote vehicle assembly, a system control station, 122 m of tether cable, and a Model DS-300B deployment system. The low-light level television camera was tested separately and was equipped with a 12.5-mm lens and an assembly that enabled the operator to pitch the angle of view $\pm 90°$ from the horizontal. All controls and displays were contained in the unit control station, including a fully proportional "joy stick" for manipulation of the RCV and television.

Vehicle depth, heading, and camera pitch angle were displayed on the control station monitor and were continuously recorded along with audio and video data on Sony V-32, 1.27-mm (0.5-inch), 60-minute videotapes by a Sony Model AV-3650 videotape recorder.

At the natural hard bottom site, the RCV-225 was flown within sight of the sea floor along transects across the feature. All observations during daylight and night were recorded on videotape.

The RCV-225 was used at the platform stations in three modes of operation. These included 1) horizontal pans covering 360° around a vertical axis; 2) horizontal transects along the sides of the platform; and 3) fixed-position observations of fixed targets (Figure 7). A diagrammatic representation of the fixed-position observation made of both the RCV-225 and CSA television sled is shown in Figure 8. Horizontal pans were conducted by rotating the vehicle through 360° while holding the unit stationary on a vertical axis. During horizontal transects, the RCV-225's television camera was directed perpendicular to a platform side, normally defined by a horizontal support member, and continuously flown back and forth along the length of the platform face. During fixed-position observations, the RCV-225 was hovered in one position while being directed toward a suitable target (i.e., leg, well conductor, or diagonal support). Observations of ten minutes duration were recorded in each mode at each station location.

In order to establish the exact water volume being viewed by the camera, divers held a measured rod at known distances from the lens and these horizontal and vertical scale "benchmarks" were recorded on videotape. Using the diver-held rod as the standard, scale correction diagrams were generated. Comparing this diagram with visual targets of known size allowed for the calculation of exact volumes based on a four-sided pyramid (see Section 3.4.2.1 and Figure 8).

3.4.1.3 Honeywell Acoustic Positioning System

A Honeywell RS-7 Model 1500 digital acoustic position indicator was tested as a method of providing RCV-225 position information relative to the survey vessel. The positioning system consisted of a Display Processor Unit (DPU), a vertical reference unit, a hydrophone, and an acoustic tracking beacon. The beacon, which was attached to the RCV-225, transmitted short-duration acoustic pulses at regular intervals for reception by the hydrophone. The hydrophone, mounted below the surface vessel, received the acoustic signals and converted these to equivalent electrical signals for transmission to the DPU. The vertical reference unit sensed the vessel pitch and roll attitude and provided a signal used by the system for

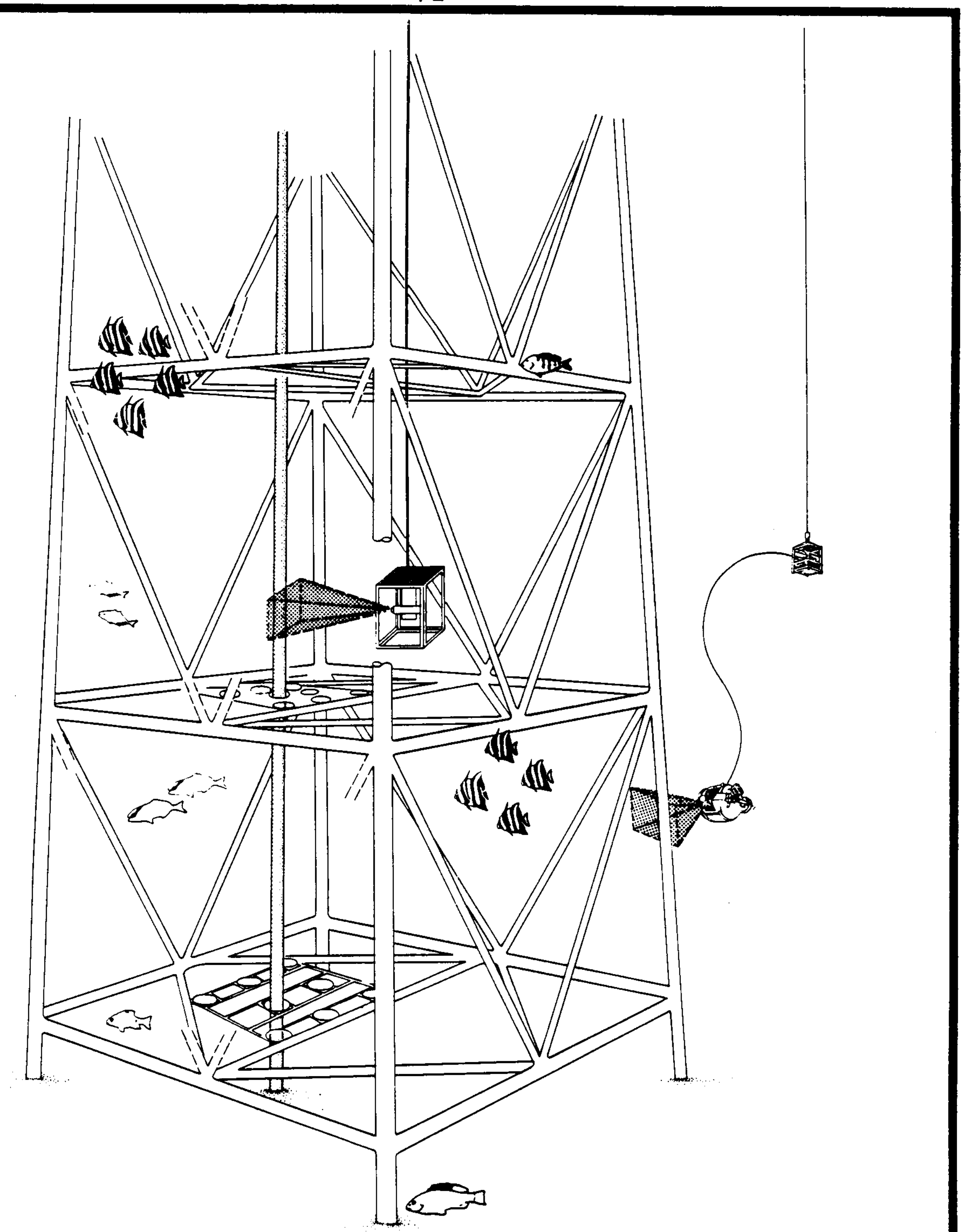


FIGURE 8. DIAGRAMMATIC REPRESENTATION OF RCV-225 AND THE CSA TELEVISION/STILL CAMERA SLED OPERATING IN FIXED-POSITION MODE.

correction of errors in the calculated position caused by vessel dynamics. The DPU contained system controls and a cathode-ray-tube (CRT) display where the position of the beacon relative to the hydrophone was indicated.

3.4.1.4 CSA Television/Still Camera Sled

Remote, real-time, videotape footage of hard bottom and platform associated fish populations was recorded using an underwater television and still camera system mounted on a Continental Shelf Associates, Inc. sled. The system consisted of a Hydro Products Model TC-125 underwater television camera, a Model RP-3 pan and tilt unit, a Model LT-7 thallium iodide light with a 250-watt thallium iodide lamp, a Benthos Model 372 deep sea standard camera with data chamber, a Benthos Model 382 deep sea standard flash, a Hydro Products Model SC-303 television system control unit, and a Sony Model AV-3650 videotape recorder. The control unit contained the television camera power supply, television monitor, lamp power supply, and all required operating controls. In addition to the video data, audio data were recorded on Sony V-32, 1.27-mm (0.5-inch), 60-minute tapes. Ektachrome ASA 200, 35-mm, color slide film was used for still photographs. The precise time (i.e., day, hour, minute, and second) for each photograph was recorded in a data insert on each slide through the use of the data chamber. The pan and tilt unit was used to observe objects of interest that were not directly in front of the sled.

The CSA television/still camera sled was lowered into position outside the platform from an A-frame at the stern of the survey vessel. For observations directly under the platform, the sled was maneuvered inside the structure while being supported by buoys, and lowered into position by way of a series of supporting blocks and cables suspended from the platform. Figure 8 shows a diagrammatic representation of the sled beneath the platform.

Once in position, the system was used in three modes of operation to record observations of fish populations., These included 1) continuous 360° horizontal pans using the system's pan and tilt unit; 2) fixed observations directed at a specific platform member target (i.e., leg, horizontal, or well conductor); and 3) fixed observations directed to a target (i.e., float) attached to the camera system sled by a six-metre length of 3.8-cm O.D. PVC pipe.

Observations of ten minutes duration were recorded in each mode at each platform observation station (Figure 7). Ten hours of CSA TV observations were recorded at the platform. Five hours of additional observations were recorded at the hard bottom area. Volume calculations were again performed using diver-held rods at known distances to construct a camera-specific scale conversion diagram.

The Hydro Products Model TC-125-SIT low-light camera and Model TC-125 underwater television camera were comparatively evaluated by having both units simultaneously observe a platform leg at sunset. Through this procedure, the low-light capabilities of the SIT (Silicon Intensified Target) camera were assessed relative to the conventional model.

Effects of the lights of the underwater television system on platform fish populations were evaluated by recording ten minutes of fixed-station observations inside the structure at night, then extinguishing the system's lights. After a ten-minute wait, still photographs of the station were taken every 30 seconds for 15 minutes using strobe lighting. Through comparisons of television and still photograph observations, potential changes in population characteristics with and without the television lights were assessed.

3.4.1.5 Time-Lapse Movie Cameras

Minolta XL-401 super-eight movie cameras in Ikelite underwater housings were used to record observations at near-surface, mid-depth, and near-bottom stations at the hard bottom site. The near-bottom camera was raised above the nepheloid layer (27 m) at the platform site. Cameras were hose-clamped to short lengths of 3.8-cm O.D. PVC pipe supported by taut-line arrays (Figure 9). Each camera was directed toward PVC targets on an adjacent taut-line array. Target and camera arrays were held at a constant distance of six metres by lengths of PVC pipe.

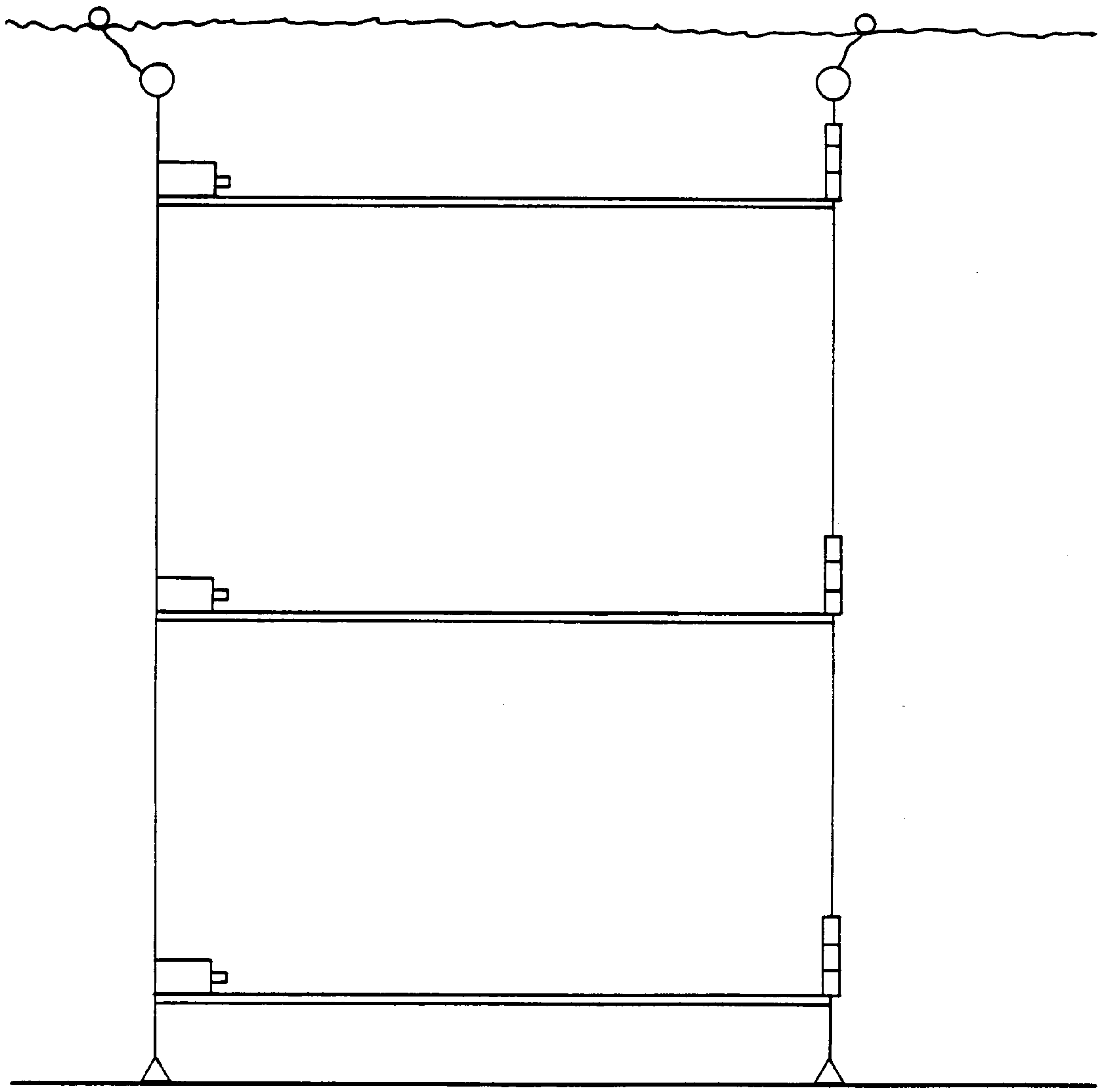


FIGURE 9. TIME-LAPSE MOVIE CAMERAS ATTACHED TO A TAUT-LINE ARRAY.

Time-lapse camera arrays were deployed on the hard bottom and outside the platform from the survey vessel or from an inflatable boat. An array was also lowered within the platform from the low level platform walkways.

With the aid of external intervalometers attached to each camera, one-second observations were recorded at approximately five-minute intervals. The times each time-lapse camera was activated, deployed, recovered, and deactivated were recorded for use in later analysis. This camera system, with similarly housed Vivitar strobes attached, was deployed for evening observations at both the hard bottom and platform areas. Single frame observations were recorded every 24 seconds.

Time-lapse observations were attempted to evaluate possible short-term (one to eight hours) fluctuations in fish concentrations. Since most of the Phase II assessment methodologies were not used simultaneously, the data concerning temporal differences in fish populations would be helpful for the comparisons of equipment types.

3.4.1.6 Diver Motion Picture Transects

A diver-held Minolta XL-401 super-eight movie camera in an Ikelite underwater housing was used to record fish population observations along transects at both the hard bottom and platform sites. Observations were recorded at Jackaman's Hole using two techniques. Initially the diver directed the camera forward and 45° down from horizontal while swimming approximately three metres above a 15-m weighted measuring tape deployed across the peak of the feature. The transect was repeated while directing the camera directly downward while swimming approximately six metres above the tape.

At the platform, the 20-m depth horizontal crossmembers were used as the transect course. Super-eight movie observations were recorded along the horizontal pipes using the two methods described above.

3.4.1.7 Fish Traps

Wire A&G curiosity fish traps were used to evaluate their effectiveness in collecting target species. Traps consisted of 3.8-cm O.D. galvanized pipe frames covered with 2.54-cm hexagonal wire mesh netting. The traps were of the general "Caribbean S-trap" design which includes two mouth openings.

Traps were deployed on the sea floor at several locations on Jackaman's Hole, and both inside and outside the platform. A total of four soaks (deployments) was made at Jackaman's Hole and ten at Platform "A". A single soak was made with the trap suspended within the platform at a depth of 24 m to evaluate the trap's suitability for capturing mid-water species. At the conclusion of each soak, traps were raised to a depth of approximately nine metres and held for at least an hour in an attempt to reduce decompression damage to trapped fish. Traps were then brought to the surface where individual fishes were identified, measured, and weighed. Individual specimens were preserved in 10% formalin for a voucher collection, kept for bait, or used for the tagging-recapture study.

3.4.1.8 Tagging-Recapture

The objectives of the limited tagging-recapture efforts were 1) to determine the effectiveness of visually censusing tagged fishes by underwater television and movie systems; and 2) to assess tagging-recapture techniques for population censusing at offshore platform sites.

Captured individuals of various species were tagged with numbered streamer tags inserted through the body just behind the dorsal fin. Tags consisted of approximately 2 x 25-cm strips of red plastic "surveyors ribbon" labeled numerically with indelible ink. The ribbon streaming from the fish served as a readily observable tag. All fishes were released at the surface.

3.4.1.9 Hook-and-Line Sampling

Twenty-eight man-hours at the hard bottom site and thirty man-hours at the platform were spent hook-and-line fishing using traditional techniques. Baits used included frozen squid and cut fish. All fishes captured were identified, weighed, and measured.

3.4.2 Laboratory Procedures

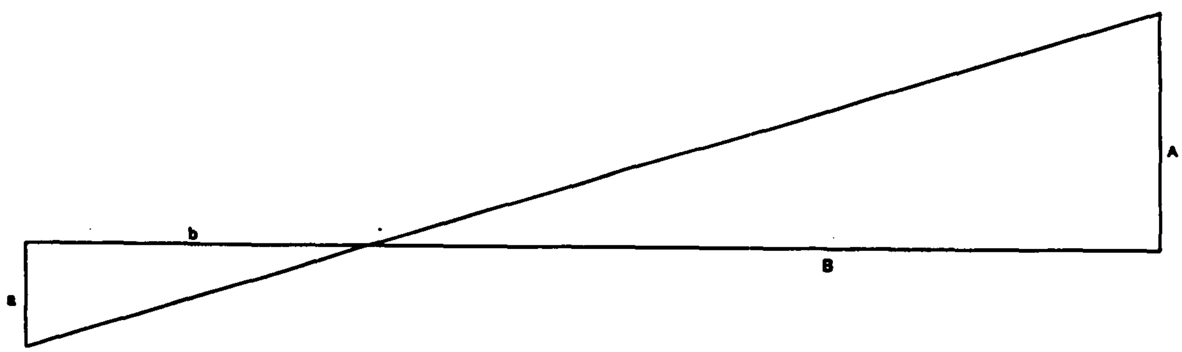
3.4.2.1 Television Observations

All television videotapes were replayed on a Sony Model AV-3650 videotape recorder and displayed on the monitor of a Hydro Products Model SC-303 television system control unit. Each minute of the ten-minute quantitative observations (fixed-station and horizontal transect modes) was divided into ten six-second segments. Five segments from each minute were randomly selected using random number tables. Thus, 50 replicate observations were analyzed from each station data set. Fishes recorded within the target volume (i.e., the volume observed from the camera lens to the target viewed) were identified and counted. When circumstances prevented positive identification of a particular fish, such an individual was classified as "unidentified" and included in the total fish population calculations.

Platform engineering drawings provided actual sizes of the various structural members (legs, well conductors, horizontals, etc.) used as targets. Comparisons of the known platform member size to television screen size provided the ratios used to calculate distances from the camera. Using camera lens angle and distance, observed water volumes were calculated.

There is a linear relationship between the apparent size of an object and its distance away from the camera lens.

This relationship may vary with the type of camera lens, therefore, field measurements of known standards at specific distances are required. Utilizing the technique of similar triangles, the following calculations were developed to determine the distance from lens to target at each station sampled.



$$\frac{a}{b} = \frac{A}{B}$$

$$A = \frac{1}{2} \quad \frac{\text{Actual Size}}{\text{Screen Size}}$$

B = Distance to target

These values were taken from the field measurements of known targets at known distances. With the similar triangle:

$$a = \frac{1}{2} \quad \frac{\text{Actual Size}}{\text{Screen Size}}$$

b = Distance to target

where:

a - is taken from the known target

b - is the distance required to calculate volume

$$\frac{a}{b} = \frac{A}{B}$$

In this case, A/B is dimensionless; however, because there is extensive variation between the lens to target distances of the field sampling stations and those of the known benchmark stations, a standardized ratio must be calculated. By plotting the ratios of A/B taken from four known distances from the lens, a scale correction diagram can be generated (Figure 10). The slope of the diagonal line represents the ratio of A/B based on all the field measurements.

