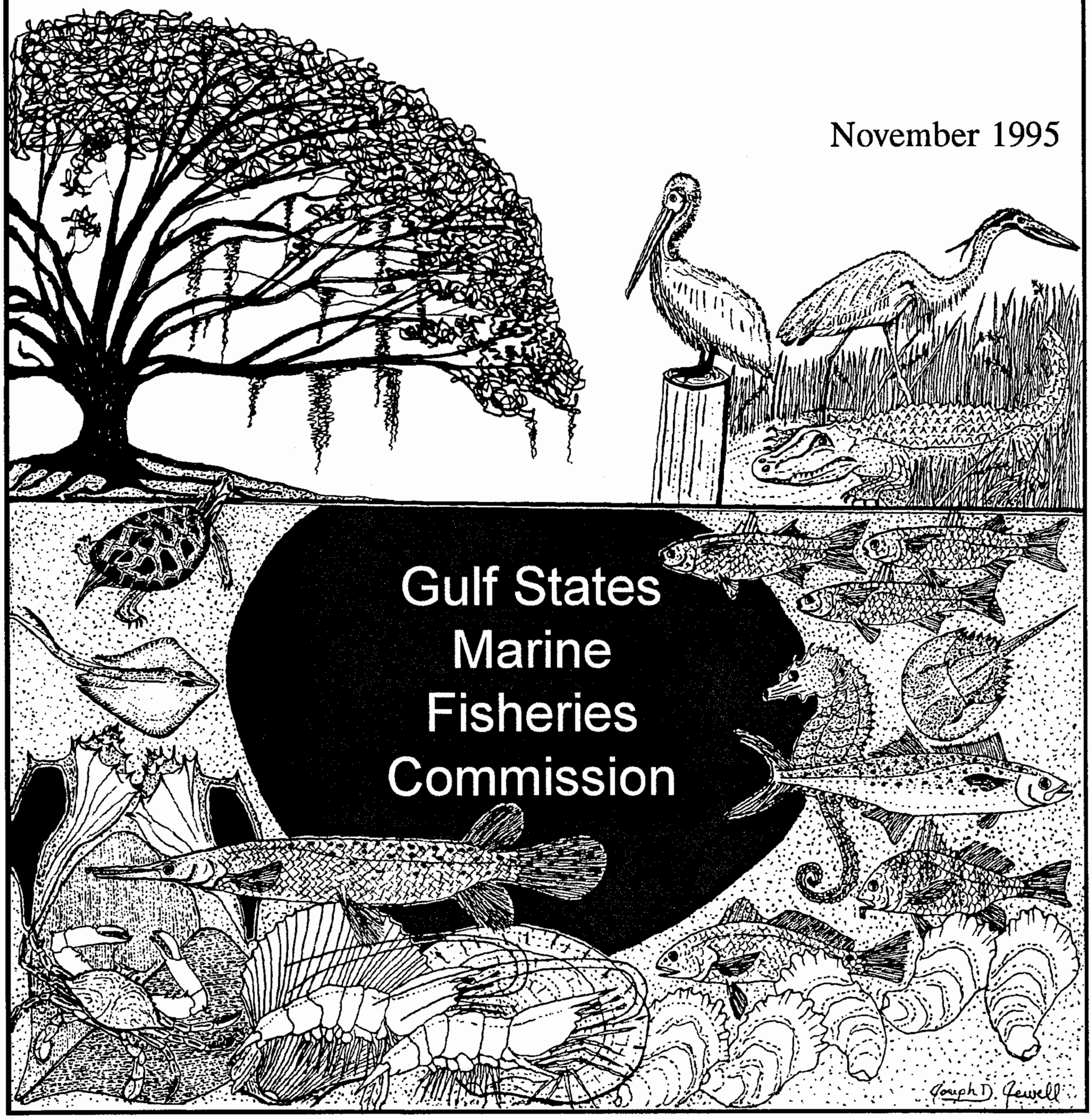
# PROCCEEDINGS OF THE REEF FISH WORKSHOP

## FOR

## THE SOUTHEAST AREA MONITORING AND ASSESSMENT PROGRAM (SEAMAP)

November 1995



# PROCEEDINGS OF THE 1995 SEAMAP REEF FISH WORKSHOP AT GRAND TERRE, LOUISIANA

By: SEAMAP Reef Fish Work Group

Gulf States Marine Fisheries Commission
Ocean Springs, Mississippi

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# ACKNOWLEDGEMENTS

The SEAMAP extends its sincere gratitude to the staff of the Louisiana Department of Wildlife and Fisheries for graciously hosting this workshop and providing the use of their facility on Grand Terre Island. In additon, appreciation is gratefully extended to all of the invited speakers who presented at the workshop for their time and effort.

# INTRODUCTION

The Southeast Area Monitoring and Assessment Program (SEAMAP) is a State/Federal/university program for collection, management and dissemination of fishery-independent data and information in the southeastern United States. The program presently consists of three operational components, SEAMAP-Gulf of Mexico, which began in 1981, SEAMAP-South Atlantic, implemented in 1983 and SEAMAP-Caribbean, formed in 1988.

The SEAMAP has been conducting a spring reef fish survey for several years. Vessels from various agencies sample inshore and offshore waters at randomly selected sites from Brownsville, Texas to Key West, Florida. These sites are chosen from known natural hard bottom locations. Data is collected using the trap/video methodology where a fish trap containing a video camera is deployed onto the selected reef site which records all fish within the camera's range. However, this methodology does not allow for sampling of verticially-distributed habitat.

Therefore, the SEAMAP Reef Fish Work Group sponsored a workshop concerning sampling artificial, vertically-distributed habitat (oil and gas structures) in the Gulf of Mexico. The workshop was conducted April 25 - 26, 1995 at the Louisiana Department of Wildlife and Fisheries' Lyles St. Amant Marine Laboratory on Grand Terre Island, Louisiana. The workshop consisted of presentations from invited speakers regarding their work as it pertained to sampling of oil and gas structures and group discussions to formulate some recommendations concerning this type of sampling. The presentations provided very useful information concerning the different methodologies for sampling these structures as well as providing necessary details regarding data needs for conducting assessments, physical processes which occur around rigs, and the types of gear which can be used to sample these platforms. In addition, the recommendations formulated by the group will provide guidance for the NMFS and SEAMAP for the development of a sampling methodology of oil and gas structures.

This document provides a summary of the presentations that were given at the workshop and presents the recommendations developed by the group concering sampling oil and gas structures in the Gulf of Mexico.

# AN INDICATION OF THE PROCESS: OFFSHORE PLATFORMS AS ARTIFICIAL REEFS IN THE GULF OF MEXICO[1]

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## ABSTRACT

Fish and biofouling communities at three artificial reef sites in the Gulf of Mexico were monitored from 1989 through 1991. South Timbalier Block 86 Platform A (86-A) was toppled by a hurricane in 1985; South Timbalier Block 128 Platform A (128-A) was detonated and toppled in place in fall of 1988; and South Timbalier Block 134 Platform D (134-D) was detonated, towed, and deployed in 1991 about 30 m from 128-A. The results of a 1989 survey of fishes and invertebrates at 86-A and at 128-A suggested that the communities were more mature at 86-A. The predominance of immature fish and the paucity of adults of those same species on 128-A indicated that this artificial reef was acting as a recruitment site. Observations in 1990 at 86-A were essentially the same as those of 1989, while the communities at 128-A showed a greater diversity and maturity; however, both communities exhibited a decrease in octocoral biomass. Observations in 1991 at 86-A were essentially the same as those of 1989 and 1990, while the communities at 128-A continued to show further development. A large number of immature fish and a pioneering biofouling community at 134-D were comparable to the 1989 observations made at 128-A. Further, adult reef-dependent species were observed moving freely between 128-A and 134-D. Observations made in 1989 at 86-A and 128-A suggest that differences were related to the manner by which each structure was toppled and the length of time each had remained undisturbed; differences observed between 1989 and 1990 were related to time undisturbed and meteorological conditions of the winter of 1989; and differences recorded between 1990 and 1991 were related to continued diversification and maturation of the community at 128-A. Observations made in 1991 at 128-A and 134-D suggest that 134-D acted as a recruitment reef as well as part of a reef complex for adult reef-dependent species moving between the adjacent structures.

## INTRODUCTION

There are approximately 3,700 oil and gas production platforms in Federal waters of the Gulf of Mexico. Production platforms are set in place by driving steel support legs (piles) deep into the seafloor. Working machinery and personnel sit above the water supported by a steel network (jacket) that is intentionally overbuilt and remarkably secure (Gallaway and Lewbel, 1982). However, offshore structures are not intended to be permanent. When production ceases, they must be removed. Platforms may be relocated for re-use, removed and scrapped, or used as artificial reefs. In the last few years the practice of converting obsolete offshore structures to artificial reefs has gathered broad public and private support; both Louisiana and Texas have legislated State programs to convert obsolete offshore structures to artificial reefs.

Despite the support for artificial reefs, opinions regarding their effects remain divided. Do artificial reefs result in an actual biomass increase, or do they simply redistribute fish populations? If artificial reefs function mainly as aggregators, concentrating otherwise naturally dispersed fish stocks, extensive reef deployment coupled with unmanaged fishing could lower fisheries production. However, if they

[1]Reprinted by permission from Edward Richards, editor, Bulletin of Marine Sciences.

serve as additional substrate in a habitat-limited environment, extensive reef development could increase production.

It is likely that platforms in the north-central Gulf of Mexico are in some manner influencing fishery resources. However, information is inadequate as to the nature and extent of this influence. Since there are few natural reefs in the north-central Gulf, the controversy regarding natural versus artificial reefs may not be germane to the issue. However, fundamental knowledge is lacking on the mechanisms of standing platforms as *de facto* reefs or on obsolete platforms used as artificial reefs.

The oil and gas platforms in the Gulf of Mexico present numerous opportunities for study. Most platforms are operated by responsible companies willing to assist in research efforts. All platforms have electrical power, refuge from weather, a stable deck, an established supply network, and are secure both above and below the surface (Bull, 1989).

It has taken decades and billions of dollars to establish this network of study opportunities. However, to our knowledge, there is but one ongoing study planned to acquire basic information regarding the function of platforms as *de facto* reefs. Until quantitative studies of repetitive regularity are performed, information regarding communities associated with any platform or artificial reef will be of a qualitative nature.

During the summers of 1989, 1990, and 1991, we had the opportunity to assess the fish and invertebrate communities of three artificial reefs at two locations in the Gulf of Mexico approximately 7 mi apart (Figures 1 and 2). South Timbalier Block 86 Platform A (86-A) and South Timbalier Block 128 Platform A (128-A) included the entire above- and below-water sections of previously standing platforms; South Timbalier Block 134 Platform D (134-D) included only the below-water sections.

In October 1985, 86-A which had been completely shut down during the 20th year of active production, was knocked over during Hurricane Juan. In September 1988, 128-A was retired, severed by use of explosives 5 m below the seafloor, and toppled in place. In 1991, 134-D was severed with explosives, towed, and placed within 30 m of 128-A (Figure 2).

The objectives of this study were to evaluate, document, and compare the fish and biofouling communities at these sites in order to assess qualitatively their function as artificial reefs.

## METHODS

Surveys of the fish communities at 86-A, 128-A, and 134-D were conducted using a stationary visual census technique for fishes (Bohnsack and Bannerot, 1986) and macrophotography for the biofouling community. Fish surveys were performed with the diver remaining stationary while listing and then counting the fishes within a horizontal range of vision. Although this method is customarily used to gather quantitative data, poor visibility at all study sites made quantification unreliable. Additional information noted during fish identification included depth, temperature, approximate lifestage/size, and behavior. The macrophotography set-up consisted of a Nikonos IV-A underwater camera and 35-mm lens, an Oceanic Model 2000 underwater strobe, and 1:2 and 1:3 extension tubes complete with framers. Components of the biofouling communities were identified from these photographs.

### South Timbalier Block 86 Platform A

At least six dives per summer from 1989 through 1991 were made at the South Timbalier Block 86 Platform A site. Recordings of fish and invertebrate communities were always hampered by very poor visibility at this location (Figure 3). Macrophotography and a qualitative survey of the fishes were completed on the same day, or the following day, after the observations were completed at 128-A.

### South Timbalier Block 128 Platform A

Fish and invertebrate distributions, densities, and diversities data were gathered during at least 12 dives per summer from 1989 through 1991 at South Timbalier Block 128 Platform A. During the first dives of any day, surveys of fishes were performed around the deck area and then from the deck along the length of the jacket towards the base of the piles (Figure 4). During subsequent dives, a concerted effort was made to survey the fishes, and photographs were taken to document the biofouling community along the entire length of a single inner leg. The

1989 effort was the first attempt to observe and record the biota of this artificial reef since it was toppled in place in 1988.

South Timbalier Block 134 Platform D

Fish and invertebrate distributions, densities, and diversities data were gathered during six dives at South Timbalier Block 134 Platform D in 1991. To assist in the logistics, a line approximately 30 m in length was attached between a central point on the eastern side of 128-A and western side of 134-D. A concerted effort was made to survey the fishes and invertebrates along the entire length of a single inner leg of the structure.

## RESULTS

### Invertebrate Biofouling Communities

Barnacles were the most conspicuous component of the 86-A, 128-A, and 134-D biofouling communities during all years of observation; however, a significant proportion of these were dead. While the cause of the mortality is unknown, the clearance of 86-A, 128-A, and 134-D from the surface was approximately 14, 18, and 18 m, respectively.

In 1989, hundreds of Atlantic winged oysters (*Pteria colymbus*) and many colonies of the octocoral *Carijoa (Telesto) riisei* were documented on 128-A. Colonies of *C. riisei* measured up to 30 cm in width. Colonies of the flower coral *Eusmilia fastigiata* and the orange tube coral *Tubastrea coccinea* were found at 86-A. In 1990, pencil urchins, the common Atlantic sea urchin *Arbacia punctulata*, and a few juvenile lobsters were also observed at 128-A; however, none of the Atlantic winged oysters were found and there were noticeably fewer live barnacles at depth. In 1991, there was an even greater diversity at 128-A including a number of different species of anemones; two species of gorgonian octocoral (tentatively identified as *Leptogorgia virgulata* and *Lophogorgia hebes*), gastropods (e.g., *Murex* sp. and *Thais haemastoma*), and the flower coral (*E. fastigiata*). Gastropod egg cases were also found in abundance; these reproductive structures are commonly observed on standing OCS platforms throughout the area. Scattered colonies of the flat tunicate, *Botrylloides nigrum*, and patches of small colonial white anemones were also widespread covering both live and dead barnacles. In 1991, the ivory bush coral, *Oculina diffusa*, was found only on 86-A, while the hidden cup coral, *Phyllangia americana*, was found on both 86-A and 128-A.

Observations made at 134-D in 1991 revealed large areas of bare metal indicative of explosive removal. The rather sparse sessile community was dominated by a number of different hydroids, colonies of the flat tunicate *B. nigrum*, small colonies of the octocoral *C. riisei*, small patches of colonial white anemones, scattered encrusting sponge colonies, and small common Atlantic sea urchins *A. punctulata*.

### Fish Communities

In 1989, the majority of the fish at 128-A were juveniles or young adults (1,2, or possibly 3 years of age). All fish species observed at 86-A were adult (3+ years), excluding immature cocoa damselfish (*Pomacaentrus variabilis*) and blennies, which were present at both 86-A and 128-A. The condition at 128-A was exceptional in that numerous immature groupers and snappers were present. In addition, of those few adult finfish species observed at 128-A, no immature of the same species were observed with the exception of blennies. Fewer immature blennies were observed at 86-A than at 128-A. At least one pair of adult cocoa damselfish was observed on 86-A.

The fish population at 128-A in 1990 appeared to be a mixture of species composed entirely of either adults or juveniles. The French angelfish (*Pomacanthus paru*) was the only species represented by both adults and juveniles. No YOY were observed and some species observed in 1989 were not seen in 1990 and vice versa. Comparison with 1989 data showed an increase in species richness with expansion into tropical and pelagic types as well as augmentation of reef-related species. Reef-related species such as cocoa damselfish (*P. variabilis*), red snapper (*Lutjanus campechanus*), and grouper were all juveniles. Some reef-related species such as cubera snapper (*L. cyanoptus*), scorpion fish (*Scorpaena* sp.), and nurse sharks (*Ginglymostoma cirratum*) were fully grown adults. Pelagic species included African pompano (*Alectis ciliaris*), crevalle jack (*Caranx hippos*), and Spanish mackerel (*Scomberomerus maculatus*).

The 1991 observations at 128-A suggested community maturation with a substantial increase in species richness and abundance. The fish population was a mixture of species each composed of juveniles, young adults, or adults. Comparison with 1989 and 1990 data showed an expansion into pelagic and reef-related types. Additional reef-related species including bigeye (*Priacanthus arenatus*), whitespotted soapfish (*Rypticus maculatus*), spotfin butterflyfish (*Chaetodon ocellatus*), and nurse sharks (*G. cirratum*) were fully grown adults.

Except for immature cocoa damselfish (*P. varabilis*), blennies, and a small school of juvenile yellowtail reeffish (*Chromis enchrysura*) observed during the summer of 1991 on 86-A, all fish observed were adult including flamefish (*Apogon maculatus*) and red grouper (*Epinephelus morio*).

Impressions of 134-D were prominent since comparisons between 128-A and 134-D could be made during the same day and often the same dive. The 1991 fish community at 134-D initially appeared depauperate. Closer inspection revealed conditions similar to those observed at 128-A in 1989. The majority of resident fishes at 134-D were YOY or immature. A number of grouper species, all YOY, were observed tucked away in nooks and crannies. A bundle of snagged rope about 1 m in diameter provided the necessary cover for numerous YOY Spanish hogfish (*Bodianus rufus*) and several immature reef butterflyfish (*Chaetodon sedentarius*). At least two species of wrasse were represented by abundant immature specimens, while a single adult bluehead wrasse (*Thalassoma bifasciatum*) was observed at 128-A. A large number of 2- to 3-year-old red snapper (*L. campechanus*) appeared to move freely between 128-A and 134-D. The only pelagic species observed at 134-D was a school of juvenile greater amberjack (*Seriola dumerili*).

## DISCUSSION

In the case of 128-A and 134-D, the use of explosives fatally concussed most of the adult fishes and certainly all of the demersal fish species associated with the platform (Bull and Kendall, 1992). At least 100 platforms per year are removed from the Gulf of Mexico. About 80 percent of these removals use explosive charges placed approximately 5 m beneath the seafloor to sever the well conductors, platform anchor pilings, and support legs (USDOI, 1987). First the conductors are severed, pulled out, and salvaged. Then the pilings and support legs are severed and the remaining subsea structure pulled free, salvaged or, as here, deployed as an artificial reef.

Direct observations by Bull and Kendall (1992) of three explosive platform removals revealed that the first detonation(s) kill(s) the most fish. After conductor detonation(s), areas of approximately 2 m in radius around their bases were littered with dead fishes, pieces of barnacles, sponges, and other biota. After the pilings were detonated, many of the fishes that had been killed previously by the conductor blast(s) were found on the bottom covered with chunks of barnacles and layers of sediment.

An underwater explosion generates a direct shock pulse as a compression wave (Connor, 1990; Regalbuto *et al.*, 1977). This direct shock strikes the water's surface and reflects back as a rarefaction decompression wave. The initial compression wave appears to concuss and traumatize mortally the internal organs of fish closest to the explosion. In addition, the combination of the compression and decompression waves apparently creates sufficient pressure gradients first to pressurize gas in the swimbladder and then expands it to the point of outward rupture. Fish higher in the water column, and thus farther from the direct explosive shock wave, experience varying degrees of concussion. However, these same fish are closer to the decompression wave, which upon reflection from the surface generates expansion of gas in their swimbladder and causes them to float.

During the toppling of 128-A, it was observed that the vibrations from the blasts ran upward through the vertical support piles, dislodging most of the biofouling community (Bull, personal communication, 1992). Bull and Kendall (1992) observed that approximately 60 percent of the biofouling communities were knocked off structures following detonations. Effects were most pronounced along the piles and conductors within which the charges were actually placed. In many instances, piles and conductors were almost entirely cleared of their fouling biota with only remnants of the initial stages of community development remaining on the bare and bryozoans long since overgrown. The premise that explosive removals may be quite destructive to biofouling organisms is further supported by the 1989 observations at 128-A of hundreds of newly settled *P. colymbus* and colonies of *C. riisei*. Both species require a clear, unobstructed area for settlement.

These impacts became less apparent away from the centers of shock (i.e., piles and conductors). For example, where supporting, horizontal cross-members joined with the piles, the metal was almost entirely cleared. However, 2-3 m away from these junctures, more of the communities survived. Towards the middle of some of the longest horizontals most, if not all, of the fouling community remained intact with the only obvious impact being that some of the larger blennies were stunned and could be handled. These survivors supported the findings of Young (1991) that marine organisms without swim bladders are much more resistant to explosive shock.

Judgment concerning hurricane versus explosive removal damage and biotic destruction was recently supported by observations made just after Hurricane Andrew struck offshore Louisiana on August 26, 1992. Ten days following the hurricane, the junior author made an inspection of an OCS 8-pile production platform located offshore Louisiana in approximately 100 m of water. The platform suffered structural damage from the surface to approximately 15 m depth. At 15 m, the welds where six horizontal cross-members supported a multiple collar conductor bay were broken and the bay itself listed. While the damage to the structure was striking, there was little damage to the biotic community. The community appeared relatively intact; in fact, just inside one of the broken welds, a sergeant major (*Abudefduf saxatilis*) was found guarding a nest of eggs. Since the area surrounding the nest was aseptic bare metal, it was concluded that this area was not available to any form of fouling (or nesting) until after the hurricane induced break.

The biofouling communities typical of offshore structures in the Gulf of Mexico have been described by Gallaway *et al.* (1979). In the coastal waters (0-30 m) of Louisiana, these communities are dominated from the surface to a depth of about 8 m by small acorn barnacles (*Balanas amphitrite* and *B. improvisus*). This almost continuous mat of barnacles is then, in turn, covered by a mat of macroalgae, hydroids, bryozoans, and encrusting sponges. The actual species composition of this secondary mat depends largely upon turbidity and the season. At deeper depths (> 8 m), and often in more turbid waters, hydroids dominate (Gallaway, 1981).

Depths beyond 18 m are greater than that suggested for a community dominated by live barnacles (Gallaway et al., 1979). As such, the histories of these structures suggest the drowned remnants of barnacle communities growing at shallower depths when the structures were intact. These remnant communities now function as shelters for many small, motile and semimotile animals living on or within them. Many motile (e.g., blennies) and semimotile (e.g., sea urchins) animals depend upon these refuges for protection from strong currents and predators, and as tranquil areas where detritus and other food materials settle out (Gallaway and Lewbel, 1982). Gallaway and Martin (1980) identified barnacle molts as a dominant food source of the crested blenny, *Hypleurochilus geminatus*. Barnacle flesh may also become available when bits are left attached to the crushed plates as a result of the feeding of large grazers (Gallaway and Lewbel, 1982). Blennies brood their eggs inside barnacle shells in the late spring and protect their young for a short period after hatching. It was unexpected that on 128-A barnacles and blennies would be living at depths of 18-20 m when they normally occupy the top 6 m beneath a standing platform (Gallaway et al., 1979).

Hydroids are an important component of the fouling mat of Louisiana OCS structures. Gallaway (1981) reported 12 species from four Louisiana platforms. Hydroids are effective, rapid colonizers of bare substrate and are capable of overgrowing competitors (Gallaway and Lewbel, 1982). Fotheringham (1981) reported that hydroids made effective use of experimentally cleared substrate, settling early and overgrowing other settlers such as sponges.

The biofouling communities of 86-A, 128-A, and 134-D can be discussed in terms of the sequences of reef development (Schuhmacher, 1977). The encrustations of barnacles, bryozoans, colonial tunicates, and filamentous algae found on 86-A and 128-A in 1989 may be considered remnants of the initial stages of reef development: the rapid and homogeneous colonization by predominantly noncalcareous fouling organisms. The second stage of reef development is the settling of mollusks, calcareous red algae, and foraminiferans not affected by grazing organisms, which often largely consume the initial settlers and subsequently attaching larvae. The colonizing organisms may include oysters, calcareous algae, and foraminiferans. Atlantic winged oysters were observed at 128-A, and calcareous algae were widely abundant at both 86-A and 128-A.

The growth of scleractinian and hydro-corals on the remains of attached shells, or on other places often inaccessible to grazers, characterizes the third stage in this sequence. While Gallaway and Lewbel (1982) consider the scleractinian corals (as well as octocorals) conspicuous but numerically unimportant on Gulf of Mexico platforms, a decade later the increase in the number of environmentally concerned/aware sport divers visiting these structures, as well as the corals' ecological significance in terms of reef development warrant their discussion here. The scleratinian corals we observed included the flower coral *E. fastigiata*; the orange tube coral *T. coccinea*; the ivory bush coral *O. diffusa*; and the hidden cup coral *P. americana*.

*T. coccinea* is known to colonize and thrive in "shady" areas (Kaplan, 1982). The ability to exist in shade may result partially from their lack of, or independence from, zooxanthellae, the endosymbiotic dinoflagellate algae upon which hermatypic (reef-building) corals depend. *O. diffusa* is considered an ahermatypic coral occurring in a variety of shallow-water habitants on reefs, including lagoonal, back reef, and sloping bottoms (Colin, 1978). A significant feature of *O. diffusa* allowing it to survive offshore Louisiana is its tolerance to high turbidity and sedimentation. *P. americana* is a small ahermatypic coral found in small groups of polyps often partly connected. Polyps are typically 10 mm in diameter by 10 mm in height (Colin, 1978). They are typically found in secluded areas under ledges and rocks. *P. americana* is a shallow water species known from 0.3 to 17 m and has been recorded from southern Florida to the southern Caribbean (Colin, 1978) and from a number of OCS structures in the northwestern Gulf of Mexico (Gallaway and Lewbel, 1982).

The final stage of reef development is characterized by dead coral colonies overgrown by calcareous foraminiferans, algae, and bryozoans consolidating the coralline structures by their deposits. These species are often followed by the recruitment and growth of more massive hermatypic coral species. While hermatypic corals have been documented growing on offshore structures, particularly on the outer shelf (Bull, personal communication, 1992), the water quality of coastal Louisiana is not conducive to their development. This area is heavily influenced by the discharge of the Mississippi River, resulting in high primary productivity and high zooplankton consumption, frequent periods of high turbidity, and even fluctuations of the physicochemical parameters.

Corals are relatively sensitive to many environmental perturbations (Jaap, 1979; Loya and Rinkevich, 1980). The effects of turbidity have been widely studied and have been implicated as a prime cause of decreased growth (e.g., Aller and Dodge, 1974; Loya, 1976; Kendall *et al.*, 1985). However, in the Caribbean, the octocoral *C. riisei* is known to grow readily on pilings in many harbor areas and may be the only octocoral of any significance as a fouling organism. Where it is found growing on reefs, it is usually in more turbid environments. These conditions are not unlike those encountered at 86-A and 128-A.

The skeleton of the octocoral *C. riisei* is a rather rigid structure composed of spicules of calcium carbonate imbedded in a horny material. This skeleton is then often colonized by a variety of other organisms. This additional relief can then be utilized as habitat by a host of other organisms. These associated biota may be involved in various biotic interactions similar to those reported for coral reef environments. While this analogy may seem extreme to some, it is a convenient reference for analyzing the community composition and interactions occurring on these artificial reefs. For example, the establishment of algal patches by damselfish, at the expense of hermatypic corals, is a common occurrence on coral reefs (Kendall and Bright, 1989). The lush communities of algae are believed to suppress the growth of corals through a reduction in available free space for recruitment and expansion.