Thus:

$$\frac{a}{b} = 0.0293$$

$$b = \frac{a}{0.0293}$$

For example, when the known target (e.g., a platform leg) is two metres across and the screen size equals 14.3 cm, then:

$$a = \frac{1}{2}\left(\frac{2}{14.3}\right)$$

$$a = 0.070$$

$$b = \frac{0.070}{0.0293}$$

$$b = 2.387$$

Therefore, the distance from the lens to the target is 2.387 m.

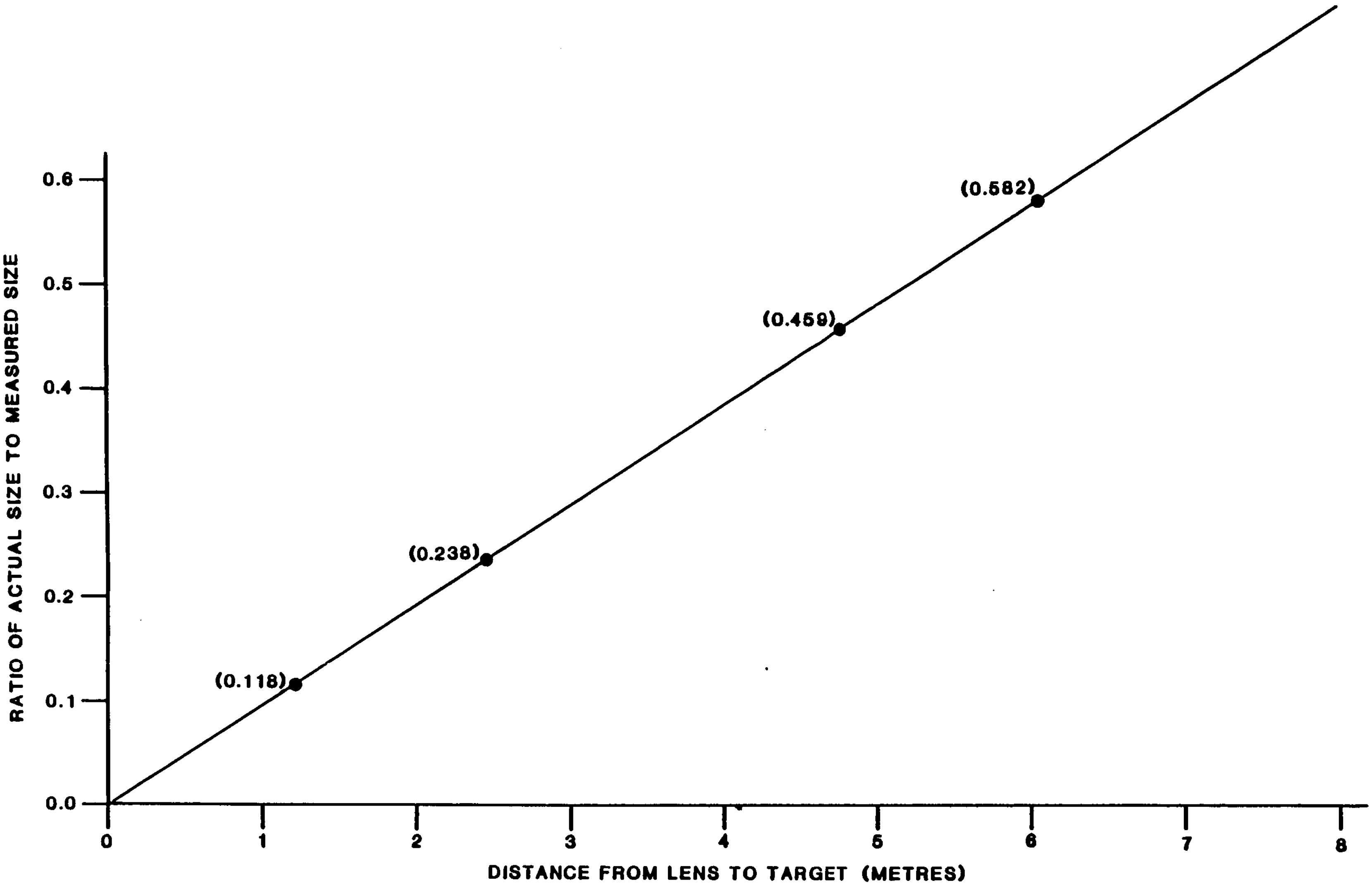


FIGURE 10. SCALE CORRECTION DIAGRAM FOR THE SONY MODEL AV-3650 MONITOR.

Assuming the viewed volume to be a four-sided pyramid, the volume can be calculated by the formula:

$$V = \frac{1}{3} \text{ Base x Height}$$

where:

V = Volume

Base = area viewed

Height = distance from lens to target

Monitoring screens are not perfect squares, therefore, a correction factor must be introduced based on the ratio of viewed height to width. For the monitor used in this study the height equaled 11.5 cm while the width equaled 17.15 cm, yielding a correction ratio of 0.671 (11.5/17.15).

The viewed volume can then be calculated as:

$$V = 0.333\ (0.671)\ (b)^3$$

where:

b = lens to target distance

Continuing our above example:

$$V = 0.333\ (0.671)\ (2.387\ \text{m})^3$$

$$V = 3.039\ \text{m}^3$$

Accuracy of the lens-to-target distance calculation is extremely important and represents a major source of potential error in standing stock estimates. Consider a sample containing three Atlantic spadefishes. If the distance to the base of the viewing pyramid is five metres, then the sample volume is 27.93 m^3 and the sample abundance is 0.1074 Atlantic spadefish per cubic metre. An increase of one-third metre in the distance from lens to target would yield a volume of 33.83 m^3 and a sample abundance estimate of 0.0887 fishes per cubic metre for the same three Atlantic spadefishes actually sampled. If the sample abundances had to be extrapolated to a total water volume of 100 m^3, the differences in standing stock estimates would be two individuals (11 - 9 = 2) or an error of 18%. Under most conditions, errors in the target to lens distance estimates of $\pm$ 0.33 m were possible. This problem must be considered when evaluating all standing stock estimates generated from remotely collected data.

All fish observation counts were recorded as fishes per cubic metre for subsequent statistical analysis.

3.4.2.2 Time-Lapse Movie Observations

All time-lapse movie film (Kodak Kodachrome 40) was developed and projected. From slow-motion and stop-action projections, fishes within the study volumes were visually identified and counted. The time, depth, and position (distance from platform) of each observation were recorded to assess the temporal and spatial variabilities of the fish populations. Standing stock estimates derived from the time-lapse photographic arrays were utilized as a cross-check or back-up evaluation technique for the estimates derived from the other remote sampling techniques. They were incorporated into the sampling scheme in an effort to establish a data base that would allow estimation of the normal, short-term, temporal variation around the sites.

3.4.2.3 Statistical Analysis

The sampling for Phase II was designed to determine if significant differences exist between fish densities as estimated by different gear types. Since fish densities have been shown to vary with depth (Shinn, 1974; Hastings et al., 1976), the gear types were deployed at different depths in order to include this natural source of variation in the data.

A two-factor analysis of variance (ANOVA) was used in the data analysis. The factors chosen were considered as fixed treatments of the response variables ($\log_{10}$ fish abundances). The factor gear type at a particular location was investigated at six levels:

1) CSA TV inside and outside platform,
2) ROV inside and outside platform,
3) CSA TV and ROV Jackaman's Hole,
4) CSA TV with deployed target,
5) CSA TV and ROV with platform member, and
6) ROV with deployed target.

The factor station depth was investigated at five levels:

1) Near surface <6 m,
2) Upper mid-water 6-12 m,

3) Mid-water 12-18 m,

4) Lower mid-water 18-23 m, and

5) Near bottom >23 m.

The two-factor model therefore can be stated as,

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{k(ij)}$$

Where:

Y_{ijk} is the response variable ($\log_{10}$ fish abundance for observation k,

μ is the grand mean for the response variable,

α_i is the effect of the i^{th} gear type,

β_j is the effect of the j^{th} station depth,

$\alpha\beta_{ij}$ is the interaction between the i^{th} gear type and the j^{th} station depth, and

$\varepsilon_{k(ij)}$ is the error associated with the k^{th} observation within the i^{th} gear type and the j^{th} station depth.

Data from the time-lapse camera arrays were analyzed by a one-way ANOVA. Unfortunately, the positioning problems associated with the size of the time-lapse arrays necessitated their placement in areas with a large amount of water column space. Very few fishes were detected as expected at the stations outside the platform and on hard bottom areas. The station inside the platform had to be located in a large open area on the down-current side of the platform and it, too, detected very few fishes. Because of the limited data collected via time-lapse arrays, specific station, depth, and time statistical comparisons were impossible. The factor chosen was station location, which was investigated at three levels:

1) Hard bottom,
2) Outside platform, and
3) Inside platform.

The ANOVA model can be stated as,

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

Where:

Y_{ij} is the response variable (fish abundance) for observation j,

μ is the grand mean for the response variable,

α_i is the effect of the i^{th} station location, and

ε_{ij} is the error associated with the j^{th} observation within the i^{th} station location.

3.5 Results

3.5.1 Field

3.5.1.1 Diver Observations

A total of 4.4 and 8.7 man-hours, respectively, was spent underwater at the Jackaman's Hole hard bottom site and East Cameron Block 229, Platform "A". All diver observations were made in water depths shallower than 33 m.

Diver observations at the hard bottom site revealed extremes in fish population distributional characteristics. During 2-4 June 1980, a significantly different fish population was present at Jackaman's Hole than was encountered during the Phase I Site Characterization Survey on 4 May 1980 (Section 2.5.2.1). Large schools with hundreds of individuals of greater amberjack, tomtate, and vermilion snapper were concentrated in the water column above the shallowest point of this feature during June 2 and 3. Numerous large rays with wing spreads of greater than one metre were seen near the bottom. As many as six to eight such rays were sighted together during each of several dives. A relatively small demersal fish population occurred away from the peak and consisted predominantly of angelfishes, bigeye, cocoa damselfish, creole-fish, and yellowtail reeffish.

On 4 June 1980, divers recorded a strong current (estimated at greater than one knot) flowing across the feature. During this period, the great numbers of fishes previously observed above the peak were no longer present. Only scattered groups of greater amberjack, tomtate, and vermilion snapper were observed and they occurred only off to the sides of the peak. In addition, no rays were observed and no changes in the demersal fish populations were noted. A large school (30 to 50 individuals) of blue runner was observed for the first time.

During diver surveillance, fish populations at the platform were found in three general distribution patterns. Pelagic species such as blue runner, crevalle jack, greater amberjack, and, to a lesser extent, Atlantic spadefish were found in what appeared to be randomly moving schools. Blue runner in large schools (several hundred individuals) would periodically swim from the surrounding water column, travel around and through the platform, and then swim off again. Individual schools did not remain within the platform for any length of time. The schools of blue runner showed no depth preference and often made rapid vertical movements of tens of metres. The other pelagic species were observed in schools of less than 30 individuals and appeared to remain within sight of the platform. They did not make the rapid vertical transitions commonly displayed by the blue runner.

Other fish species were found only in close proximity (within approximately one metre) to platform surfaces. This group included blennies, blue angelfish, cocoa damselfish, sergeant major, spotfin butterflyfish, tomtate, and whitespotted soapfish. These fishes were observed predominantly at the junction of the platform's well conductors, well guides, and horizontal supports located at approximately 8 and 19-m depths.

During Phase II field operations, large numbers (thousands) of vermilion snapper were present at the platform. Although a few individuals were found near the platform surfaces, the vast majority were distributed throughout the water column from 3 to 30 m, but only on one side of the structure. A school of vermilion snapper occurred on the up-current side of the structure, from approximately the center to occasionally as much as ten metres outside of the platform. Individuals within the school appeared to uniformly distribute themselves through this volume while feeding on plankton. Occasionally, the school would exhibit a defensive behavior response and swim rapidly back within the platform. Moments later, it would again spread out into the oncoming current. No vermilion snappers were observed beyond approximately ten metres from the platform or near the down-current (leeward) side of the structure.

Diver observations showed that natural variability of fish populations was high. Over time intervals as small as one day, large differences in fish standing stocks were observed in relation to depth and horizontal position at both the hard bottom and platform sites.

3.5.1.2 Hydro Products RCV-225

Several problems were encountered during the use of the Hydro Products RCV-225. Divers were required to assist in the recovery of the RCV-225 following separate malfunctions of the buoyancy control, the thruster motor, the tether cable rewind mechanism, and the instrument tether. Divers were required to recover the RCV-225 on one occasion because fishing line became tangled in the unit's propellers.

The RCV-225 vehicle and tether were approximately neutrally buoyant underwater. As a result, the unit was easily moved by currents or surge. Its thrusters had to be used continuously to maintain position. Maneuvering was satisfactory as long as the vehicle remained near its launcher and only a relatively small amount of neutrally buoyant tether cable was released from the tether winch. When the unit was moved farther away from the launcher, drag produced from water currents on the tether cable often prevented the RCV-225 from maintaining position or performing required maneuvers. This was especially evident at the platform when observations on the opposite side of the structure from the support vessel were required, and at the hard bottom site when transects near the sea floor were attempted. While performing observations close to and within the structure of the platform, the tether was susceptible to entanglement with the heavily fouled platform members. The threat of entanglement was increased by the unit's inability to maintain position in currents or surge. Attempts to wedge the unit against platform members to stabilize it also increased the chances of entanglement.

The RCV-225 appeared to have little impact on the behavior of the fishes it observed. The water clarity found at the study sites generally allowed for fish observation from outside their normal escape distance (i.e., the distance at which an organism responds to escape a potential predator). In turbid water, such as that observed within the nepheloid layer, the ROV was required to move very close to fishes. Fishes then became frightened and avoided the moving vehicle.

The RCV-225 system could be operated by a single individual. Movement of the remote vehicle underwater was relatively slow and the time needed to return the vehicle to the launcher (15 to 20 minutes) often exceeded the total time of required observations at a station. Movement of the vessel, transmitted down the deployment cable, resulted in considerable movement of the launcher. The sometimes violent movements of the launcher made flying the vehicle into its appropriate space within the launcher extremely difficult.

The RCV-225's low-light level television camera compared favorably with the conventional television unit (CSA sled). The SIT (Silicon Intensified Target) vidicon tube was far more sensitive and recorded suitable observations 10 to 15 minutes beyond the time available light was insufficient for the conventional camera. The SIT camera could also "see" better after dark with its accompanying lights than could conventional television systems. Neither system could "see" after sunset without some form of illumination.

Seven hours of observations were recorded at the hard bottom area. A total of 11 hours of RCV-225 observations were recorded at the platform.

No targets of known size were available at the hard bottom site. Transects across the sea floor were attempted to record fish population characteristics, but such transects proved unrealistic because the RCV-225 frightened fishes when moving toward them and could not maintain either a constant height or speed across the bottom. Transects were run directly away from the launcher. In this manner, an accurate measure of transect distance was provided by the system's tether release counter. Attempted transects using other configurations resulted in snagging of the vehicle's tether on the uneven sea floor. Due to the inconsistent volumes viewed and vehicle speeds, no quantitative data could be collected by this method. Although large numbers of fishes were observed in the water column above the peak, the ROV was unable to assess this population due to the lack of an accurate method of viewing volume determination.

The length of tether available prevented the ROV from maneuvering farther than 121 m from the survey vessel. As the ship swung at anchor, the ROV often was not able to maintain its position at, or reach, particular features. This limited operating scope resulted in the survey vessel having to be re-anchored for the surveillance of even the relatively small feature at Jackaman's Hole.

Each operational mode of the RCV-225 employed at the platform (i.e., 360° pans, horizontal transects, and fixed-position observations) had both strengths and weaknesses. Circular pans were the only method of making television observations directed away from the structure and, thus, the only mode to record differences between fish concentrations near (<10 m) the structure and away (>10 m) from the structure. Without examining the water column from directions other than just toward or away from platforms, the spatial relationship of fish schools near the platforms could not be accurately determined. Unfortunately, observations of the open water column could not be quantified as no estimates of water volumes viewed could be made. In the case of horizontal transect and fixed-position observations, a target of known size was constantly within the television field of view. The RCV-225 had difficulty at times moving sideways along horizontal transects because the heading indicator was not functional during the survey and continuous perpendicular orientation to the platform's horizontal supports was impossible.

3.5.1.3 Honeywell Acoustic Positioning System

The acoustic receiver of the Honeywell RS-7 system scanned a cone shaped volume beneath the unit. The maximum viewing angle of 80° was such that, in the water depths encountered within East Cameron Block 229 (37 m), the unit could track the ROV a maximum horizontal distance of only 30 m from the hydrophone. This precluded the desired measurements of transect lengths or distances from the ROV to specific observation targets (hard bottom features, platform members, etc.) other than those almost directly beneath the hydrophone.

3.5.1.4 <u>CSA Television/Still Camera Sled</u>

A television/still camera sled was used as an alternative to the ROV. Since video data of fish populations could be recorded effectively from both the RCV-225 system and the sled mounted television system, field evaluation of the sled mounted system consisted largely of determining the difficulty in positioning the sled in the required areas.

When supported by the ship, the sled was subject to the movements (rolling and pitching) of the vessel. Vertical movements of up to two metres were not uncommon. Such movement prevented fishes from swimming within approximately two metres of the sled, but did not appear to affect fish movement and behavior beyond this distance. When platform members were being used as targets, this surge effect introduced considerable error potential into volume calculations. When observations were attempted of a target held by a length of PVC pipe, sled movement tended to cause the pipe to whip through the water. This action prevented fishes from coming near the rod and eliminated fishes from within much of the observed water volume.

When deployed inside the platform and supported by the structure, the sled hung motionless (except for very slight rotations due to currents) and had no observable effect on fish behavior. Fishes were periodically observed swimming through the sled framework. The process of rigging the sled to hang within the platform was extremely time-consuming, and could be attempted only because relatively calm seas were encountered and the size and configuration of the platform allowed this type of deployment. Such an operation would have been far more difficult, if not impossible, at a smaller platform. Once deployed, the pan and tilt capabilities of the system enabled operators to direct the TV at several selected targets without moving the sled. This enabled observations of greater water volumes than would be possible from fixed-position cameras.

At the hard bottom site, near-bottom fish population observations were recorded by allowing the sled to rest on the sea floor. This proved difficult at times due to the relief present at the top of Jackaman's Hole. The camera sled frequently came to rest either leaning severely to one side or positioned very close to a high-relief feature or ledge which blocked the field of vision.

It was extremely difficult to deploy and operate the TV sled and the ROV at the same time due to the close physical proximity of both systems' control stations on the survey vessel. Movements of the vessel while at anchor made simultaneous operations dangerous. Such operations were attempted only once to allow direct comparison of the low light and standard television cameras' characteristics.

Still camera and strobe units were attached to the camera sled and used to assess the possible impact of television lights on fish populations at the platform. Very few fishes were observed by the television unit during the nocturnal observations. Likewise, few fishes were recorded by still photography. The only observed impact of light on fishes was due to the still camera's strobe. The strobe's flash frightened greater amberjack during both day and night, but had no observable effect on other species. It appeared that the reaction of the greater amberjack was related to the ambient light. During the day, when the amount of ambient light was high, schools of greater amberjack, photographed within approximately three metres of the sled, would respond by a rapid, short distance (i.e., less than one metre), escape reaction. The severity of the fish reaction increased as ambient light decreased. After sunset, a strobe burst would result in the complete dispersal of a school of greater amberjack from view in less than a second. No signs of fishes being either attracted or frightened from television system lights were observed.

3.5.1.5 Time-Lapse Movie Cameras

Time-lapse photography using super-eight movie cameras is a generally effective means of recording quantitative observations over extended periods of time without extensive manpower requirements. Time-lapse camera deployment methodologies were limited during this study to those applicable to deep water, exclusive of diver assistance. Due to these restrictions, cameras could not be attached to the platform. To quantify the water volumes viewed, a time-lapse array design was developed (Figure 9). This array was difficult to deploy within the platform because of its size, and at least four men were required during each deployment and recovery effort.

The size of the array would have prevented deployment within many of the smaller well-jacket platforms found in the northwestern Gulf of Mexico. The array was also susceptible to being pushed into, and ultimately entangled with, platform surfaces by currents when deployed within or close to these structures.

The PVC pipe used to direct the cameras occasionally bowed in the current to such an extent that the camera was no longer directed correctly at the target. A similar situation occurred at the hard bottom site when anchors from each taut-line fell close to one another and the interconnecting PVC pipe bowed upward. Only observations in which the array target was recorded were included in the quantitative data set.

Evening observations were attempted with attached strobes for lighting. Additional underwater housings used to protect strobes and batteries during these observations resulted in significant additional difficulty in deployment and recovery of the system. Several problems encountered during the nocturnal observations prevented quantitative data from being collected. Reflection of strobe light from plankton and fishes into the camera lens shadowed the PVC target. When a school of fishes was observed, the individuals nearest the strobe and camera would reflect light and shadow other fishes to the extent that only those nearest to the camera were recorded. The type of Vivitar strobe employed was susceptible to failure when repeatedly cycled (charged and fired) in short intervals (i.e., 24 seconds). Many strobes were firing only intermittently when arrays were recovered after nocturnal sequences.

Due to the program objective of developing "remote" techniques applicable to both shallow and deep waters, time-lapse cameras had to be deployed in an array configuration and were not attached to platform members by divers. Observations of the open areas large enough to allow array deployment within the platform did not record those fish species associated with specific platform surfaces (i.e., legs, well conductors, and horizontals). Such observations probably did not accurately record the fish populations present at the structure. The ability to reposition cameras by divers or ROVs would increase the chance of recording fish aggregations or patches within the community.

Workman and Jones (1979) and Putt (manuscript) have demonstrated that time-lapse cameras can be used successfully to assess short-term (one to five hours) temporal variations. Their studies are not completely analogous to those conducted in this project, however, because both these authors used divers to position their cameras. Part of the criteria for this program required developing time-lapse camera arrays which could be deployed completely without scuba diver assistance.

3.5.1.6 Diver Motion Picture Transects

Visual observations recorded on film by divers swimming along transects were influenced by two major factors: 1) some fishes were frightened away from the observed volumes by the divers' presence, and 2) it was very difficult for divers to cover prescribed distances in consistent time frames due to changing currents. The speed at which divers moved along the transects influenced the population sampled. For example, more rapidly swimming schooling fish species, such as blue runner, could be observed than sedentary species, such as red snapper, along a transect. The more rapidly the diver moved along the transect, the less time was allowed for blue runner to pass through the observation volume and be recorded, while the numbers of more sedentary species were unaffected. When currents were present, the divers found it difficult to duplicate previous transect techniques (i.e., time) and the impact of changing technique introduced significant error to the data.

The super-eight film used has coarse and, at best, fair resolution qualities. The inability of a diver to hold the camera perfectly still while swimming further hampered film quality. Specific identifications of fishes filmed from distances greater than approximately five metres were very difficult. In general, the diver-held movie observations are man-hour intensive, extremely difficult to quantify, limited to relatively shallow depths, and are not capable of the resolution required for the continuous identification of fish species.

3.5.1.7 Fish Traps

Six fish trap soaks were conducted at Jackaman's Hole, with a catch of 23 fishes comprising six species. Ten fish trap soaks were conducted at the platform site during Phase II operations. The total catch was 200 individuals representing 13 species. Tables 3 and 4 list the bottom depth, capture time, decompression time, and catch data for each fish trap deployed.

Fish traps showed limited success in capturing the fishes present at the hard bottom feature. Deployment and recovery of traps were often difficult (especially near the platform) and time-consuming. Fishes captured within the wire traps became abraded as the traps were removed from the water. Survival of fishes collected in this manner after release was questionable.

The traps deployed at the platform showed some success in capturing tomtate and vermilion snapper. Seven large greater amberjacks were captured in one of the two initial trap soaks. Schools of greater amberjack had been observed

TABLE 3. FISH TRAP DATA FOR EAST CAMERON AREA, BLOCK 229, HARD BOTTOM, JACKAMAN'S HOLE.

Trap	1*	2*	3*	4*	5	6
Bottom Depth (metres)	32	32	28	28	23	27
Capture Time (hours; bottom)	10.8	10.8	9.0	9.0	5.3	5.0
Decompression Time (hours; <13 m)	5.8	5.8	2.7	2.7	-	-

Taxa	1*	2*	3*	4*	5	6	Total	$\bar{x}$ length (cm)
Tomtate	2	4	-	2	-	8	16	16
Gray triggerfish	-	-	-	-	-	2	2	23
Greater amberjack	1	-	-	-	-	-	1	56
Whitespotted soapfish	-	-	1	-	-	1	2	18
Slippery dick	-	-	-	-	-	1	1	22
Cubbyu	-	1	-	-	-	-	1	18
Total Catch	3	5	1	2	0	12	23	

*Unbaited trap.

TABLE 4. FISH TRAP DATA FOR EAST CAMERON AREA, BLOCK 229, PLATFORM "A".

Trap	1	2	3*	4	5	6	7	8	9	10
Bottom Depth (metres)	35	35	35	35	35	35	35	35	35	35
Capture Time (hours; bottom)	8	8	4	4	15.8	11.3	6.5	6.5	22	22
Decompression Time (hours; <13 m)	14.5	14.5	-	6.5	1	2	1	1	1.3	1.3
Species										
Tomtate	12	1	-	18	25	18	18	-	1	37
Gray triggerfish	1	-	-	4	1	1	2	3	1	-
Greater amberjack	-	7	-	2	-	1	-	-	-	-
Rock hind	-	1	-	-	-	-	-	-	-	-
Red snapper	-	-	-	1	-	-	-	-	-	-
Lane snapper	-	-	-	-	-	-	-	-	-	1
Cubbyu	-	-	-	1	1	1	-	-	1	-
Vermilion snapper	-	-	-	-	15	8	-	-	1	7
Pinfish	-	-	-	-	-	1	-	-	-	-
Cocoa damselfish	-	-	-	-	-	-	1	-	-	1
Porgy	1	-	-	-	-	-	-	1	-	1
Bigeye	-	-	-	-	-	-	-	-	1	1
Total Catch	14	10	0	26	42	30	21	4	5	48

*Deployed at mid-depth of 24 metres.

**Total catch (mean fork length in cm).

swimming around the traps after they had been raised to <13 m to decompress captured fishes, and these fishes may have entered the trap near the surface. This idea was tested during the following trap deployment by lowering one trap back to the bottom, and one trap to a depth (24 m) where numerous greater amberjacks had been sighted. Schools of greater amberjack appeared to be attracted to the caged fishes and it seems likely that the fishes within the traps baited the greater amberjacks. Diver inspection of trap catches as they were being raised revealed no fishes within the mid-water trap and 26 fishes, including two greater amberjacks, within the near-bottom trap.

3.5.1.8 Tagging-Recapture

Ninety-seven fishes were tagged and released at the platform. These included 50 tomtates, 29 vermilion snappers, eight greater amberjacks, seven gray triggerfishes, one red snapper, one cubbyu, and one pinfish.

No fishes were tagged at the hard bottom site. No tagged fishes were recaptured by trap or hook-and-line, and none were observed by any of the remote visual assessment tools (television, movie, or still cameras). Individually tagged greater amberjack and gray triggerfish were observed by divers beneath the platform.

The limitations associated with tagging-recapture studies are well-known. Tagging-recapture methodologies are both time-consuming and tend to damage the target species.

In outer continental shelf water depths, the impact of bringing fishes to the surface for tagging can have a significant effect on their survival rates. Attempts were made in this study to reduce decompression effects by holding trapped fishes at approximately ten-metre depths for varying periods of time (Tables 2 and 3). Even after decompression, snappers and grunts reached the surface with fully expanded swim bladders, but appeared to have little difficulty in descending upon release. The applicability of tagging-recapture, either by traps or *in situ*, is questionable due to the excessive man-hour effort required.

Combining tagging-recapture with visual census techniques may be worthwhile in certain instances. The lack of recapture success in this study may have been due to the large numbers of fishes present at the platform in relation to the few fishes tagged and released, or due to the possible low survival rates among the released fishes. Fishes damaged by traps and changes in ambient pressure were probably rapidly culled from normal populations. Fishes released at the surface were also subject to heavy mortality from schools of predators. Schools of greater amberjack were drawn to the surface when tagged fishes were released.

3.5.1.9 Hook-and-Line Sampling

Table 5 lists the species and number of fishes caught via hook-and-line sampling at the platform and

TABLE 5. NUMBERS OF FISH TAXA COLLECTED BY HOOK-AND-LINE AT HARD BOTTOM AND PLATFORM STUDY SITES IN EAST CAMERON BLOCK 229 DURING PHASE II.

Species	Location: Jackaman's Hole	Location: Platform "A"
Red snapper	-	*3(26)
Greater amberjack	-	2(58)
Blue runner	-	2(40)
Tomtate	-	2
Gray triggerfish	7(36)	-
Rock hind	1(29)	-
Remora	1(62)	-

*Number collected (mean total length in cm).

hard bottom sites. Very limited success was achieved using angling as a collection method. A total of nine fishes from three taxa was collected at the hard bottom site, and a total of nine fishes from five taxa was collected at the platform. Only three specimens, a remora and rock hind at the hard bottom area and a blue runner at the platform, were taken solely by hook-and-line sampling.

3.5.2 Laboratory Analysis

Table 6 presents the results of the two-factor ANOVA on the Phase II quantitative data for the total fish assemblage. No significant differences ($F=0.26$; $P<0.92$) were found between fish abundance estimates by gear type. This suggests that there is no selective advantage or disadvantage in using the ROV or television sled systems. Both gave statistically similar estimates of fish abundance. Although no pair-wise comparisons were made between total fish assemblage estimates using deployed targets and platform members as a target for volume calculations, the lack of significant difference in the two-way factorial ANOVA suggests that the fish assemblage estimates for the two types of targets are also not significantly different.

The species specific data were also tested using the two-way factorial ANOVA model followed by Duncan's multiple range test. The results were compared to the qualitative *in situ* observations by divers. Due to an insufficient number of species specific observations within each of the

TABLE 6. RESULTS OF ANOVA MODEL AND DUNCAN'S MULTIPLE RANGE TEST GROUPING FOR PHASE II.

Factorial ANOVA Model

Class	Sum of the Squares	F Value	PR>F
Location/Gear Type	0.04167	0.26	0.92
Depth	0.01670	0.13	0.97
Location/Gear Type*Depth	0.1831	0.82	0.59

Duncan's Grouping*

Location/Type			Depth		
Level	Mean (log^{10})	Grouping[1]	Level	Mean (log^{10})	Grouping[1]
CSA TV Platform	0.3483	A	Nearsurface	0.1559	A
ROV Platform	0.3405	A	Uppermidwater	0.3026	A
CSA-ROV-Jackson's Hole	0.3181	A	Midwater	0.3459	A
CSA-Target	0.2608	A	Lower midwater	0.2481	A
CSA-ROV-Platform Member	0.2525	A	Near bottom	0.2602	A
ROV-Target	0.2027	A			

[1]Groupings with the same letter indicate no statistically significant variation.
*Indicates factor interaction tested for.

location-gear type and depth levels only four species could actually be evaluated. All of the species (Atlantic spadefish, $F=3.47$, $P<0.01$; greater amberjack, $F=10.40$, $P<0.01$; blue runner, $F=3.99$, $P<0.01$; vermilion snapper, $F=7.91$, $P<0.01$) showed significant differences between fish densities. Both factors of location/gear type and depth showed significant differences in all instances except depth in the case of Atlantic spadefish ($F=0.31$; $P<0.81$). The contradictory findings of the ANOVAs for the total fish assemblage and these four species are not surprising. They may be explained as the total fish assemblage data represent a mean of each individual species distribution pattern and are much less likely to show the variable densities of fishes with location and depth as do the species specific data. Some species (i.e., blue runner and spadefish) tended to show distributional patterns which agreed with diver reports. Blue runner showed definite depth stratifications, while spadefish seemed to be more numerous near the platform. Other species distributions, such as the vermilion snapper, did not reflect diver observations.

The time-lapse camera system for total fish abundance was also tested using a one-way ANOVA model. No significant differences ($F=0.10$; $P<0.90$) were detected among the three groups (i.e., hard bottom, inside platform, and outside platform) of data tested. This finding is in agreement with the results from the other gear types (ROV and CSA TV) which also show no significant differences ($F=1.72$; $P<0.20$). The reason for these findings is that as in the case of the two-way factorial ANOVA the total fish assemblage data represent a mean of each individual species distribution pattern. In order for time-lapse arrays to provide a more accurate estimate of actual fish abundances many more deployments would have been required.

The species-specific data for the three species for which sufficient observations were made were also analyzed using a one-way ANOVA model. Blue runner and greater amberjack abundances showed significant differences ($F=5.33$; $P<0.02$ and $F=7.79$; $P<0.01$). These species were not detected on the hard bottom area. Atlantic spadefish showed a significant difference ($F=55.5$; $P<0.01$) in abundance between the hard bottom, inside platform, and outside platform. A significantly higher number of individuals (Duncan's multiple range test) was encountered outside the platform as compared to the other two locations.

3.6 Conclusions

Each of the five types of equipment and 13 assessment techniques evaluated during Phase II had advantages and disadvantages in estimating fish standing stocks near oil and gas platforms and/or natural hard bottoms.

Visual observations using underwater television yielded the most accurate record of true fish population characteristics. Low-light level SIT cameras are capable of viewing populations in far lower light levels than the traditional model, though this capability is not a significant advantage during daylight hours at water depths in which most observations during this study were made. The low-light level cameras also require accessory lighting and thus do not totally remove potential influences of lights on observations.

The characteristics of the particular sleds or vehicles to which television cameras are attached are very important. The sled-mounted television system proved extremely difficult to deploy (especially within the platform) and could not be moved horizontally without repositioning of the support vessel. Mobility of the ROV allowed relatively rapid movement either along transects or between stations. The RCV-225 unit utilized in this study was subject to mechanical breakdown. Maintenance and specific utilization by the owner/operator were probably as responsible for such mechanical difficulty as were the manufacturer's engineering design and construction. The RCV-225 was also restricted in its movement by its inability to overcome effects of currents.

Each visual assessment technique required an observation target of known size before observed water volume estimates could be calculated. Television observations that were directed toward specific platform members whose diameters could be determined from engineering drawings (i.e., legs, horizontals, and well conductors) were quantifiable. Observations (360° pans) directed away from structural targets were qualitative.

Photogrammatic techniques used in stereographic aerial surveys can be applied to visual assessment techniques in the sea. Such techniques involving stereo cameras allow measurements of the relief and/or size of objects appearing in photographs (Schuldt et al., 1967). Unfortunately, these techniques have provided limited enhancement to studies such as the one undertaken here. In visual fish population assessments, the most important parameter is the volume sampled. This requires a target of some type no matter what combination of cameras are employed. Stereophotography would allow the use of other than previously known targets to calculate the sampling volume, as well as provide information on the relative sizes of the individuals with each sample. Actual techniques utilized in calculating the sampled volume would remain the same.

Fouling sometimes presented a problem when platform members were utilized as targets. At some locations extensive growths of fouling organisms could greatly expand the apparent diameter of a platform member observed on CCTV. When this occurred, the operator was forced to search up and down the target member until he located an area sufficiently free of encrusting growth to permit accurate measurement of the true screen size diameter of the subject member. In actual practice, this was not a difficult task. Fouling represents a potential rather than a real source of error in required viewing volume calculations.

The small size of the RCV-225 prevented attachment of volume assessment targets to the unit, while the sled system was sufficiently large to allow attachment of distance targets. Quantitative observations were thus recorded at the hard bottom site by the sled-mounted television system while none were possible using the ROV.

The time-lapse, super-eight movie camera system was relatively easy to deploy, recorded quantitative data, and was suitable for assessing fish populations in both hard bottom and platform areas. However, the system viewed relatively small volumes of water and, thus, did not accurately assess the very patchy distribution of populations found near platforms and hard bottom features. When real-time motion picture observations were recorded by divers, the potential error introduced by variations in fish behavior (i.e., swimming rates) and diver motion due to fluctuating currents prevented quantitative assessment of the records. The utilization of scuba divers is not applicable to deep waters of the Gulf of Mexico, but was included in the evaluations to: 1) allow the subjective evaluation of techniques (such as movie-transects) previously used only on natural reef areas at an offshore platform; and 2) provide a qualitative picture of fish population characteristics with which to compare subsequent remote visual techniques and quantitative data.

The capture techniques of fish traps and hook-and-line fishing were species specific and of limited success in capturing the target species. When incorporated with weight, length measurements, and tagging-recapture efforts, these techniques were extremely time-consuming.

The limited tagging-recapture efforts at the platform showed that trap-induced injury and predation on released fishes, together with the difficulty in rapidly capturing and tagging suitable numbers of fishes, prevent this technique from being effectively used in short time frames. Extensive tagging efforts may, however, provide data concerning the movement of fishes between platforms and hard bottom areas.

Based on Phase II results, the most applicable equipment types and assessment techniques were selected for further evaluation during Phase III. The potential mobility offered by a remotely operated vehicle (ROV) was judged a distinct advantage over other visual assessment tools. Due to the limitations encountered in the operation of the RCV-225, a search was conducted for a ROV which might more readily perform to the specified requirements. Such a ROV should incorporate a wide-angle television camera, thrusters powerful enough to maneuver the vehicle in currents, and still photographic capabilities to aid in positive identification of observed fish species. Following a reevaluation of available remote vehicles, the Perry Oceanographic's RECON III-B was selected for utilization during Phase III operations. This ROV was larger than the RCV-225, contained more powerful thrusters, included a wide-angle television camera, and could carry a still photography system (Photosea 1000 still camera system).

The assessment technique recommended for Phase III included a three-dimensional sampling strategy with observations at fixed positions and/or along horizontal transects at several depths at each study site. Targets of known size would be deployed at natural hard bottom sites to allow for calculations of water volumes viewed.

Several other items were recommended for inclusion in Phase III on an as-time-allows basis. Despite the problems mentioned earlier, time-lapse movie observations at near-surface, mid-depth, and near-bottom locations were suggested as a possible method to provide estimates of short-term (e.g., 1 to 12 hours) temporal variation within fish populations. Fish traps and some hook-and-line fishing were included to add length-weight data for biomass estimates. These techniques would require relatively little additional effort and might provide important data for the further evaluation of the primary technique: underwater television observations.

4.0 PHASE III - SITE ASSESSMENTS

4.1 Objectives

The objectives of Phase III were 1) to quantitatively assess and compare the standing stocks of reef fishes at selected hard bottom sites and oil and gas production platforms; and 2) to further develop sampling techniques and methodologies for reef fish stock assessments that were applicable to both shallow and deep waters of the continental shelf.