Coral mortality within these patches may result from algal overgrowth, increased sedimentation, and a persistent biting by the resident damselfish (Potts, 1977). While such territories develop at the expense of other organisms, they do function as centers of primary productivity (Brawley and Adey, 1977). They also provide infaunal organisms safe refuge and protection from carnivores. The diversity and abundance of small motile invertebrates have been found to be significantly greater in such patches than in nearby nonalgal areas (Lobel, 1980).

High fish abundances often occur at artificial reefs. There are several factors that are important for artificial reefs to attract fish successfully and/or increase local fishery biomass. Artificial reefs must attract and retain fish from other reefs or attract settling fish larvae to increase production. It is well known that fish have an innate, positive attraction to underwater structures (thigmotropism). Pre-settlement larvae may be attracted in response to physical, chemical, and biological stimuli. Juvenile and young adult reef-dependent species (e.g., snapper, grouper, and damselfish) may recruit in response to sensory stimuli, insufficient food, or shelter. Ocean pelagic species use the vertical relief as a visual cue for their transient movements (Gallaway and Lewbel, 1982).

Bohnsack (1989) concluded that the presence of artificial reefs is more important for reef-dependent species in locations more isolated from natural reef habitats. Structures 86-A, 128-A, and 134-D are over 100 mi from natural reef habitats. However, they are not far from standing platforms that are likely acting as established artificial reefs (Scarborough-Bull, 1989).

Stone et al. (1979) concluded that an artificial reef in proximity to an established reef initially attracts only the juveniles or young adults of reef-dependent species from the nearby structure. Further, they observed that transient species begin to key on artificial reefs as soon as the artificial structure is emplaced. They concluded that artificial reefs did not diminish the resident population of nearby natural reefs by attracting adult reef-dependent species to the new habitat.

## CONCLUSIONS

Fishes and invertebrates were present for at least 20 years prior to the designation of 86-A, 128-A, and 134-D as artificial reefs. While these communities were undoubtedly beyond the initial stages of recruitment and colonization when the structures were last standing, they were in different conditions when they were designated as artificial reefs.

In the case of 86-A, sinking from the force of a hurricane was no doubt disturbing, but it was also a relatively slow process and not as disturbing as explosive removal. Initial observations suggest that fish associated with 86-A prior to its sinking may have remained with the structure after the hurricane and that this artificial reef serves less as a recruitment site than 128-A and 134-D.

While the use of explosives and toppling activity removed most of the adult fish from 128-A, real-time video surveys documented that blennies originally within 6 m of the surface were alive after the platform was toppled (Bull, personal communication, 1992). Whether those same blennies continued to live or remain on 128-A is unknown. Our surveys did confirm that blennies were living and apparently successfully reproducing at depths in excess of 15 m. Because of the relationship between blennies and empty barnacle shells, it is understandable that blennies typically appear depth-limited because their habitat is normally limited to water depths less than 9 m. However, when the essential habitat is relocated to a much deeper water, blennies can adapt.

The winter of 1989-1990 was exceedingly cold with coastal marsh areas freezing several times and unusually cool, brackish water extending at least 50 mi into the Gulf (USDOC, 1990). Although this probably delayed finfish spawning to some extent, whether this affected recruitment to 128-A in 1990 is unknown. One would like to hypothesize that the juvenile damselfish, snapper, and grouper observed in 1990 were the YOY's recruited to 128-A during 1989. However, without tagging and documentation this is only interesting conjecture.

The cold, less saline water of the winter of 1989-1990 possibly affected the growth of tropical invertebrates such as *C. riisei*. It can be speculated that the depressed growth of this octocoral observed during the summer of 1990 at 86-A and 128-A resulted from the coastal meteorological conditions of the winter of 1989-1990. Furthermore, the more extensive growth of *C. riisei* observed during the summer of 1991 may be a reflection of the less severe conditions of the winter of 1990-1991 (USDOC, 1992).

The 2- to 3-year-old red snapper (*L. campechanus*) observed in 1991 at 128-A and 134-D may represent the year class recruited to 128-A during 1989. The lack of red snapper of any other age-group supports this opinion. It is assumed that use of explosives and towing of 134-D removed most of the associated fish community; the predominance of immature fish suggests that 134-D acted as a recruitment reef in 1991 in much the same manner as did 128-A in 1989. The presence of several viable finfish nests and gastropod egg cases indicates that 128-A provided acceptable conditions that will likely increase biomass.

Our initial observations (1989) suggest that, while both 86-A and 128-A retained remnants of what may have been very similar biofouling communities prior to submergence, subtle differences between their communities were evident. The 1989 observations of two scleractinian coral species at 86-A, and not at 128-A, suggest that the invertebrate communities were more diverse and extensive at 86-A. As with the fish communities, these differences could be due to the manner in which each structure became an artificial reef and to the length of time each had remained undisturbed.

Similarly, 128-A and 134-D were removed with the use of explosives, which undoubtedly fatally concussed most of the adult fish and certainly all of the demersal species associated with the platform and dislodged most of the biofouling community. The encrustations of barnacles, bryozoans, colonial tunicates, and filamentous algae found in abundance on 134-D during the summer of 1991 can be considered the initial stages of reef development. However, substantially different grazing pressures may be operating on 134-D than were operating initially on 128-A. The nearest structure to 128-A during its initial tenure as an artificial reef was a standing structure approximately 100 m west. At this distance it is unlikely that the initial or "pioneering" fouling community of 128-A was under additional pressure from adult grazers regularly traversing the 100-m distance separating the two structures. This may not have been the situation for the first year of 134-D. With as little as 30 m separating 128-A from 134-D, it may have been within a "halo" zone of 128-A. If so, then the initial pioneering community of 134-D would be under additional grazing pressure.

Ultimately, whether or not there will be further recruitment to, and development of, the marine communities of 86-A, 128-A, and 134-D will depend upon a number of environmental, biological, and chemical parameters acting synergistically. Site selection by the larvae, tolerance to turbidity, hypoxic events, susceptibility to predation, competition for space, and resistance to biological disturbances will have direct and indirect influences. Studies examining the relationships between these components may provide information invaluable in predicting the developmental stages, community structure, and possibly the productivity of artificial reef communities.

## ACKNOWLEDGMENTS

The authors wish to acknowledge the Minerals Management Service (MMS) Dive Officer, Mr. Les Dauterive; the MMS Gulf of Mexico Regional Dive Master, Dr. Rik Anuskiewicz; the coordinator for the Louisiana Artificial Reef Program (LARP), Mr. Rick Kasprzak; and the Friends of LARP, Messrs. David Stanley and Joel Chalky for their diving support. The authors wish to thank Ms. Debbie Miller and Mr. Mike Dorner for their assistance in preparation of the manuscript. The contents do not necessarily reflect the views and policies of the U.S. Department of the Interior, Minerals Management Service.

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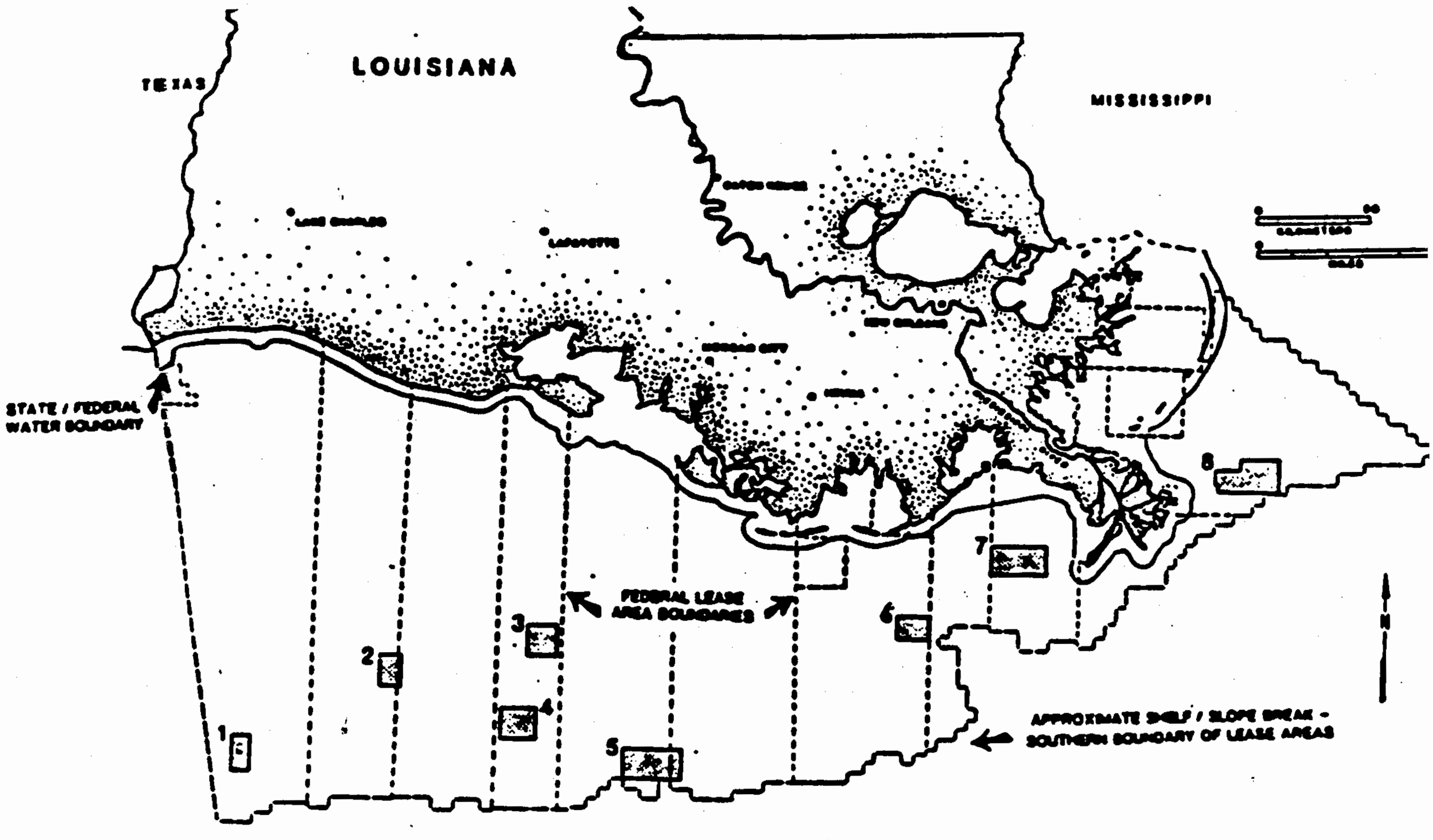


1. West Cameron Planning Area
2. East Cameron Planning Area
3. South Marsh Island (76) Planning Area
4. South Marsh Island (146) Planning Area
5. Eugene Island Planning Area
6. South Timbalier Planning Area
7. West Delta Planning Area
8. Main Pass Planning Area

Figure 1. Louisiana offshore artificial reef planning areas. South Timbalier, offshore planning area 6, was the study location (Figure from Stanley and Wilson, 1989).

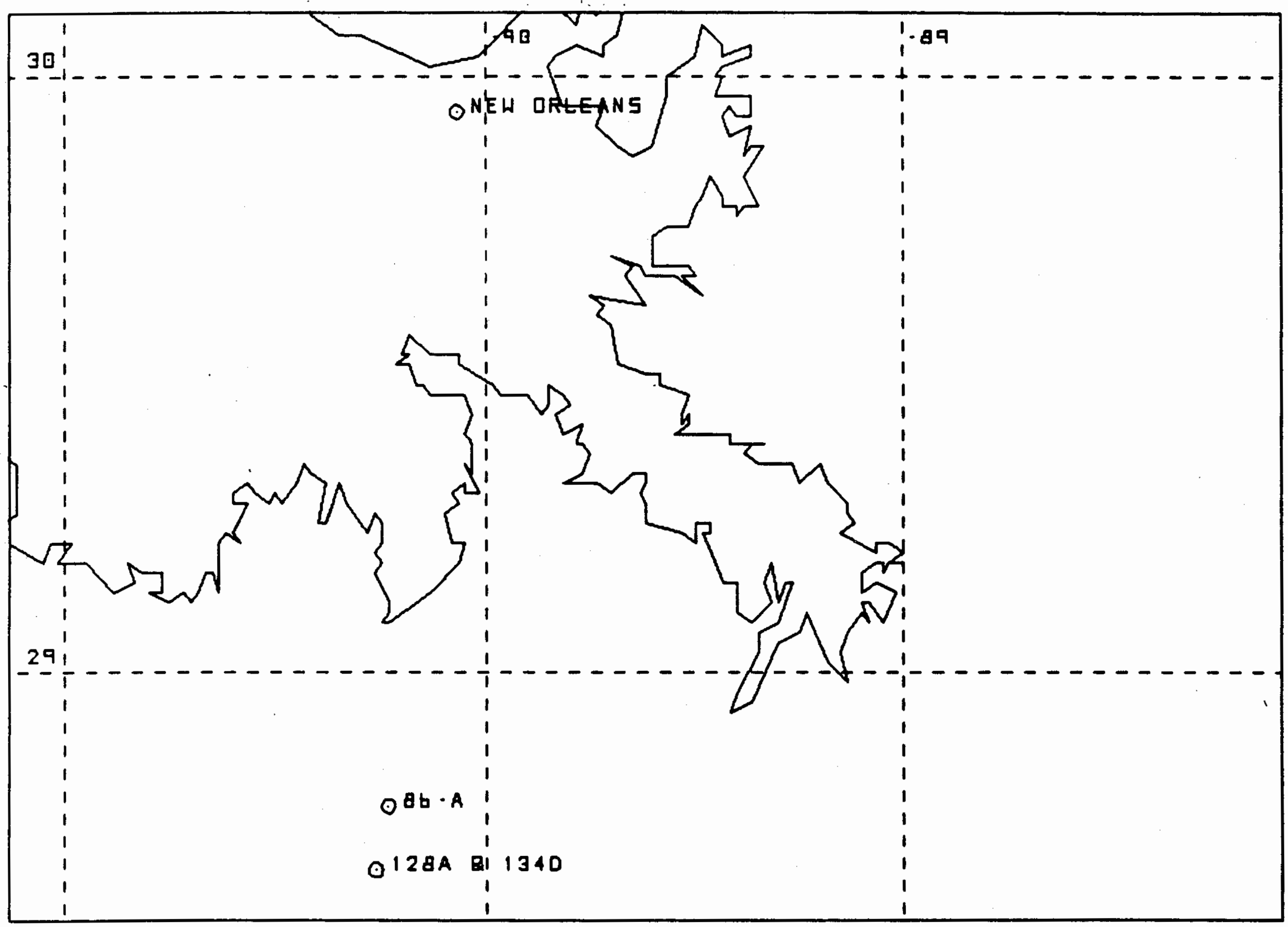


Figure 2. Location of the artificial reefs at South Timbalier Block 86 Platform A (86-A), South Timbalier Block 128 Platform A (128-A), and South Timbalier Block 134 Platform D (134-D) within Louisiana offshore planning area 6.

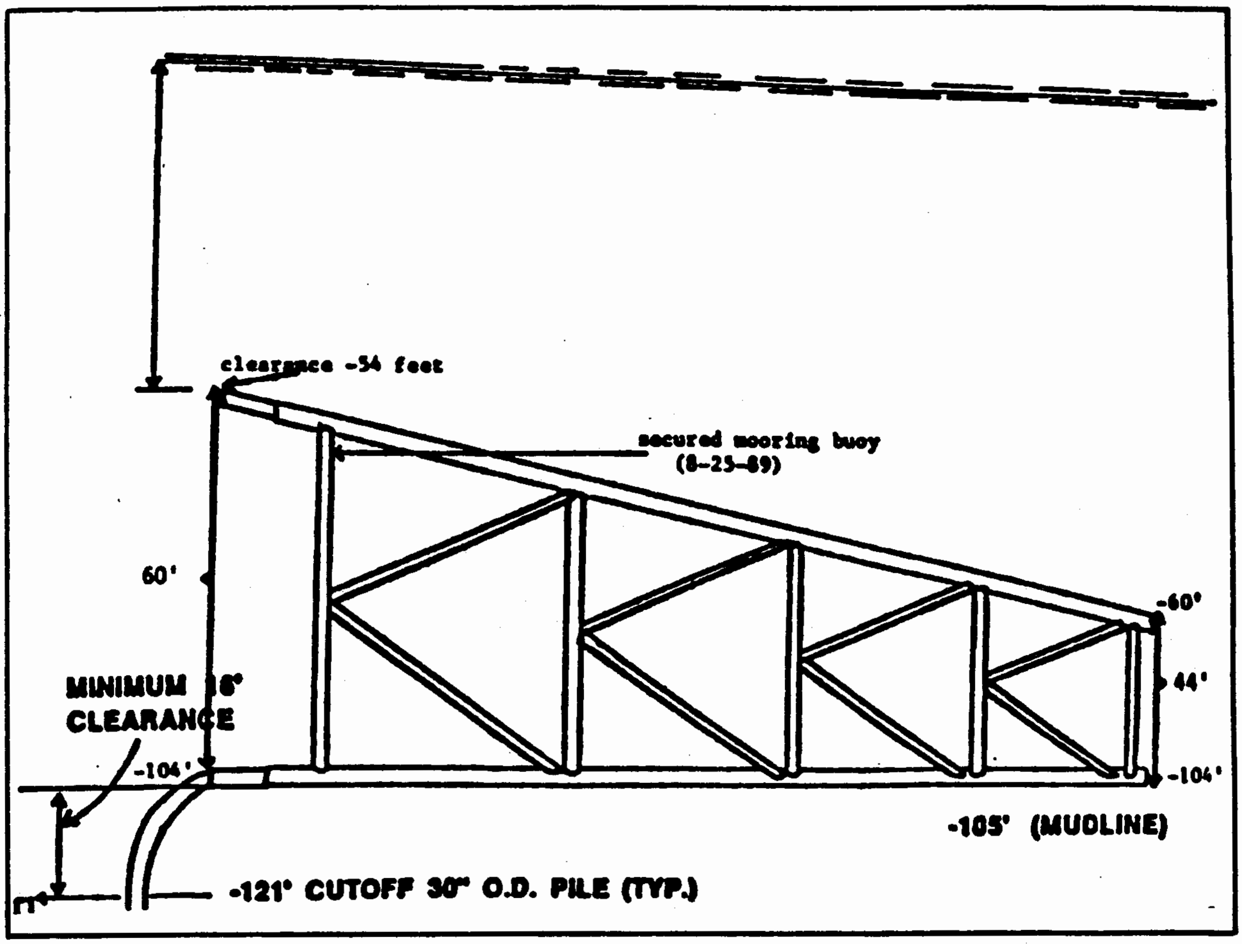


Figure 3. Schematic of sunken platform (and now artificial reef) at South Timbalier Block 86 Platform A (86-A) as viewed from above (courtesy of ODECO Oil and Gas Co.).

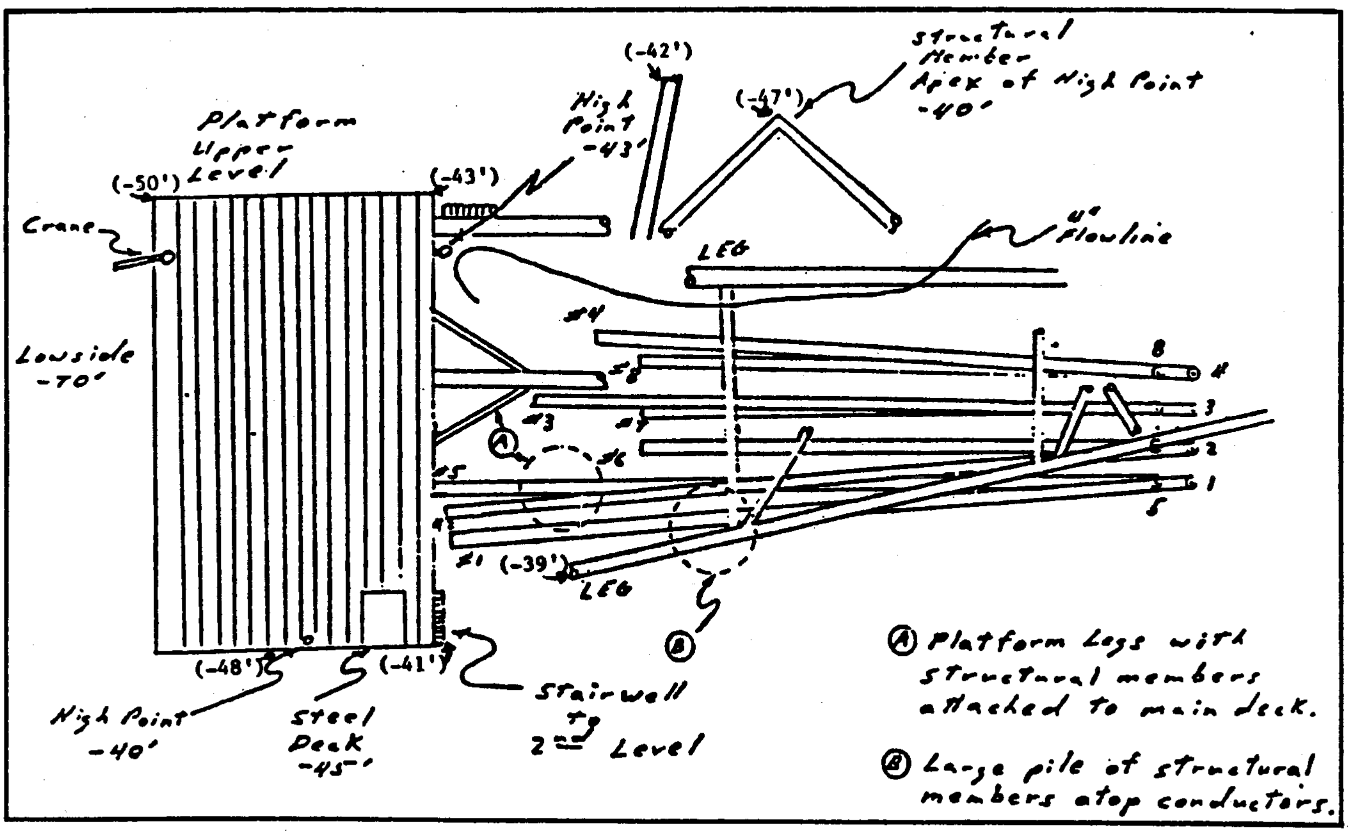


Figure 4. Schematic of toppled platform (and now artificial reef) South Timbalier Block 128 Platform A (128-A) as viewed from the side (courtesy of Chevron U.S.A., Inc.).

# DENSITY AND SIZE DISTRIBUTION OF FISHES ASSOCIATED WITH A PETROLEUM PLATFORM IN THE NORTHERN GULF OF MEXICO

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## INTRODUCTION

The large number and extensive nature of offshore structures in the northern Gulf of Mexico has undoubtedly influenced the marine environment and its inhabitants. Past research has emphasized environmental impacts of petroleum production, focusing on the effects of discharges such as produced waters, drilling fluids, and spills (Boesch and Rabalais 1987). The ecological significance of habitat modification provided by the petroleum platforms is, however, unknown and much is left to speculation.

The placement of these structures has significantly increased the available hard substrate within the area (Reggio and Kasprzak 1991). Researchers have estimated that natural reefs constitute only 1.6% or 2,571 $km^2$ (737 to 6,385 $km^2$, 95% CL) of the total substrate, which is dominated by clay, silt and sand, from Pensacola, Florida, to Pass Cavallo, Texas (Parker et al. 1983). Hard substrate provided by petroleum structures is estimated to be 5,000 $km^2$, increasing available reef habitat by 78% to 195% in the northern Gulf of Mexico (Gallaway et al. 1981).

Fish populations are thought to be limited by recruitment, competition, available energy and habitat, and predation (Menge and Sutherland 1987, Doherty and Williams 1988, Bohnsak 1989, Bohnsak et al. 1991). The additional habitat provided by petroleum platforms can potentially influence all of these processes. Information on population dynamics acquired from the measurement of fish assemblages associated with offshore structures may help to determine whether these structures aggregate prey or predators, or provide critical habitat for reproduction and/or survival of fragile life history stages.

Petroleum platforms are an important component of recreational and commercial fisheries along the Gulf Coast and have long been recognized as defacto artificial reefs by fishermen. Petroleum platforms are the destination of over 70% of all recreational fishing trips in the Exclusive Economic Zone off coastal Louisiana (Reggio 1987), and it is estimated that 30% of the recreational fish caught off Louisiana and Texas coasts, approximately 15 million fish, are caught near petroleum platforms each year (Avanti 1991). Although these resources are important to fishermen, there is little information upon which fisheries scientists can base management decisions. This paucity of available information is primarily due to the difficulty of sampling these habitats with traditional fisheries sampling methods.

## METHODS

Between 1990 and 1992 we conducted research in cooperation with Mobil USA Inc. to demonstrate the utility of the relatively new fisheries sampling technique, dual-beam hydroacoustics, in conjunction with standard visual reef fish assessment techniques. The purpose of this research was to document the abundance, size distribution, and species composition of fishes associated with a petroleum platform in the northern Gulf of Mexico. Monthly dual-beam hydroacoustic and visual surveys were conducted from September 1990 to June 1992 at petroleum platform West Cameron 352 (WC 352), located approximately 80 km south of Cameron, Louisiana in a water depth of 22 m (Stanley, 1994).

## RESULTS AND DISCUSSION

The coupling of two fisheries independent techniques, dual-beam hydroacoustics and visual point count surveys, provided the best description of the fish population associated with a petroleum platform to date. Fish size ranged from 2.5 cm to 1.1 m in length and did not change significantly ($P > 0.01$) with depth or time of day, however, significant differences were detected ($P < 0.01$) between platform sides and months (Figure 1). Detected fish were smaller during spring and summer, increased in size through late summer and fall, and reached a maximum in the winter. This pattern suggests recruitment of smaller fish to the platform in the spring and summer, and either growth of fishes remaining around the platform or immigration of larger fish to the platform through the fall and winter. Fish were consistently larger on the south side of the platform and smallest on the north and east sides.

Fish density around the platform was highly variable with space and time. Fish density varied significantly ($P < 0.01$) with side of the platform as highest densities were found on the north and east sides. Fish density also varied with depth; fish densities were significantly higher ($P < 0.01$) from 2 to 12 m than from 16 to 20 m (Figure 2). Perhaps the most interesting results were the large and significant changes ($P < 0.01$) in fish density from month to month. Monthly densities varied by up to a factor of 5 and did not appear to follow any pattern (Figure 3). No change in fish density was detected over 24 hour periods. Fish density decreased significantly ($P < 0.01$) with distance from the platform. We calculated that the near-field effect of WC 352 on fishes was 16 m from the platform. Fish densities were greater from 2 to 16 m than from 16 to 72 m away from the platform (Figure 4).

The total abundance of fish at WC 352 was estimated based on the volume occupied by platform, the near-field area of influence of the platform, and densities of the associated fishes. Total abundance estimates followed the pattern of density estimates with high variation from month to month. Total abundance estimates varied from 1988 ± 413 (± 95% CL) for January 1991 to a high of 28138 ± 5532 in February of 1992. The average number of fish around WC 352 by month was approximately 12470 ± 3251.