4.2 Survey Plan

Delays due to late delivery of both the RCV-225 for Phase II and the RECON III-B for Phase III caused the Phase III efforts to fall far later in the season than the originally proposed July/August sampling period. Unusually poor weather and the accompanying reduced water clarity during September/October prevented suitable visual observations at the primary hard bottom sites (see Table 2). As a result, a mid-cruise redirection of assessment efforts was made away from nearshore sites to offshore sites. Figure 11 shows the geographic locations of the study sites assessed during Phase III. The study sites are described in Section 2.0, with the exception of Vermilion 201, Platform "A" which had not been previously surveyed, but was added because its size (four-piles), distance from shore (86 km), and age (nine years) were similar to the other platforms. It was located in 30 m of water at latitude 92° 30' 35"N and longitude 28°

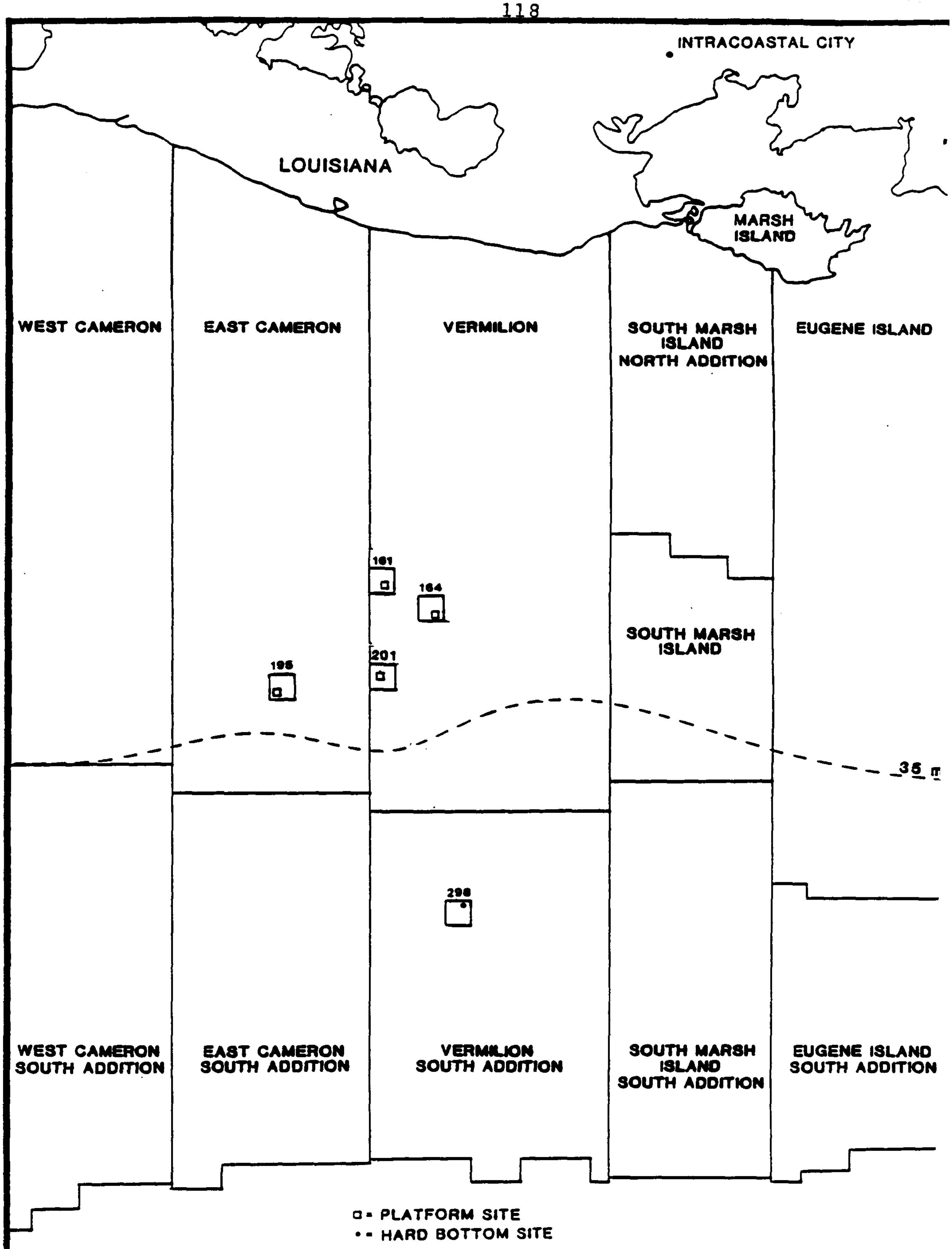


FIGURE 11. GEOGRAPHIC LOCATIONS OF SITES FOR FISH SPECIES POPULATION ASSESSMENTS CONDUCTED DURING PHASE III.

48' 30"W (LORAN C coordinates: 11193.8, 26820.6). In addition, vertical television transects and hydrographic profiles were conducted at East Cameron Area, Block 229, Platform "A" to relate nepheloid layer conditions with those observed at nearshore stations during Phase III and with those found at the platform during Phase II operations. Profiles at Vermilion Area, Block 179, Hard Bottom were conducted both at the beginning (29 September 1980) and end (October, 1980) of Phase III operations to assess possible fluctuations in the nepheloid layer.

4.3 Field Operations

The M/V JIM LYTAL, a 30-m vessel, was used for all operations conducted during Phase III.

4.3.1 Television and Still Cameras

Remote, real-time, video footage of fish populations was recorded using a Perry Oceanographics RECON III-B Remote Controlled Vehicle System. The system consisted of an operating vehicle, a tether cage, a surface control station, a handling system, and a control van. The operating vehicle contained a Sub-Sea Systems Model CM-8 television camera, lights, pan and tilt mechanism, compass, depth sensor, and thrusters. The tether cage was designed to free the vehicle from support vessel heave and/or surface current movement and to provide housing and control for 122 m of vehicle-to-cage umbilical. The surface control station was housed within a deck control van where all primary vehicle controls were accessible to the ROV pilot/operator. The RECON III-B handling system consisted of a large skid-mounted hydraulic U-boom and umbilical winch. Two pilot/operators were assigned to the survey to enable continuous daylight utilization of the vehicle without operator fatigue.

Digital data concerning time (day, hour, minute, and second) and vehicle depth were continuously displayed and recorded along with audio and video data on Sony 1.9-mm, 60-minute, video cassettes. A Sony Model VO-1800 video cassette recorder was used to make all video recordings.

A Photosea Model 1000 35mm still camera and strobe were attached to the RECON III-B to provide color photographs of fish populations and to aid in specific identifications.

The RECON III-B was used in two modes of operation: 1) horizontal transect observations along the sides (i.e., horizontal support members) of the platforms and 2) stationary position observations of fixed targets. During stationary position observations, the RECON III-B was hovered in position while the television camera was directed toward a suitable target. Targets included legs, well conductors, and diagonal supports of the platforms. Lengths of PVC pipe supported by taut-line arrays at near-surface, mid-water, and near-bottom depths were used as observation targets outside of the platforms and at hard bottom sites (Figure 12). PVC pipe targets were marked at one-foot intervals with black

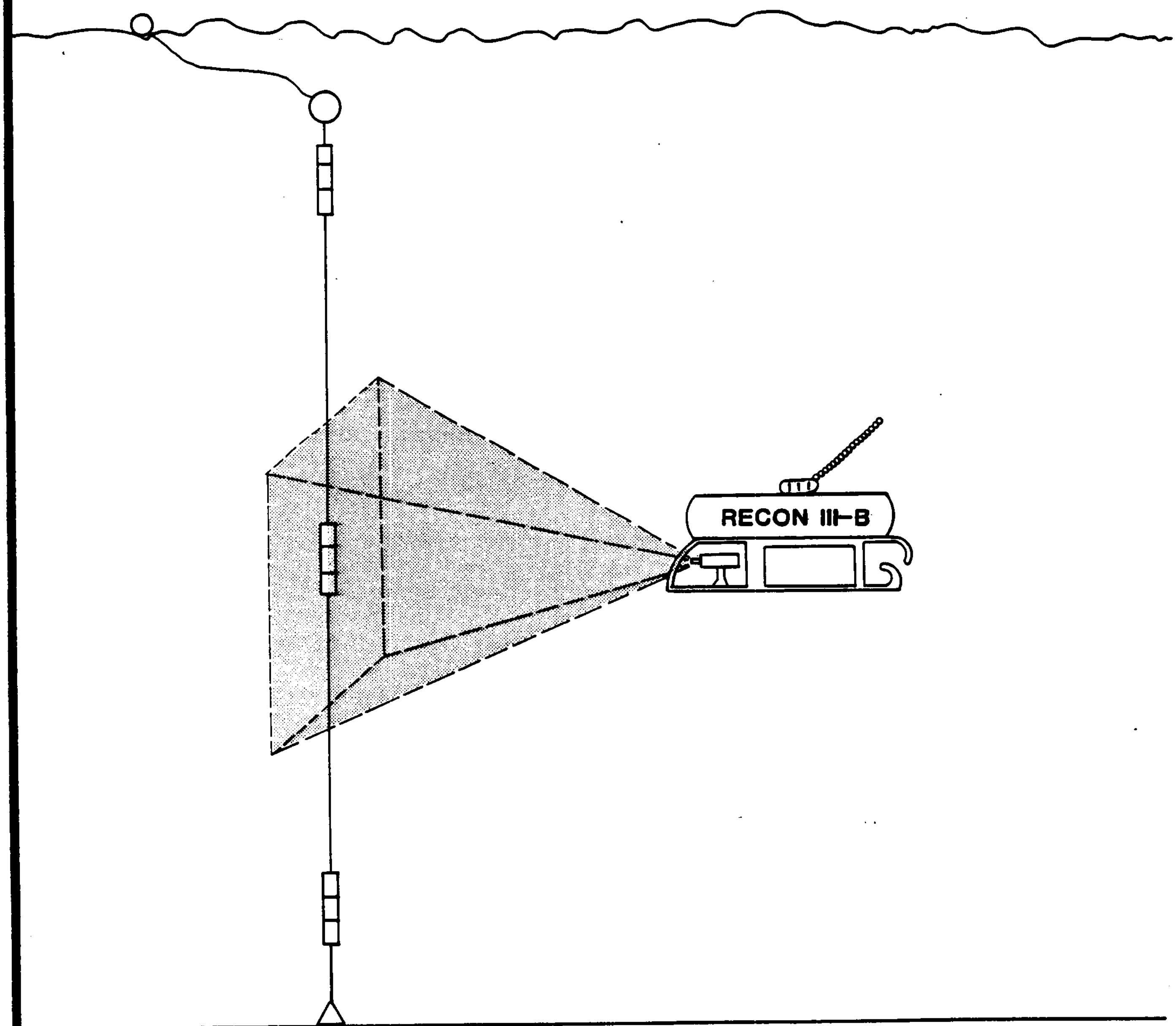


FIGURE 12. RECON III-B CONDUCTING OBSERVATIONS AT A MID-WATER STATION USING A PVC TARGET ATTACHED TO A TAUT-LINE ARRAY.

tape to aid in the calculation of observed volumes. Television observations of three minutes duration were recorded at each station location.

Due to the patchy distribution of fish populations, a three-dimensional sampling design was utilized at both the platforms and hard bottom sites. At platform sites, observations were attempted at a minimum of four depths on each leg, along each face of the structure at depths corresponding to horizontal supports, and at three locations inside the structure.

At the initial platforms surveyed, near-surface, mid-depth, and near-bottom targets on taut-line arrays were deployed varying distances away from the structures. Observations directed toward these targets were recorded to assess whether significant numbers of platform-associated reef fishes were found away from the platforms.

The sampling design at the natural hard bottom site (Sonnier Bank) consisted of taut-line arrays being deployed in a wagon-spoke pattern across the feature (Figure 13). Television observations were recorded at all near-bottom and mid-depth target locations and at alternating near-surface locations.

4.3.2 Time-Lapse Movie Cameras

The time-lapse, super-eight movie camera system evaluated during Phase II was utilized again during Phase

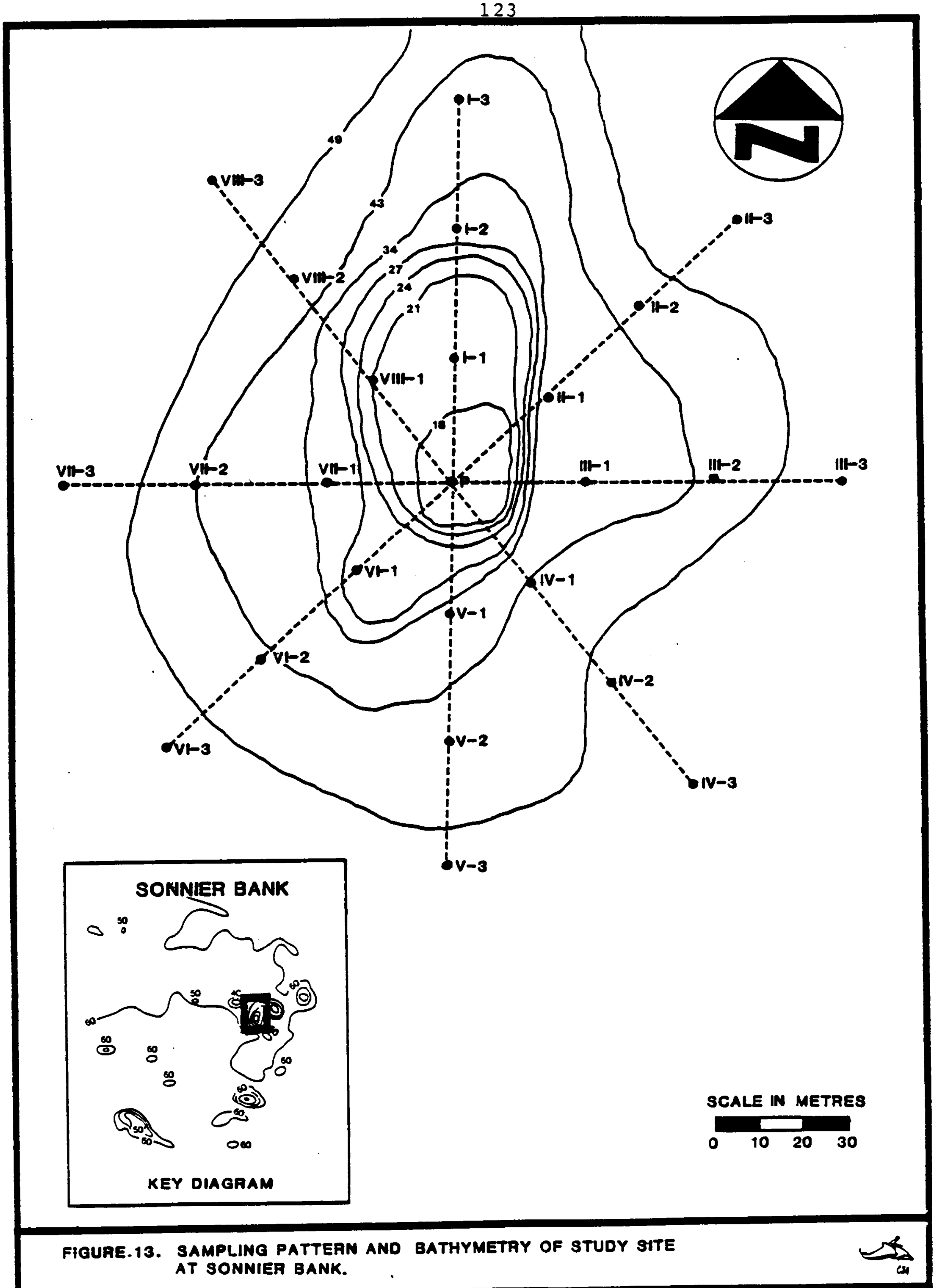


FIGURE.13. SAMPLING PATTERN AND BATHYMETRY OF STUDY SITE AT SONNIER BANK.

III. Approximately one-second duration observations were recorded at four to six-minute intervals by cameras positioned at near-bottom, mid-depth, and near-surface locations (Figure 8). Observations were made only during daylight hours. The time-lapse array size (i.e., the distance between cameras and PVC targets) was reduced to three metres, allowing the system to be deployed within platforms smaller than the one evaluated during Phase II operations. Lengths of wooden doweling were inserted into horizontal PVC pipe segments to strengthen the array and to prevent the excessive bowing of these segments that occurred during Phase II evaluations. A single deployment of the time-lapse camera system was made within each platform and at the shallowest point (or peak) of the hard bottom sites.

4.3.3 Fish Traps

Overnight soaks of at least three baited A&G curiosity fish traps were incorporated to provide representative collection specimens of the target species from each of the study sites. All fishes captured were identified, measured (standard length), and weighed. Representatives of each species were placed in rigid containers with identifying labels and preserved in 10% buffered formalin.

4.3.4 Supportive Water Column Sampling

Water column measurements of temperature, salinity, dissolved oxygen, and transmissivity were made every five metres at each study site using a Hydrolab Model 6D water quality analyzer and a Hydro Products Model 912S transmissometer. Near-surface and near-bottom water samples were collected with Niskin bottles to confirm the near-surface and near-bottom salinity and dissolved oxygen values measured with the Hydrolab system. Salinity samples taken from the Niskin bottles were stored in labeled, glass, sample bottles for later laboratory analysis. Dissolved oxygen samples were fixed immediately after collection and analyzed by Winkler titration methods outlined by Strickland and Parsons (1972).

4.4 Laboratory Procedures

All video data were transferred from video cassettes to Sony V-32, 3.8-mm, 60-minute videotapes. Each minute of the three-minute quantitative observations was divided into ten six-second segments. Five segments from each minute were randomly selected for analysis using random number tables. From slow-motion and stop-action projection, fishes within the 15 replicate observations from each station's data set were identified and counted. All television data were then digitized for computer input. The information included within each data set was station number, observation volume, date, time, number of species observed, and number of individuals per species. The estimated water volume viewed during each observation was calculated following the method outlined during Phase II (Section 3.4.2.1).

4.5 Results

4.5.1 Field Operations

4.5.1.1 Television and Still Cameras

The Perry Oceanographics RECON III-B Remote Controlled Vehicle System was susceptible to many of the limitations common to most ROVs. The system required a stable platform and could not be safely operated off the survey vessel in seas greater than 1.5 m. Operations with swells only slightly greater than one metre were judged marginally safe by the ROV operators due to movement (rolling) of the vessel.

The ROV and instrument tether became easily entangled in the platform's surfaces and taut-line arrays. The vehicle was especially susceptible to entanglement in turbid water where disorientation due to the loss of visual references was increased. Visibility within the nepheloid layer at the nearshore sites was extremely limited (i.e., less than one metre) and often approached zero at the sea floor where the ROV's thrusters tended to resuspend the fine bottom sediments. Under these conditions, the ROV operator would often lose sight of the reference (i.e., platform or taut-line) and be required to return the ROV to the surface to regain orientation. The RECON III-B vehicle and tether had slightly positive buoyancy and tended to float to the surface. On occasion, release of extra tether resulted in the excess becoming entangled in a platform or the ship's propellers. The RECON III-B vehicle and tether could not successfully overcome the currents and surge encountered within near-surface sections of several platforms. Even though the system contained more than 200 m of tether cable, the practical working range was approximately 65 m. At greater distances, the impact of current on the tether was too great for the vehicle thrusters to overcome. The survey vessel was required to re-anchor several times to allow the ROV to reach all portions of the hard bottom sites, especially at Sonnier Bank.

The proficiency of the pilot/operator was extremely important to the efficient and cost-effective utilization of the assessment tool. During normal observations, an experienced professional with a sincere scientific interest in the operations being conducted regularly guided the ROV through twice the number of successful observations per unit time than a less experienced pilot could.

4.5.1.2 Time-Lapse Movie Cameras

Changes in the time-lapse movie camera array design from that used during Phase II generally improved the operational characteristics of the system. Wooden doweling inserted into the PVC pipes served to increase their strength and prevented excessive bends between the cameras and targets. A metal pipe positioned between the vertical taut-lines at the sea floor prevented the taut-lines from falling too close together on uneven bottoms.

The cameras operated satisfactorily, although the reduction in array size (i.e., distances from cameras to target) further reduced areas viewed and increased the chances of recording an inadequate sample size. This was especially evident at Sonnier Bank, where clear water enabled the cameras to view fishes far beyond the array targets.

4.5.1.3 Fish Traps

Soaks of baited fish traps were completed at each of the study sites where fish assessment measurements were attempted. Data concerning the catch and effort made at each site are summarized in Table 7. There appeared to be no significant difference in effectiveness between the two sizes of traps used. Position relative to major features (platform or reef) appeared to be the most important factor affecting trap catches. This was especially evident at platform sites where traps deployed even 10 to 20 m from the structures rarely captured fishes. The fish traps did not prove to be an effective tool for the capture of reef fishes. The traps did not capture enough of the predominant fish taxa to provide estimates of length versus weight ratios, and were largely species specific. Of the 292 fishes representing 17

TABLE 7. SUMMARY OF FISH TRAP DATA FROM PHASE III SURVEY SITES.*

	Location				
	VR179HB	VR164PA	VR161PA	VR201PA	VR298HB Sonnier Bank
Number of Soaks	4	3	5	5	3
Total Soak Time (hrs)	48	42	75	60	57
Species					
Tomtate	19(19.9)	-	69(19.7)	58(19.7)	75(19.8)
Gulf toadfish	-	-	-	2(35.0)	-
Gafftopsail catfish	-	3(22.7)	4(22.8)	-	-
Atlantic croaker	4	6(15.9)	4(44.7)	-	-
Lane snapper	-	1(12.5)	2(26.0)	1(38.0)	-
Sheepshead	-	-	2(22.8)	-	-
Red snapper	18(21.1)	-	-	2(23.0)	-
Atlantic spadefish	1(13.5)	-	-	1(24.0)	-
Cubbyu	2	-	-	-	-
Whitespotted soapfish	-	-	-	1(20.0)	-
Gray triggerfish	-	-	-	5(32.3)	-
Pinfish	-	-	-	1(22.0)	-
Blue angelfish	-	-	-	-	4(33.0)
Vermilion snapper	-	-	-	-	3(25.0)
Reef butterflyfish	-	-	-	-	1
Spotfin butterflyfish	-	-	-	-	2
Spotfin hogfish	-	-	-	-	1
Total Catch	44	10	81	71	86

*Units are numbers of individuals (mean length in cm).

species captured during Phase III field efforts, tomtate represented 221, or 75%, of the total catch.

4.5.1.4 Water Column Observations

All reliable water column data collected during *in situ* sampling at each Phase III site are presented in Table 8. The Hydrolab salinity and dissolved oxygen readings were judged inaccurate due to instrument malfunction and are not included. The only water column parameters that appeared to affect fish population distributions were current direction (not contained in Table 8) and percent transmissivity. Fishes tended to orient themselves on the up-current side of the platform, and several species seemed to occupy the interface zone between turbid and clear water layers. None of the stations sampled during Phase III showed the marked turbid water surface lens seen during Phase I.

4.5.2 Statistical Analysis

4.5.2.1 Platform Sites

No diver observations were made during Phase III, therefore, no qualitative baseline data were available to compare with the estimates of total fish populations derived from quantitative analysis of videotapes. From the literature reviewed and the experience gained during Phase II, the distributions of the fish populations were expected to be patchy and highly variable. In order to understand the spatial patterns of variation, series of comparisons were made as follows:

TABLE 8. WATER COLUMN PARAMETERS MONITORED DURING PHASE III.

Site	In Situ Measurements Depth (m)	Temp. (°C)	Trans. %	Laboratory Analysis Salinity (ppt)	DO (ppm)
VR164PA	5	30.0	38.0	34.547	6.5
(9-22-80)	10	29.5	40.0		
	15	30.0	41.0		
	20	31.0	40.0		
	25	30.0	37.0		
	28	31.0	10.0	35.057	5.6
VR161PA	5	28.0	48.0	33.653	6.0
(9-28-80)	10	27.0	40.0		
	15	28.5	22.0		
	20	28.5	42.0		
	23	28.5	38.0	34.044	5.8
VR179HB	5	29.2	58.0	33.406	6.5
(9-29-80)	10	29.0	46.0		
	15	29.0	72.0		
	20	29.0	33.0		
	24	28.8	12.2	35.879	4.0
VR201PA	0	28.5	77.0	33.959	6.6
(10-1-80)	5	28.5	78.2		
	10	28.5	78.0		
	15	29.0	76.0		
	20	29.0	71.0		
	25	29.0	34.0	35.832	5.9
EC195PB	0	28.6	81.0	34.619	6.6
(10-2-80)	5	28.4	83.0		
	10	28.4	82.0		
	15	29.0	68.0		
	20	29.0	32.0	35.838	6.8

TABLE 8. (CONTINUED).

	In Situ Measurements			Laboratory Analysis	
Site	Depth (m)	Temp. (°C)	Trans. %	Salinity (ppt)	DO (ppm)
EC229PA	0	28.0	82.5	35.887	6.7
(10-4-80)	5	28.0	84.5		
	10	28.0	84.2		
	15	28.0	84.5		
	20	28.0	88.0		
	25	27.8	88.0		
	27	27.8	84.0		
	30	27.5	62.0		
	33	27.0	42.0		
	34	26.8	22.0	35.920	5.4
VR298HB	0	27.5	88.0	36.030	6.8
Sonnier Bank	5	27.5	88.0		
(10-7-80)	10	27.5	88.0		
	15	27.5	91.0		
	20	27.5	96.8		
	25	27.5	94.0		
	30	27.4	94.0		
	35	27.4	94.0		
	40	24.5	88.0		
	45	23.8	86.0		
	50	22.5	76.0		
	52	22.0	38.0	36.223	5.4
VR179HB	0	26.5	82.0	33.368	8.6
(10-9-80)	5	26.8	83.7		
	10	26.6	88.0		
	15	27.2	56.0		
	20	29.0	49.0		
	25	27.5	32.0		
	28	27.8	14.0	35.590	8.1

1) Between individual platforms,
2) Between depth ranges at each platform,
3) Between legs at each platform,
4) Between stationary observations and horizontal transects: a) at the same depth, b) between depths, c) at each platform, and d) between platforms.

Two analysis of variance models were used to make the above comparisons. The first is a completely crossed factorial design with each level of each factor considered as fixed treatments of the response variables. The factors chosen were platform, depth, and station type, each represented by three or more levels. The model can be stated as:

$$Y_{ijkl} = \mu + P_i + D_j + T_k + PD_{ij} + PT_{ik} + DT_{jk} + PDT_{ijk} + \xi_{e(ijk)}$$

where:

μ is the grand mean,

P is platform,

D is depth,

T is transect type.

In the second ANOVA, differences between platform legs were tested by nesting legs within platforms. Depth and platforms were still crossed. The nested-factorial ANOVA model can be stated as:

Comparison of the two analysis of variance models, using percent of the total variance explained by each model, revealed important sources of variability in fish abundance estimates.

Table 9 shows the results of the crossed-factorial design. Overall, the model explained 50% of the total variance. If the probability level for a statistical test of hypothesis is less than five percent but not less than one percent, then the result is said to be significant. If the probability level is less than one percent, then the result is said to be highly significant (Steel and Torrie, 1960). Differences between platforms were highly significant ($F=4.28$; $P<0.01$) and significant interactions both between platform and station type and platform and depth were observed (Table 9). The significant interaction precludes any _a posteriori_ multiple testing of the significant main effect of platform.

Table 10 presents the results of the nested-factorial ANOVA. The effect of legs within platforms is highly significant ($F=6.63$; $P<0.01$), and a significant interaction was found between legs within platforms and depth ($F=2.60$; $P<0.05$). This model explained 98% of the total variance and points out the need to include in future experimental designs estimates of fish orientation around any given platform. The remotely collected data indicate that, although fish populations may vary from platform to platform, the most significant source of variation within each platform is the

TABLE 9. THREE-FACTOR ANALYSIS OF VARIANCE OF PHASE III DATA.

Source of Variation	dF	MS	F	P>F
Platform	3	1.618	4.28	0.007
Depth	4	0.322	0.85	0.495
Transect	2	0.348	0.92	0.401
Depth*Platform	9	0.042	0.11	0.999
Platform*Transect	6	0.985	2.61	0.022
Depth*Transect	6	1.581	4.19	0.001
Depth*Transect*Platform	8	0.490	1.30	0.255
Error	92	0.377		

$r^2 = 0.5073$

(dF, degrees of freedom; MS, mean squares; F, F statistic; P, probability of exceeding F).

*Indicates factor interaction tested.

TABLE 10. NESTED-FACTORIAL ANALYSIS OF VARIANCE OF PHASE III DATA.

Source of Variation	dF	MS	F	P>F
Depth	4	0.734	2.21	0.078
Platform	3	2.224	2.63	0.064
Depth*Platform	9	0.171	0.51	0.859
Leg (Platform)	40	0.847	6.63	0.009
Depth*Leg (Platform)	63	0.332	2.60	0.430
Error	11	0.128		

$r^2 = 0.980$

(dF, degrees of freedom; MS, mean squares; F, F statistic; P, probability of exceeding F).

*Indicates factor interaction tested.

( )Indicates factor(s) nested within enclosed factor.

leg upon which the observation station is conducted. This is very important because it confirms the behavioral phenomena observed during Phase I, namely, that fish populations congregate on the up-current sides of platforms. Similarities between the observed behavioral patterns and remotely collected data suggest that remote sensors are quantitatively sampling the same population distributions observed by divers.

Literature reports and diver observations suggest that a stronger relationship exists between distributions of populations and depth than was indicated by this study. The reason for the failure of either model to indicate a significant relationship between total abundance and station depth is probably similar to that for the Phase II data. This was because the total fish abundance data may represent a mean of each individual species distribution pattern which in itself may show variable densities of fishes with depth.

In order to test this possibility, factorial ANOVAs were run on species specific data for the nine species most frequently encountered at the platform sites during the study. These nine species were Atlantic spadefish, blue runner, gray triggerfish, greater amberjack, red snapper, scamp, sheepshead, tomtate, and vermilion snapper. Table 11 gives the results of these analyses. Blue runner abundance was significantly related to depth. The blue runner population detected by the remote sensor above 12 m was significantly more abundant than below 12 m. The greater

TABLE 11. SPECIES SPECIFIC FACTORIAL ANOVA WITH DUNCAN'S MULTIPLE RANGE TEST.

			Location[1]				Depth[2]				
Species and Factors	F Value	PR>F	VR164PA	EC195PA	VR161PA	VR201PA	<6 m	6-12 m	12-18 m	18-23 m	>23 m
Blue Runner											
Platform	4.89	0.0025									
Depth	4.17	0.0064									
Depth*Platform	2.51	0.0575									
Duncan's Test			A	A	A	A	A	A	B	B	-
Amberjack											
Platform	5.43	0.0047									
Depth	0.82	0.4867									
Depth*Platform	0.06	0.9382									
Duncan's Test			-	A	B	B	B	A	A	A	-
Vermilion Snapper											
Platform	31.94	0.0001									
Depth	16.14	0.0001									
Depth*Platform	26.17	0.0001									
Duncan's Test			-	A	-	B	C	B	C	A	-
Gray Triggerfish											
Platform	8.37	0.0001									
Depth	3.74	0.0049									
Depth*Platform	2.84	0.0026									
Duncan's Test			A	B	A	A	B	A	A	B	B
Spadefish											
Platform	80.13	0.0001									
Depth	11.96	0.0001									
Depth*Platform	16.10	0.0001									
Duncan's Test			B	C	A	C	B	B	B	B	A

*Indicates factor interaction tested.
1) Platform - Platform sites with the same letter are not significantly different.
2) Depth - Depths with the same letter are not significantly different.

TABLE 11. (CONTINUED).

Species and Factors	F Value	PR>F	Location[1]				Depth[2]				
			VR164PA	EC195PA	VR161PA	VR201PA	<6 m	6-12 m	12-18 m	18-23 m	>23 m
Red Snapper											
Platform	0.19	0.8248									
Depth	11.68	0.0001									
Depth*Platform	0.07	0.7966									
Duncan's Test			A	B	B	-	-	C	B	B	A
Tomtate											
Platform	6.66	0.0014									
Depth	12.52	0.0001									
Depth*Platform	-	-									
Duncan's Test			A	-	A	A	C	B	B	B	A
Sheepshead											
Platform	0.53	0.6690									
Depth	1.47	0.2095									
Depth*Platform	1.96	0.0994									
Duncan's Test			B	B	A	B	A	B	C	C	C
Scamp											
Platform	1.83	0.1636									
Depth	1.14	0.3223									
Depth*Platform	-	-									
Duncan's Test			A	A	A	A	A	-	A	A	-

*Indicates factor interaction tested.
1) Platform - Platform sites with the same letter are not significantly different.
2) Depths - Depths with the same letter are not significantly different.

amberjack population showed no relationship to station depth while vermilion snapper showed significant differences. Vermilion snapper abundance above six metres was statistically similar with populations observed between 12 and 18 m, while abundance estimates observed in the 6 to 12-m range and the 18 to 23-m range were distinct from all others. Vermilion snapper appeared to move higher or lower in the water column depending upon the presence or absence of turbidity layers. The species appeared to remain above the nepheloid layer and below any lens of turbid surface water which might have been present. Changing environmental conditions during the various observational periods may be a further complicating source of variability in the inconsistent relationships observed with depth. Gray triggerfish showed a significant variation with depth. Abundance estimates between 6 and 18 m varied significantly from those above and below. Statistically, the Atlantic spadefish showed a strong depth effect. Duncan's multiple range test showed, however, that Atlantic spadefish populations below 23 m were significantly different from those above. Red snapper exhibited a reverse distribution pattern. The species was strongly associated with depth, showing the largest populations in the near-bottom (>23 m) depth range. Their populations were statistically equivalent in the 12 to 23-m depth range, but declined in the 6 to 12-m range. Red snapper was never seen in the near-surface (less than six metres) depth range. Tomtate abundance varied significantly with depth, showing the largest concentrations near the bottom and the smallest near the surface. Sheepshead showed its greatest concentration near the surface. No definitive depth relationships were indicated for scamp.

Results of this species-specific analysis correlate closely with the qualitative distributions observed by others (e.g., Shinn, 1974; Hastings et al., 1976; Sonnier et al., 1976) and with diver observations recorded during Phases I and II. These results (i.e., the agreement between Duncan's multiple range tests and diver observations), together with those yielded by the ANOVAs for the remotely collected data on production platform fish populations, validate the sampling techniques and help to substantiate the standing stock estimates developed at each platform (Section 4.5.3).

4.5.2.2 Sonnier Bank

An attempt was made to analyze the Sonnier Bank data using the same type of factorial model applied to the platform stations. The initial factors chosen were 1) depth, 2) time of day, 3) distance from the peak, and 4) direction from the peak. Diver observations (Phase I) had shown that the vast majority of fishes encountered at Sonnier Bank were found associated with the highest point of the bank. Our sampling design, therefore, was centered on this peak (Figure 13). By analyzing both direction from and distance to the peak, we hoped to determine if differences existed between stations on the bank crest (north versus south) and stations on the bank shoulders (east versus west). We hypothesized that time of day might produce shifts in fish population distributions, so time of sampling was included in the model.

After excluding samples where no fishes were observed, only observations within one metre of the bottom remained, and these were combined in such a way as to obtain the following two-factor ANOVA model:

$$Y_{ijk} = \mu + L_i + D_i + LD_{ij} + \xi_{k(ij)}$$

where:

μ represents the grand mean,

L represents the distance from the peak,

D represents direction from the peak,

LD represents the first order interaction between distance and direction.

This model accounts for 79% of the observed variance in the Sonnier Bank data. It indicates that there were no significant differences ($F=1.27$; $P<0.26$) within fish populations relative to their distance from the peak, and no significant difference ($F=2.55$; $P<0.14$) between populations relative to direction.

4.5.3 Standing Stock Estimates

4.5.3.1 Platform Sites

Standing stocks (fishes/m^3) were estimated using the mean value for each species reported from each platform surveyed. The actual subsurface volume of each platform sampled was calculated from engineering drawings. An additional ten metres were added (five metres to all sides) to the actual horizontal dimensions of each platform. This addition was made in order to encompass the territory inhabited by such structure-associated fishes as Atlantic spadefish or vermilion snapper, which normally swim outside the platform (Table 12). Our sampling procedure had been designed to incorporate this volume in an effort to accurately census these species. The calculated volume (m^3) surveyed was multiplied by the mean number of individuals per cubic metre to yield the standing stock estimate. An error term, based on the standard deviation between samples, was calculated in terms of plus or minus a number of individuals by dividing the standard deviation by the frequency with which a given species appeared at a given site, then multiplying by the volume surveyed at that site.

Estimated standing stocks for the 25 species identified from videotapes plus the unidentified species lumped together are given in Table 13. Total standing stocks, in terms of numbers of individuals, indicate that Vermilion Block 161, Platform "A" supported the largest abundance of fishes. In

TABLE 12. VOLUME SURVEYED AND SURFACE AREA (TOTAL AREA OF THE PLATFORM STRUCTURAL MEMBERS BELOW WATER) OF PLATFORM SITES.*

Platform	Surveyed Volume	Surface Area
Vermilion Block 164 Platform "A"	35,269 m^3	3,711 m^2
East Cameron Block 195 Platform "B"	23,860 m^3	1,919 m^2
Vermilion Block 161 Platform "A"	9,313 m^3	6,233 m^2
Vermilion Block 201 Platform "A"	15,041 m^3	1,174 m^2

*All measurements are taken from the engineering diagrams of each respective platform.

TABLE 13. STANDING STOCK ESTIMATES FOR THE SURVEYED PLATFORMS.

Species	VR164PA Ind/m^3	VR164PA Standing Stock*	EC195PB Ind/m^3	EC195PB Standing Stock*	VR161PA Ind/m^3	VR161PA Standing stock*	VR201A Ind/m^3	VR201A Standing Stock*	Ind/M^3 Totals
Blue runner	0.0158	557 ± 210	0.0007	17 ± 2	0.0011	10 ± 1	0.0005	8 ± 2	0.0181
Greater amberjack	0.0001	1 ± 0.2	0.0026	63 ± 3	–	– –	0.0006	10 ± 1	0.0033
Vermilion snapper	–	– –	0.0045	106 ± 18	–	– –	0.0005	7 ± 1	0.0050
Gray triggerfish	0.0058	205 ± 20	0.0012	28 ± 2	0.0174	162 ± 42	0.0020	30 ± 2	0.0264
Atlantic spadefish	0.0401	1413 ± 97	0.0007	16 ± 2	0.2086	1942 ± 249	0.0042	64 ± 3	0.2536
Cocoa damselfish	0.0002	8 ± 1	–	– –	0.0030	28 ± –	–	– –	0.0005
Sergeant major	0.0012	42 ± –	–	– –	0.0161	150 ± 85	–	– –	0.0173
Spanish hogfish	–	– –	–	– –	–	– –	0.0014	21 –	–
Red snapper	0.0088	312 ± 48	0.003	8 –	0.0019	18 ± 2	–	– –	0.0110
Bigeye	–	– –	–	– –	0.0916	853 ± –	–	– –	–
Tomtate	0.0287	1014 ± 232	–	– –	0.0211	196 ± 43	0.0045	65 ± 6	0.0543
Sheepshead	0.0050	18 ± 2	0.0005	11 ± 2	0.0326	304 ± 42	0.0008	11 ± 1	0.0389
Cobia	0.003	2 ± 0.2	–	– –	–	– –	–	– –	–
Blue angelfish	0.005	17 –	–	– –	–	– –	–	– –	–
Scamp	0.0010	3 ± 0.2	0.0003	8 ± 3	0.0010	9 –	0.0005	8 ± 1	0.0028
Atlantic moonfish	0.0020	8 –	–	– –	.0007	6 –	–	– –	0.0027
Pigfish	0.002	8 –	–	– –	–	– –	–	– –	–
Bermuda chub	0.0012	42 –	0.0587	1402 ± 976**	0.0021	20 –	0.0026	39 ± 12	0.0648
Reef butterflyfish	0.0002	7 –	0.0002	4 ± 2	–	– –	–	– –	0.0004
Great barracuda	0.0001	2 –	0.0001	3 ± 1	–	– –	–	– –	0.0002
Rainbow runner	–	– –	–	– –	0.0004	4 ± 1	–	– –	–
Almaco jack	–	– –	–	– –	0.0003	3 ± 0.1	–	– –	
Bluefish	–	– –	–	– –	0.0265	247 ± 107	–	– –	
Spotfin butterflyfish	–	– –	–	– –	–	– –	0.0010	14 –	
Blue tang	–	– –	0.0010	24 ± 7	–	– –	–	– –	
Unidentified Species	0.0045	157 ± 37	– –	– –	0.0003	3 ± 0.2	0.0004	6 ± 0.5	0.0052
Total		3816 ± 648		1690 ± 1018**		3955 ± 572		283 ± 30	

*Total number of individuals ± standard error.

**This high error factor is attributable to the siting of a single large school of bermuda chub at this platform.

terms of species present, Vermilion Block 164, Platform "A" had the largest number of species.

Total standing stock and standing stock per species were correlated with total platform surface area, as calculated from the engineering drawings, using linear regression and curve fitting equations (Table 14). Results of these analyses indicated that there was high correlation (r^2 = 0.79, linear; 0.93 exponential) between overall fish abundance and the availability of habitat area. This correlation was particularly high for the smaller territorial coral reef fishes (i.e., cocoa damselfish and sergeant major). It was virtually nonexistent for larger or transient species (i.e., blue runner and greater amberjack).

4.5.3.2 Sonnier Bank

Standing stock estimates for Sonnier Bank were calculated in essentially the same manner as those for the surveyed platforms. Virtually no fishes were observed within the water column at the surface and mid-water stations. Based upon this fact, we concluded that the observed species were directly associated with the hard bottom habitat. To extrapolate their population estimates throughout the entire water column would have grossly exaggerated their abundance. For this reason, only the data obtained from bottom stations were used in both the statistical analysis and standing stock calculations for Sonnier Bank.

TABLE 14. RESULTS OF LINEAR REGRESSION AND EXPONENTIAL CURVE FITTING ANALYSIS OF STANDING STOCK ESTIMATES AGAINST PLATFORM SURFACE AREA (HABITAT).