A total of 19 species were observed during visual point count surveys with SCUBA divers or the ROV; of these, seven species made up 97% of the fish observed. The seven most common species were Atlantic spadefish (*Chaetodipterus faber*), blue runner (*Caranx crysos*), bluefish (*Pomatomus saltatrix*), gray triggerfish (*Balistes capriscus*), greater amberjack (*Seriola dumerili*), red snapper (*Lutjanus campechanus*), and sheepshead (*Archosargus probatocephalus*). The abundance of individual species changed with time, as some species (e.g. red snapper and blue fish) were most abundant in the fall and winter while others (e.g. blue runner) were more abundant during warmer months. Economically important species such as red snapper, greater amberjack and gray triggerfish constituted an average of 21.2%, 2.4% and 0.2% of the fishes around the platform. Averaged numerically there were 2,644 ± 689 red snapper, 299 ± 78 greater amberjack, and 25 ± 7 gray triggerfish around WC 352 at any one time.

Based on this first study, we concluded that fishes associated with the petroleum platform were highly transient. While the fish may be dependent on the structure for habitat, they exhibit migration to other areas. The higher abundance of fishes detected at WC 352 than described during other studies was probably due to our utilization of dual-beam hydroacoustics which did not influence fish behavior, was not limited by visibility, and measured the entire area of influence of the reef.

The obvious next step in determining the effect of platforms on fish populations was to expand our research efforts to gain insight into the fish communities around other platforms. We are currently using the technology developed at WC 352 to study the fish population around a platform in the Grand Isle lease area (water depth 65 m), a platform in the Green Canyon lease area (water depth 225 m) and a platoform in the South Timbalier lease area (water depth 21 m). This research effort is being sponsored by the Coastal Marine Institute with MMS funding, Mobil USA Inc and Exxon Inc. Our objectives over the next several years are to:

1) measure the abundance, size distribution and species composition of fishes at these sites;
2) determine the effect of temporal, physical and environmental variables on abundance and size distribution of fishes at the platforms; and
3) define the near-field area of influence of each platform.

Research began in July 1994 on the deep sites and the shallow site in August of 1995. Results from this and future research will enable researchers and managers to better understand how artificial reefs function in the northern Gulf of Mexico and evaluate their effectiveness as potential management tools. Since the fisheries resources associated with petroleum platforms are not currently included in management plans, and given the current emphasis on reef fish management, information collected from this work may provide estimates of abundance and species composition of fishes near petroleum platforms and ultimately improve management of the resource.

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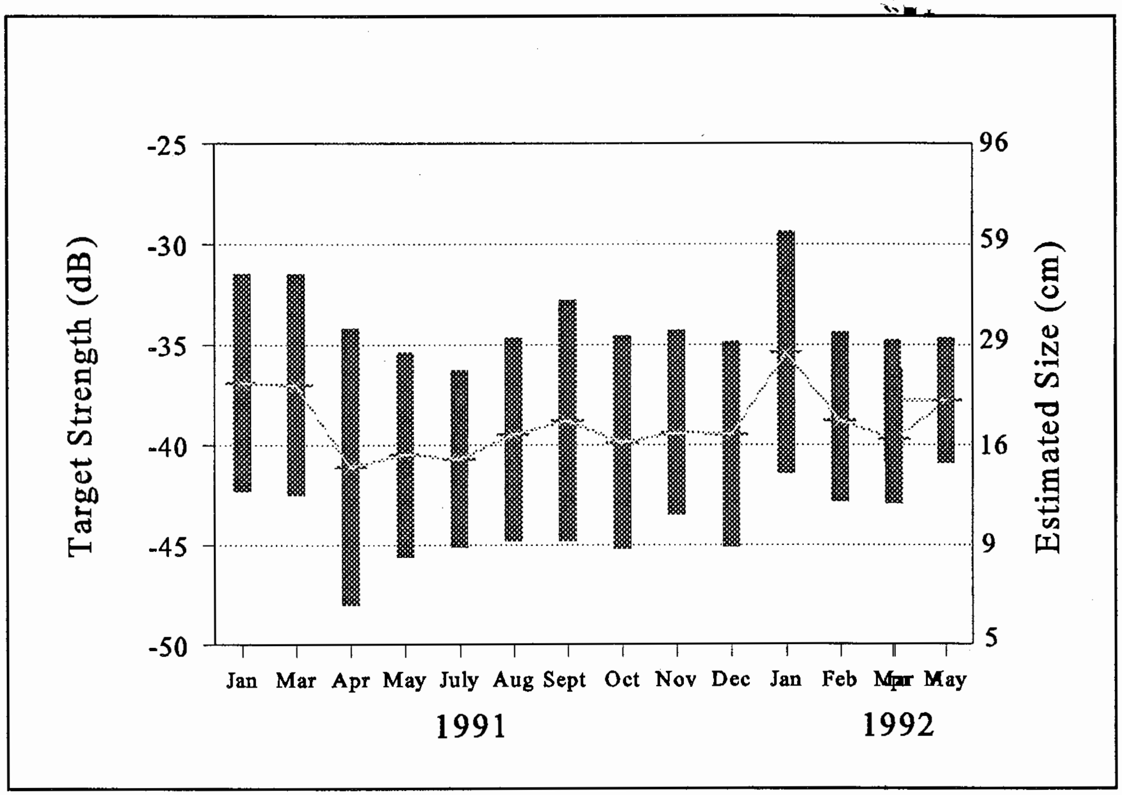


Figure 1. Mean target strengths (dB) and 95% CL and estimated length (cm) of fishes associated with petroleum platform WC 352 by month for the study period of January 1991 to May 1992.

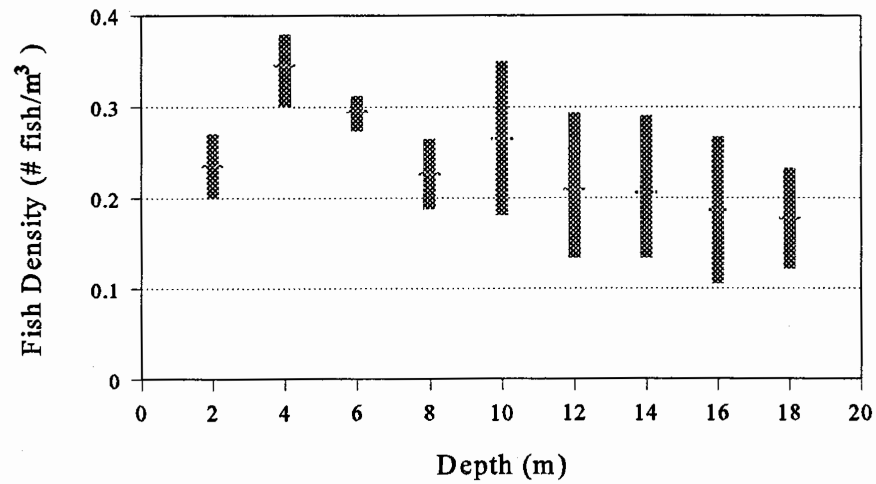


Figure 2. Estimated fish density (number / m$^3$) and 95% CL by depth at WC 352 from January 1991 to May 1992, based on dual-beam hydroacoustics.

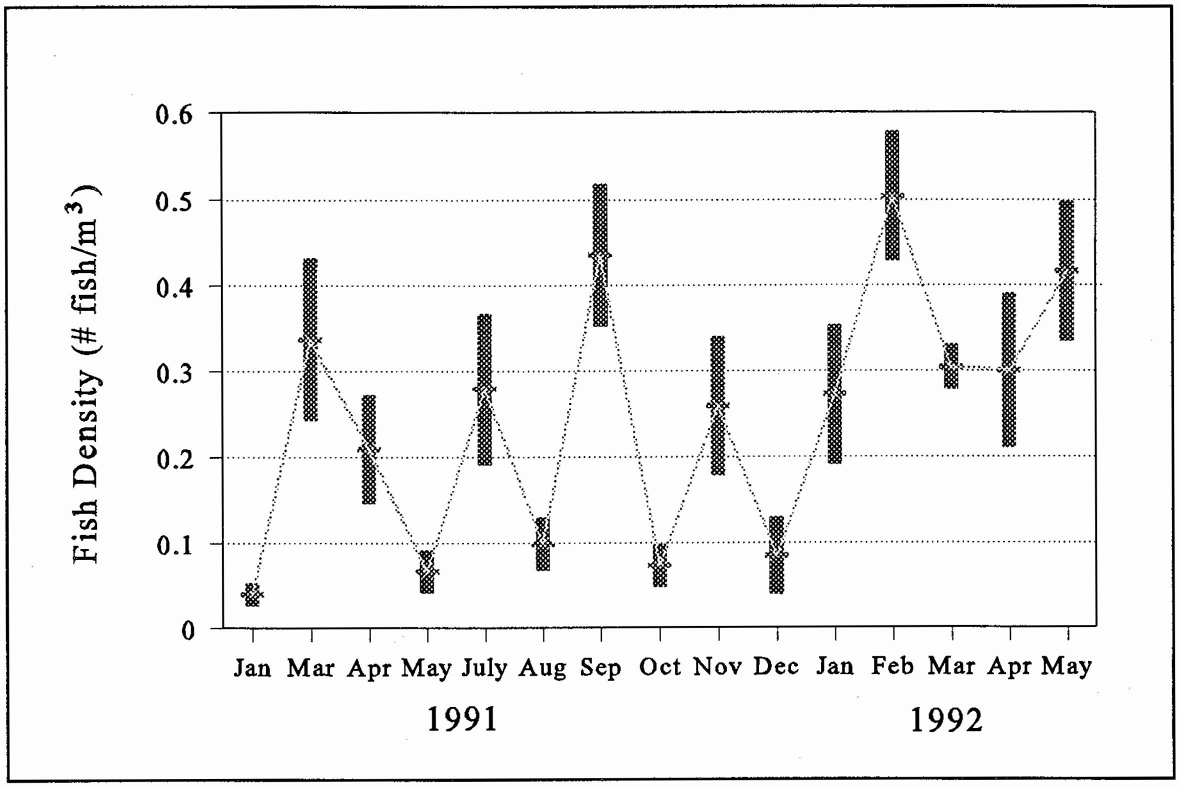


Figure 3. Mean density of fish (number / $m^3$) and 95% CL around WC 352 from January 1991 to May 1992 based on dual-beam hydroacoustics.

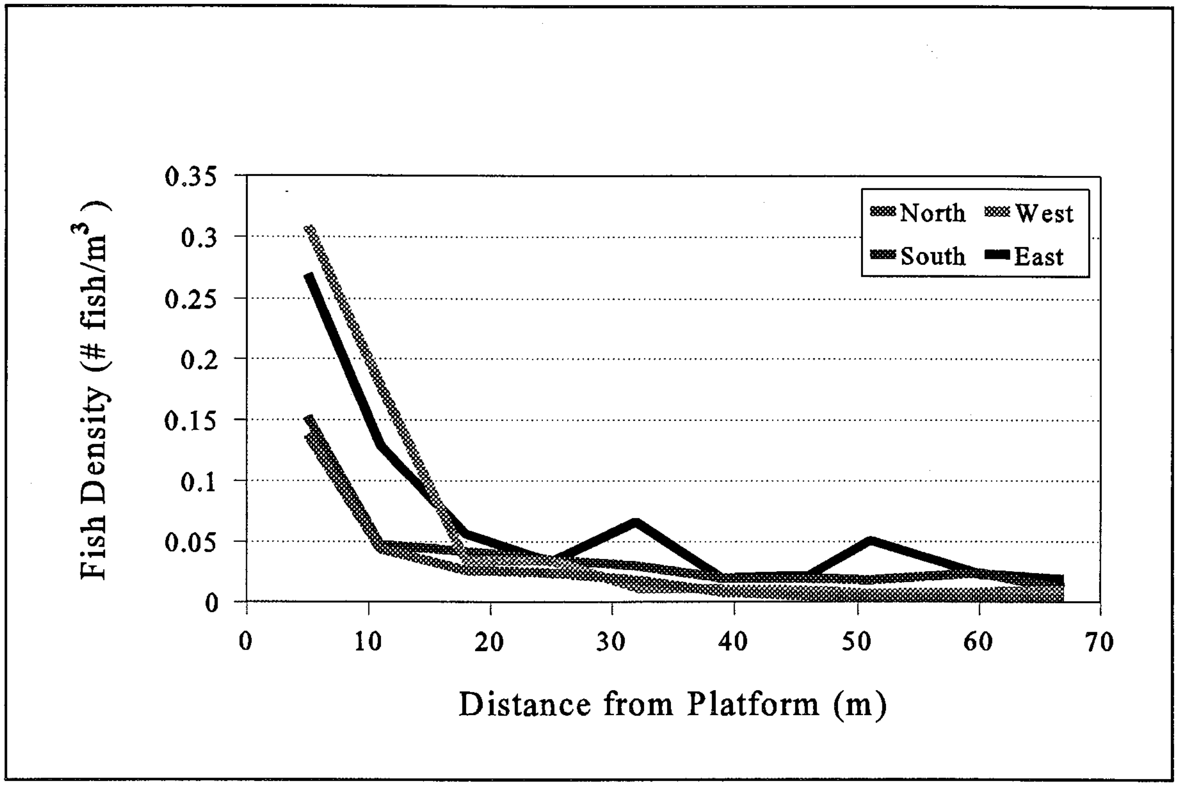


Figure 4. Mean fish density (number / m$^3$) with distance from the WC 352 platform over the study period of January 1991 to May 1992 for each side of the platform.

# REMOTELY OPERATED STATIONARY VIDEO AS A BEHAVIORAL ASSESSMENT TOOL FOR FISH ASSOCIATED WITH OIL AND GAS PLATFORM HABITAT


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## INTRODUCTION

Although progress has been made in our understanding of the life history of fish species that occupy reef habitat, little detail is known about inter and intra-specific behavior of these species relative to their habitat on any broad scale. Observations on the behavior of these species have generally been from diver surveys in shallow water or indirectly obtained (i.e. from age and growth studies, food habit studies, tagging studies, etc.) . Although these observations and studies have contributed to our knowledge of the life histories of a number of reef oriented species, further work is warranted that includes behavior as a life history component for comprehensive understanding.

Oil and gas platforms serve as 'de facto' reefs in the northern Gulf of Mexico since natural hard substrate is limited and far from shore. The significance of artificial structures as habitat for reef fish species populations has been strongly debated in terms of whether these structures enhance populations by creating habitat or whether populations are simply redistributed (Bohnsack and Sutherland, 1985; Munro and Williams, 1985; Solonski, 1985; Bohnsack 1987). Regardless, it cannot be debated that the presence of these structures has influenced the distribution of reef fish in the northern Gulf of Mexico. Platform habitat along the continental shelf of the Gulf of Mexico west of the Mississippi River may be of particular significance to the distribution of reef fish populations in the northern Gulf of Mexico since these structures rise above the nepheloid layer. The distribution and abundance of reef fish on natural hard bottom features in the western Gulf has been shown to be strongly influenced by the depth of those features relative to the nepheloid layer (Rezak et al. 1983, Putt et al. 1986, Dennis and Bright 1988, Rezak et al. 1990) with reef fish species diversity and abundance higher above the nepheloid layer. Although oil and gas platform habitat in the northern Gulf of Mexico is considered to be important, little quantitative data exists to describe it.

Oil and gas platform habitat is generally difficult to characterize in terms of species abundance and composition due to the vertically distributed nature of the habitat, depth and structural and ecological complexity. Since platform habitat is represented in three dimensions, fish species can be distributed in patterns and depth strata not normally observed on natural hard substrates (Figure 1).

Figure 1. Red snapper associated with platform habitat at Mobil West Cameron 352.

Stanley (1994) found that in general, fish concentrate within 16 m of oil platforms and may vary spatially with depth and side of a given platform. In addition, he observed that overall fish abundance associated with a given structure could vary widely on a relatively short temporal scale (one month) and suggested that platforms represent a non-equilibrium system.

Investigations of sampling methodologies to survey the fishes that aggregate on or over live bottom, ledges, outcrops, banks, mud lumps, sink holes, rocks, and oil and gas platforms have been conducted by the NMFS, university, and state scientists (Huntsman et al., 1982). Collection (fishing) gears used have included: bottom longlines; gill nets; traps; and, power assisted handlines (Haynes 1988). In general, these gears have not proven effective around oil and gas structures. Fisheries acoustic technology can be successfully used around these structures to enumerate fish density and estimate biomass (Stanley 1994), however, species composition cannot be independently derived from acoustic data.

Underwater video techniques have evolved rapidly in recent years due to advancements in electronic technology that have resulted in miniaturization of components. Remotely operated underwater video systems offer several advantages over traditional sampling gear including that they: 1) are non-destructive, 2) are non-obtrusive (i.e. do not effect normal behavior of individuals observed), 3) have greater depth and time capabilities than diver surveys, and 4) are relatively inexpensive.

The purpose of this paper is to briefly describe a video system we used to observe red snapper, *Lutjanus campechanus,* around oil and gas platform habitat. Further we will discuss how this type of data may be integrated into our understanding of the life histories of various species.

## METHODS

The study site was a gas platform owned by Mobil Corporation (West Cameron 352), located approximately 90 km south of Cameron, Louisiana, in 21 m water depth. The video system employed was designed by Fuhrman Diversified, 2912 Bayport Blvd.,Seabrook, Texas, and consisted of a low lux (0.1) black and white video camera encased in a waterproof housing (100 m depth maximum) (Figure 2).

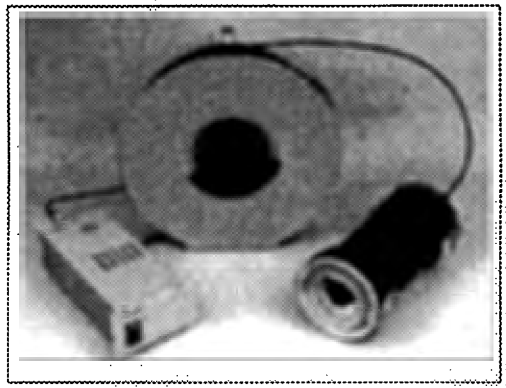

Figure 2. Video system designed by Fuhrman Diversified.

Power input and video output was designed to operate with coaxial cable, and thus data could be seen in real time and/or recorded on tape for later analysis and processing. The camera housing was mounted on a weighted sled and the system could be deployed and lowered at different locations and depths around the platform. A separate line was attached to the sled to control direction of view and to keep the camera and sled from rotating with the current. Following data collection, tapes were returned to Louisiana State University for processing. All video data were viewed and observations on behaviour were recorded. Observations noted included depth, number of individuals, position relative to structure, orientation, feeding, inter and intra-specific interactions, and other notable events.

## RESULTS AND DISCUSSION

During the study approximately 40 h of video data were collected from May 1992 through October 1992. Most of the observations gathered were of large schools (30 to over 100) of small juvenile red snapper (180 - 300 mm). Though less frequent, larger individuals of adult size were also observed (> 300 mm). Several general patterns emerged regarding the behavior patterns of red snapper relative to platform habitat. We observed, for example, that red snapper were not necessarily a bottom fish when associated with platform habitat and could select a depth location from bottom to near surface. Juveniles were almost always observed in close association with platform structure (i.e. rig legs, cross beams etc.) along the vertical structure gradient of the platform habitat. Adults, conversely, tended to be solitary or in small groups, and did not appear to be obligate to structure based on their movement patterns. Additionally, adult and juvenile red snapper appeared to partition habitat by selecting different depth locations along the vertical gradient.

Although these data are qualitative in nature, the patterns observed are useful for hypothesis development and ultimately quantitative hypothesis testing. For example, our results suggest that juvenile and adult red snapper occupy shared platform habitat differently both in affinity for physical structure and in vertical distribution. We presume that structural affinity by juveniles is related to predation risk since the physical structure of the platform habitat may provide refuge from large predators. Large fish are generally less vulnerable to predation than smaller conspecifics (Schmitt and Holbrook 1984, Werner and Gilliam 1984, Osenberg and Mittlebach 1989) resulting in the opportunity for larger fish to expand niche width. Mueller et al. (1994) noted that changes in body size during ontogeny is associated with the outcome of intraspecific social interactions for most reef fish. Older larger fish, for example, may have a more diverse diet than younger fish due to greater foraging flexibility, decreased vulnerability to predators, and superior prey location and handling experience. A combination of these dynamics (and others) may explain the partitioning of platform habitat observed between adults and juveniles.

In summary, video data and qualitative analysis can be a useful tool for preliminary investigation of fish behaviour. Observation of inter and intra-specific behaviors can and should lead to the development of quantitative methodology and experimentation for describing behaviour in these complex and difficult environments. Our challange is to design experiments which lead to comprehensive, detailed understanding of fish life history and the dynamic interactions which occur within and among species relative to the habitat they occupy.

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# THE POSTLARVAL AND JUVENILE FISH NURSERY GROUND/REFUGIA FUNCTION OF OFFSHORE OIL AND GAS PLATFORMS

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## INTRODUCTION

The introduction and proliferation of offshore oil and gas structures (defacto artificial reefs) in the northern Gulf of Mexico has undoubtedly affected the marine ecosystem. Subsequent research on impacts, driven mostly by environmental concerns, has focused primarily on production-based discharges and oil spills. Consequently the effects of habitat alteration (i.e. placement of oil and gas structures/creation of hard bottom) on OCS fisheries are unknown, although speculation bordering on dogma runs rampant. Our proposed research has four specific objectives. (1) Provide foundational information on the role oil and gas platforms play as important nursery grounds or refugia for postlarval and juvenile fish, which could thereby contribute to and enhance overall fish production. (2) Supplement and compare a relatively new sampling technique, light trap methodology (which is capable of sampling large numbers of late stage postlarval and juvenile fishes in structurally complex environments) with traditional sampling techniques (i.e., vertical or passive horizontal plankton net collections). (3) Respond to specific fisheries management requests for basic biological information on reef fish, e.g., larval, postlarval and juvenile taxonomy, seasonality, vertical and across shelf distribution, relative abundance, and possibly otolith daily ring validation and age/growth estimation. (4) Within a statistically-rigorous sampling design and program, begin the across shelf characterization of the early life stages of the fish community utilizing offshore oil and gas platform habitat in central Louisiana.

If we are to begin to address the yet-unresolved, fundamental and larger question of whether offshore rigs simply attract/concentrate fish or indirectly enhance production (increase biomass = increase spawning or nursery ground habitat, growth, survivorship of young, etc.), we must begin to document the habitat function of rigs and the species which utilize this unique, hard-bottom habitat; to assess the role that rigs play in influencing the distribution and abundance of young fishes; and to address rigs as nursery grounds or refugia for postlarval and juvenile fishes associated with hard bottom habitat (i.e., Are rigs areas of higher abundance than background water column densities as estimated by the State-Federal Southeastern Area Monitoring and Assessment Program (SEAMAP) or MMS-LATEX surveys utilizing plankton or neuston net collections? What is the larval, postlarval and juvenile seasonality, relative abundance (based on light trap catch per unit effort), distribution (vertical and across shelf), and growth rate of fish associated with rigs? Specifically, over a three-year period, we will investigate whether there is a substantial temporal (daily, lunar or seasonal) or spatial (sampling across shelf at 229m, 61m and 22m depth platforms and vertically at two depths per rig) nursery ground/refugia function to rig structure as determined by statistically-rigorous collections of reef and pelagic finfish species showing consistent affinity for platform architecture, i.e., Do rigs have a fisheries production component? We hypothesize that catch rates, densities or species composition are greater and more diverse than background (non-platform) conditions determined from historical data from oceanographic cruises. Consequently, we propose the first directed study addressing this basic question of platform fisheries production of early life history stages (i.e., it is the first systematic determination of baseline data on the larval, postlarval and juvenile fish community within the vertical structure of rigs). This proposed research would also synergistically benefit from, and directly contribute to, the C.A. Wilson and D.R. Stanley MMS-LSU-CMI funded project entitled, "Seasonal and Spatial Variation in the Biomass and Size Frequency Distribution of Fish Associated with Oil and Gas Platforms in the Northern Gulf of Mexico", which utilizes hydroacoustical techniques to document the horizontal and vertical distribution of adult and juvenile fish associated with offshore platforms.

The Gulf of Mexico yields about 40% of the nation's commercial fish landings (NOAA/NMFS 1991, 1992, 1993) and supports 33% of the country's recreational fishery (Essig et al. 1991; Van Voorhies et al. 1992). Louisiana is responsible for the bulk of these statistics, consistently ranking on the national level as the first or second highest state in pounds landed and among the highest in dockside value (NOAA/NMFS 1991, 1992, 1993). The State of Louisiana is very concerned with habitat issues and the relationship between fishery production and habitat, since from 1780-1980 it has lost 46% of its wetlands (Dahl 1990), the nursery grounds for a large number of our commercially- and recreationally-important fisheries. What do offshore oil and gas platforms (deep, hard bottom habitat) have in common with shallow, soft bottom estuarine wetlands? The very characteristics that are attributed to estuarine nursery-ground function: 1) increased food availability; 2) potentially lower predation pressure; and, 3) spatial or structural complexity of habitat (i.e. many ecological niches, "nooks and crannies", and refugia). The continual loss of estuarine and wetland areas makes knowledge of the potential nursery function of other habitats (artificial hard bottom) critical. In fact, some species of fish may be experiencing nursery habitat limitation, especially during the postlarval stage (Ursin 1982). Habitat limitation is especially significant within the reef fish community (those species dependent on reef habitat for at least a portion of their life history). Reef fish have adopted a myriad of behavioral and life history patterns; however, the vast majority are iteroparous spawners which produce pelagic larvae in an attempt "to win the space-competition lottery" and are thought to be habitat limited (Moran 1986, Parrish 1987, Sale 1991). Since reef fish assemblages are among the most diverse and taxonomically rich in the aquatic biosphere (Sale 1991), Louisiana's platform communities may be significantly enhancing the biodiversity of the northern Gulf. The extensive artificial substrate of the numerous platforms may also be serving as migratory routes for exotic species.

In any event, the introduction and proliferation of offshore oil and gas structures in the northern Gulf of Mexico (Gulf) has undoubtedly affected the marine ecosystem. Subsequent research on impacts, driven mostly by environmental concerns, has primarily focused on discharges (i.e. drilling fluids and produced waters) and oil spills (Boesch and Rabalais 1987; Avanti 1991). Consequently the effects of habitat alteration (i.e., placement of oil and gas structures/creation of hard bottom) on OCS fisheries are unknown, although speculations bordering on dogma run rampant. The goal of our proposed research is to gain insight into a critical OCS question: What is the effect of the habitat modification on regional fish populations caused by the installation of the Gulf's numerous offshore oil and gas platforms? More specifically, can we begin to characterize either in a static sense the across shelf habitat utilization of platforms, i.e., the inshore/offshore (depth-related) species zonation of Gallaway (1981) or Continental Shelf Associates (1982), or in a dynamics sense the across transport/recruitment/export regimes of the early life history stages of fish in a statistically rigorous fashion that can be built upon to develop a larger, more geographically meaningful characterization of the continental shelf waters of the northern Gulf?

The adult fish communities around natural and artificial reefs are known (Seaman and Sprague 1992) and the fisheries aggregation value of oil and gas structures is well-recognized in the Gulf (CDOP 1985). Despite research efforts, biologists still disagree over the paradigm of whether rigs simply attract fish or enhance production. This debate has in fact shadowed the creation of artificial reefs in some areas and raised questions about the value of oil and gas platforms as reefs (Wilson and Stanley 1991). Existing data on adult fishes support both sides of the debate (Stone et al. 1979, Alevizon et al. 1985). Bohnsak (1989) theorized that reef effects fell along a continuum between attraction of existing organisms and production of organisms, with increased productivity occurring for reef dependent species in areas of limited hard substrate habitat. Since the northern Gulf has little natural reef habitat, it is unlikely that the introduction of 4,488 oil and gas platforms has simply attracted the fish from other areas. We believe that the contribution of artificial reefs to existing reef habitat has enhanced reef fish populations, but the extent of this augmentation is not known.