Platform Frequency	Species	Linear Regression (r^2)	Exponential Curve (r^2)
4	Blue runner	0.02	0.09
3	Greater amberjack	0.27	0.20
2	Vermilion snapper	0.20	0.13
4	Gray triggerfish	0.60	0.71
4	Atlantic spadefish	0.91	0.91
2	Cocoa damselfish	0.95	0.81
2	Sergeant major	0.95	0.81
3	Red snapper	0.03	0.37
3	Tomtate	0.08	0.18
4	Sheepshead	0.79	0.61
4	Scamp	0.0015	0.02
2	Atlantic moonfish	0.59	0.71
3	Bermuda chub	0.17	0.10
2	Reef butterflyfish	0.01	0.01
2	Great barracuda	0.19	0.23
	Total All Species	0.79	0.93

The Sonnier Bank sampling site (Figure 13) was a much more diversified habitat area than the oil production platforms previously sampled. The bank habitat encompassed by the 25 sampling stations ranged from a coral reef community at the peak or crest of the bank to flat mud bottom at the outlying stations. Standing stock estimates were based on the entire sampling area of 180 by 180 m and the water column was limited to within one metre of the bottom (32,400 m^3). To account for the patchiness of species distribution with respect to habitat, an additional term, percent appearance, was introduced into the standing stock equation. This term was calculated by dividing the frequency of appearance by the total number of stations (25). Table 15 lists the standing stock estimates for all species encountered at Sonnier Bank. Error, in terms of plus or minus a specific number of individuals, was calculated by multiplying the standard error value times the standing stock estimate.

4.6 Discussion and Conclusions

Statistical analysis of the quantitative data from remotely controlled television systems indicated that the sampling design accurately sampled the fish populations above the nepheloid layer. Naturally occurring variations in fish population distribution patterns are reflected by analysis of videotapes. Observations of the remote sensor quantitatively corresponded with the qualitative observations of *in situ*

TABLE 15. STANDING STOCK ESTIMATES FOR SONNIER BANK.

Species	Ind/m^3	Freq.	Standing Stock*
Creole-fish	0.4446	13	7491 ± 3071
Vermilion snapper	0.7518	4	3897 ± 8807
Tomtate	0.1501	10	1945 ± 404
Bigeye	0.0878	6	683 ± 89
Blue angelfish	0.0566	8	587 ± 35
French angelfish	0.0427	10	553 ± 66
Blue runner	0.1813	2	470 ± 650
Spotfin hogfish	0.0162	8	168 ± 12
Rock beauty	0.0173	5	112 ± 3
Spotfin butterflyfish	0.0231	2	60 ± 1
Queen angelfish	0.0127	3	49 ± 1
Reef butterflyfish	0.0115	2	30 ± 1
Bermuda chub	0.0081	2	21 ± 1
Doctorfish	0.0046	2	12 ± 1
Porgy	0.0046	2	12 ± 1
Rainbow runner	0.0081	1	10 ± 1
Spanish hogfish	0.0058	2	6 ± 1
Cottonwick	0.0023	1	3 ± 1
Squirrelfish	0.0012	1	2 ± 1
Scamp	0.0012	1	2 ± 1
Greater amberjack	0.0012	1	2 ± 1
Unidentified Fish	0.0115	3	45 ± 1

*Total number of individuals ± standard error.

observers during Phases I and II. Behavioral patterns qualitatively observed and reported were statistically verified. This correlation of *in situ* observations with quantitative numerical data from these shallow water sites lends support to the hypothesis that remote sensors alone can accurately census deep water (100+ m) fish populations.

The RECON III-B did eliminate some of the operational problems encountered with the RCV-225, however, it still remains subject to the common problems associated with tethered, free-swimming vehicles.

The question of how well calculated, standing stock estimates reflect reality still remains. Standing stock estimates given here are generated according to basic mathematics and, therefore, may be considered as reliable as any other fisheries population estimating techniques. Standing stock estimates appear to reflect qualitative observations by divers and are proportional from site to site with regard to the relative abundance of the detected species.

Very few quantitative ichthyological studies of oil and gas production platforms have been conducted in the northern Gulf of Mexico. Gallaway (1979) conducted an underwater videotape study of pelagic and structure-associated fishes at four platforms in the northern Gulf. His quantitative data were presented in terms of fishes-per-minute of videotape record and no viewing volumes were calculated. Putt (manuscript) utilized simultaneous time-lapse photography at three depths on a small production platform to analyze seasonal variations in the fish community. Putt calculated the volume of his viewing area, and presented his data in terms of fishes per cubic metre. Table 16 ranks by abundance estimates the species encountered in both of these studies and compares them with the most abundant species encountered during Phase III. The abundance calculations of Putt and those recorded in this study are similar and suggest that remote techniques yield comparable and reproducible population estimates. Ranking of the more abundant species is very similar for all studies. Individual shifts in species-specific rankings are attributed to the natural variability evidenced between sites.

Despite the agreement between data collected in this study and those obtained by others using remote visual methods, some additional factors must be considered when evaluating standing stock estimates. To date, there have been no quantitative studies comparing TV camera population estimates to diver fish counts. Based on the restriction of viewing geometry produced by the camera lens angle, we believe there may be a bias in the overall population estimates obtained.

Behaviorally, hard bottom and platform associated fishes can be classified into several major groups. How well each of these groups are quantified via remote visual sampling

TABLE 16. SPECIES ABUNDANCE RANKING AS INDICATED BY THE STUDIES OF GALLAWAY (1979), PUTT (MANUSCRIPT), AND CONTINENTAL SHELF ASSOCIATES, INC.*

Gallaway (1979; Fish/min videotape)		Putt (Manuscript; Fish/m^3)		CSA (1981; Fish/m^3)	
Atlantic spadefish	30.28	Atlantic spadefish	0.1520	Atlantic spadefish	0.2536
Gray triggerfish	27.80	Grunt	0.1010	Bermuda chub	0.0648
Snapper	5.08	Gray triggerfish	0.0337	Tomtate	0.0543
Sheepshead	2.00	Sheepshead	0.0225	Sheepshead	0.0389
Blenny	1.68	Sergeant major	0.0108	Gray triggerfish	0.0264
Grouper	1.61	Red snapper	0.0105	Blue runner	0.0181
Blue runner	1.56	Amberjack	0.0017	Sergeant major	0.0173
Jack	0.84	Beaugregory	0.1017	Red snapper	0.0110
Lookdown	0.57	Great barracuda	0.0004	Unknown	0.0052
Atlantic moonfish	0.21	Bermuda chub	0.0001	Vermilion snapper	0.0050
Bermuda chub	0.02			Greater amberjack	0.0033
Blue angelfish	0.01			Scamp	0.0028
				Atlantic moonfish	0.0027

*Where seasonal data were available, dates most closely approximating those of Phase III were selected for this table.

techniques remains in question. Given time to field test a remote viewing system against *in situ* diver observations, specific correction factors for each behavioral fish grouping could be developed. These factors could then be applied to data obtained strictly by remote sensor, thus improving the accuracy of the standing stock estimates obtained.

In their present state, the techniques tested during this study can be applied to outer continental shelf areas as reliable methods of obtaining comparative estimates of standing stocks of commercially valuable species. It has been demonstrated that ROVs are relatively practical vehicles in which the remote monitoring system can be housed and maneuvered into position. In order to fully evaluate the potential of the ROV-CCTV remote sensing method for deep water fish community analysis, comparative ROV-manned submersible tests should be made.

Results from Phase III provide quantitative support for several qualitative assumptions previously made about fish populations around oil and gas platforms. In the northern Gulf of Mexico, offshore structures are responsible for concentrating fish populations vertically in the water column. Remote monitors stationed approximately 6 and 23 metres from platforms, and in the water column above hard bottom areas, failed to detect any significant concentrations of fishes. There appears to be a direct correlation between the abundance of smaller sedentary reef fishes and schooling species which remain near the structure and the amount of available habitat. Large hard bottom associated species (e.g., red snapper) and transient near-surface species (e.g., greater amberjack) showed no relationship to subsurface platform area.

Standing stock estimates for Sonnier Bank had to be calculated by extrapolating the sampled volumes at the near-bottom stations through only the first metre above the bottom. No significant populations were detected within the water column at the mid-water and near-surface depths. Extrapolating the bottom standing stock estimates through the entire water column at this site would have greatly biased population estimates. By restricting the sample volume in this manner, a considerable portion of the fish abundance in the upper water column or upper canopy is lost in the generated estimates. These fishes were not present in significant numbers at Sonnier Bank. Their absence implies some interesting facts about artificial offshore structures. Artificial offshore structures act as vertical mixing grounds for the stratified fish populations of the northern Gulf of Mexico. Pelagic species tend to concentrate near the structures, possibly because of the visual reference points they provide, and certain bottom species expand into and live on the newly available subsurface habitat areas. Other hard bottom fishes utilize the vertical relief offered by the platforms as a ladder with which to expand their own vertical migratory range. Platforms offer an opportunity to increase population size only to those species which actually become residents upon the subsurface platform substrate.

5.0 DISCUSSION AND RECOMMENDATIONS

5.1 Phase I

Numerous low-relief, shallow water (<35 m), hard bottom areas were identified and visited during Phase I of this study. Despite the fact that such hard bottom areas are extremely important to local commercial and sports fishing interests, very little data have been published concerning them. Observations during Phase I suggest that these areas support substantial reef fish populations. None of these low-relief fishing banks are currently protected under oil and gas biological lease stipulations. However, it is the opinion of some fishermen (Sonnier, 1981) that the snapper populations at these often small-sized features are depleted significantly, not by oil and gas activities, but by over-fishing.

One previously unidentified high-relief feature (East Cameron Area, Block 293, Hard Bottom, 29 Fathom Place) was described during this study (EC293HB; Section 2.5.2.2). This rock outcrop feature, rising from a depth of 57 m to within 30 m of the surface, supports extensive invertebrate and fish communities which are typical of those associated with previously described topographic highs (Bright et al., 1976; Bright and Rezak, 1978a,b, 1981). The feature is not presently shown on any bathymetric charts, nor is it included on the BLM, OCS topographic features list. Since this feature is within five kilometres of seven previously leased oil and gas tracts, further investigation is probably warranted to determine whether it should be protected via a biological lease stipulation.

5.2 Phases II and III

5.2.1 Spatial and Temporal Variability of Fish Assemblages

Direct, quantitative comparisons of fish assemblages between hard bottom habitats and oil and gas production platforms are extremely difficult because of the natural variability of the fishes associated with these habitats. Throughout this study, several types of fish distribution patterns were observed.

A three-story or three-layered partitioning of the water column by the associated fish assemblage appears to occur at the hard bottom areas. In the upper and upper-middle layers of the water column are the pelagic or transient species which may utilize the reef only as a reference point or for feeding (e.g., blue runner and greater amberjack). Within the middle and near-bottom layers of the water column are the demersal bottom dwellers, such as the groupers, grunts, porgies, and snappers. Along the bottom are the truly epibenthic species, such as flounders, searobins, and most of the tropical species.

During Phase II, fishes were observed concentrated in the water column directly above the peaks of hard bottom features. This pattern was pronounced at East Cameron Block

229, Hard Bottom Site, Jackaman's Hole (Figure 4) where large numbers of greater amberjack, stingrays, tomtate, and vermilion snapper were noted only above the peak. During Phase III, remote sensing efforts at Sonnier Bank failed to document this phenomenon.

The natural temporal variability of hard bottom associated fish populations was also evident at Jackaman's Hole. Within a 24-hour time span, the high concentrations of fishes observed above the feature's peak completely dispersed. An accompanying marked increase in current speed was considered the principal cause of the change in spatial distribution. It appears that natural fluctuations in environmental conditions can result in extreme variations in fish population characteristics.

Placement of an oil and gas production platform provides a potential new habitat. Some of the hard bottom associated species appear to be able to utilize this newly available habitat, while others are not. Thus, the resource partitioning of the natural hard bottom will not be identical with that of the oil and gas platform.

A large segment of what was originally the lower story of the natural hard bottom fish community remains at the lower story of the platform fish community. This portion of the community includes species such as the flounders (Bothidae), searobins (Triglidae), and sole (Soleidae) which are adapted for bottom dwelling, and do not accept the platform surfaces as "suitable" substrate. Other demersal fishes such as the angelfishes (Pomacanthidae), blennies (Blenniidae), butterflyfishes (Chaetodontidae), and damselfishes (Pomacentridae) are able to expand their range up the entire length of the structure. These forms remain close by the platform surfaces in patches near platform areas which offer the most protection (e.g., horizontals and well conductor guides) (Figure 14).

Other fish distribution patterns at platforms appear to be related to both water depth and water clarity (Figure 15). Fishes such as large groupers and/or red snapper, which are bottom dwelling species, migrate upward into the water column to a depth which is just above the nepheloid layer. These species do not migrate completely to the surface, but they may move up into mid-water. This same phenomenon is noted over hard bottom areas, but because of the vertical relief offered by the platform, these species rise much higher into the water column at platform sites. It is interesting to note that the small omnivorous species of the normal reef community, such as the grunts (Pomadasyidae) and porgies (Sparidae), migrate up the entire vertical relief of the platform, while the large primarily bottom dwelling piscivores remain in the lower portions of the water column.

The upper story of the platform's ichthyocommunity remains essentially the same as that of a natural hard bottom area. The presence of the structure itself seems to serve as a visual reference point or optical stimulus for certain schooling fishes (Gallaway, 1979), thus increasing their

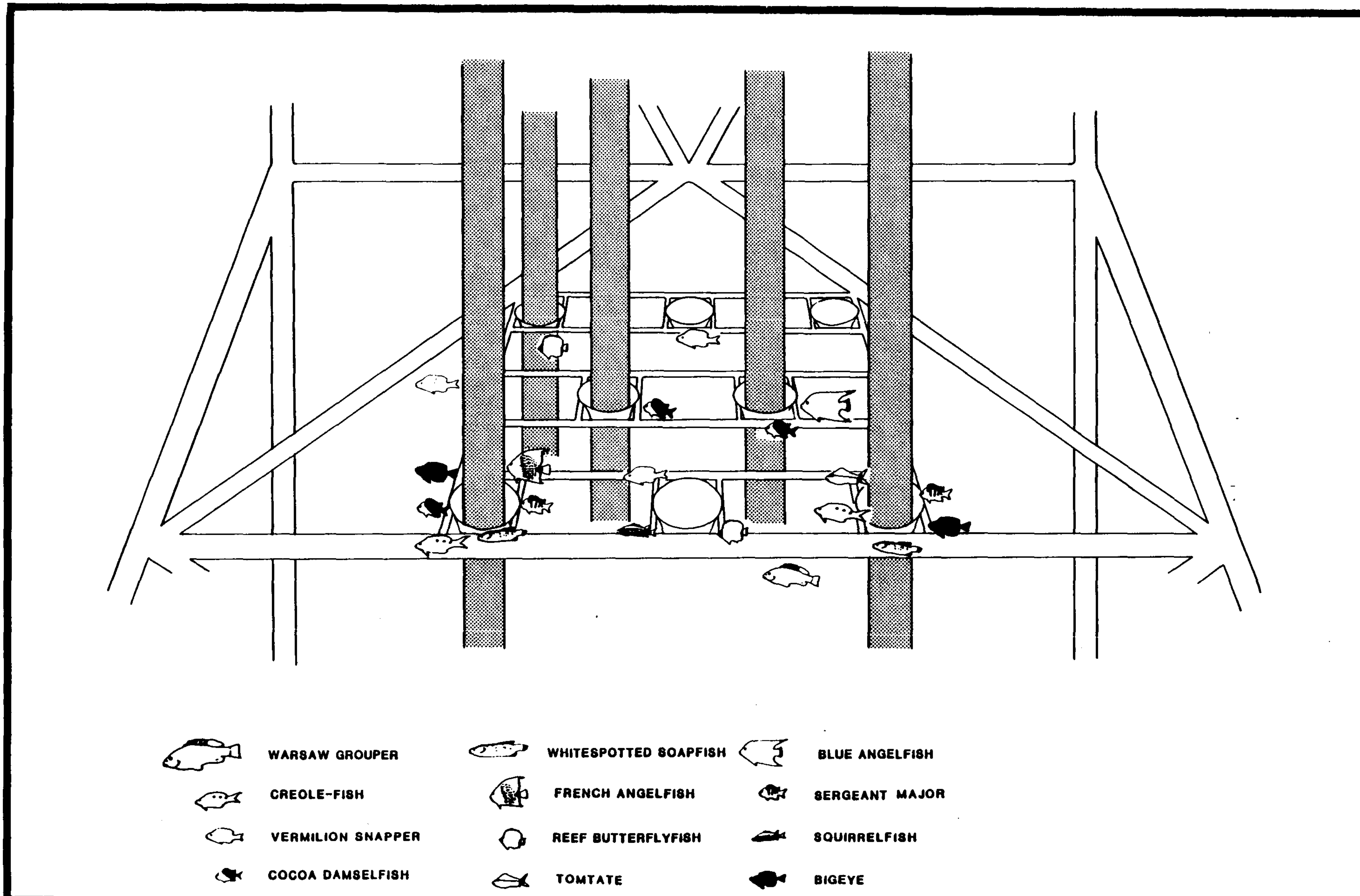


FIGURE 14. REEF FISHES CLUSTERING AROUND WELL GUIDES.

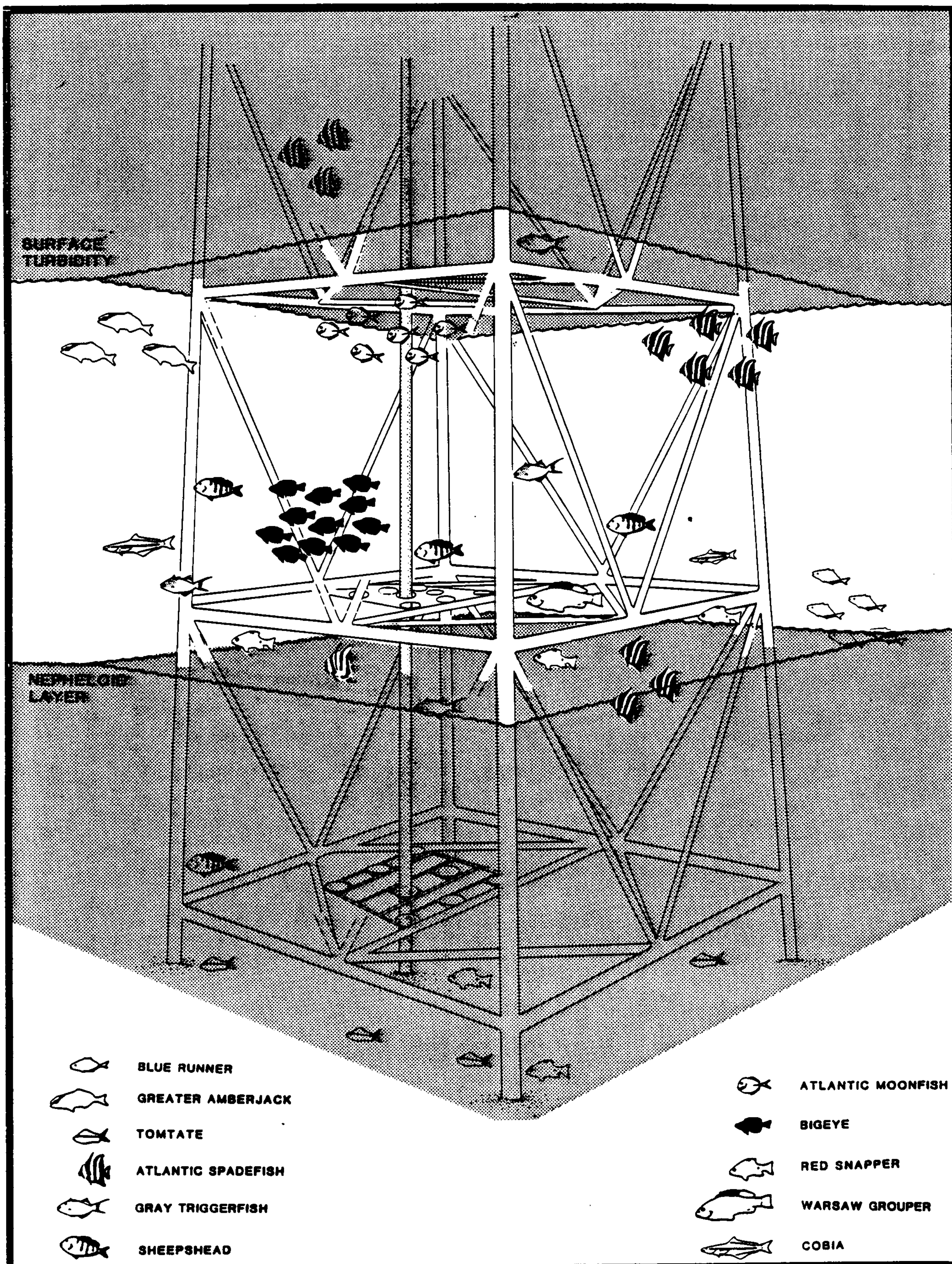


FIGURE 15. DIAGRAMMATIC REPRESENTATION OF FISH DISTRIBUTION RELATED TO NEPHELOID AND SURFACE TURBIDITY LAYERS.

concentrations within a given area. Large pelagic predators are then drawn to the platform because of food availability. Because of their visual association, the schooling fishes apparently prefer depths with the clearest water. When surface water layers are turbid, these fishes tend to concentrate within the clear water layers at mid-depth. Figure 15 illustrates the distribution of fishes observed during such conditions.

As in hard bottom ichthyocommunities, platform associated fish distributions are apparently influenced by currents. Figure 16 illustrates a lateral phenomenon recorded at East Cameron Area, Block 229, Platform "A". During observations at the platform, water clarity was consistent throughout the water column above the nepheloid layer and a slight current flowed past the structure. Virtually the entire fish community was positioned on the up-current half of the platform. Species such as vermilion snapper, which do not show a strong bottom affinity, ranged vertically throughout the water column and up-current of the platform. A similar distribution pattern was previously described by Hastings et al. (1976).

Both the spatial and temporal variations of fish distributions around hard bottom areas and platforms have greatly affected this study. To evaluate the standing stock of fishes associated with a hard bottom or platform using a remote sampling technique, a sampling design that is

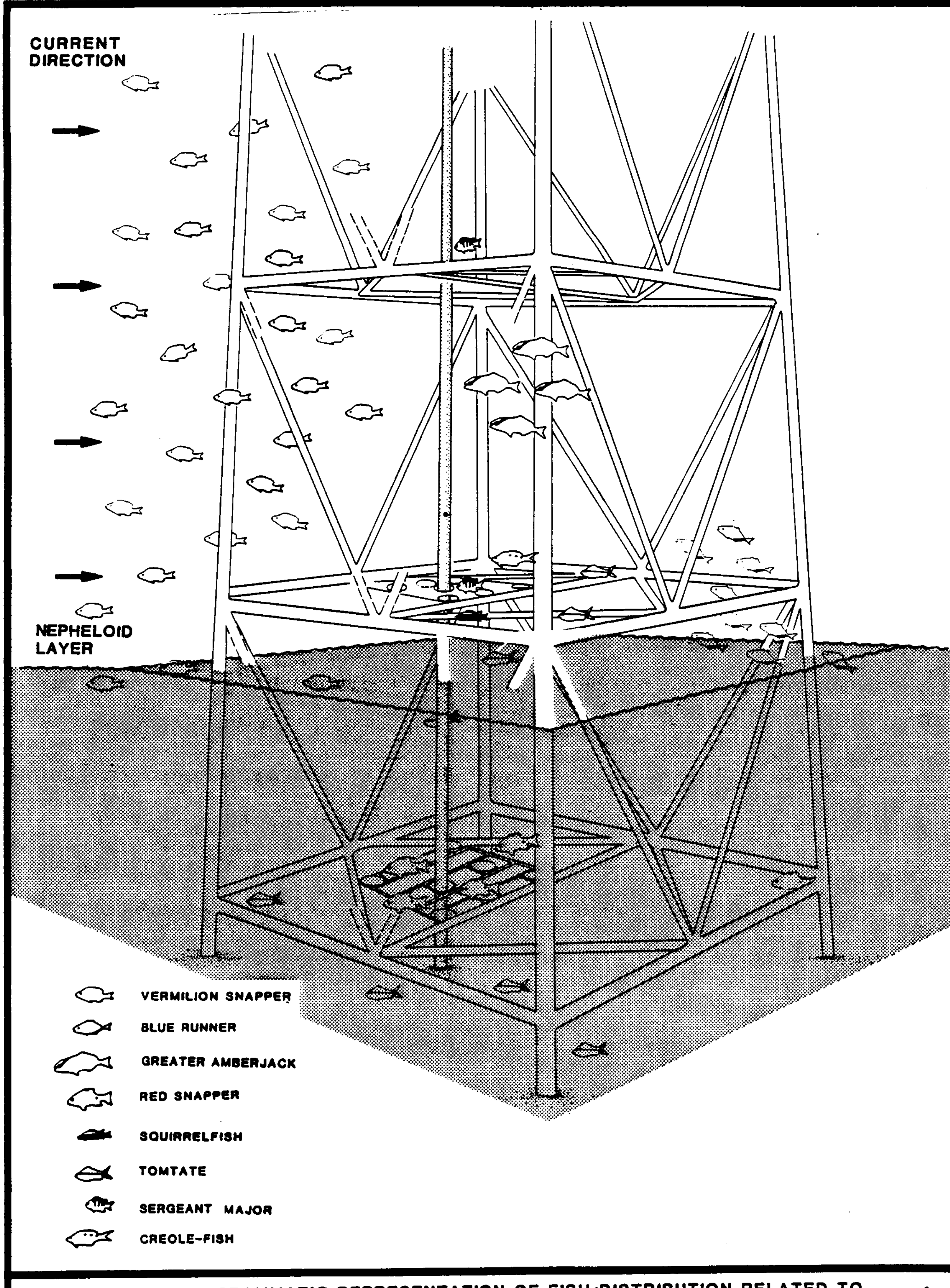


FIGURE 16. DIAGRAMMATIC REPRESENTATION OF FISH DISTRIBUTION RELATED TO CURRENT.

capable of assessing spatial and temporal variations is required. Without prior knowledge of the distribution of a given fish population, sampling techniques must be devised which cover a sufficiently large segment of the available habitat to ensure an adequate sample of the species present.

5.2.2 Sampling Design

Phase III has shown that statistically significant differences exist in the abundance of fishes between depths and legs at platforms and between transects at natural hard bottom areas. These differences suggest that a sampling pattern must be designed so that observations are made at numerous positions at a platform and at a hard bottom area. Problems of natural spatial variability could be overcome by saturating a platform or relatively small hard bottom area with observation stations, thus obtaining a very good estimate of the true population mean. Unfortunately, there are two additional problems associated with such a plan. The first problem involves the difficulty of making accurate and comparable visual observations in an area of high turbidity. This problem was identified during this study, but no solution was found. It appears that accurate standing stock estimates cannot be made using visual techniques on the nearshore hard bottom areas and platforms except during a very short time period in the year when turbidity may be low. The deep water, hard bottom areas generally rise above the near-bottom nepheloid zone (Bright and Rezak, 1978a,b, 1981).

This condition would allow for an accurate assessment of the abundance and distribution of fishes at these areas. A small portion (perhaps ten percent) of a deep water platform in 150 m of water would potentially remain in a nepheloid layer and the fishes located there would be difficult to observe.

The second problem of this study was finding that the abundance and distribution of fishes changed radically at individual study sites within even the narrow time frame of the study. Temporal variations over periods of hours, days, seasons, and years need to be evaluated prior to making reliable standing stock estimates and prior to evaluating the potential impact of oil and gas operations on reef fish standing stocks.

An additional factor in the designing of sampling patterns for reef fish standing stock estimates involves the relatively large size (e.g., only one of five peaks was surveyed on Sonnier Bank) of the deep water, hard bottom areas. It may be exceedingly difficult to evaluate the temporal changes that may occur in a fish assemblage while studying the spatial variability of the assemblage over a period of several weeks.

5.2.3 Viewing Geometry

Viewing geometry and non-random distribution problems are minimized when the purpose of a study is merely to classify and to characterize a site by ranking its ichthyofauna in order of abundance (Jones and Thompson, 1978).

Viewing geometry becomes a critical parameter in study design, however, when a visual fish censusing method is employed to develop reliable standing stock estimates. When remote sampling devices are employed (i.e., CCTV or cameras), the viewing geometry is limited to the lens angle. This problem is not corrected by utilizing camera mounts capable of a 360° pan because, at any given observation, the fixed-lens angle remains the limiting factor. The exact extent of influence that observation geometry has on the accuracy of fish population estimates is unknown, but based on the preliminary work of Parker (1981), who compared diver versus submersible observations, the "geometry effect" is quite large. This potential source of error in transect observations is probably minimized when the observation is made with the gear in a fixed position and a specific volume of water is viewed.

5.2.4 ROV Evaluation

R. Frank Busby Associates, Inc. (1979) recommended to NOAA that ROVs be evaluated on considerations unique to the scientific user. Some specific aspects recommended for evaluation are as follows:

1) Data quality,

2) Viewing quality (resolution/range),

3) Depth and scale perception,

4) Visibility limits,

5) Navigation/positioning,

6) Vehicle effect on organism behavior,

7) Manipulator/sampling effectiveness, and

8) Durational limits of the observer.

This present study evaluated two ROVs (RECON III-B and RCV-225) in terms of the first six parameters. Numerous problems were encountered using both ROVs; however, these problems are probably inherent to all tethered, free-swimming vehicles, and do not reflect problems unique to the design of either vehicle. The ROVs utilized in this study were leased from owner-operators other than the manufacturers. Both units were industrial working pieces of equipment that were used to perform tasks other than those for which they were actually designed.

Both units performed equally well in terms of their data quality, viewing quality (resolution/range), depth and scale perception, and visibility limits (Items 1 to 4 of R. Frank Busby Associates, Inc. recommended evaluation list).

Major problems with both vehicles' applicability to fish censusing work seemed to be in the areas of navigation and positioning (station keeping). Some operators were consistently able to achieve better results in maneuvering and station keeping than others. This seemed to be the result of experience, both with the unit and also with the requirements of the scientific observer.

Statistical comparisons between standing stock estimates made with both ROVs and the CSA CCTV system show no significant differences between these systems when all were used in a fixed-position mode. A marked effect on fish behavior was observed when the ROVs were utilized in the transect mode. Observed fright-flight responses were attributed to the noise of the ROVs' motors, rather than to the visual aspect of the vehicles. Neither vehicle, when motionless, had any effect on observed fish species behavior.

Results of this study indicate that, for calculating standing stock estimates, ROVs should be used for observations when stationary. All television systems tested showed similar advantages and disadvantages when utilized for collecting data at fixed-position sampling stations. ROVs are necessary, however, to achieve accurate standing stock estimates for hard bottom areas or platforms because the natural variability of the community requires many fixed-position sampling stations at each site. This type of multiple sampling is impractical with television systems that are not self-propelled.

5.2.5 Design Problems and Recommendations for ROVs

Despite the lack of a consistent, overall, ROV development program, several areas where design improvements are needed have been identified by R. Frank Busby Associates, Inc. (1979). These areas are enumerated below:

1) Stronger, abrasion-proof tether,

2) Lighter weight cables (less drag in water),

3) More powerful thrusters,

4) Through-the-water TV transmission,

5) Three-dimensional viewing capability,

6) High definition color TV,

7) Improved internal navigation systems,

8) Increased data handling capability, and

9) Faster launch and retrieval systems.

Through field operations and laboratory analysis conducted during this study, a number of areas where design improvements are needed in ROVs has been identified. This study showed that even in low current speeds (<0.5 knots) that the two ROVs employed had very limited mobility when more than approximately 60 m of cable were deployed from their cages. Either a cable with less drag or vehicles with greater power would greatly decrease the time required to assess the standing stock of fishes at a platform or at a hard bottom area.

If quantitative missions are to be conducted in anything other than perfect weather, then some form of heave compensation must be developed to isolate the television from the motion. Tethered, free-swimming and towed vehicles are affected by the vertical motion of their support vessels.

This motion periodically takes the subject out of focus, thus leaving gaps in the quantitative data being collected. Techniques for surface to bottom location pin-pointing also need to be improved to enable the observer/operator to better orient himself within the environment.

Investigations need to be conducted to determine how various viewing geometries bias samples. Specific viewing geometry and species behavior correction factors may be developed by intensive sampling of known fish populations at specific target areas by both remote viewing devices and divers.

Miscalculation of the sampled volume can introduce errors into standing stock estimates. These errors arise primarily from fluctuations in the lens to target distance. These errors are greatly reduced by increasing the stability of a ROV's station keeping capacity. Any increased capability in the CCTV system to detect relative depth of field (such as stereo television) would also greatly reduce this source of error. This study has also indicated that standing stock biomass estimates would not be accurate using visual length data and comparing that to length:weight relationships generated from samples. A major problem is that fish trap or hook-and-line sampling does not obtain sufficient numbers of the different species of fishes observed. In addition, accurate length measurements of individual fishes are very difficult to determine using conventional television. Stereo television, such as the Sub-Sea Model ST-1000, may be a possible solution for this portion of the problem.

The Hydro Products Model TC-125-SIT low-light level camera tested during Phase II did not provide superior data to that of conventional cameras. The low-light level camera could not provide a suitable picture past sunset without additional television lights. This negated the possibility of testing the low-light level television at night without lights to determine the effect of lights on night-time fish observations.

When ROVs are utilized to remotely sample fish populations in less accessible depths of the continental shelf and continental slope, specialized camera systems, as well as other non-visual remote sensing technologies (i.e., acoustic systems), may be mounted on the ROVs for specific purposes. Each new remote censusing system would require specific field testing to determine its operational limits.

5.3 Conclusions and Evaluation of Objectives

This study has not provided sufficient data that can be used to determine long-term or cumulative impacts of offshore oil and gas platform development on reef or hard bottom associated fish species. The natural variability encountered within reef fish assemblages and the short duration of this study coupled with the prototype or experimental nature of the techniques employed here introduced too many unresolved variables into this data set, for reliable comparisons between platform and hard bottom stations to be made. In addition, there are a large number of factors other than oil and gas operations (e.g., platform age, water depth, and basal area; hard bottom area and relief) that probably influence abundance and distribution patterns, but those effects are very difficult to separate from those of oil and gas operations.

Stone et al. (1979) experimentally demonstrated that artificial reefs placed in close proximity (25 m) to natural reef patches do not diminish the resident populations of the natural reef. Within seven months, Stone et al. recorded approximately equal numbers of fishes and similar species compositions on both the artificial reef and the natural reef. They concluded, after two years of observations, that the artificial reef actually increased the fish biomass carrying capacity of the general area.

Extrapolating this concept to the northern Gulf of Mexico would suggest that the intensive OCS development activities which have taken place there may have increased the abundance and diversity of the ichthyocommunity present there. Quantitative data collected during Phase III suggest that the ichthyocommunities of the surveyed offshore oil and gas platforms differ in terms of abundance from that of the hard bottom site surveyed. There was a high degree of species overlap, however, between the hard bottom and platform fish communities. These differences in abundance and distribution patterns are probably related to water depth and other factors in addition to substrate.

5.4 Recommendations for Future Studies

1) Further study of the newly identified shallow water features and the deep water hard bottom feature (East Cameron Area, Block 293) needs to be considered to determine if they should be included under biological lease stipulations.

2) Further evaluations of the natural spatial and temporal variations in fish assemblages associated with hard bottom areas and platforms should be made. These evaluations would require short and long-term (hour, day, week, month, season, and year) observations at specific sites. Quantitative assessments of natural fluctuations are required before accurate impact assessments are possible.

3) Further study of the interactions between hard bottom and platform fish communities is needed. One item of critical concern in these studies should be defining the movement of fishes between hard bottom areas and platforms. The life stage (i.e., age, size, sex, reproductive state, etc.) of the fishes moving between hard bottom areas and platforms should also be determined. To test the hypothesis that placement and presence of an offshore structure do not reduce reef fish populations on neighboring hard bottom areas, a specific study should be designed. An area of study should be selected where a natural hard bottom site exists

and where there are plans for placement of an offshore structure in close proximity. Investigations should be conducted to assess the composition and abundance of the ichthyofauna prior to platform placement. A large number of fishes at the hard bottom site should be tagged just prior to positioning the platform. After platform placement, assessment techniques should be utilized to ascertain community successsion at both sites, via tracking tagged fishes.

4) Future studies utilizing ROVs for the censusing of deep water fish populations along the outer continental shelf or continental slope would include selection of vehicle, camera, and observation technique. The manufacturer, the vehicle, the operator (pilot), and the manufacturer's support and maintenance capabilities must all be evaluated in the vehicle selection. Camera selection depends on both the objectives of the study and the physical conditions likely to be encountered at the study site. The selection of operating technique would depend upon the objectives of the survey and the environmental conditions (e.g., currents, relief, size of structure, and water clarity) anticipated at the study area. Techniques range from those yielding only a qualitative species list to those yielding specific standing stock or biomass estimates.

Once these initial decisions have been made, an extensive period of shallow water (within scuba range) field testing should be undertaken to compare the remotely collected data with that of diver observations. When the investigators are satisfied that their remotely collected data either correspond to that of direct observation, or can be made to correspond through the use of specifically developed correction factors, the program may enter the deep water phase, which would involve only remotely corrected data. To evaluate ROV remote sensing methods for deep water fish community analysis, tests should be conducted to compare ROV and manned-submersible results.

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8.0 APPENDICES

APPENDIX A

ALPHABETICAL LIST OF COMMON AND SCIENTIFIC NAMES OF FISHES

APPENDIX A. ALPHABETICAL LIST OF COMMON AND SCIENTIFIC NAMES OF FISHES (AFTER ROBINS ET AL., 1980).

Common Name	Scientific Name
Almaco jack	Seriola rivoliana
Atlantic bumper	Chloroscombrus chrysurus
Atlantic croaker	Micropogonias undulatus
Atlantic moonfish	Vomer setapinnis
Atlantic spadefish	Chaetodipterus faber
Banded butterflyfish	Chaetodon striatus
Bar jack	Caranx ruber
Beaugregory	Pomacentrus leucostictus
Belted sandfish	Serranus subligarius
Bermuda chub	Kyphosus sectatrix
Bigeye	Priacanthus arenatus
Blackbar soldierfish	Myripristis jacobus
Blenny	Blenniidae
Blue angelfish	Holacanthus isabelita
Blue chromis	Chromis cyaneus
Bluefish	Pomatomus saltatrix
Bluehead	Thalassoma bifasciatum
Blue runner	Caranx crysos
Blue tang	Acanthurus coeruleus
Brown chromis	Chromis multilineatus
Cobia	Rachycentron canadum
Cocoa damselfish	Pomacentrus variabilis
Cottonwick	Haemulon melanurum
Creole-fish	Paranthias furcifer
Creole wrasse	Clepticus parrai
Crevalle jack	Caranx hippos
Cubbyu	Equetus umbrosus
Cubera snapper	Lutjanus cyanopterus
Doctorfish	Acanthurus chirurgus
French angelfish	Pomacanthus paru
Gafftopsail catfish	Bagre marinus
Gray triggerfish	Balistes capriscus
Great barracuda	Sphyraena barracuda
Greater amberjack	Seriola dumerili
Grouper	Mycteroperca sp.
Grunt	Haemulon sp.
Gulf toadfish	Opsanus beta
Lane snapper	Lutjanus synagris
Lemon shark	Negaprion brevirostris
Lookdown	Selene vomer
Mangrove snapper	Lutjanus griseus
Ocean triggerfish	Canthidermis sufflamen
Orangespotted filefish	Cantherhines pullus
Pigfish	Orthopristis chrysoptera
Pinfish	Lagodon rhomboides

APPENDIX A. (CONTINUED).