Reef fishes are especially vulnerable to overfishing because they concentrate over specific types of habitats (natural and artificial hard bottoms) that are patchily distributed and because some species are territorial. These factors make fishing effort highly efficient, increasing chances for overexploitation as habitat is lost or as more of the remaining habitat becomes known (Nichols et al. 1991). In addition to receiving substantial commercial fishing pressure, natural and artificial hard bottom habitats receive significant recreational fishing pressure (e.g., oil and gas platforms are currently the destination of over 75% of all coastal recreational fishing trips originating in Louisiana - Wilson et al. 1987). The extent to which aggregation increases exploitation (or overexploitation) is important to fishery management (CDOP 1985). Where reefs enhance fisheries, sound management (which requires solid scientific knowledge of the life histories of the target and/or bycatch species) is necessary to avoid overexploitation (Nichols et al. 1991).

In 1976 the Fishery Conservation and Management Act required the Gulf of Mexico Fishery Management Council (GMFMC) to develop fishery management plans for each fishery within its jurisdiction. The GMFMC submitted their Reef Fish Fishery Management Plan (RFFMP) in 1981, which was implemented November 1984. Several of the goals of the first amendment to the RFFMP (GMFMC 1989) were: (1) "To encourage research on the effects of artificial reefs" (pg.8); (2) begin to address clearly identified and critical research/management needs such as "Biological profile data . . . throughout the Gulf of Mexico on a continuing basis" (pg.20); (3) "Improved quantitative assessment techniques are needed to describe artificial reefs, reef communities, and to monitor biological changes .... The importance of fish attraction versus fish production and the relationship between standing crop and fish catch have not been adequately addressed" (pg.29); (4) "Quantify the relationships between reef fish production and habitat" (pg.34); and, (5) research should be directed towards "Recruitment to reefs and the effectiveness of artificial reefs as habitat" (pg.383; GMFMC 1989).

Few baseline ecological ichthyoplankton studies have been conducted in the oil field (Finucane et al. 1977; Bedinger et al. 1980). In addition, no studies have specifically targeted oil and gas structures as nursery habitat/refugia for postlarval and juvenile fishes. The SEAMAP and general NOAA/National Marine Fisheries Service (NMFS) Gulfwide fisheries surveys do not sample in the immediate vicinity of oil and gas platforms because of their half degree grid-based sampling design and the ship's conservative navigation/safety requirements; nor does the MMS LATEX Program. Thus, fisheries-independent assessment of early life stages is presently not being adequately addressed in federal waters where such structures exist. Reef-associated species landed commercially include groupers, snappers, sheepshead, bluefish, triggerfish, and Atlantic spadefish (Gallaway 1981; Stephan et al. 1990). Some coastal pelagic fishes and highly migratory pelagics (e.g., amberjacks, dolphin, sharks, jack cravelle, cobia, Spanish and king mackerel, and tuna) are also associated with hard structure habitat (Leis et al. 1991). Concentrations of resident, hard bottom postlarval and juvenile fishes may themselves influence other trophic dynamics by potentially offering enhanced feeding opportunities for the commercially- and recreationally-important adult fishes listed above.

The unique challenges/opportunities associated with Louisiana's offshore and structurally-complex oil and gas platforms have previously thwarted research on the tractable and legitimate scientific question of artificial reef habitat utilization. This research is now feasible with the application of light trap methodology, a relatively new assessment technique for postlarval and juvenile fishes, life history stages which are universally acknowledged to be consistently undersampled with traditional plankton techniques. It is believed that both of these stages hold definitive clues to very fundamental and basic ecological and recruitment research questions and may provide the most reliable estimates of yearly variability in modeling recruitment to exploitable stocks (Sissenwine 1984).

The structurally complex architecture (vertical and horizontal) associated with oil and gas platforms presents a formidable challenge to conventional sampling for early life stages of fish. A number of sampling methods are available, but all have biases in number, composition, and size of postlarvae or juveniles collected. More recently, various types of aggregation devices which passively attract fish with light into collection traps have been successfully used to sample hard bottom or reef habitat. Light traps, originally constructed to sample shallow and weedy limnetic environments (Faber 1981, 1982; Secor et al. 1993), have been used to sample such diverse marine environments as under Antarctic fast ice (Kawaguchi et al. 1986) and tropical coral reefs (Doherty 1987; Choat et al. 1993 and papers cited within).

No single sampling gear can, however, provide a comprehensive collection of early life stages (Choat et al. 1993), and a program which utilizes several collection methodologies will allow for a more accurate estimation of abundance and size composition (Gregory and Powles 1988). Therefore, we will augment the trap catch data with replicate vertical plankton hauls or passive horizontal plankton net collections. The vertical tows will be cantilevered and taken up through the water column along a vertical guidewire or monorail (which minimizes tow-line-induced net avoidance; Filion et al. 1993) at the light trap station within the central portion of the rig.

This proposal represents the first directed study addressing the contribution that platforms make to postlarval and juvenile production; and as a first attempt, it <u>IS NOT</u> intended at this time to be a comparison involving the community structure/dynamics of rigs vs. subtropical (or tropical) natural reefs or bottom-oriented artificial reefs. It <u>IS</u> the first systematic and definitive determination of baseline data on the larval, postlarval, and juvenile fish community within the vertical structure of oil and gas platforms. Such baseline data, when acquired within a statistically-rigorous, conceptually sound sampling design are needed before more specific ecological/environmental tests of the fish production question can be formulated or before the larger and more practical geographical extrapolations/ characterizations can be synthesized.

We will build upon research experience gained from an unfunded pilot project at Mobil West Cameron (WC) 352, which allowed us to acquire preliminary experience with light traps within the submerged internal structure of rigs and to satisfactorily demonstrate that the gear effectively collects a highly diverse community of postlarval and juvenile fish (see species composition and seasonality table in appendix). WC 352 is a mid-shelf platform in approximately 20m (65 ft) of water off the Louisiana-Texas border. Two of the sampling sites for this research, Green Canyon 18 (229m) and Mobil Grand Isle 94 (61m depth) platforms, are larger, deeper platforms and the third site, Exxon South Timbalier 54 (22m) is of similar depth but all are significantly upstream and much closer to the nutrient- and food-rich waters of the Mississippi River. Site selection for this project is based upon the work of Gallaway (1981) and Continental Shelf Associates (1982) who reported that nekton communities around platforms differed due to water depths in the northern Gulf. Three communities were characterized; coastal assemblage (water depths <27m), offshore assemblage (water depths 27 to 64 m) and a bluewater/tropical assemblage (water depths >64m). The eight-pile platforms selected for this project encompass all three zones.

As mentioned above, samples were collected at WC 352 from 7 sampling periods between November 1991 to August 1992, 8562 fish and 117 squid were collected from 1368 minutes of sampling. This is the highest catch-per-unit-effort reported from light trap literature. The most fish caught in a single 10-minute set was 671. Significantly more fish were obtained in surface samples than in bottom samples; however, more squid were collected in bottom samples.

Inshore lizardfish was by far the most abundant fish collected, making up 52% of the total catch. The largest number collected during a single set was 569, and several other sets obtained numbers over 400. Gulf menhaden was also common and made up 21% of the total catch. A number of reef species were also collected.

Although these results are preliminary, they do indicate that platforms support a large biomass composed of early stages of fishes. Further work must be done to confirm the possible nursery function of platform habitat.

We have gained additional light trap experience from two small Sea Grant-funded pilot projects.

To determine the effect of trap size, three sizes of our modified quatrefoil light trap design were constructed with 3, 5, and 6 inch diameter tubing. One estuarine and three freshwater habitats were sampled during August and September, 1995, consisting of: Grand Terre estuary, LSU Lake, and a hatchery pond and lake at LSU's Ben Hur aquaculture research facility. All three trap sizes were sampled three times per habitat for 10-min sets. Thus, the sampling design resembled a split-plot model. No significant effects were found among locations and trap sizes and the interaction term was also not significant. This suggests that smaller and easier to handle light traps will produce the same results as larger, an costlier, traps. However, it must be noted that most of the sample areas had low fish densities and were highly turbid. Thus, light penetration was low and few animals may have entered the small light field. In oceanic (clear-water), productive environments, as such reef systems, the effective light field would be much larger and would consequently act upon a greater number of animals.

In a second Sea Grant-funded pilot study, we investigated the effect of trap design on catch with several co-PIs. Trap designs included a Doherty trap, courtesy of Andreas Ropke at University of Miami, a quatrefoil-type trap from Joan Holt at University of Texas, and our standard, 6" tube quatrefoil trap. We sampled Mobil's West Cameron 71-D, an oil and gas platform in approximately 11m of water, in July of 1995. Again, we utilized a split-plot sampling design. We found that catch differed among light trap designs. Several factors may have contributed to this result. One thought may be to compare the internal chamber volume to entrance surface area. If a trap has a large volume relative to the entrance area, then more fish would likely be retained by the trap (less escapement). All of the traps had similar sized entrances.

The light source was different among the traps. The Doherty trap was lit by fluorescent lights, while the quatrefoil-type designs utilized a much brighter halogen bulb. Organisms typically show a greater affinity towards greater light intensities, although a limit may be reached at which animals are repelled. In addition, organisms may respond differently to various light wavelengths given off by different lights. Also, organisms may respond differently to various reflected and scattered light fields produced by the different shaped traps.

The shape of the trap may have influenced the outcome in other ways. The Doherty trap is box shaped, while the quatrefoil traps are rounded. Thus, microscale water currents may have acted differently within and around the traps thereby enhancing or retarding entry into and retention within the traps. In conclusion, light trap size did not have an effect on catch rate within the environments studied. However, trap design produced a notable effect.

METHODS

Year 1. We will begin to address all four objectives. We will sample monthly for a 3 night period at Green Canyon 18 (229m depth). All sampling will be associated with the new moon phase and will begin after sunset and be completed before sunrise. New moon phases are associated with peak recruitment periods of many reef-dependent fishes (Johannes 1978; Robertson et al. 1988). In May we will also conduct three additional, 2-day, sampling periods associated with 1/4, 3/4, full moon phases (Table 1). The major sampling station for each rig will be located in the internal central region along a stainless steel, small diameter guidewire (monorail) tethered to the first set of underwater cross-member support structures. At this central station, replicate trap collections (N = 2) will be taken three times each night at near-surface and at a depth between 15 and 23m, depending upon the underwater configuration of the first set of cross-member supports. At depth samples will be collected by lowering a trap without floatation. A battery pack consisting of 10 NiCad D cells encased in PVC tubing powers the light during bottom collections. For surface samples, power will be supplied by a 12-volt marine battery located on the lower deck of the platform. The light source will be a 12-volt Starfire II halogen fishing light (250,000 candlepower; Brinkmann Corp.). Traps will be deployed for 10-15 minutes periods. The light trap design that we are using is a modified version of the "quatrefoil" design (Floyd et al. 1984; Conrow et al. 1990; Secor et al. 1993). We also plan to take either vertical plankton hauls or passive surface plankton collections (depending upon current conditions) three times during the night at the central station. The plankton net will consist of a metered (General Oceanics flowmeter model 2030 with slow velocity rotor), 60-cm diameter, 333$\mu$m mesh net dyed dark green. The vertical haul net, which is held rigidly to the guidewire, will be lowered codend first to the bottom of the monorail, left at depth for 5 minutes for water column restabilization, and then hauled to the surface at approx. 1m/s via a portable davit and electric winch. The passive collections will be taken for 10 minutes during times when the combination of tidal and oceanic current velocities are too high to effectively fish the light traps. Therefore, the passive plankton net collection will then be on the same schedule as the light traps. For example, preliminary observations along the continental shelf break at platforms near the Flower Gardens by the LA-TX border indicate that velocities sometimes exceed light trap guidelines. These exceedingly high velocities, however, may be influenced by LOOP eddies in that area. Unlike the light traps, the plankton net collections will sample fish eggs, yolk-sac and early stage larvae. In addition, 3 collections each night will be made with a floating light trap (or a surface plankton net, depending upon the current regime) which will be tethered and free drifted away from the rig on the down current side of the platform. The tethered light trap will be fitted with a timer so as to begin sampling 20m away from the rig.

All samples will either be preserved in ethanol (for future otolith age and growth analyses) or kept alive for subsequent species identification, for marking with buffered alizarin complexone for validation of daily otolith ring formation, or for growth experiments). All fish will be removed from all samples, enumerated and measured to the nearest 0.1 mm SL with an ocular micrometer. We will measure temperature, salinity, and conductivity at the surface and at depth with a Beckman Salinometer (Model No. RS5-3) and water current speed with a Montedoro-Whitney current meter (Model No. PVM2). In addition, water turbidity samples will be taken. We have already purchased a large, self-contained, aerated live well (approx. 45 gallons) for life support and transport of experimentally held fish.

Year 2. We will continue to address all four objectives. During Year 2, we will utilize the seasonality and species composition information gained from Year 1 to tailor a more temporally-intensive (but seasonally-limited) sampling design specifically targeting the short-term temporal variability of reef fish which spawn (or, more appropriately, have larvae, postlarvae, and juveniles present) during April to August (e.g., snappers, amberjacks, spadefish, etc.) at Mobil Grand Isle 94 (61m depth). The specific sampling procedures remain the same as in Year 1. We will sample for 3 consecutive nights twice monthly. The second monthly sample collections will occur around the full moon phase, another peak recruitment period (Johannes 1978). The month of May dedicated to two additional sets of 2-day sampling periods so that collections will be made during new, 1/4, 3/4, and full moon phases.

Year 3. We will continue to address all four objectives and we will conduct a similar, tailored, short-term, and intensive sampling protocol as in Year 2 only at the Exxon South Timbalier 54 (22m depth) platform.

Statistical Analyses

The order of light trap (surface, at depth, and tethered farfield) and net samples will be randomized for each set. The ultimate statistical model implemented at the end of Year 3, when all three locations (across shelf) have been sampled, will be a randomized blocked, split-plot design with location and month as factors. Night will be blocked and the three sets of replicates per night will be a nested factor within night (gains power). Depth (surface and 15-23m depth) will be a split plot on night. The two replicates per trap set (3 sets/night) will be used as sampling error (gains power). Moon phase will be considered in a separate, smaller model, run only on the three (year 1-3) sets of May collections and will be a factor blocked on night and split or blocked on depth.

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# INTEGRATION OF VIDEO AND ACOUSTIC INDEX METHODS TO ASSESS REEF FISH POPULATIONS

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ABSTRACT

Since 1991 the National Marine Fisheries Service (NMFS) has used a video camera/trap system to assess the relative abundance of reef fishes in the Gulf of Mexico occurring on natural hardbottom substrates at depths between 9 and 110 meters. The relative index of reef fish abundance resulting from these annual Gulfwide surveys is based on counts of fish recorded during a one hour set of the video camera on the bottom.

During the 1993 reef fish survey a total of 180 video camera/trap sites were sampled. At 85 of those sites both video and acoustic data were collected. The video estimate of total fish abundance (fish/h) and the acoustic estimate of abundance (fish/hectare) were not correlated (n=85, r=-0.05). The video and acoustic data were, therefore, treated as independent surveys and combined in a product estimate of individual species abundances. The proportion of each fish species estimated from the video data was used to partition the acoustic estimate of total fish/hectare by species.

## INTRODUCTION

The term "reef fish" can refer to species that are associated not only with coral reefs, but also artificial structures like oil and gas platforms; or other bottom features such as ledges, outcrops, banks, mud lumps, sink holes, or rocks. Reef fishes in the Gulf of Mexico can be found at depths ranging from near the coast to about 150 m. Spatial, vertical and temporal distribution patterns vary among species and have been described for Gulf species by various workers (Starck 1968, Smith *et al.* 1975, Rezak *et al.* 1983, Putt *et al. 1986,* Dennis and Bright 1988, Rezak *et al.* 1990). With over 100 reef fish species supporting important commercial or sport fisheries in the U.S., the primary purpose of the National Marine Fisheries Service (NMFS) reef fish survey is to assess the relative abundances of reef fishes on natural hardbottom substrates in the Gulf of Mexico, especially populations that have been subjected to intense commercial and recreational fishing pressure such as snappers (Lutjanidae) and groupers (Serranidae)(U.S. Department of Commerce 1992). Reef habitats pose unique problems for resource managers due chiefly to their physical complexity, biological diversity, and mobility of fauna making the populations of fishes they support difficult to examine, assess, and, therefore, manage (Russell *et al.* 1978). Gear types that have been employed to collect reef fishes include bottom longlines, gill nets, traps, poisons, explosives and visual techniques using SCUBA divers, remotely operated vehicles, and video cameras (Russell *et al.* 1978, Rezak *et. al.* 1983, Parker *et al.* 1994, Ellis and DeMartini 1995). A video camera/trap system for assessing species on natural and artificial hardbottoms (exclusive of oil rigs) between 9 and 110 m was first employed in 1991, and provides a solution to some of the most important data collection problems: observing enough fish at a site for statistical reliability; making individual stations brief enough to enable broad-scale surveys; nondestructive sampling on sensitive reef habitats; and relatively non-selective "collection" (observation) of reef fish species. The relative index of reef fish abundance using counts of fish recorded during a one hour camera/trap set has limitations that include variable sampling volume and interspecific differences in fish behavior. Synoptic fisheries acoustic mapping of sampling sites was added to the survey design in 1993 in an attempt to offset some of the shortcomings of video census techniques. In this paper, we establish a quantitative methodology for the assessment of reef fish populations in the Gulf of Mexico by combining video and acoustic data. We first determine the reef fish species that are insonified, then compare the video and acoustic estimates of total reef fish abundance; and finally, present a combined estimate of reef fish abundance.

## METHODS

A two-stage sampling design was employed to select "reef" sites. Primary sample units (PSUs) were defined as 18,520 m by 18,520 m square blocks, with boundaries set along lines of latitude and longitude. Sample units within a PSU were 100 m by 100 m sites. Data from bottom topography surveys conducted in the Gulf of Mexico were used to designate each sample unit as a "reef" or "nonreef" site. The number of "reef" sites in each PSU is the measure-of-size of that PSU. For the 1993 survey, PSUs were selected proportional-to-size, where the estimator of the mean reduces to that for simple random sampling (Cochran 1977). Sample sites were then selected randomly within a PSU. The video/trap gear was used to sample each selected reef site during daylight hours;ie. from one hour after sunup and to one hour before sunset. Several different models of Hi-8 video cameras were used in an underwater housing to record habitat and fish activity. The camera was mounted on a single-funnel fish trap (2.13 m long by 0.76 m square) which was baited with squid and allowed to set on the bottom for one hour.

The procedure to view video tapes was analogous to that for aging fish using hard parts. Each tape was viewed separately by two viewers who identified all fish to the lowest possible taxonomic level while enumerating them. Species identifications and counts for each viewer were compared. Discrepancies between the two viewers were resolved either through discussion among the viewers (eg. cases where one viewer made an identification to the generic level, while the other viewer went to species); or viewing of the tape jointly for cases where counts between viewers differed greatly.

The fisheries acoustic system (FAS) used to survey sample sites operated at 120 kHz. This was a dual-beam system that consisted of a BioSonics Model 102 Echo Sounder with a 120 kHz dual-beam (7°/16°) transducer mounted in a V-fin towed body, and the BioSonics Dual-Beam and Echo Integrator software. A total of four or five parallel 185 m transects were sampled, centered around the sample site. The video/trap gear was dropped during the first or second pass with the FAS. Completion of five passes at a speed of 1-3 knots took approximately 30 minutes. The V-fin was towed at a depth of approximately 10 m below the surface. Volume backscatter was determined at each reef site and scaled using *in situ* estimates of target strength (TS). The scaled acoustic estimates were converted to fish hectare$^{-1}$. The video and acoustic estimates of fish abundance were compared using product-moment and Spearman's correlation coefficients. The null and alternative hypotheses tested were: $H_o$: $r = 0$, and $H_{A:} = r \neq 0$.

## RESULTS

A total of 180 reef sites were sampled with the video/trap gear during the 1993 survey (Figure 1). Acoustic volume backscatter data (echo integration) and TS data (dual-beam processing) together with clear video data were obtained at only 85 sites. A total of 148 fish taxa plus unidentified large (approximately > 30 cm in length) and unidentified small (< 30 cm) fish were observed on video tapes. Unidentified fish were located near the 5 m limit of detection by the video camera. Video estimates of total fish at each site averaged 594 h$^{-1}$ (Table 1). Video abundance estimates of snappers, groupers and amberjacks ranged from 0.01 h$^{-1}$ to 88 h$^{-1}$.

The detection of fish targets depends on their height above the dead zone where the bottom echo obscures fish echoes (Johannesson and Mitson 1983). When the 1993 video tapes were viewed, each species was classified as "off-bottom", if, at any time during the one hour set, individuals were estimated to be at least 0.5 m above the bottom. The rationale for this criterion being if any individuals of a species spent any time above the dead zone, they had a probability of being insonified. The overall probability of any single species being classified as off-bottom was estimated as the frequency of sites where it occurred above the bottom. Using all readable tapes from the 1993 survey, frequency of occurrence above the bottom was estimated for only those taxa that were observed at a minimum of 5 sites (Table 2). These data should be considered as preliminary since, for many species, sample sizes were small. However, the data indicate that many of the fish species associated with natural hardbottom features have a chance at being detected with the FAS. Commercially and recreationally important species such as groupers (*Epinephelus spp. and Mycteroperca sp.*) snappers (Lutjanidae), triggerfish (*Balistes spp.*) and amberjacks (*Seriola spp.*) were observed off-bottom at 65% to 91% of the sites where they were observed. While other taxa; lizardfishes (*Synodus spp.*), wrasses (Labridae), small sea basses (*Serranus spp.*), parrotfishes (Scaridae), butterflyfishes (*Chaetodon spp.*), and damselfishes (Pomacentridae) were rarely found greater than 0.5 m above the bottom.

Echoes from fish found over reef sites were observed to a range of 12 m above the bottom. Target strengths ranged from -63 dB to -23 dB, with a mean of -52.9 dB (n = 7136, se = 8.29). Average reef fish abundance was estimated as 1290 fish hectare$^{-1}$ (Table 3). The correlation between acoustic estimates of fish hectare$^{-1}$ and video estimates of fish h$^{-1}$ were not significantly different from zero (r= -0.056, n=85, Figure 2). Ranked abundance data were also not correlated (Spearman's r = -0.02, n=85).

Examination of species composition data at sites where the acoustic estimate of abundance was high relative to the video estimate, and at sites where the video estimate was high relative to the acoustic estimate provide insight into the factors causing poor correlations between abundance estimates. At 10 sites, the acoustic estimate was very high relative to the video estimate. The species composition at those sites were either dominated by amberjacks, or by wrasses and damselfishes. When the wrasses and damselfishes dominated, jacks (Carangidae) were also present. The discrepancy between the two abundance estimates for these sites may have resulted from the wider area sampled by the FAS. The FAS may have insonified schooling fish (eg. amberjacks or other jacks) passing the site that remained out of the camera's view for all or most of the recorded set. At six sites where the video abundance estimates were high relative to the FAS estimates, species composition was dominated by damselfishes, wrasses, parrotfishes and unidentified small fishes, taxa that are mostly found within 0.5 m of the bottom. No amberjacks or other jacks were observed at these sites. Additionally at several sites, vermilion snapper (*Rhomboplites aurorubens*) comprised 73% of the fish observed. It is likely that the abundance of this species was overestimated due to multiple counts of the same individuals since these fish school around the video/trap gear.

The approach used to combine video and acoustic observations treated each as data from two independent surveys. Species identifications and the proportion of each species for the survey were estimated from the video data. These proportions were then used to partition the acoustic estimate of total fish abundance (fish hectare$^{-1}$). The proportion of each species was calculated from the video data excluding taxa that occurred above the bottom at less than 50% of the sites where they were observed. Since the number of any single species (i-th species), and the total number of fish at any site were both random variables, a ratio estimator was used to calculate the proportion of each species observed during the survey (Cochran 1977). The ratio estimate and it's variance were calculated as:

$$p_i = \frac{\sum y_{ij}}{\sum Y_j} \qquad (1)$$

$$V(p_i) = \frac{1}{n\bar{Y}^2}\,[s_{yi}^{\,2} + p_i^2 s_Y^{\,2} - 2p_i^2 s_{yiY}] \qquad (2)$$

where $p_i$ is the proportion of the i-th species, $y_{ij}$ is the number of the i-th species at the j-th station, $Y_j$ is the total number of fish at the j-th station, and $s_{yi}^2$, $s_Y^2$, and $s_{yiY}$ are the variances and covariance for the number of the i-th species and the total number of fish.

The estimated number of fish hectare$^{-1}$ for the i-th species was estimated as the product of the proportion of the i-th species and the FAS estimate of total fish hectare$^{-1}$, with the variance estimated as the product of two random variables (Goodman 1961):

$$\overline{N}_i = p_i\overline{N} \tag{3}$$

$$V(N_i) = p_i^2V(N) + \overline{N}^2V(p_i) - V(N)\ V(p_i). \tag{4}$$

The proportions of all snappers, groupers and amberjacks, and estimates of average numbers hectare$^{-1}$ ranged from 0.00003 for *Lutjanus analis* to 0.33 for unidentified small fish (Table 3). Corresponding individual species estimates of abundance ranged from 0.03 fish hectare$^{-1}$ to 421 fish hectare$^{-1}$.

## DISCUSSION

Fisheries-independent surveys to assess reef fish populations are difficult due to the diversity and mobility of fishes found on reef habitats. The cryptic nature of some species and behavioral differences among species further compounds the problems with obtaining estimates of reef fish abundance (Sale 1980, Sale and Douglas 1981, Bortone and Kimmel 1991). Methodologies that employ SCUBA diver census techniques are not feasible because of the time limitations imposed by our need to survey the entire broad extent of reef habitats in the U.S. Gulf of Mexico. We are, therefore, limited to remote sensing techniques that employ video cameras that can be rapidly deployed and retrieved from depth. Use of video techniques for population assessments have recently increased. Parker *et al.* (1994) used a video transect method with divers, and Ellis and DeMartini (1995) used a baited stationary video camera. Ellis and DeMartini (1995) obtained a good correlation between the video estimate of pink snapper and indices of abundance estimated with long-lines.

There are still problems with the single video camera technique employed for our offshore reef fish survey. The lack of correlation between video and acoustic estimates of reef fish abundance makes this clear. The poor correlations we obtained may have resulted from: 1) differences in the area surveyed by the FAS and video camera, 2) FAS biases due to fish in the dead zone, 3) FAS biases associated with *in situ* TS estimation, 4) video biases due to fish behavior, 5) single video camera bias introduced at some sites where the camera field-of-view does not encompass the reef habitat, and 6) the choice of the video fish counting method. Biases with the single stationary video camera method may be mitigated by the use of a multiple camera gear and/or a change in the method of counting fish on the video tape. We have devised a multiple camera gear that consists of four cameras mounted orthogonal to each other providing nearly a 360° field-of-view. This gear may solve multiple count problems, and prevent situations where a single camera-trap array lands on the bottom pointing away from the reef habitat.

One aspect of the current video technique that we are examining is the method of counting fish. At present, each fish is counted every time it appears on the screen over the entire length of the video tape. The 1993 video tapes were also counted by a procedure where viewers attempt to count fish that are identifiable as individuals only once. This is a simple task for many fish that swim back and forth, or in and out of a burrow. It is more problematic with fish that school around a camera. However, viewers estimated a MIN (minimum) count for each species observed. An alterative approach employed by Ellis and DeMartini (1995) who use a video index for maximum number of fish that is weighted by the duration of each occurrence when it is viewed.

The results from the 1993 survey, however, demonstrate a statistically valid methodology to combine video and acoustic data. The use of acoustics along with video cameras provides two estimates of reef fish abundance. Video data provide species identification, while the acoustic system offers the advantage of providing an areal estimate of abundance that can be extrapolated to give a Gulf-wide estimate of population totals.

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Table 1. Average number of selected reef fish per hour observed with video gear in the Gulf of Mexico during the 1993 reef fish survey (n = 85).

| COMMON NAME | SCIENTIFIC NAME | mean | se |
|---|---|---|---|
| Unidentified Large | | 27.534 | 9.499 |
| Unidentified Small | | 149.202 | 45.621 |
| Grouper subfamily | *Epinephelinae* | 1.004 | 0.309 |
| Red grouper | *Epinephelus morio* | 3.348 | 1.406 |
| Grouper | *Mycteroperca spp.* | 0.166 | 0.108 |
| Gag | *Mycteroperca microlepis* | 0.120 | 0.080 |
| Scamp | *Mycteroperca phenax* | 6.223 | 2.108 |
| Yellowfin grouper | *Mycteroperca venenosa* | 0.012 | 0.012 |
| Amberjack | *Seriola spp.* | 3.327 | 1.511 |
| Greater amberjack | *Seriola dumerili* | 6.018 | 2.675 |
| Lesser amberjack | *Seriola fasciata* | 0.235 | 0.235 |
| Alamaco jack | *Seriola rivoliana* | 1.643 | 0.902 |
| Snapper | *Lutjanus spp.* | 0.154 | 0.070 |
| Mutton snapper | *Lutjanus analis* | 0.012 | 0.012 |
| Red snapper | *Lutjanus campechanus* | 0.226 | 0.123 |
| Gray snapper | *Lutjanus griseus* | 5.929 | 2.418 |
| Vermilion snapper | *Rhomboplites aurorubens* | 87.701 | 81.644 |
| Yellowtail snapper | *Ocyrus chrysurus* | 7.526 | 3.800 |
| All Fish Taxa | | 594.324 | 130.715 |
| All Offbottom Taxa[1] | | 456.449 | 119.395 |

[1]Wrasses, small sea basses, damselfishes, butterflyfishes parrotfishes, and angelfishes excluded.

Table 2. Frequency of occurrance 0.5 m or more above the bottom. (n = number of stations where fish were observed, f = number of stations where fish were obseved above the bottom).

| COMMON NAME | SCIENTIFIC NAME | n | f | PERCENT |
|---|---|---|---|---|
| Lizardfishes | *Synodus spp.* | 8 | 0 | 0.0 |
| Wrasses | Labridae | 134 | 5 | 3.7 |
| Small sea basses | *Serranus spp.* | 105 | 10 | 9.5 |
| Parrotfishes | Scaridae | 36 | 6 | 16.7 |
| Butterflyfishes | *Chaetodon spp* | 94 | 33 | 35.1 |
| Damselfishes | Pomacanthidae | 70 | 33 | 47.1 |
| Angelfishes | Pomacanthidae | 119 | 58 | 48.7 |
| Groupers | *Epinephelus spp.* | | | |
| | *Mycteroperca spp.* | 102 | 66 | 64.7 |
| Snappers | Lutjanidae | 79 | 55 | 69.6 |
| Triggerfishers | *Balistes spp.* | 58 | 49 | 84.4 |
| Amberjacks | *Seriola spp.* | 91 | 83 | 91.2 |

Table 3. Estimates of the average number of snappers, groupers, amberjacks and unidentified fish per hectare in the Gulf of Mexico during the 1993 reef fish survey. (n = 85).

| SCIENTIFIC NAME | Proportion | se (p) | Fish | se (fish) |
|---|---|---|---|---|
| All Fish | 1.00000 | - | 1290.190 | 331.241 |
| Unidentified Large | 0.06020 | 0.00107 | 77.670 | 19.721 |
| Unidentified Small | 0.32617 | 0.0139 | 420.821 | 103.341 |
| *Epinephelinae* | 0.00220 | 0.00009 | 2.839 | 0.682 |
| *Epinephelus morio* | 0.00734 | 0.00019 | 9.464 | 2.385 |
| *Mycteroperca spp.* | 0.00036 | 0.00003 | 0.470 | 0.095 |
| *Mycteroperca microlepis* | 0.00026 | 0.00002 | 0.339 | 0.068 |
| *Mycteroperca phenax* | 0.01363 | 0.00061 | 17.590 | 4.223 |
| *Mycteroperca venenosa* | 0.00003 | 0.00001 | 0.034 | 0.003 |
| *Seriola spp.* | 0.00729 | 0.00042 | 9.404 | 2.132 |
| *Seriola dumerili* | 0.01318 | 0.00075 | 17.010 | 3.875 |
| *Seriola fasciata* | 0.00052 | 0.00006 | 0.665 | 0.060 |
| *Seriola rivoliana* | 0.00360 | 0.00024 | 4.643 | 0.990 |
| *Lutjanus spp.* | 0.00034 | 0.00002 | 0.435 | 0.098 |
| *Lutjanus analis* | 0.00003 | 0.00003 | 0.034 | 0.003 |
| *Lutjanus campechanus* | 0.00049 | 0.00003 | 0.639 | 0.137 |
| *Lutjanus griseus* | 0.01299 | 0.00066 | 16.758 | 3.928 |
| *Rhomboplites aurorubens* | 0.19214 | 0.01494 | 247.893 | 48.869 |
| *Ocyrus chrysurus* | 0.01649 | 0.00099 | 21.274 | 4.723 |

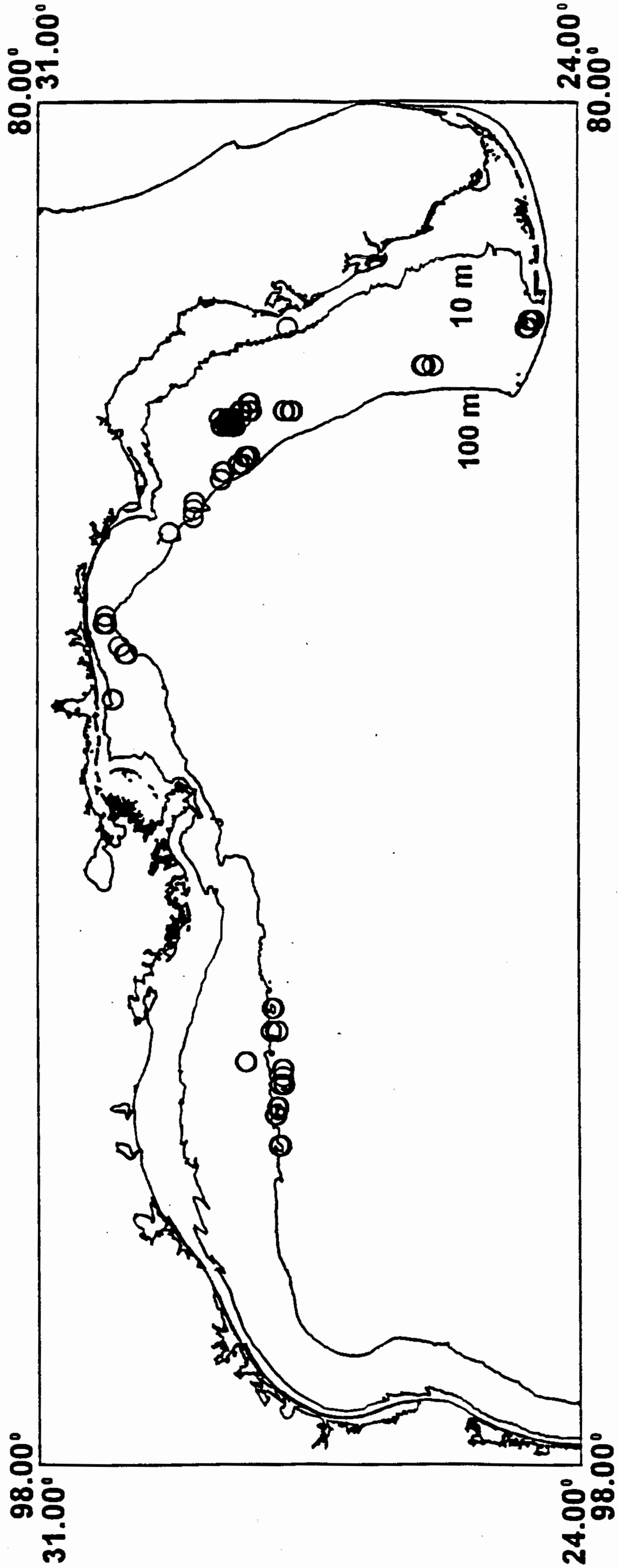


Figure 1. Reef sites sampled during the NMFS 1993 reef fish survey.

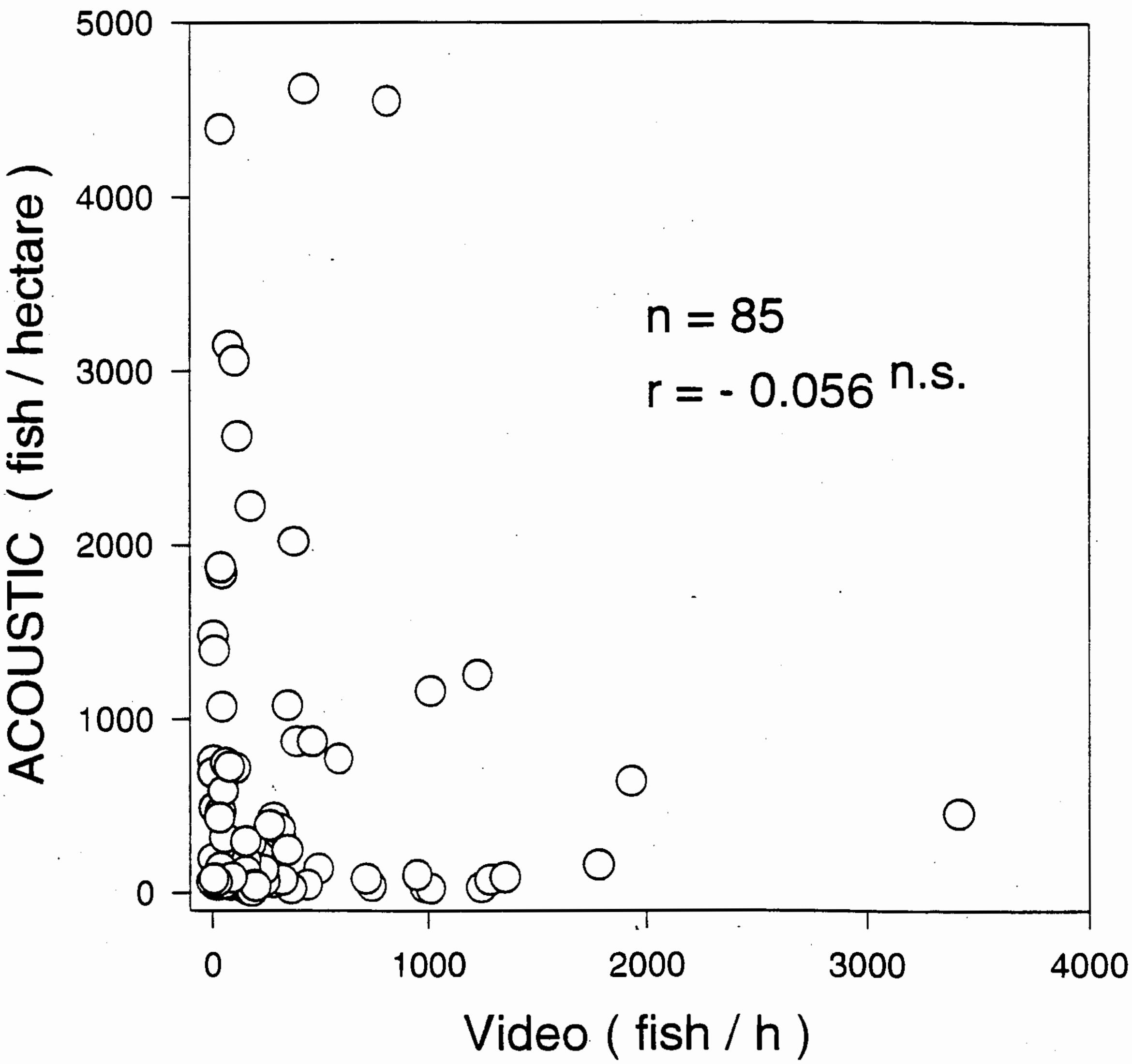


Figure 2. Scatterplot of the video and acoustic estimates of reef fish abundance.

# TWO VISUALLY BASED METHODS FOR MONITORING CORAL REEF FISHES

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ABSTRACT

Two visual methods are described to monitor coral reef fishes. The Roving Diver Technique (RDT) developed by REEF (Reef Environmental Education Foundation) uses volunteers to collect reef fish species presence, frequency of occurrence, and an abundance data. The more quantitative Stationary Sampling Technique (SST) requires more highly trained divers to collect quantitative data on sizes, frequency of occurrence, and abundance for all visually observable species. From these data in index of biomass and importance value can be calculated. Both methods can be used to answer a wide variety of monitoring and scientific questions although each has advantages and disadvantages.

## ROVING DIVER TECHNIQUE (RDT)

The RDT technique takes advantage of thousands of highly trained divers that are looking for an interesting new challenge. Volunteer divers are trained in reef fish identification using the book: *Reef Fish Identification* by Paul Human and Ned Deloach. On each dive, divers list on underwater slates every species that they can find. Buddy teams are allowed to move freely and search as they wish, but are not allowed to turn over rocks for environmental reasons. Dive time, depth, temperature and other environmental information is recorded. After the dive, and species observed are marked on a preprinted data sheet (Figure 1) along with an estimate of how many individuals were observed for each species according to the following $\log_{10}$ categories: 1, 2-10, 11-100, or >100. Data sheets are submitted, optically scanned at the University of Miami, and then stored in a data base supported by the Nature Conservancy.

Data analyses primarily is based on frequency of observation using large numbers of dives. Data can show differences in community composition between sites or between seasons (e.g. number of species, individuals and kinds of species) and can show distribution patterns of various species around the Caribbean. Over time, data should show long-term (years) changes in distribution and abundance and could be extremely valuable for monitoring species, such as jewfish and Nassau grouper, that are under protection from fishing.

An indirect benefit of the program is that divers develop a greatly increased knowledge of the marine environment. Divers quickly learn where and what habitats are used by specific species. Trained observers are useful for alerting scientists and managers to problems or unusual changes that might otherwise go unnoticed, such as outbreaks of algae or disease, and changes in abundance. Currently over 5,000 divers have enrolled in REEF and over 2,000 data sheets have been submitted in the first full year of the program.

The advantages of the method are its simplicity and avid enthusiasm by divers. disadvantages are the high variability in searches and differences in skill levels among divers, although data can be edited based on diver experience and other performance criteria. Data collected probably offer less interpretation problems than typical fishery data bases that rely on voluntary and involuntary reporting by fishers.

## STATIONARY SAMPLING TECHNIQUE (SST)

Stationary sampling (Bohnsack and Bannerot, 1986) was designed to provide standardized quantitative data on reef fish community structure over a variety of habitat types in an effective and efficient manner. It is based on plot techniques used in terrestrial studies except that visual samples were taken of circular areas by stationary SCUBA divers. At random points on a reef, divers attempt to count all individuals and species within five minutes in an imaginary, 7.5 m (24 ft.) radius cylinder extending from the bottom to the surface. New species are listed while rotating in one direction and scanning the field of view. Except being able to rotate, the observer remains stationary in the center of the sampling cylinder. Five minutes was chosen as an optimum time to determine species presence. It allows sufficient time for most fish to habituate to a diver and to adequately scan all areas, but not too much time to accumulate mobile species initially outside the sample cylinder. The 7.5 m sample radius was chosen to maximize the amount of area that could be adequately searched based on average visibility. The radius was large enough to detect the presence of larger, shy, and economically important species that were unlikely to closely approach a diver, and yet, the smallest species could usually be distinguished at the edge of the sample cylinder. Statistical data are collected for each species including the estimated number of individuals in the cylinder and their minimum, maximum, and mean length.

Species are only listed during the first 5 min with the exception of a few solitary species and highly mobile species in large schools (e.g. Carangidae, Kyphosidae, Scrobridae). Based on previous experience, these species were unlikely to remain in the sampling area and were evaluated when first observed. If individuals of these species were observed later, they were ignored to prevent bias by inflating the importance of highly mobile species.

After the 5-min listing, divers systematically record data for each remaining species working from last to the first observed species. This procedure avoids overlooking a species and avoids bias caused by a natural tendency to count species when they are particularly conspicuous or abundant. This procedure effectively forces counts for each species to be made at random times. Data were recorded from memory for many conspicuous species in which only a few individuals appeared within the sampling cylinder during the initial 5-min listing period. Species always present in the sample area (e.g. Pomacentridae, Labridae, Haemulidae, Scaridae) were individually evaluated by starting at one point on the underwater horizon and rotating 360 degrees while counting all individuals until the entire area was scanned. For species with large numbers of individuals present, fish were counted in multiples of 10, 20, 50, or even 100. Fork lengths were estimated in centimeters by comparing fishes to a ruler attached perpendicular to the end of a 1 m rod.

After recording fish data, divers recorded data on habitat features within the sample cylinder including depth, substrate composition, and maximum vertical relief. Estimated percentage composition of various substrates within the sample cylinder was based on the observer's field of view from the center of the sample cylinder.

The SST method is simple, well-established, and is being used in many areas around the world. It provides quantitative data for most reef species includes a number of variables that can not be effectively collected using other methods. Statistical power comes from large sample sizes. The method reduces bias caused by moving divers and increases the useful bottom time by conserving air. It is best suited for sampling suprabenthic reef species, but is less well suited for cryptic, secretive, and nocturnally active species. It has limited use under conditions of very poor visibility, high surge, and deep depths. A disadvantage is that it provides an index of abundance and biomass but can not easily be used to develop absolute abundance estimates without extensive ground-truth calibration or use of stereo video technology.

Abundance codes:

(S) Solitary = 1
(F) Few = 2 - 10
(M) Many = 11 - 100
(A) Abundant = over 100

Please return completed survey forms to:

**R.E.E.F**
**Marine Wildlife Survey**
**P.O. Box 246**
**Key Largo, FL 33037**

- USE A NO. 2 PENCIL ONLY
- DO NOT MAKE ANY STRAY MARKS
- ERASE CLEANLY ANY MARKS YOU CHANGE

| CORRECT MARK | INCORRECT MARKS |
|---|---|
| ●●●● | ⊗ ⊘ ⊙ ◒ |

## DISKS & OVALS/COLORFUL

(S) (F) (M) (A) 1. Spotfin Butterflyfish
(S) (F) (M) (A) 2. Foureye Butterflyfish
(S) (F) (M) (A) 3. Banded Butterflyfish
(S) (F) (M) (A) 4. Reef Butterflyfish
(S) (F) (M) (A) 5. Longsnout Butterflyfish
(S) (F) (M) (A) 6. Rock Beauty
(S) (F) (M) (A) 7. Queen Angelfish
(S) (F) (M) (A) 8. Blue Angelfish
(S) (F) (M) (A) 9. French Angelfish
(S) (F) (M) (A) 10. Gray Angelfish
(S) (F) (M) (A) 11. Cherubfish
(S) (F) (M) (A) 12. Flameback Angelfish
(S) (F) (M) (A) 13. Ocean Surgeonfish
(S) (F) (M) (A) 14. Gulf Surgeonfish
(S) (F) (M) (A) 15. Doctorfish
(S) (F) (M) (A) 16. Blue Tang

## SILVERY

(S) (F) (M) (A) 17. Bar Jack
(S) (F) (M) (A) 18. Blue Runner
(S) (F) (M) (A) 19. Yellow Jack
(S) (F) (M) (A) 20. Horse-Eye Jack
(S) (F) (M) (A) 21. Crevalle Jack
(S) (F) (M) (A) 22. Black Jack
(S) (F) (M) (A) 23. Almaco Jack
(S) (F) (M) (A) 24. Greater Amberjack
(S) (F) (M) (A) 25. Rainbow Runner
(S) (F) (M) (A) 26. Permit
(S) (F) (M) (A) 27. Florida Pompano
(S) (F) (M) (A) 28. Palometa
(S) (F) (M) (A) 29. African Pompano
(S) (F) (M) (A) 30. Lookdown
(S) (F) (M) (A) 31. Saucereye Porgy
(S) (F) (M) (A) 32. Silver Porgy
(S) (F) (M) (A) 33. Jolthead Porgy
(S) (F) (M) (A) 34. Sheepshead Porgy
(S) (F) (M) (A) 35. Whitebone Porgy
(S) (F) (M) (A) 36. Pluma
(S) (F) (M) (A) 37. Littlehead Porgy
(S) (F) (M) (A) 38. Knobbed Porgy
(S) (F) (M) (A) 39. Bermuda Chub
(S) (F) (M) (A) 40. Yellow Chub
(S) (F) (M) (A) 41. Yellowfin Mojarra
(S) (F) (M) (A) 42. Slender Mojarra
(S) (F) (M) (A) 43. Atlantic Spadefish
(S) (F) (M) (A) 44. Great Barracuda
(S) (F) (M) (A) 45. Southern Sennet
(S) (F) (M) (A) 46. Cero
(S) (F) (M) (A) 47. Spanish Mackerel
(S) (F) (M) (A) 48. Tarpon
(S) (F) (M) (A) 49. Bonefish
(S) (F) (M) (A) 50. Ladyfish
(S) (F) (M) (A) 51. Snook
(S) (F) (M) (A) 52. Houndfish
(S) (F) (M) (A) 53. Timucu
(S) (F) (M) (A) 54. Redfin Needlefish
(S) (F) (M) (A) 55. Atlantic Needlefish
(S) (F) (M) (A) 56. Boga
(S) (F) (M) (A) 57. Bonnetmouth
(S) (F) (M) (A) 58. Cobia
(S) (F) (M) (A) 59. Mirrorwing Flyingfish
(S) (F) (M) (A) 60. Silversides, Herrings, Anchovies & Scad

## SLOPING HEAD/TAPERED BODY

(S) (F) (M) (A) 61. Schoolmaster
(S) (F) (M) (A) 62. Mahogany Snapper
(S) (F) (M) (A) 63. Dog Snapper
(S) (F) (M) (A) 64. Cubera Snapper
(S) (F) (M) (A) 65. Gray Snapper
(S) (F) (M) (A) 66. Mutton Snapper
(S) (F) (M) (A) 67. Lane Snapper
(S) (F) (M) (A) 68. Yellowtail Snapper
(S) (F) (M) (A) 69. Bluestriped Grunt
(S) (F) (M) (A) 70. Spanish Grunt
(S) (F) (M) (A) 71. Smallmouth Grunt
(S) (F) (M) (A) 72. Striped Grunt
(S) (F) (M) (A) 73. White Grunt
(S) (F) (M) (A) 74. Caesar Grunt
(S) (F) (M) (A) 75. Cottonwick
(S) (F) (M) (A) 76. French Grunt
(S) (F) (M) (A) 77. Tomtate
(S) (F) (M) (A) 78. Sailors Choice
(S) (F) (M) (A) 79. Black Grunt
(S) (F) (M) (A) 80. Margate (White)
(S) (F) (M) (A) 81. Black Margate
(S) (F) (M) (A) 82. Porkfish

## SMALL OVALS

(S) (F) (M) (A) 83. Yellowtail Damselfish
(S) (F) (M) (A) 84. Dusky Damselfish
(S) (F) (M) (A) 85. Longfin Damselfish
(S) (F) (M) (A) 86. Cocoa Damselfish
(S) (F) (M) (A) 87. Beaugregory
(S) (F) (M) (A) 88. Bicolor Damselfish
(S) (F) (M) (A) 89. Threespot Damselfish
(S) (F) (M) (A) 90. Sergeant Major
(S) (F) (M) (A) 91. Night Sergeant
(S) (F) (M) (A) 92. Blue Chromis
(S) (F) (M) (A) 93. Brown Chromis
(S) (F) (M) (A) 94. Sunshinefish
(S) (F) (M) (A) 95. Purple Reeffish
(S) (F) (M) (A) 96. Yellowtail Reeffish
(S) (F) (M) (A) 97. Barred Hamlet
(S) (F) (M) (A) 98. Butter Hamlet
(S) (F) (M) (A) 99. Masked Hamlet
(S) (F) (M) (A) 100. Black Hamlet
(S) (F) (M) (A) 101. Indigo Hamlet
(S) (F) (M) (A) 102. Blue Hamlet
(S) (F) (M) (A) 103. Golden Hamlet
(S) (F) (M) (A) 104. Yellowbelly Hamlet
(S) (F) (M) (A) 105. Shy Hamlet
(S) (F) (M) (A) 106. Yellowtail Hamlet

## HEAVY BODY/LARGE LIPS

(S) (F) (M) (A) 107. Jewfish
(S) (F) (M) (A) 108. Warsaw Grouper
(S) (F) (M) (A) 109. Nassau Grouper
(S) (F) (M) (A) 110. Red Grouper
(S) (F) (M) (A) 111. Yellowfin Grouper
(S) (F) (M) (A) 112. Black Grouper
(S) (F) (M) (A) 113. Gag
(S) (F) (M) (A) 114. Yellowmouth Grouper
(S) (F) (M) (A) 115. Scamp
(S) (F) (M) (A) 116. Comb Grouper
(S) (F) (M) (A) 117. Tiger Grouper
(S) (F) (M) (A) 118. Marbled Grouper
(S) (F) (M) (A) 119. Red Hind
(S) (F) (M) (A) 120. Rock Hind
(S) (F) (M) (A) 121. Graysby
(S) (F) (M) (A) 122. Coney
(S) (F) (M) (A) 123. Chalk Bass
(S) (F) (M) (A) 124. Harlequin Bass
(S) (F) (M) (A) 125. Belted Sand Bass
(S) (F) (M) (A) 126. Tobaccofish
(S) (F) (M) (A) 127. School Bass
(S) (F) (M) (A) 128. Peppermint Bass
(S) (F) (M) (A) 129. Candy Bass
(S) (F) (M) (A) 130. Cave Bass
(S) (F) (M) (A) 131. Lantern Bass
(S) (F) (M) (A) 132. Orangeback Bass
(S) (F) (M) (A) 133. Snow Bass
(S) (F) (M) (A) 134. Mutton Hamlet
(S) (F) (M) (A) 135. Creolefish
(S) (F) (M) (A) 136. Sand Perch
(S) (F) (M) (A) 137. Dwarf Sand Perch
(S) (F) (M) (A) 138. Aquavina
(S) (F) (M) (A) 139. Yellowcheek Basslet
(S) (F) (M) (A) 140. Threeline Basslet
(S) (F) (M) (A) 141. Fairy Basslet
(S) (F) (M) (A) 142. Heliotrope Basslet
(S) (F) (M) (A) 143. Blackcap Basslet

## SWIM WITH PECTORAL FINS OBVIOUS SCALES

(S) (F) (M) (A) 144. Queen Parrotfish
(S) (F) (M) (A) 145. Rainbow Parrotfish
(S) (F) (M) (A) 146. Princess Parrotfish
(S) (F) (M) (A) 147. Emerald Parrotfish
(S) (F) (M) (A) 148. Blue Parrotfish
(S) (F) (M) (A) 149. Striped Parrotfish
(S) (F) (M) (A) 150. Midnight Parrotfish
(S) (F) (M) (A) 151. Stoplight Parrotfish
(S) (F) (M) (A) 152. Redband Parrotfish
(S) (F) (M) (A) 153. Yellowtail Parrotfish
(S) (F) (M) (A) 154. Redtail Parrotfish
(S) (F) (M) (A) 155. Greenblotch Parrotfish
(S) (F) (M) (A) 156. Bucktooth Parrotfish
(S) (F) (M) (A) 157. Hogfish
(S) (F) (M) (A) 158. Spanish Hogfish
(S) (F) (M) (A) 159. Spotfin Hogfish
(S) (F) (M) (A) 160. Puddingwife
(S) (F) (M) (A) 161. Creole Wrasse
(S) (F) (M) (A) 162. Yellowhead Wrasse
(S) (F) (M) (A) 163. Slippery Dick
(S) (F) (M) (A) 164. Rainbow Wrasse
(S) (F) (M) (A) 165. Yellowcheek Wrasse
(S) (F) (M) (A) 166. Bluehead Wrasse
(S) (F) (M) (A) 167. Clown Wrasse
(S) (F) (M) (A) 168. Blackear Wrasse
(S) (F) (M) (A) 169. Dwarf Wrasse
(S) (F) (M) (A) 170. Rosy Razorfish
(S) (F) (M) (A) 171. Green Razorfish
(S) (F) (M) (A) 172. Pearly Razorfish

Figure 1. Species observation data sheet.