Common Name	Scientific Name
Porgy	*Calamus* sp.
Queen angelfish	*Holacanthus ciliaris*
Queen triggerfish	*Balistes vetula*
Rainbow runner	*Elagatis bipinnulata*
Red snapper	*Lutjanus campechanus*
Reef butterflyfish	*Chaetodon sedentarius*
Remora	*Remora remora*
Rock beauty	*Holacanthus tricolor*
Rock hind	*Epinephelus adscensionis*
Scamp	*Mycteroperca phenax*
Sergeant major	*Abudefduf saxatilis*
Sharpnose puffer	*Canthigaster rostrata*
Sheepshead	*Archosargus probatocephalus*
Smooth trunkfish	*Lactophrys triqueter*
Southern stingray	*Dasyatis americana*
Slippery dick	*Halichoeres bivittatus*
Squirrelfish	*Holocentrus ascensionis*
Spanish hogfish	*Bodianus rufus*
Spotfin butterflyfish	*Chaetodon ocellatus*
Spotfin hogfish	*Bodianus pulchellus*
Tomtate	*Haemulon aurolineatum*
Vermilion snapper	*Rhomboplites aurorubens*
Warsaw grouper	*Epinephelus nigritus*
Whitespotted soapfish	*Rypticus maculatus*
Yellow goatfish	*Mulloidichthys martinicus*
Yellowtail reeffish	*Chromis enchrysurus*

APPENDIX B

PHYLOGENETIC LISTING OF IDENTIFIED TAXA FROM PHASES I AND II

This appendix lists phyla, classes, orders, families, genera, and species in phylogenetic sequence. The following typing sequence was used in the arrangement of the groups:

Phylum
  Class - Subclass
    Order - Suborder
          - Section
      Family
        Genus, Species

Identifications based on collected specimens are denoted by the letter x. Occurrences based on *in situ* visual identifications are denoted by an asterisk (*).

<u>Shallow Hard Bottom Sites</u>

A East Cameron Area, Block 115, Hard Bottom

B East Cameron Area, Block 118, Hard Bottom

C East Cameron Area, Block 126, Hard Bottom

D East Cameron Area, Block 159, Hard Bottom

E East Cameron Area, Block 178, Hard Bottom

F East Cameron Area, Block 198, Leg Wreck

G Vermilion Area, Block 162, Hard Bottom

H Vermilion Area, Block 179, Hard Bottom

<u>Deep Hard Bottom Sites</u>

I East Cameron Area, Block 229, Hard Bottom

J East Cameron Area, Block 293, 29 Fathom Place

K Vermilion Area, Block 298, Sonnier Bank

<u>Shallow Platform Sites</u>

L West Cameron Area, Block 237, Platform "A"

M East Cameron Area, Block 118, Platform "B"

N East Cameron Area, Block 160, Platform "A"

O East Cameron Area, Block 195, Platform "A"

P Vermilion Area, Block 161, Platform "A"

Q Vermilion Area, Block 164, Platform "A"

R Vermilion Area, Block 182, Platform "A"

<u>Deep Platform Sites</u>

S East Cameron Area, Block 229, Platform "A"

T East Cameron Area, Block 231, Platform "A"

U East Cameron Area, Block 257, Platform "A"

V East Cameron Area, Block 286, Platform "A"

W Vermilion Area, Block 265, Platform "A"

X Vermilion Area, Block 287, Platform "A"

APPENDIX B. PHYLOGENETIC LIST OF IDENTIFIED TAXA FROM PHASES I AND II.

Taxon	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Porifera																								
Demospongia																								
Keratosa																								
Spongiidae																								
Ircinia sp.	–	–	–	–	*	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–
Haplosclerida																								
Haliclonidae																								
Haliclona (Reniera) aquaductus	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–
Niphates erecta	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
Adociidae																								
Adocia carbonaria	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
Strongylophora sp.	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–
Poecilosclerida																								
Agelasidae																								
Agelas clathrodes	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–
Mycalidae																								
Neofibularia nolitangere	–	–	–	–	–	–	–	–	–	*	*	–	–	–	–	–	–	–	–	–	–	–	–	–
Axinellida																								
Bubaridae																								
Bubaris mastophora	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cnidaria																								
Hydrozoa																								
Anthomedusae/Athecata																								
Eudendriidae																								
Eudendrium carneum	x	*	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–	–	–

APPENDIX B. (CONTINUED).

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Cnidaria (continued)																								
Leptomedusae/Thecata																								
Plumulariidae																								
Aglaophenia elongata	–	*	x	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sertulariidae																								
Sertularella sp.	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–
Hydrocoralline																								
Milleporidae																								
Millepora sp.	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–
Anthozoa																								
Octocorallia (Alcyonania)																								
Telestacea																								
Telestidae																								
Telesto riisei	*	–	–	–	–	*	–	*	*	–	–	–	–	–	*	*	–	x	x	*	*	*	*	*
Zoantharia (Hexacorallia)																								
Zoanthidae																								
Colonial Zoanthid	x	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Gorgonacea																								
Gorgoniidae																								
Lophogorgia hebes	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Leptogorgia virgulata	x	–	–	–	–	x	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–
Leptogorgia setacea	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Leptogorgia sp.	–	–	*	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scleractinia																								
Oculinidae																								
Oculina cf. *diffusa*	*	*	*	–	*	*	*	*	x	–	–	–	–	–	*	–	*	x	–	*	–	*	–	*

APPENDIX B. (CONTINUED).

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Anthozoa (continued)																								
Rhizangiidae																								
Phyllangia americana	-	-	-	-	*	*	-	x	-	-	-	*	-	-	-	-	-	x	-	-	*	x	*	-
Siderastreidae																								
Siderastrea radians	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Poritidae																								
Porites sp.	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Astrocoeniidae																								
Stephanocoenia sp.	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Antipatharia																								
Antipathidae																								
Cirrhipathes sp.	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Annelida																								
Polychaeta																								
Sabellida																								
Serpulidae																								
Filograna sp.	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spirobranchus giganteus	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	*	-	-	*	-
Amphinomida																								
Amphinomidae																								
Hermodice carunculata	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	*	-
Spionida																								
Chaetopteridae																								
Chaetopterus variopedatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-

APPENDIX B. (CONTINUED).

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Mollusca																								
Gastropoda - Prosobranchia																								
Archaeogastropoda																								
Fissurellidae																								
Diodora cayenensis	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbinidae																								
Astrea tecta tecta	-	-	-	-	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-
Mesogastropoda																								
Cerithiidae																								
Cerithium litteratum	-	-	-	-	-	-	-	-	-	-	x	-	x	-	-	-	-	x	-	-	-	-	-	-
Cypraeidae																								
Cypraea cervus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Ovulidae																								
Simnialena uniplicata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
Turritellidae																								
Vermicularia knorri	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Neogastropoda																								
Muricidae																								
Muricanthus fulvescens	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
Thaididae																								
Thais haemostoma canaliculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	x	x
Conidae																								
Conus ermineus	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX B. (CONTINUED).

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Mollusca (continued)																								
Bivalvia (Pelecypoda) -Pteriomorpha																								
Arcacea																								
Arcidae																								
Arca zebra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-
Barbatia candida	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	x	-	-	x	-	-
Mytilacea																								
Mytilidae																								
Lithophaga aristata	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
Lithophaga antillarum	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
Pinnacea																								
Pinnidae																								
Pinna carnea	-	-	-	-	-	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-
Pteriacea																								
Anomidae																								
Pododesmus rudis	-	-	-	-	x	-	-	-	-	-	x	-	x	-	-	-	-	-	-	-	-	x	-	-
Pteriidae																								
Pteria colymbus	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Pinctada imbricata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	x	x	x	-
Isognomonidae																								
Isognomon bicolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	-	-
Limidae																								
Lima scabra	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
Pectinacea																								
Spondylidae																								
Spondylus americanus	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	*	*	*	*

APPENDIX B. (CONTINUED).

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Mollusca (continued)																								
Anomiacea																								
Anomiidae																								
Anomia simplex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
Ostreacea																								
Ostreidae																								
Ostrea equestris	-	-	-	-	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
Lopha frons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
Heterodonta																								
Chamidae																								
Chama congregata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	x	x	-
Pseudochama radians	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	x	-	-
Arthropoda																								
Crustacea - Cirripedia																								
Thoraciea																								
Balanidae																								
Balanus amphitrite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
Xanthidae																								
Panopeus cf. *occidentalis*	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
Decapoda-Caridea																								
Synalpheus fritzmuelleri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
Decapoda-Macrura																								
Palinuridae																								
Panulirus argus	-	-	-	-	-	-	-	-	-	*	x	-	-	-	-	-	-	-	-	-	-	-	-	-
Decapoda-Brachyura																								
Majidae																								
Stenorhynchus seticornis	*	*	*	-	-	-	*	*	-	-	-	-	*	-	*	-	-	-	-	*	-	-	*	-

APPENDIX B. (CONTINUED).

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Bryozoa																								
Stenolaemata																								
Cyclostomata																								
Crissidae																								
Crisia elongata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
Crisulipora occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
Gymnolaemata																								
Cheilostomata																								
Membraniporidae																								
Membranipora savartii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
Bugulidae																								
Bugula neritina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
Hippoporinidae																								
Cleidochasma contractum	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petraliidae																								
Hippopetraliella marginata	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Celleporidae																								
Celleporaria cf. *albirostris*	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microporellidae																								
Microporella tractabilis	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eschanira pesaneris	x	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schizoporellidae																								
Smittinidae sp.	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stelleroidea-Ophiuroidea																								
Ophiuroida																								
Ophiactis savignyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
Ophiothrichidae																								
Ophiothrix angulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-

APPENDIX B. (CONTINUED).

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Echinodermata																								
Holothuroidea																								
Dendrochirotida																								
Isostichopus sp.	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Echinoidea																								
Cidaridae																								
Eucidaris tribuloides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
Diadematidae																								
Diadema antillarum	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	*	-	*	-	-
Arbaciidae																								
Arbacia punctulata	-	*	*	-	*	x	-	*	*	-	*	*	-	x	*	-	-	*	-	*	*	*	*	*
Stelleroidea-Asteroidea																								
Spinulosida																								
Echinasteridae																								
Echinaster sp.	-	-	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chordata-Urochordata																								
Ascidiacea																								
Distaplia bermudensis	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chordata-Cranista																								
Chondrichthyes																								
Squaliformes																								
Carcharhinidae																								
Negaprion brevirostris	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rajiformes																								
Dasyatidae																								
Dasyatis americana?	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX B. (CONTINUED).

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Osteichthyes																								
Beryciformes																								
Holocentridae																								
Holocentrus ascensionis	-	-	-	-	-	-	*	-	*	*	*	-	-	-	-	-	-	-	-	*	-	*	*	-
Myripristis jacobus	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Perciformes																								
Serranidae																								
Epinephelus adscensionis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	*	x	-	-	-	-	-
Mycteroperca phenax	-	-	-	-	-	-	-	-	*	-	*	*	-	*	*	*	*	*	*	*	*	-	*	-
Mycteroperca sp.	-	-	-	-	*	*	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Paranthias furcifer	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	*	-	*	-	-
Serranus subligarius	*	-	-	-	*	*	-	*	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-
Grammistidae																								
Rypticus maculatus	-	-	-	-	*	-	-	-	x	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-
Priacanthidae																								
Priacanthus arenatus	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
Pomatomidae																								
Pomatomus saltatrix	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	*	*	-	-	-	-	-	-	-
Rachycentridae																								
Rachycentron canadum	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	*	*	-	-	-	-
Echeneidae																								
Remora remora	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-

APPENDIX B. (CONTINUED).

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Osteichthyes (continued)																								
Carangidae																								
Caranx ruber	–	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–
Caranx crysos	*	–	–	–	*	*	–	–	–	–	*	*	*	*	*	*	*	*	x	*	*	*	*	*
Caranx hippos	–	–	–	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	*	*	–	*	–	–
Seriola dumerili	–	–	–	–	–	*	–	–	x	*	*	–	–	*	*	–	*	*	x	*	*	*	*	*
Seriola rivoliana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Elegatis bipinnulata	–	–	–	–	–	–	–	–	–	–	–	*	*	–	–	*	–	–	–	–	–	–	–	–
Vomer setapinnis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Selene vomer	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–
Lutjanidae																								
Lutjanus campechanus	*	x	*	–	*	*	*	*	–	*	–	*	*	*	*	*	*	*	x	–	–	*	–	–
Lutjanus cyanopterus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lutjanus synagris	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
Lutjanus griseus	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Rhomboplites aurorubens	–	–	*	–	–	*	–	–	*	*	*	–	–	–	*	–	–	*	x	*	*	*	*	–
Haemulidae																								
Haemulon aurolineatum	*	–	–	–	*	–	*	*	x	*	*	–	–	–	–	*	*	–	x	–	–	–	–	–
Haemulon melanurum	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Orthopristis chrysoptera	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sparidae																								
Lagodon rhomboides	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
Archosargus probatocephalus	*	*	–	–	–	–	–	–	–	–	–	*	*	*	*	*	*	*	*	–	–	–	–	–
Calamus sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–
Sciaenidae																								
Micropogon undulatus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Equetus umbrosus	–	–	*	–	*	–	–	*	x	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–
Mullidae																								
Mulloidichthys martinicus	–	–	–	–	–	–	–	–	–	–	*	–	–	–	–	–	–	–	–	–	–	–	–	–

APPENDIX B. (CONTINUED).

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Osteichthyes (continued)																								
Kyphosidae																								
Kyphosus sectatrix	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	*	*	-	-
Ephippidae																								
Chaetodipterus faber	*	*	*	-	-	-	*	-	*	-	-	*	*	*	*	*	*	*	*	-	*	*	*	-
Chaetodontidae																								
Chaetodon ocellatus	-	-	-	-	-	-	-	-	*	*	*	-	-	*	*	-	-	*	-	*	-	-	-	-
Chaetodon sedentarius	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	*	-
Chaetodon striatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacanthidae																								
Holacanthus isabelita	-	-	-	-	-	-	-	-	*	*	*	-	-	-	*	-	-	*	*	*	*	*	*	-
Holacanthus ciliaris	-	-	-	-	-	-	-	-	*	*	*	-	-	-	-	-	-	-	-	-	*	-	-	-
Holacanthus tricolor	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacanthus paru	-	-	-	-	-	-	-	-	*	*	*	-	-	-	-	-	-	-	-	*	*	*	*	-
Pomacentridae																								
Abudefduf saxatilis	-	-	-	-	-	-	-	-	-	-	*	*	*	*	*	-	-	-	*	*	*	*	*	-
Chromis cyaneus	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromis multilineatus	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	*	-	-
Chromis enchrysura	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentrus leucostictus	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentrus variabilis	-	*	-	-	*	-	-	-	*	*	*	*	*	*	*	*	*	*	x	*	-	*	*	-
Labridae																								
Bodianus pulchellus	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bodianus rufus	-	-	-	-	-	-	-	-	*	*	*	-	-	-	-	-	-	-	*	-	*	*	-	-
Clepticus parrai	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Thalassoma bifasciatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres bivittatus	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraenidae																								
Sphyraena barracuda	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	*	-	-	-	-	*	-	*	-
Blenniidae																								
Blennius sp.	-	-	-	-	-	-	-	-	-	-	*	*	-	*	-	*	-	*	-	*	*	-	-	*

	Shallow Hard Bottom Sites								Deep Hard Bottom Sites			Shallow Platform Sites							Deep Platform Sites					
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Osteichthyes (continued)																								
Acanthuridae																								
Acanthurus chirurgus	-	-	-	-	-	-	-	-	*	-	*	-	-	-	*	-	-	*	-	*	*	*	*	*
Acanthurus coeruleus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	*	*	-
Tetraodontiformes																								
Balistidae																								
Balistes capriscus	*	-	*	-	-	*	*	*	x	-	-	*	-	*	*	*	*	*	x	*	*	*	*	*
Cantherhines pullus	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	*	-	-
Canthidermis sufflamen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ostraciidae																								
Lactophrys triqueter	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
Tetraodontidae																								
Canthigaster rostrata	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	*	-

APPENDIX C

PHYLOGENETIC LISTING OF FISHES IDENTIFIED DURING PHASE III

This appendix lists classes, orders, families, genera, and species of fishes in phylogenetic sequence. The following typing sequence was used in the arrangement of the groups:

Class
  Order
    Family
      Genus, Species

Identifications based on collected species are denoted by the letter x. Occurrences based only on *in situ* visual identifications are denoted by an asterisk (*). Sites surveyed include:

Vermilion Area, Block 179, Hard Bottom (VR179HB)
Vermilion Area, Block 164, Platform "A" (VR164PA)
Vermilion Area, Block 161, Platform "A" (VR161PA)
Vermilion Area, Block 201, Platform "A" (VR201PA)
East Cameron Area, Block 195, Platform "B" (EC195PB)
Vermilion Area, Block 298, Hard Bottom, Sonnier Bank (VR298HB)

APPENDIX C. PHYLOGENETIC LISTING OF FISHES IDENTIFIED DURING PHASE III.

	Shallow Hard Bottom Site	Shallow Platform Sites				Deep Hard Bottom Site
	VR179HB	VR164PA	VR161PA	VR201PA	EC195PB	VR298HB Sonnier Bank
Osteichthyes						
Siluriformes						
Ariidae						
Bagre marinus	–	x	x	–	–	–
Batrachoidiformes						
Batrachoidea						
Opsanus beta	–	–	–	*	–	–
Beryciformes						
Holocentridae						
Holocentrus ascensionis	–	–	–	–	–	*
Myripristis jacobus	–	–	–	–	–	*
Perciformes						
Serranidae						
Epinephelus nigritus	–	–	*	–	–	–
Mycteroperca phenax	–	*	*	–	*	*
Paranthias furcifer	–	–	–	–	–	*
Grammistidae						
Rypticus maculatus	–	–	–	x	–	–
Priacanthidae						
Priacanthus arenatus	–	–	–	–	–	*
Pomatomidae						
Pomatomus saltatrix	–	–	*	–	–	–
Rachycentridae						
Rachycentron canadum	–	*	*	–	–	–
Carangidae						
Chloroscombrus chrysurus	–	*	*	–	–	–
Caranx ruber	–	–	–	*	–	–
Caranx crysos	*	*	*	*	*	*
Caranx hippos	–	–	*	–	*	*
Seriola dumerili	–	*	*	*	*	*

APPENDIX C. (CONTINUED).

	Shallow Hard Bottom Site	Shallow Platform Sites				Deep Hard Bottom Site
	VR179HB	VR164PA	VR161PA	VR201PA	EC195PB	VR298HB Sonnier Bank
Osteichthyes (continued)						
Seriola rivoliana	-	-	*	*	*	-
Elagatis bipinnulata	-	-	*	-	*	*
Decapterus punctatus	-	*	-	*	-	-
Vomer setapinnis	-	*	*	-	-	-
Lutjanidae						
Lutjanus campechanus	x	*	*	x	-	-
Lutjanus synagris	-	x	x	x	-	-
Rhomboplites aurorubens	-	-	-	*	*	x
Haemulidae						
Haemulon aurolineatum	x	*	x	x	-	x
Haemulon melanurum	-	-	-	-	-	*
Orthopristis chrysoptera	-	*	x	-	-	-
Sparidae						
Archosargus probatocephalus	-	*	x	*	-	-
Calamus sp.	-	-	-	-	-	*
Lagodon rhomboides	-	-	-	x	-	-
Sciaenidae						
Micropogon undulatus	x	x	x	-	*	-
Equetus umbrosus	x	-	-	-	-	-
Kyphosidae						
Kyphosus sectatrix	-	-	*	*	*	*
Ephippidae						
Chaetodipterus faber	x	*	*	x	*	-
Chaetodontidae						
Chaetodon ocellatus	-	-	-	x	-	x
Chaetodon sedentarius	-	*	-	*	*	x
Pomacanthidae						
Holacanthus isabelita	-	*	-	-	-	*
Holacanthus ciliaris	-	-	-	-	-	*
Holacanthus tricolor	-	-	-	-	-	*
Pomacanthus paru	-	-	-	-	-	*

APPENDIX C. (CONTINUED).

	Shallow Hard Bottom Site	Shallow Platform Sites				Deep Hard Bottom Site
	VR179HB	VR164PA	VR161PA	VR201PA	EC195PB	VR298HB Sonnier Bank
Osteichthyes (continued)						
Pomacentridae						
Abudefduf saxatilis	-	*	-	*	*	*
Chromis multilineatus	-	-	-	-	-	*
Chromis enchrysurus	-	-	-	-	-	*
Pomacentrus variabilis	-	*	-	*	*	*
Labridae						
Bodianus pulchellus	-	-	-	-	-	x
Bodianus rufus	-	-	-	-	-	*
Thalassoma bifasciatum	-	-	-	-	-	*
Sphyraenidae						
Sphyraena barracuda	-	*	-	*	*	*
Acanthuridae						
Acanthurus chirurgus	-	-	-	-	*	*
Acanthurus coeruleus	-	-	-	-	*	-
Tetraodontiformes						
Balistidae						
Balistes capriscus	-	*	*	x	*	-
Canthidermis sufflamen	-	-	-	-	-	*

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.