# CURRENT GEAR TECHNOLOGY FOR ASSESSING FISH POPULATIONS IN THE VICINITY OF OFFSHORE STRUCTURES

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Estimating the fish population in and around offshore structures presents many unique problems not associated with other environments. An even spatial distribution cannot be assumed thus complicating any trap sampling. High turbidity found around many shallow structures hinders video work. Acoustic reflections caused by the structure itself limits the usefulness of hydroacoustic methods. Depth and limited visibility will hinder divers. Trawl nets will not be useful for obvious reasons. Any reasonable sampling methodology must take into account the potential of different methods while realizing the limits placed on each method. This presentation will focus on the potential and limits of candidate gear for assessing fish populations in this unique environment.

Hydroacoustic sampling techniques most commonly used are echo integration and echo counting (Figures 1 and 2). Echo integration is most effective in open water conditions with concentrations of same species fish having the same size (target strength). Echo counting is more effective when a lower concentration of fish are encountered with a more varied target strength. Both of these methods have the advantage that a large area can be surveyed quickly. The main disadvantage of hydroacoustics in this case is the interference of the structure in creating acoustic reverberations and false targets and the fact that species cannot be differentiated. Hydroacoustic techniques can best be used for sampling the periphery of the structure. In certain cases where the configuration of the structure is well known and a transducer can be carefully aimed, hydroacoustics may be used for internal sampling of the structure.

Another hydroacoustic method for fish sampling, but less commonly used is direct imaging. This method uses a scanned acoustic beam to produce a high resolution, 2 dimensional image. By slowly translating the transducer, a 3 dimensional mosaic can by generated. The resolution obtainable with this type system should be capable of discerning individual fish and the structure.

A remotely operated underwater vehicle (ROV) could perform a variety of functions for an offshore structure survey (Figures 3 and 4). A very promising application is to use the ROV as a mobile platform for hydroacoustic work. A transducer can be mounted to look up, down, or forward depending on the survey requirements. The ROV could then be up and down in the water column and around or in the structure. An advantage of performing some of the hydroacoustic survey with an ROV is that the position and movement of the transducer can be carefully controlled. The ROV cameras can be used to identify species in this scenario as well as performing straight video sampling. The ROV can be equipped with a low light camera greatly enhancing its utility in deep or turbid water. An ROV equipped with a manipulator arm could be used for placing fish traps around and inside the structure. An ROV should be considered for any type work that would normally be performed by a diver where depth and/or endurance is critical. The most serious drawback to depending on an ROV for a major portion of the survey data is environmental limitations. Most ROVs cannot operate in currents greater than 4 to 5 knots.

In many sampling methods, the precise location of the sampling gear must be known. For example, when using an ROV to move a transducer around a structure the track of the transducer must be known in order to compute the area covered for echo integration calculations. Trap recovery by a diver in turbid water could be made much easier if a precise location of the diver and the trap are known in real time and fed back to the diver. These locations can be obtained easily with an ultrashort baseline navigation system. This system uses a roll compensated acoustic transducer array mounted on a retractable arm to interrogate a transducer at the target. Time delay and phase angle of the return signal are used to calculate range, bearing and depression angle (and thus depth) of the target.

Probably no single sampling technique will provide adequate information for assessing fish population in the vicinity of offshore structures. Due to the diversity of structure architecture and environmental parameters a valid sampling scheme for one location may not work at another location. A good sampling methodology must take into account the potentials and limitations of a variety of sampling gear and carefully plan their utilization.

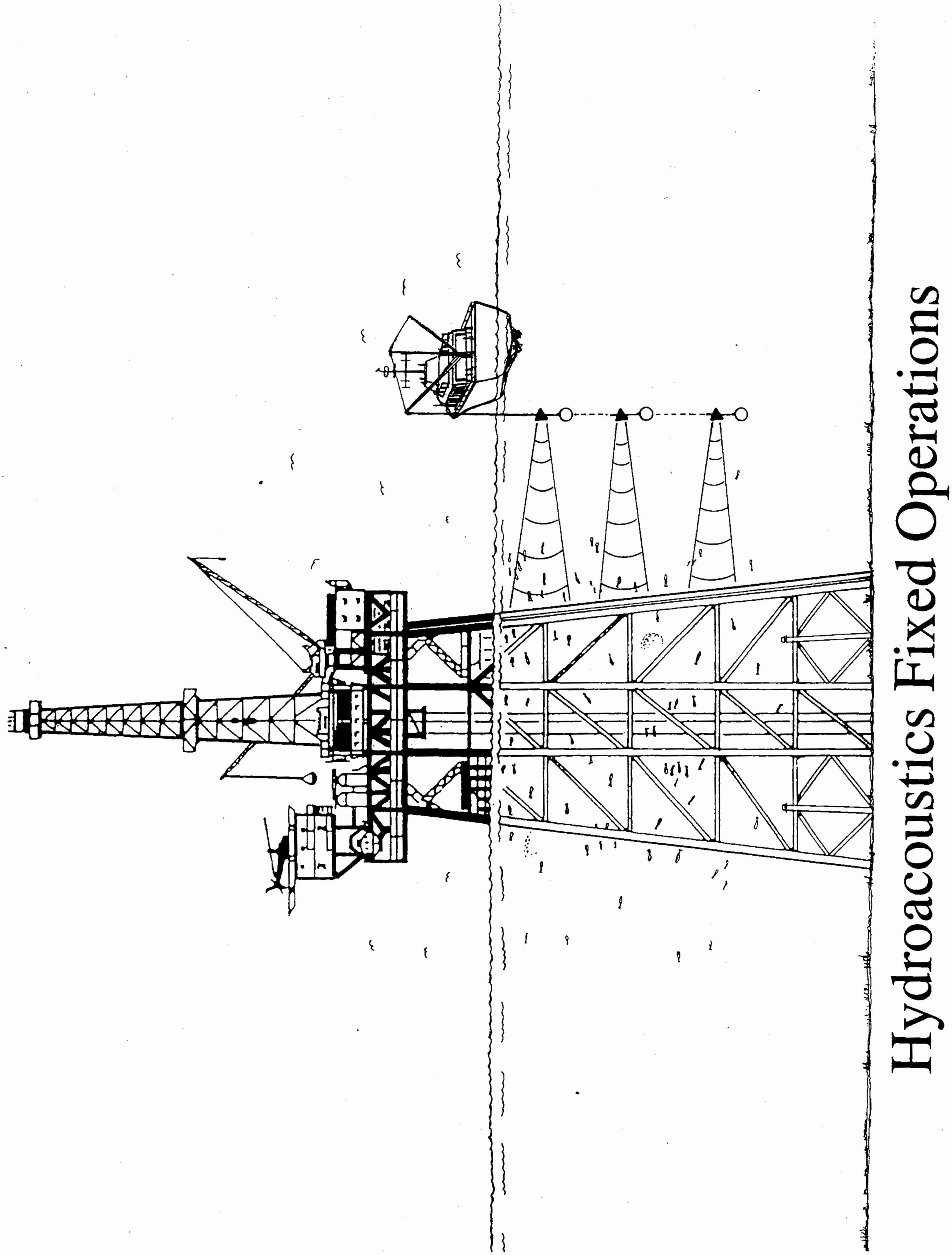


Figure 1. Hydroacoustics sampling gear set up for fixed operations.

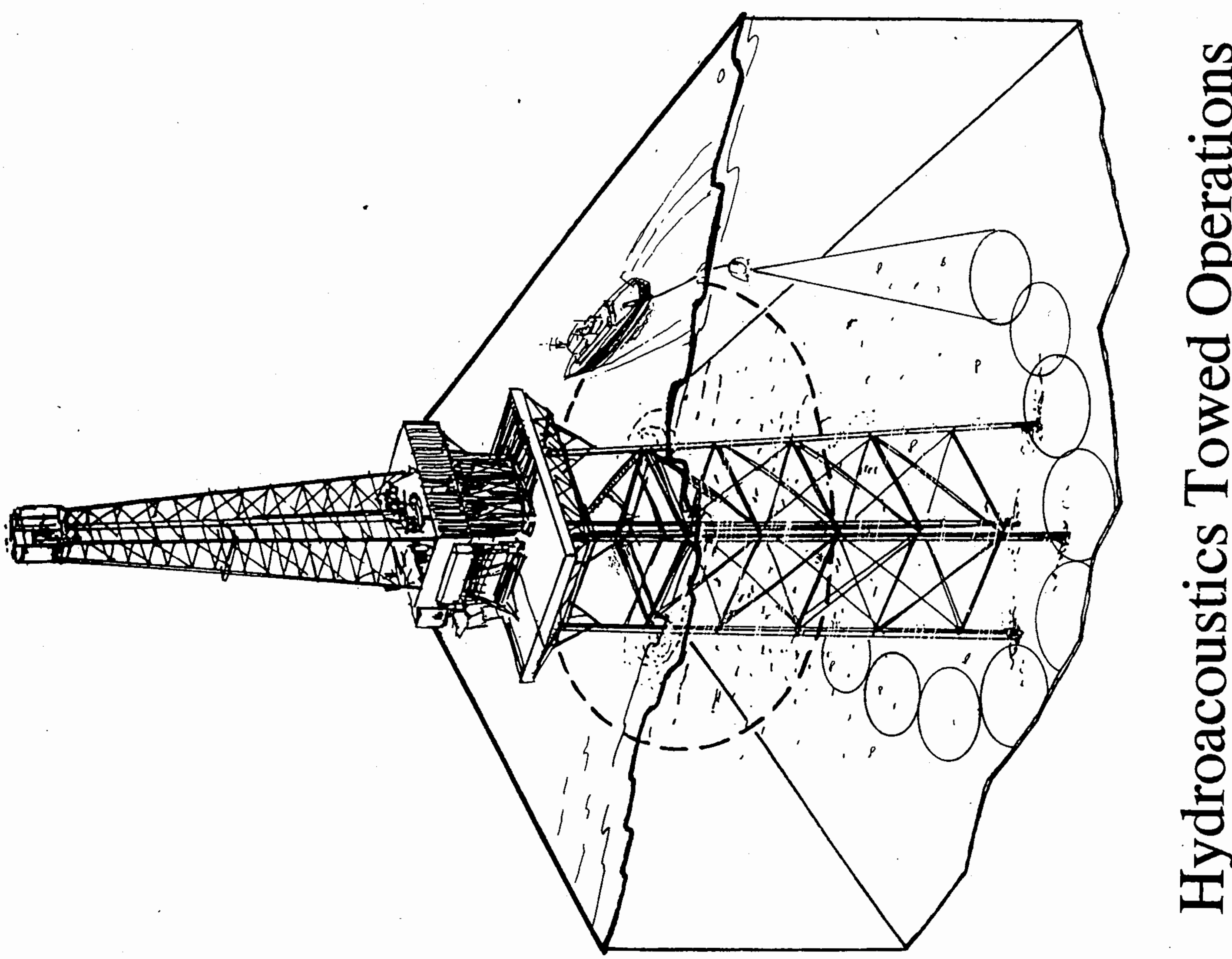


Figure 2. Hydroacoustics sampling gear set up for towed operations.

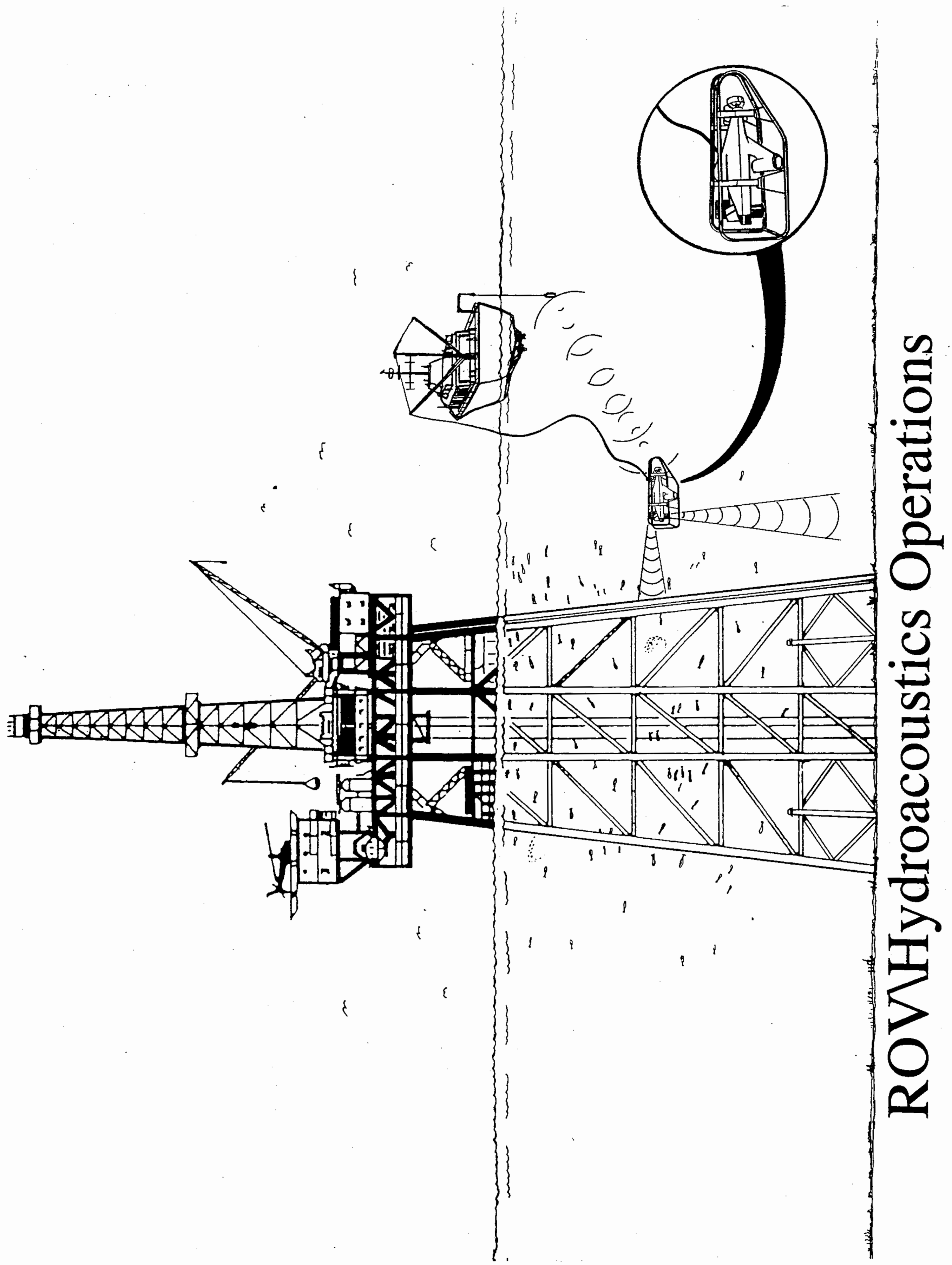


Figure 3. ROV gear set up for sampling around the oil platform.

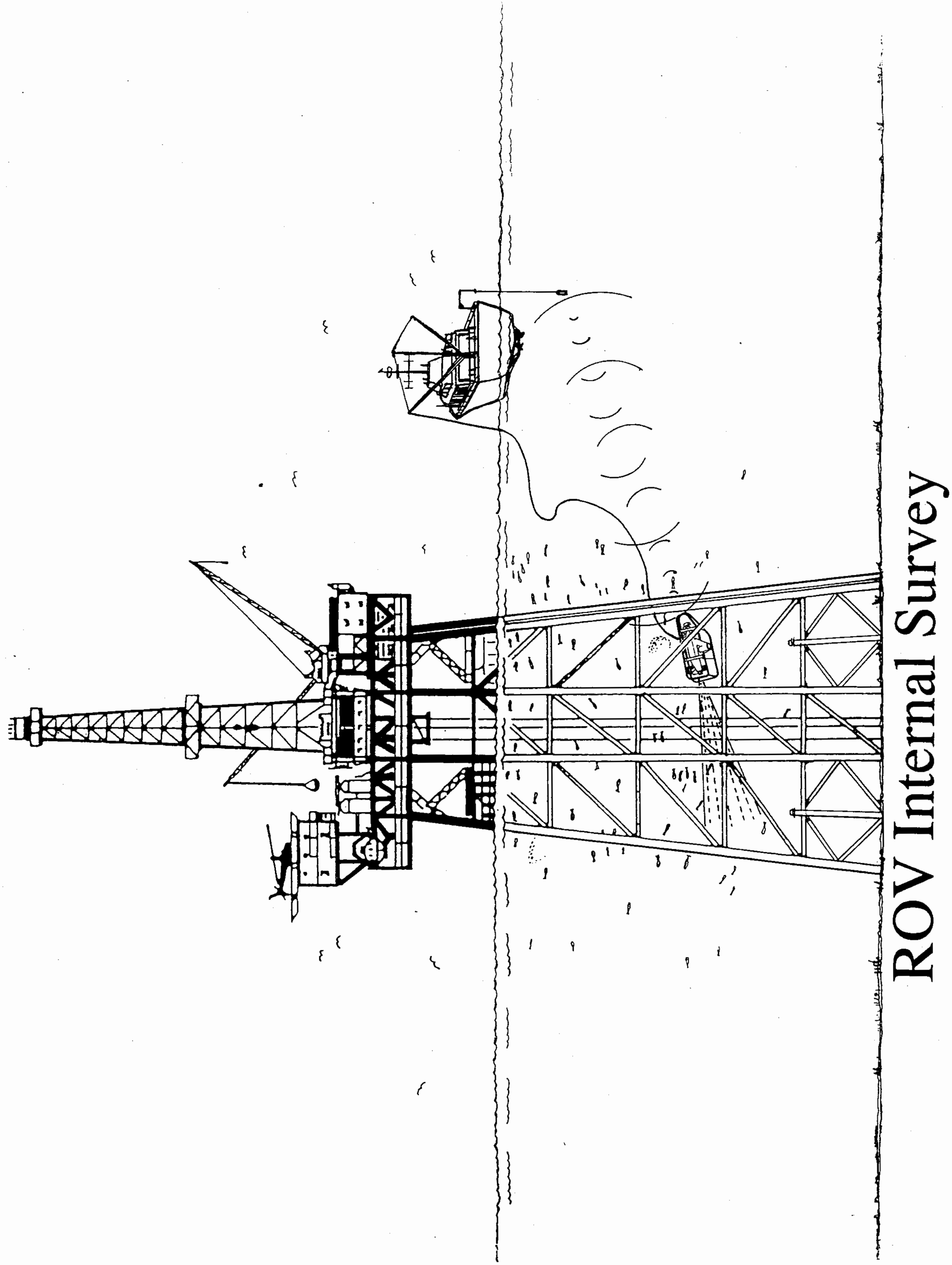


Figure 4. ROV gear set up for sampling inside of the oil platform.

# PHYSICAL OCEANOGRAPHY AND HYDRODYNAMICS RELATED TO SAMPLING OF NORTHERN GULF OF MEXICO ARTIFICIAL REEFS

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## INTRODUCTION

There are a large number of artificial reefs in the northern Gulf of Mexico. The Minerals Management Service maintains a data set that lists over 3700 oil and gas structures in northern Gulf of Mexico continental shelf waters (Figure 1). Although it is not clear from this data set if any of these structures have been removed, it is clear that there are a vast number of structures on the continental shelves from the U.S.-Mexican border to Florida state waters. This brief discussion will focus on two physical oceanographic aspects pertinent to the fisheries sampling of these artificial reefs. The first is the large scale circulation, the continental shelf scale circulation which would affect larval recruitment to these artificial reefs. The second might be considered small scale circulations, namely the flow conditions expected in and around the artificial reefs and some considerations in sampling these habitats.

## LARGE SCALE CIRCULATIONS

Recruitment of reef fishes to these artificial reefs demands some knowledge of the large scale circulation or mean flow patterns. These mean flows are the result of wind, density, and tidally driven flows. In this discussion mean flow will infer the time averaged net flow from all components over a time period of weeks to months; event flows will infer time scales of days and will be considered wind driven events. Flow magnitudes, directions, and durations play an important role in the larval stages when these fishes are carried by the flow.

There are three continental shelves in the northern Gulf of Mexico (GOM). These are separated, to some extent, by the Mississippi River Delta and the De Soto Canyon. To the west of the Mississippi River Delta is the Louisiana-Texas (LATEX) Shelf, to the east of the De Soto Canton is the West Florida Shelf (WFS), and between the two is the Mississippi-Alabama Shelf (MAS). All are relatively broad shelves, with the shelfbreak in water depths that allow shelf widths greater than 150 km. For the purposes of this discussion the focus will be the LATEX and MAS shelves as these have the overwhelming number of artificial reef structures.

Mean circulations or flows are predominantly wind driven over these shelves (Cochrane and Kelly, 1986; Dinnel, 1988). River outflows and the resulting density driven circulations contribute to the flows in the winter, spring and summer generally on the inner and middle shelves, but the MAS outer shelf is also heavily influenced by the eastward flowing portion of the Mississippi River (Dinnel, 1988). Seasonal mean flow patterns on the LATEX shelf are dominated by a cyclonic circulation (Figure 2). These flow patterns are based upon geopotential height distributions and coastal wind stress orientation through the year (Cochrane and Kelly, 1986). Flows are westward on the inner and middle shelf over most of the year with returning eastward flow over the outer shelf and upper slope. The inner shelf circulation is enhanced by the freshwater discharge from the Mississippi and Atchafalaya Rivers in the winter and spring. The alongshore wind direction along the LATEX coast is toward Texas in the fall, winter, and into the spring. In the late spring and summer an opposing alongshore wind, starting in south Texas and moving progressively towards Louisiana along the shelf in the summer months, usually reverses the inner shelf flow along Texas and western Louisiana. During some summers the entire LATEX shelf flows eastward, a reversal
that extends to the Mississippi River Delta. Fall winds from the northeast resume the westward inner shelf flows and the cyclonic pattern reestablishes.
The generalized mean seasonal flow patterns suggested by Dinnel (1988) for the

Mississippi-Alabama Shelf is also dominated by a cyclonic circulation (Figure 3). Inner shelf waters flow westward along the Mississippi-Alabama barrier islands and southward along the Louisiana Barrier islands, outer shelf and upper slope flows return eastward. These circulation patterns are the combination of three seasonal, inner shelf current meter deployments and a geopotential height analysis using historical hydrographic data for the outer shelf and upper slope waters. Although no inner shelf information was available for the fall, it was hypothesized that westward flow prevails through out the year. Recent MAS outer shelf and slope moored current meter information (Kelly, 1991) suggests the eastward return flow should be adjusted seaward, closer to the 100 m isobath shelf break. That the cyclonic circulation covers the entire shelf.

Mean surface flows are usually sub-parallel the isobaths on both shelves. Statistical mean flows, determined from multiple month, moored current meter information, are 0.05-0.1 m/s. But these means are the results of shorter duration event type flows, which can reach magnitudes greater than 0.5 m/s. Durations of these flow events are 2-5 days in the fall-spring, and 5-10 days in the summer. Statistically 80% of the flows on the inner and middle shelf regions are less than 0.25 m/s. These flows are at times alternating along-isobathic flows and at other times energetic cross-isobath flows, both linked to wind events. Wind events, the passage of atmospheric fronts, create multiple day episodes of currents up to 0.5 m/s on the inner and middle shelf regions. These frontal passages statistically occur at five-day intervals from November to April (Dimego et al., 1976) and last from one to three days. These wind events can temporarily reverse the alongshore current directions (Dinnel, 1988; Kelly, 1991), and can cause cross-isobathic 'squirts' that transport inner shelf waters to the outer shelf (Schroeder et al., 1987).

The outer shelf-upper slope currents are affected by the Loop Current and detached eddies and associated features such as filaments and intrusions. The Loop Current itself, as well as, detached eddies affect the outer MAS, while only detached eddies affect the outer LATEX shelf. Effects of the presence of the Loop Current next to MAS are increased outer shelf current speeds to the east and increased exchanges of shelf water with GOM waters (Schroeder et al., 1987; Kelly, 1991). Kelly (1991) found that Loop Current features (eddies and intrusions) were present on the outer MAS 41% of the time over a two year period. Yet (SAIC, 1989) found that the Loop Current itself was only within 0.5 degrees latitude of the MAS 5% of the time and eddies were present on the shelf <5% of the time. When eddy features were present on the shelf, higher magnitude currents, >0.5 m/s, could persist from days to weeks. These increased currents were usually limited to the slope and outer shelf regions. Loop Current eddies that detach and migrate westward across the northern GOM can interact with the outer LATEX and upper slope (SAIC, 1989). Statistical analyses have indicated that these eddies exist over any give section of the outer shelf and slope approximately 5% of the time.

Excursion distances for selected flow velocities and durations of flows are presented in Table 1. With low magnitude, statistical mean flows, excursion distances are reactively small. Long cross-shelf excursions, ~100 km, would only be possible on a monthly time scale. Yet, higher magnitude events would be able to travel 100-200 km over 5-10 days periods. Coupling the possible flow driven excursion distances with seasonal flow directions makes interpretations possible for first guess distribution capabilities. Actual identification of particular region and time period excursions would need *in situ* wind and current information. The interannual variation makes prediction based on these statistical flows subject to considerable error.

## SMALL SCALE CIRCULATIONS

Small scale circulations are defined here on the scale of the artificial reef itself and are included for their importance to various sampling considerations near the structures. The two physical situations that would affect sampling immediately around the structures would be effects of a steady flow and the effects of non-steady flow with the structure. Here we can include tidal currents, as well as wind driven currents, as the steady flow, as 'steady' would be determined over a time period of hours. Non-steady flow is taken here to be that induced by wind waves, and would accordingly have an influence on time scales similar to the waves themselves. Both these situations would affect sampling by creating current shears or velocity gradients, that may interfere with sampling techniques or procedures.

Steady Flow

In a steady flow around a cylinder, current shear or a wake, is created downstream of the cylinder and is dependent upon the magnitude of the flow velocity and the horizontal cylinder dimension normal to the flow. Wakes are perturbations in the flow that occur downstream of the obstacle, in this case the cylindrical legs and supports of an oil or gas structure. These wakes could have impacts on the sampling timing, gear limitations, or sampling location as the physical flow regions may induce a behavior response in the sampling targets.

As flow moves around an obstacle a boundary layer forms in which the flow is modified in a region close to the obstacle (Tritton, 1988). When the obstacle is fairly smooth and round, the usual shape of the oil and gas structure supports, and the flow velocity and diameter is small, flow separates, moves completely around the obstacle and resumes its path downstream (Figure 4a). When flow velocity increases sufficiently a turbulent wake develops downstream of the obstacle. Within this wake there are counter circulating eddies, attached to the downstream side of the obstacle. Flow within these eddies can have reduced magnitudes and can be upstream, creating a shadow region in the flow. As flow velocity increases, the boundary layer separates and trails out behind the obstacle (Figure 4b). Flow in this region fluctuates in magnitude and direction. At very large flow magnitudes, these eddies will detach and be carried with the flow, this is referred to as a von Karman Vortex Street (Figure 4c).

Quantitative description of the flow around a cylinder in a steady flow can be made using of the dimensionless parameter, the Reynolds' Number (Re), defined as $Re=VD/\nu$. Where V is the steady flow velocity, D is the diameter of the cylinder, and $\nu$ is the kinematic viscosity of the fluid (taken here as $1.4x10^{-6}$ $m^2/s$). In general, wake formation occurs when $Re>10^4$, turbulent separation of the boundary layer when at $Re>10^6$, and vortex shedding at $Re>10^7$ (Tritton, 1988) (Figure 4). The implications of these values to sampling of the artificial reefs is in the near-support turbulence, its presence and extent.

If an entire 50 m wide structure was used to determine the Reynolds Number in a 0.25 m/s current, the Re would be $9x10^6$. This is between Re values for turbulent separation of the boundary layer and vortex shedding. But oil and gas structures are designed to be porous, they have separate legs designed not to present a solid silhouette or cross-section to inhibit the flow. Re must be evaluated at the diameter of the legs themselves in order to investigate the interaction of the flow and the structure. Gaythwaite (1981) states that proximity, the distance between supports, can be ignored when spacing is greater than three support diameters. This spacing design is likely observable for most oil and gas structures. Table 2 provides Reynold's Numbers for different diameter cylinders and characteristic flows found in the northern GOM. At high flows, >0.50 m/s, and/or high leg diameters, >4 m, conditions would be met for turbulent separation of the boundary layer. In the flow conditions presented, Re values do not reach the eddy shedding levels. In a worst case situation, one where turbulent eddies are shed by the structure supports, detached eddies would affect sampling away from the structure for possibly ~100 meters downstream of the structure. This would affect support legs downstream of another, the downstream support would be in the wake of the upstream support. This shadow effect would create reduced flow velocities both up- and downstream of the following support. In the extreme case of eddy shedding by supports, the magnitude of the current can be determined for a 1 meter diameter support. If the onset of vortex shedding occurs at $Re=10^7$, then rearranging the expression to solve for velocity gives U=7 m/s, an unrealistic current velocity.

The currents on the northern GOM shelves can vary with depth and time. This variation can occur as both a magnitude and a direction change. The subsurface currents can be quite different from the surface currents, although there is usually a surface maximum, there can be a severe direction shift with depth. Wakes will also change orientation relative to the oil and gas platforms as current directions change with depth. Moored current meter studies indicate bottom currents have lower magnitude means and a anticlockwise deviation relative to the surface currents. If tidal currents are considered, there is a usually clockwise rotation of the current through the tidal period. Close to shore the motion becomes rectilinear and shore parallel. Over the inner and mid-shelves, surface-bottom tidal direction differences will be smaller then for the outer shelf regions.

Non-Steady Flow

Non-steady flows also produce near structure turbulence, in this case wind-wave induced motions, that could affect near structure sampling. The oscillatory nature of waves can produce turbulent eddies on both sides of a structural support during the passage of a single wave. Both sides of the support are affected as the orbital motion due to the wave passage is in the direction of the wave at the crest, generating turbulence on the side of the support in the direction the wave is moving. Orbital motion is in the opposite direction at the trough, generating turbulence on the opposite side of the support. This turbulence is generated with the same periodicity as the wave period, and can be either attached to the support or detached from the support dependent upon the height of the wave and the size of the support.

Wave in northern GOM have been statistically described with 20 years of hindcast data (Hubretz and Brooks, 1989). Approximately 90% of the wave heights are less than 2 m, with 40-50% less than 1 m (Table 3). These wave heights are characterized by periods of less than ˜6 seconds. The larger waves, >2 m, might be characteristic with a wave period of 7 s or more. Extreme wave heights, ≥3 m, and extreme wave periods, >9.5 s, occur less than 1% of the time in the northern GOM.

From linear wave theory the depth of wave influence can be estimated for deep water waves. Theory states that motion equivalent to 4% of the surface wave height will be observed at water depths equal to one half the wavelength (Pond and Pickard, 1983). This depth is usually defined as the wave base. Using a large, but not extreme, northern GOM characteristic wave, a 7 s wave would have a wave base at 38 m (wavelength, L=76 m). The water depth with 50% of the surface motion, knowing the exponentially decrease in energy with increasing depth, would be approximately L/9. For the 7 s wave (L=76 m) the depth of 50% the surface motion is 8.4 m.

Non-steady flow around a cylinder is described by the dimensionless Keulegan Number, (Gaythwaite, 1981; Teng, 1986), which is defined as $K=V_mT/D$. Where D is the diameter of cylinder, T is the wave period, and $V_m$ is the maximum horizontal wave velocity, defined in linear wave theory as $V_m=(H\pi/T)\exp(2\pi z/L)\cos(\Theta)$, a function of wave height (H), wave length (L), water depth (z), and the phase of the wave ($\Theta$). The maximum wave velocity occurs under the crest (in the direction of the wave) and the trough (in the opposite direction), at $\Theta=0$ and $\pi$, and at the sea surface, z=0 m. When the velocity due to the wave is maximum the Keulegan Number can be determined as $K=\pi H/D$, a function of the wave height and cylinder diameter.

When Keulegan Numbers are less than 3 no vortices are formed due to the wave passage (Figure 5). Symmetric pairing of attached vortices on both sides of cylinder occur when K¼4. When 8>K>4 asymmetric pairing of attached vortices occur. When 15>K>8 asymmetric vortices occur with detachment of the larger one, while the smaller vortex is swept to opposite side of the cylinder as a seed for subsequent larger vortex. At 24>K>15 asymmetric vortices occur with the detachment and growth of a second vortex on same side of the cylinder (Teng, 1986).

Using a northern GOM 7 s wave, a cylinder diameter of 1 m, and a wave height of 2 m, the maximum velocity is estimated to be 0.45 m/s. If K=3, no vortices form and wave height must be approximately equal to the cylinder diameter, H˜D. As the wave height increases for a particular cylinder diameter, so does the K value. If K=12, approximately in the mid-range of shedding vortices, $K=\pi H/D$, the wave height must be 4 times the cylinder diameter, 4D˜H. If the cylinder was 1 m in diameter then for vortices to be shed the wave height would need be 4 m. This wave height is a rare occurrence in the GOM (Table 3).

Interaction With Steady Flow

The interaction between the steady flow field and the non-steady flow fields is additive. The steady flow would drag these wave created vortices downstream. This could be from one support to another, possible from one structure to a second, nearby (but within ˜100m) structure. When the steady flow direction and the wave field advance are in oblique orientation there could be turbulence created almost completely around the structure supports.

## RECOMMENDATIONS

Questions that arise when determining stock assessment in the immediate vicinity of an oil or gas structure in the northern GOM 1) identification and quantification of the stock, and 2) the understanding of their distribution around a rig, can have physical oceanographic interaction. To correlate stock information it is recommended that the following physical oceanographic information be collected.

Wind speed and direction, significant wave height, period and direction. Current profile measurements. Hydrographic profiles of conductivity, temperature, depth (CTD), light transmission, photosynthetically available radiation, dissolved oxygen and florescence. If possible there should be two CTD/velocity profiles taken. One immediately down stream of the structure, within a boat length, to capture the disturbed water column. The other upstream, a few boat lengths away from the structure, to capture the undisturbed water column parameters.

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Table 1. Excursion distances (km) driven by steady flows of selected magnitudes and durations.

| Current Magnitude (m/s) | Duration of Current (days) 1 | 5 | 10 | 30 |
|---|---|---|---|---|
| 0.05 | 4.3 | 21.5 | 43.2 | 129.6 |
| 0.1 | 8.6 | 43.2 | 86.4 | 259.2 |
| 0.25 | 21.5 | 108.0 | 216.0 | |
| 0.5 | 43.2 | 216.0 | | |
| 1.0 | 86.4 | 432.0 | | |

Table 2. Reynolds' Numbers in a steady flow at selected flow velocities and cylinder diameters.

| Cylinder Diameter (m) | Flow Velocity (m/s) 0.1 | 0.25 | 0.5 | 1.0 |
|---|---|---|---|---|
| 1 | $7.1\times10^4$ | $1.8\times10^5$ | $3.6\times10^5$ | $7.1\times10^5$ |
| 2 | $1.4\times10^5$ | $3.5\times10^5$ | $7.1\times10^5$ | $1.4\times10^6$ |
| 3 | $2.1\times10^5$ | $5.4\times10^5$ | $1.1\times10^6$ | $2.2\times10^6$ |
| 4 | $2.8\times10^5$ | $7.1\times10^5$ | $1.4\times10^6$ | $2.8\times10^6$ |

Table 3. Percentages of time for significant wave heights (H) and periods (T) for the northern Gulf of Mexico (Hubretz and Brooks, 1989). Based on 20 years of hindcast statistics from US Army Corps of Engineer regional Wave Information Study (WIS). Data stations are offshore of Galveston TX, (10), Sabine, TX (15), the Mississippi River Delta, LA (24), and Pascagoula, MS (27).

| | WIS Station 10 | 15 | 24 | 27 |
|---|---|---|---|---|
| $T\leq6.5$ (H~1m) | 68.8 | 84.4 | 72.1 | 85.7 |
| $T>6.5$ (H~2m) | 31.2 | 15.6 | 27.9 | 14.3 |
| $H\leq1$m | 30.6 | 59.7 | 36.8 | 43.5 |
| $H\leq2$m | 96.6 | 99.6 | 90.5 | 94.8 |
| $T>9.5$s | 0.06 | 0.11 | 0.07 | 0.11 |
| $H\geq3$m | 0.07 | 0.03 | 0.85 | 0.35 |

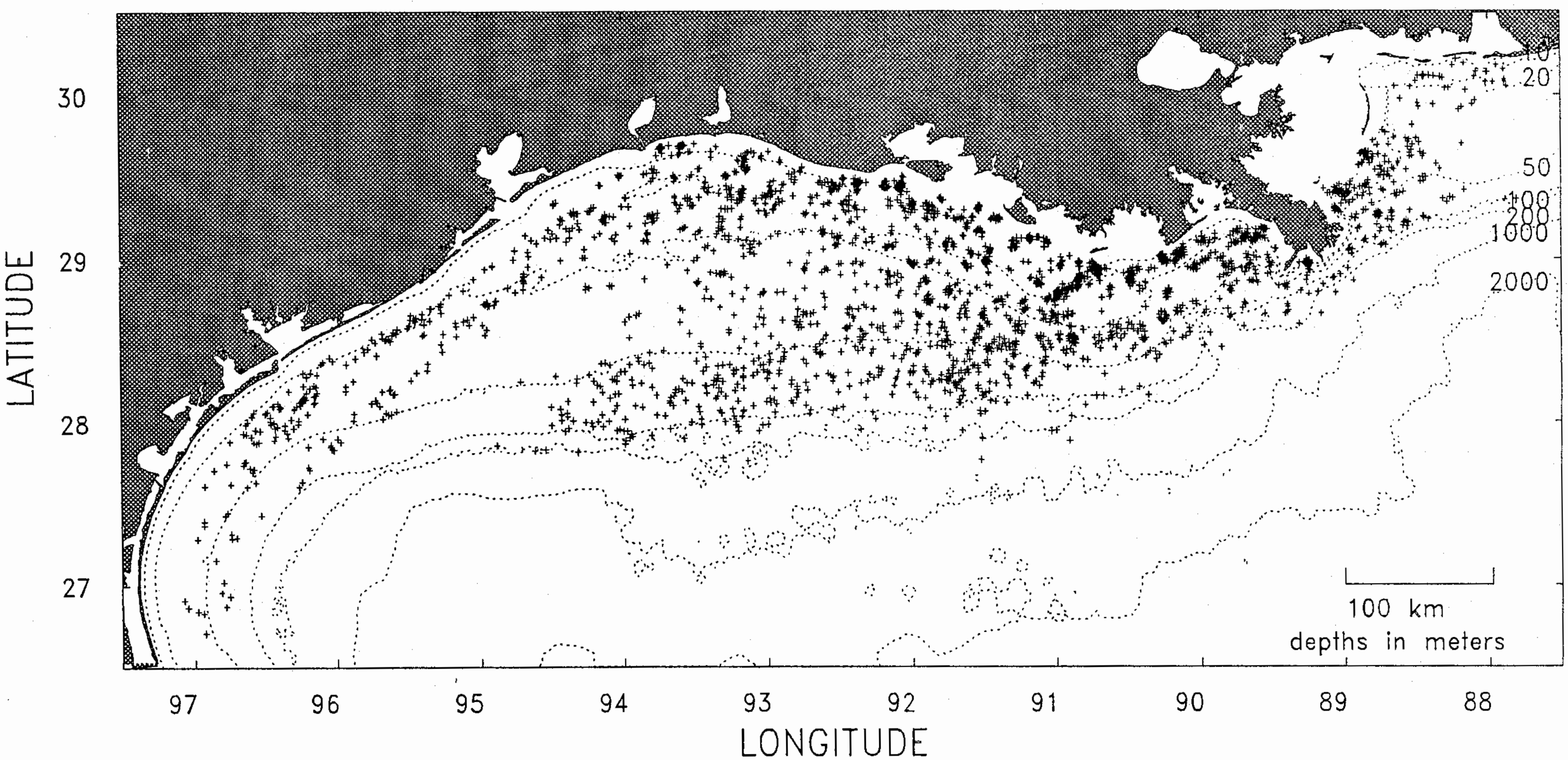


Figure 1. Oil and gas platforms (+) in the northern Gulf of Mexico. Platform data supplied by the U.S. Minerals Management Service.

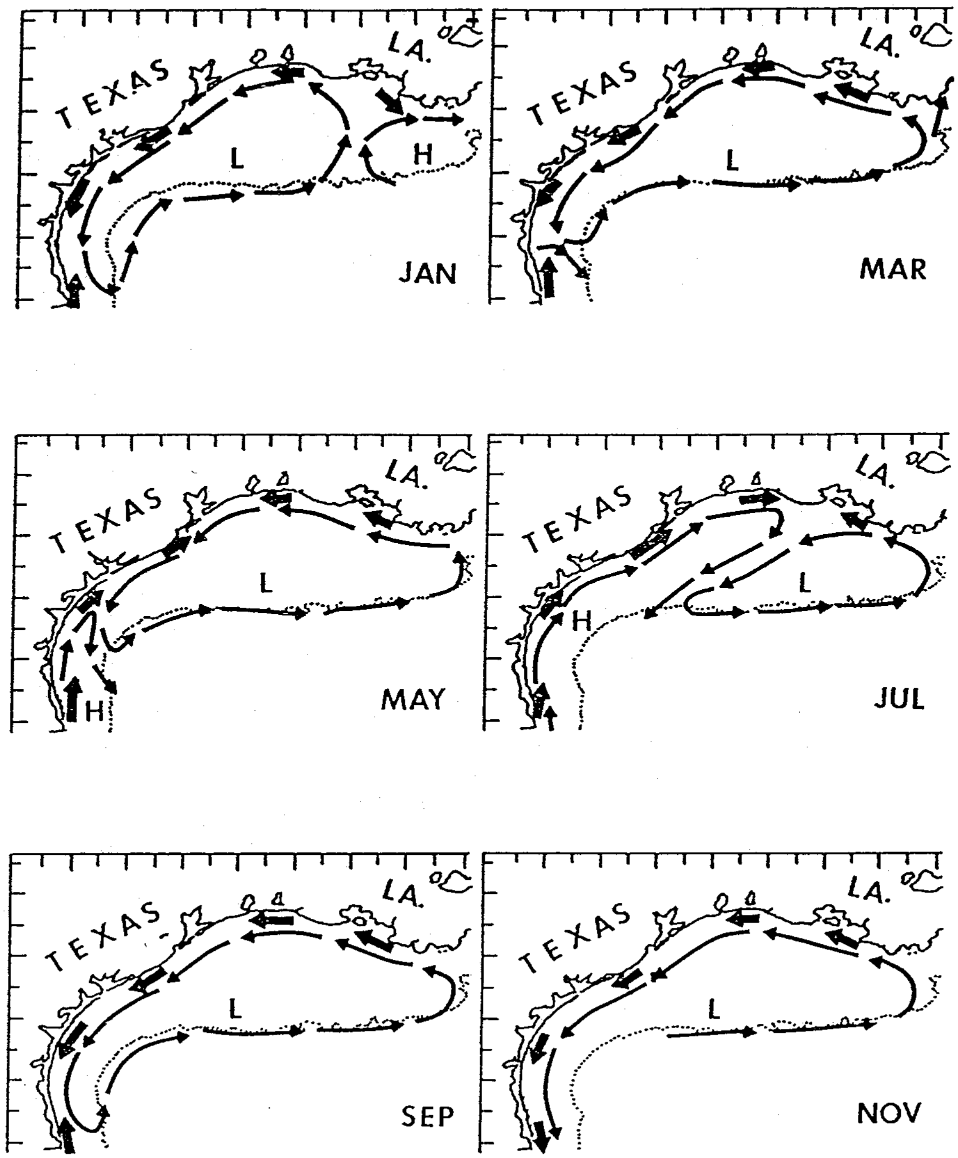


Figure 2. Estimated mean flow patterns for the LATEX shelf as interpreted from mean monthly geopotential anomalies (dyn cm) of sea surface relative to 70 db from RV Gus III data (Cochrane and Kelly, 1986). Current directions are indicated by the fine arrows, mean alongshore windstress is indicated by thick arrows. High and low dynamic topography is indicated by 'H' and 'L', respectively.

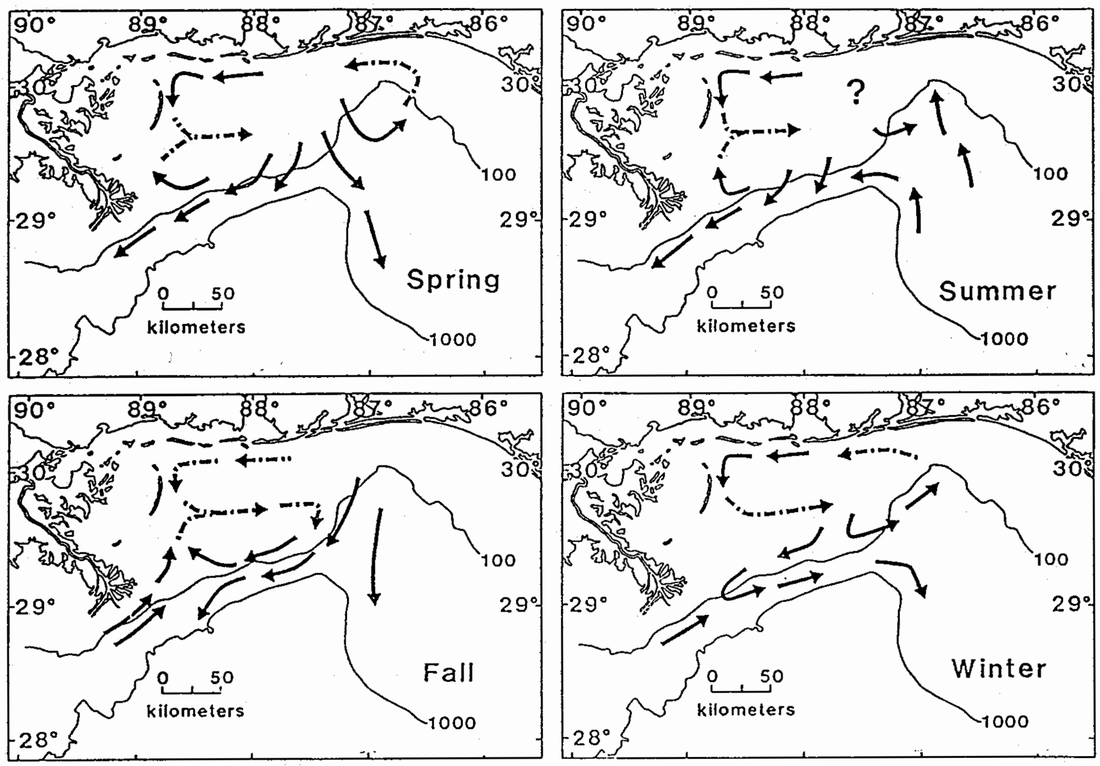


Figure 3. Generalized mean seasonal flow patterns suggested by (Dinnel, 1988) for the Mississippi-Alabama Shelf. Recent outer shelf mooring information (Kelly, 1991) suggests the mid-shelf eastward flow is closer to the shelf break (100 m isobath). Solid arrows are based on dynamic topography of historical hydrographic data (outer shelf and slope) and moored current meter data (inner shelf). Note the seasonal flow depicted by broken arrows is simply conjecture.

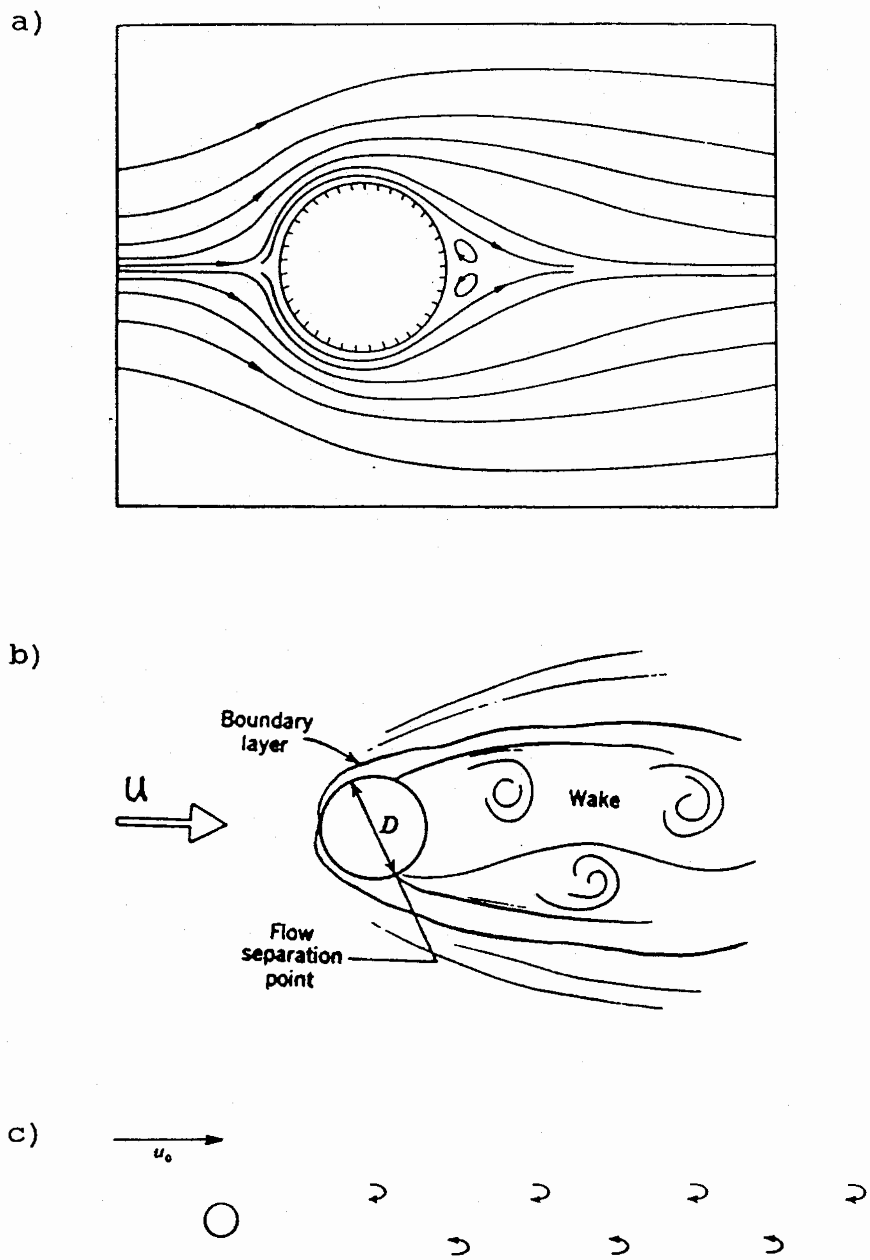


Figure 4. Flow characteristics for different Reynolds Numbers, i.e. different flow magnitudes (Tritton, 1988). a) Laminar flow past a cylinder with $Re=10^2$, no vortex shedding. b) Turbulent flow past a cylinder, $Re>10^6$, boundary layer separation as wake. c) Downstream vortices as von Karmen Vortex street, $Re>10^7$.

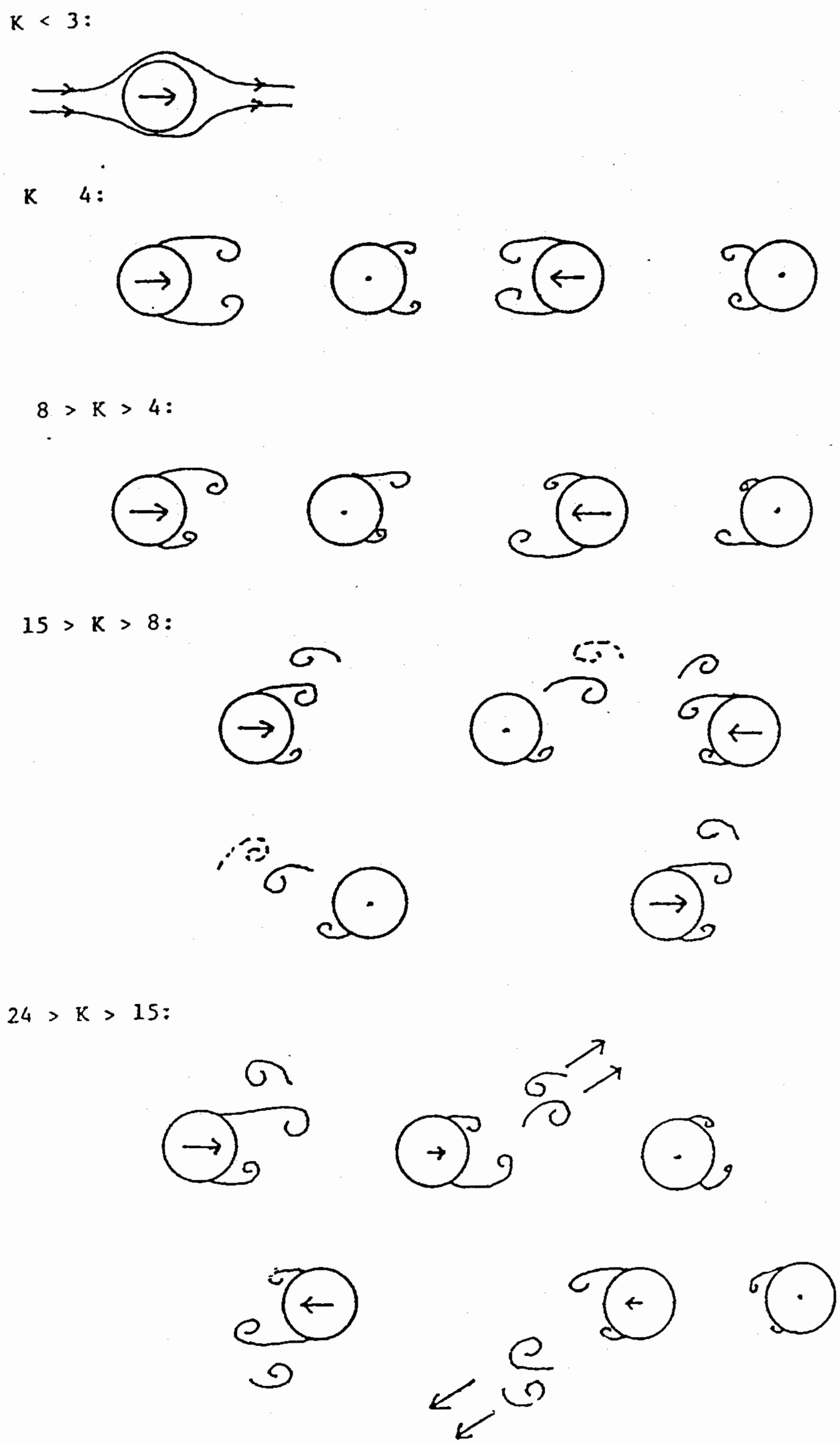


Figure 5. Schematic of flow separation for various Kuelegan Numbers (Teng, 1986). Arrows within cylinder depicts the flow direction driven by the wave passage.

# CURRENT CONSIDERATIONS FOR TRAP-VIDEO SURVEYS OF OIL RIGS AND REEFS

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## INTRODUCTION

Knowledge of water currents is critical to the success of planned trap-video surveys of reefs and oil rig sites in the north-central Gulf of Mexico. Because the survey sites have been only vaguely identified, the discussion of the currents can only be general in nature. The currents addressed here pertain to the region of the continental shelf and slope between 87°W and 90°W longitude (Figure 1). Currents in this region are associated with wind, water density differences, eddies, tides, and other waves.

## DESCRIPTION OF THE STUDY REGION AND CURRENTS

The shelf isobaths are generally oriented southwest-northeast with the shoreline geometry of the northern mainland and Mississippi River Delta forming a reversed "Z". The orientation of the isobaths and configuration of the shoreline have an appreciable influence on the circulation patterns. The shelf is relatively shallow, broad and gently sloping. The shallow depths make the area particularly prone to forcing by winds and tides.

The presence of the bird-foot delta of the Mississippi River plays a prominent role in the circulation regime of the study area. It provides the major source of freshwater introduced onto the shelf within the study area via Main Pass, Pass a Loutre, Southeast Pass, and South Pass with an average flow of 13,025 $m^3s^{-1}$ as recorded at Tarbert's Landing. Having analyzed the distribution of flow through the passes, it was found that the following percentages of the total flow existed: Southwest Pass, 31.5%; South Pass, 17.0%; Pass a Loutre, 31.5%; Main Pass, 11.0%; Baptiste Collette Bayou, 4.0%; and Grand Pass, 5.0%. This means that approximately 63% of the total flow of the Mississippi River is discharged onto the shelf south or east of the delta. The period of high river flow is January-July with the peak flow normally occurring during the March-May period. The low flow period is August-December with the minimum usually occurring in October or November. Additional low-salinity water is contributed by the Mobile Bay, Mississippi Sound, and Pensacola Bay estuaries.

The tides in the study area are predominantly diurnal, but the semidiurnal components become noticeable in the tidal record at certain times during the lunar month. The primary diurnal components are $K_1$, $O_1$, and $P_1$ with periods of 23.93 hrs, 25.82 hrs, and 24.07 hrs, respectively. The important semi-diurnal components in the area are $M_2$ and $S_2$ with periods of 12.42 hrs and 12.00 hrs, respectively. The average diurnal range on the shelf is less than 0.5 m. Determinations of tidal currents indicate the maximum speed of the non-symmetrical, rotary currents to be approximately 0.25 $m^3s^{-1}$ over the outer shelf, which increases toward the mainland with the decrease in water depths.

The Loop Current, the primary circulatory feature of the Gulf of Mexico, enters the Gulf through the Yucatan Straits, makes an anti-cyclonic turn and then exits through the Florida Straits. When the Loop Current impinges on or is in close proximity to the shelf, it influences the shelf circulation by dragging shelf waters parallel to the isobaths via lateral friction and by the formation of eddies which entrain shelf waters.

Currents on the shelf are also generated by winds. Eleuterius and Beaugez (1979) presented monthly distributions of wind directions and speeds for this region which showed that the predominant source of winds has an easterly component. In spring, winds switch from winter northerlies to predominantly southeasterly and southerly winds which prevail through the summer. Although the spring and summer wind speeds are normally much lower than those of winter and fall, storms bring strong winds from the southeast which may last for several days. In early fall, northwesterlies accompany the advance of continental weather systems. Associated winds often maintain high speeds for a period of several days to a week. With the onset of winter, strong northerly winds accompanying cold fronts from the northeast dominate the region.

Circulation in the area has been the subject of approximately 15 investigators. Contributions by these investigators have been summarized in Eleuterius and Criss (1994). Although conducted at different times, the results of the different studies have generally been in agreement. From the report prepared in 1994, the authors refer here to several illustrations which depict circulatory features which should be of interest to those contemplating the trap-video study. In the winter of 1965 (Figure 3), the configuration of surface isohalines shows that there was westward flow over a broad area of the shelf which was guided, in part, southward by the Chandeleur Islands. High salinity water near the shelf indicates the close proximity and influence of the Loop Current. During March-April of the same year (Figure 4), surface isohaline patterns again show the westward flow across the entire shelf. The surface isohalines for June-July of 1964 (Figure 5) along with other data for other periods provide evidence that a westward flow of the middle to inner shelf is common with greater variability in the flow near the outer shelf, likely a function of the presence of the Loop Current. Satellite AVHRR imagery almost always show the presence of eddies in the area. Eddy currents may attain speeds of 2 $m^3s^{-1}$.

Wind wave statistics as percentage occurrence by height were computed and presented by Eleuterius (1974) for the mid-shelf region. Depending on the water depth, currents associated with wind waves and swell could adversely impact trap-video surveys. A generally accepted rule states that currents at a depth equal to one-half the wave length (measured from trough to trough) are of sufficient strength to move sandy sediments. Given the wave heights and wave periods for this area as shown in Eleuterius (1974), waves could be a factor during most months of the year. Currents associated with large waves in the vicinity of the rigs and reefs could reach speeds in excess of 0.5 $m^3s^{-1}$. Because wave currents are oscillatory, i.e reverse direction every one-half wave period, effects on trap-video equipment could be damaging.

In summary, plans to conduct trap-video surveys in the region described should consider the prevailing and transient currents. Because of the simultaneous occurrence of currents produced by different generating forces, resulting net current speeds can be greater or less than any individual current. In phase, currents due to tides, wind waves, eddies, winds, and density-differences could pose a substantial threat to trap-video surveys. With tidal currents of 0.25 $m^3s^{-1}$, wind waves approaching 0.5 $m^3s^{-1}$, density-driven currents of 0.2 $m^3s^{-1}$, and eddies with speeds in excess of 2 $m^3s^{-1}$ acting in concert, the resulting currents could attain substantial speeds. Safety guidelines normally prevent divers from operating when current speeds are in excess of 0.25 $m^3s^{-1}$. Tethered diving operations are halted when currents are in excess of 0.5 $m^3s^{-1}$. Current speeds in the area frequently are in excess of these speeds.

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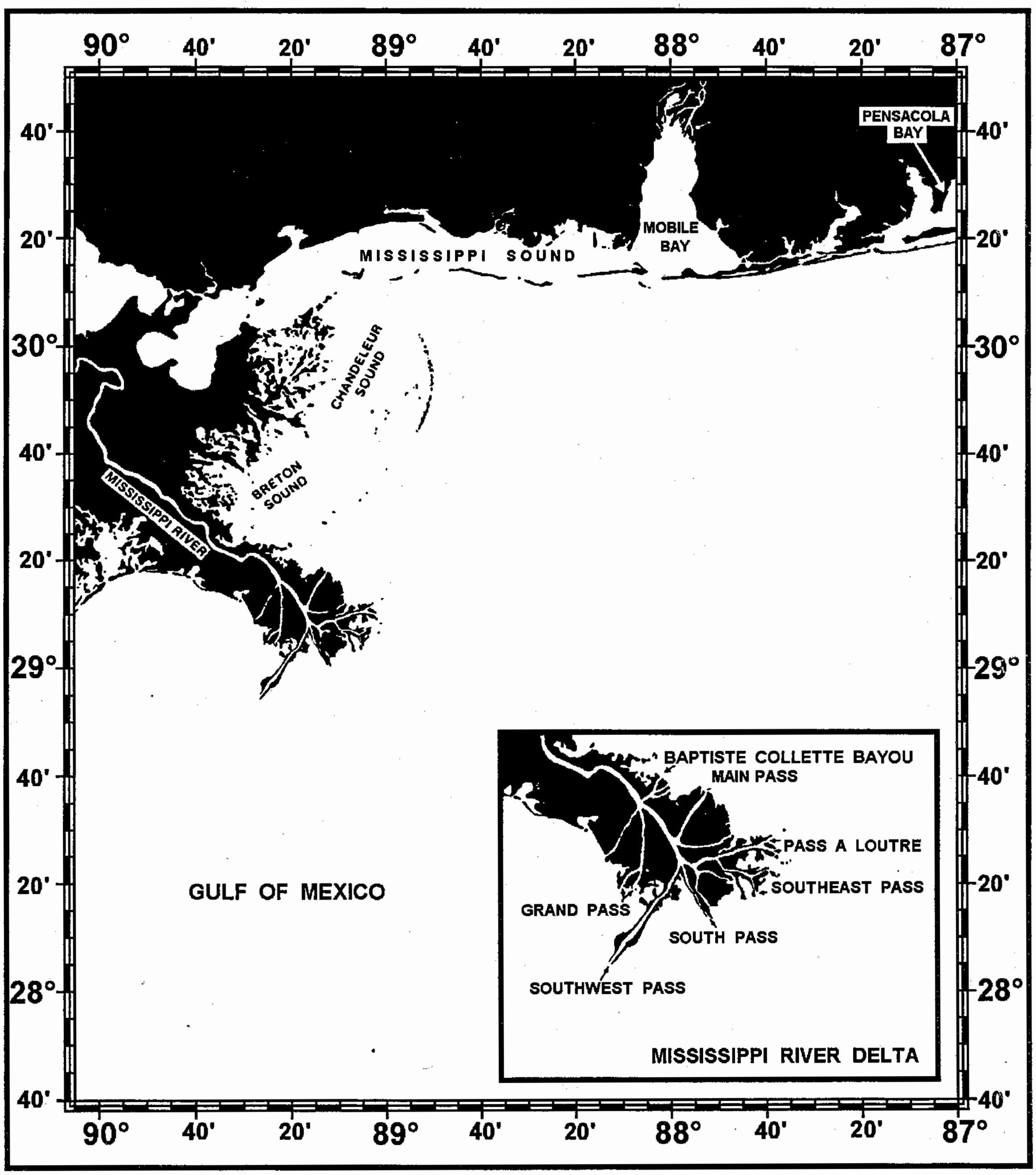


**Figure 1.** Study Area

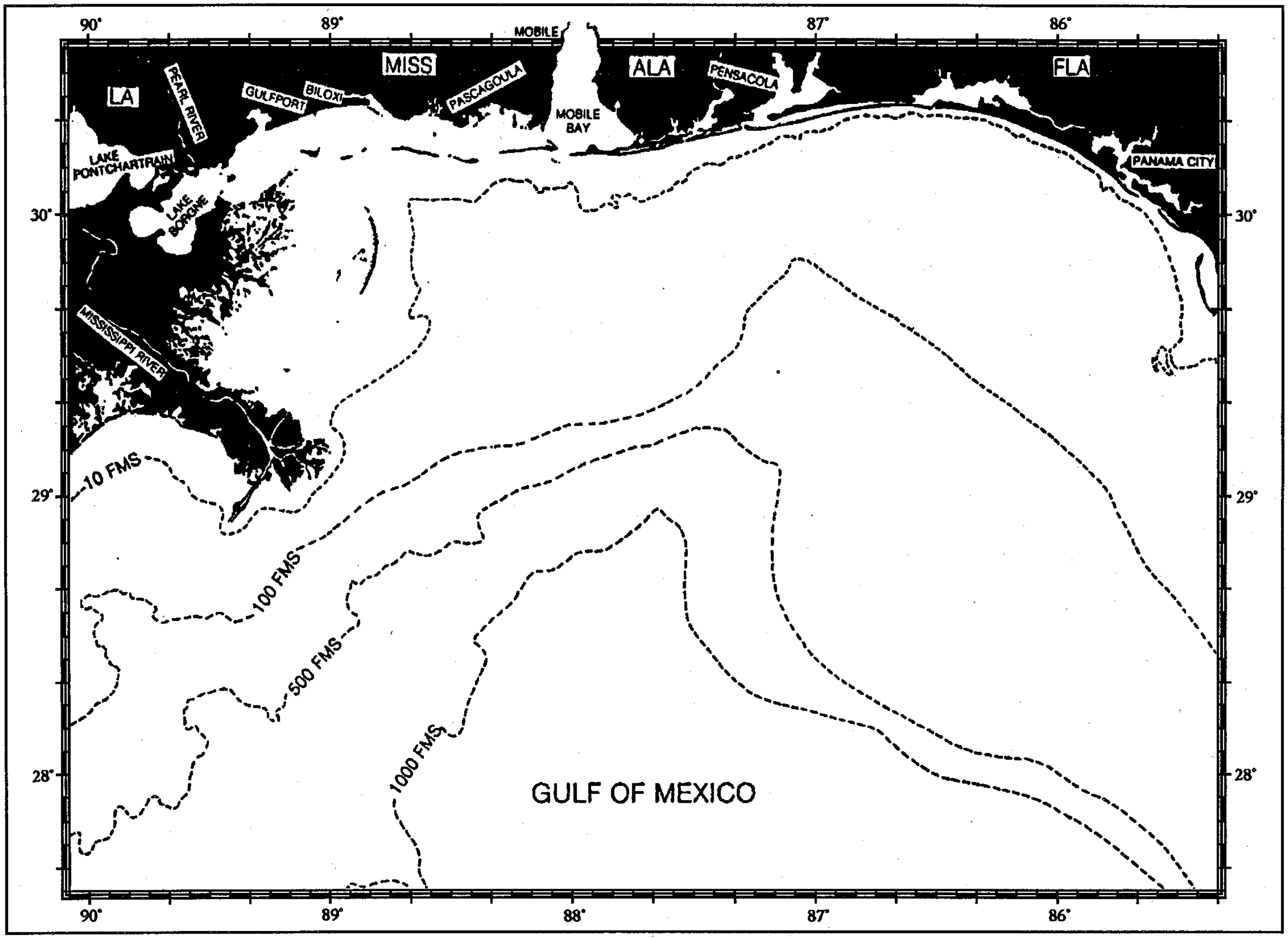


**Figure 2**. General bathymetry and shoreline geometry

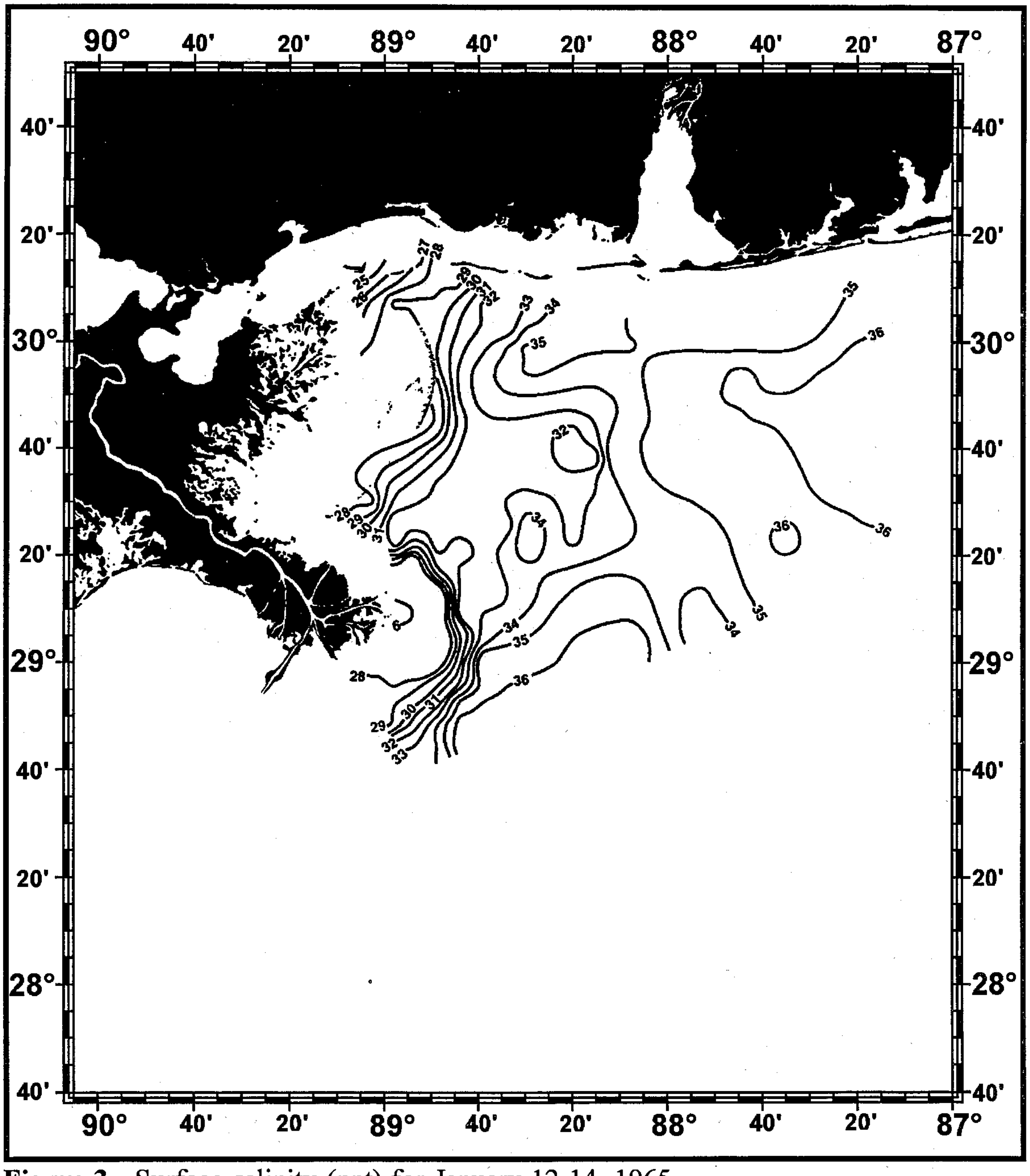

**Figure 3.** Surface salinity (ppt) for January 12-14, 1965

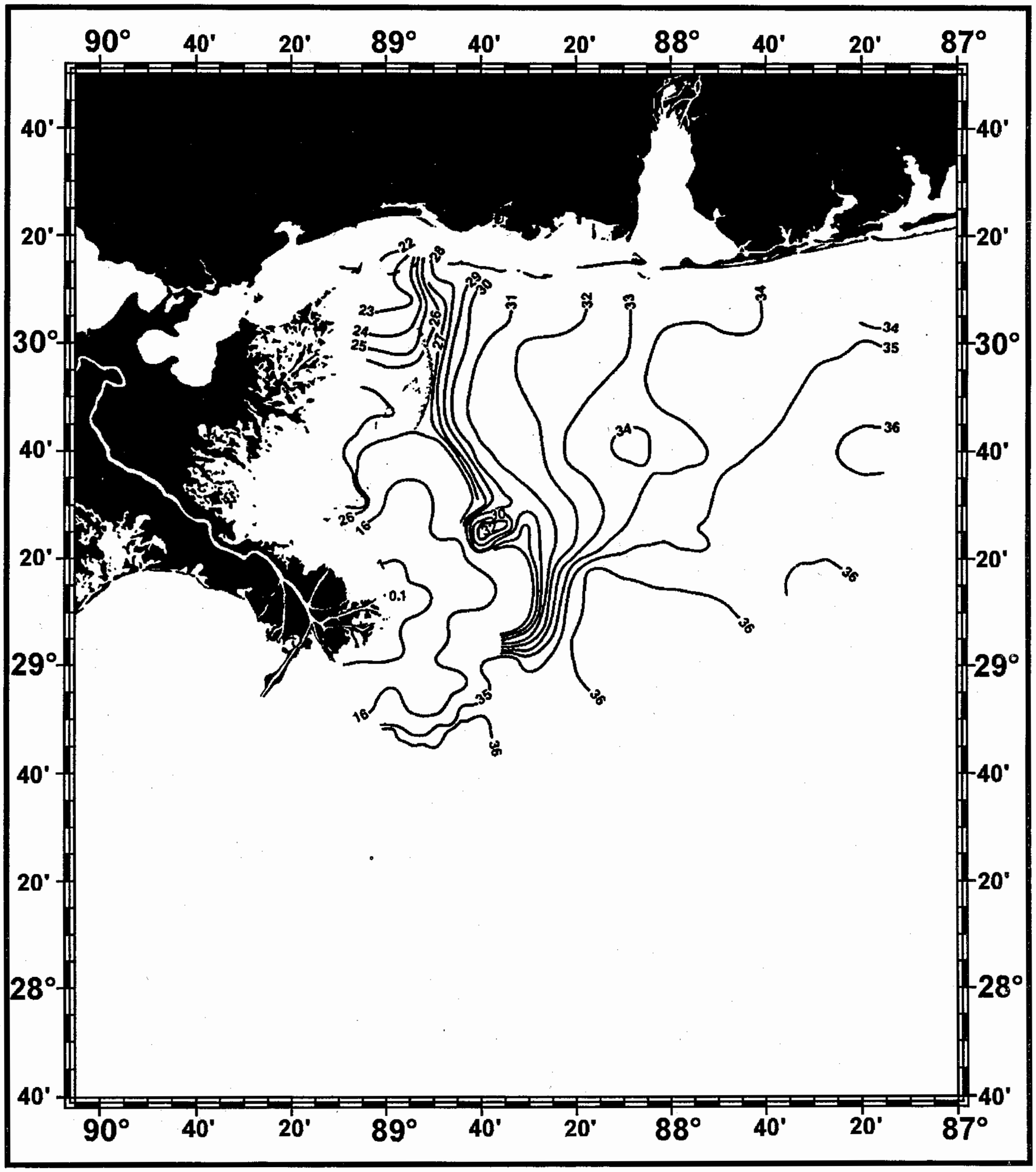


**Figure 4**. Surface salinity (ppt) for March 31-April 3, 1965

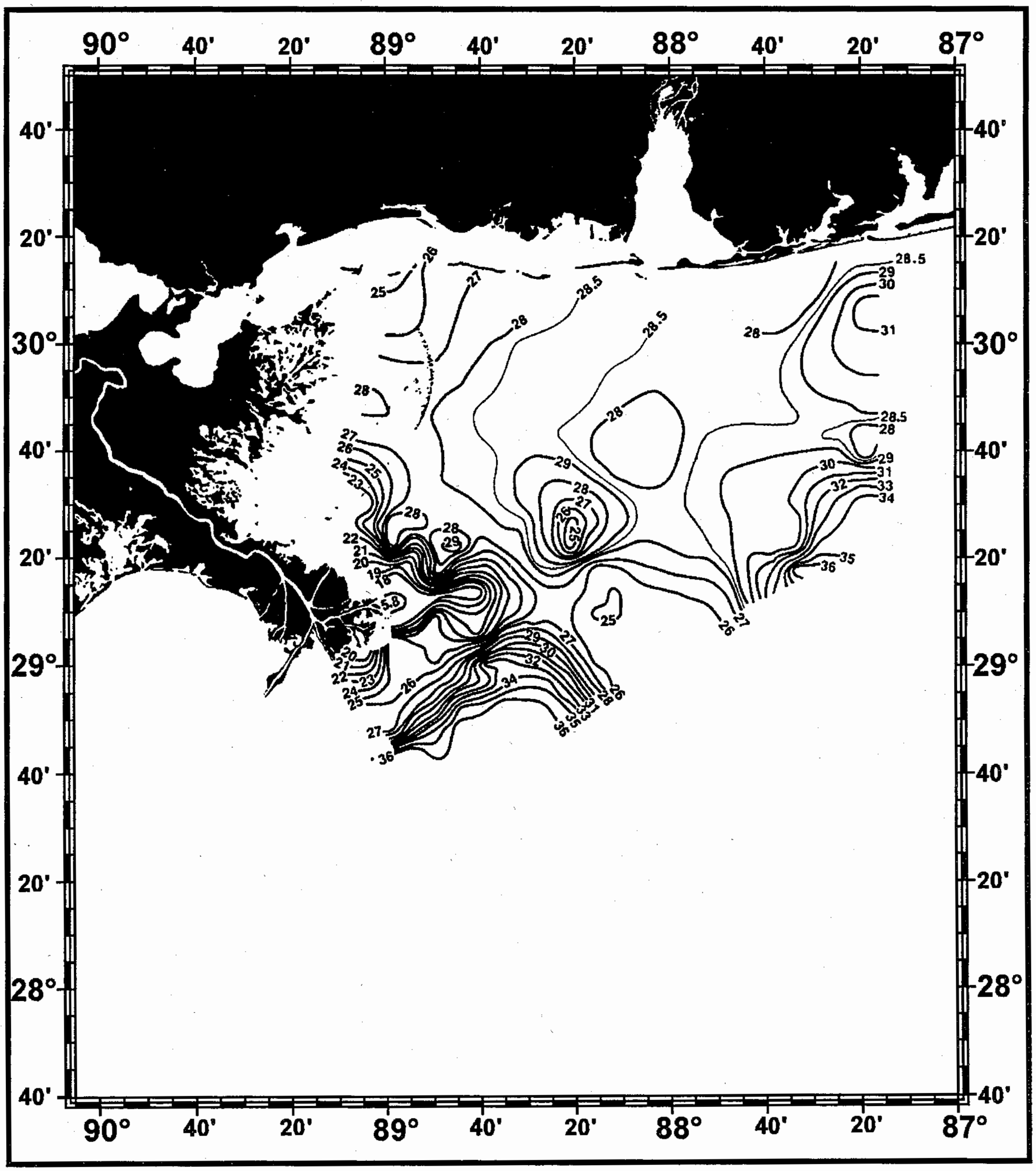


**Figure 5**. Surface salinity (ppt) for June 30-July 3, 1964

# POTENTIAL USE OF ICHTHYOPLANKTON DATA TO ASSESS POPULATIONS OF REEF FISHES THAT INHABIT OIL AND GAS STRUCTURES

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Surveys of adults and juveniles that inhabit oil and gas structures will target organisms that are attracted to particular rigs. This is not the case with ichthyoplankton, as fish larvae collected in the vicinity of an oil rig probably have little association with that particular rig because of the water current regime. Ichthyoplankton data would be most useful when used in the context of larger areas in which there is a relatively high concentration of oil and gas structures.

Two primary goals would be to determine which species are spawning in areas with high concentrations of oil and gas structures, and what is the relative abundance of the adults. Ichthyoplankton studies will be restricted to larval analyses because most of the species that inhabit oil and gas structures are in the order Perciformes, and the eggs of most of these fishes are very similar.

It is crudely possible to estimate the relative abundance of spawning adults of a particular species between different areas (or species with similar fecundities) by comparing mean larval abundances. For instance, vermilion snapper larvae are more abundant in plankton collections from the northcentral Gulf than red snapper larvae, not because vermilion snapper are more fecund than red snapper, but simply because there are a lot more vermilion snapper than red snapper. However, groups of collections to be compared should have a similar mean size of larvae because a given number of small larvae represent less spawning activity than an equal number of larger larvae. If possible, a larval index should be made by comparing abundance estimates of the same age-group of larvae. This can be accomplished by constructing a survival curve based on larvae collected at a relatively large number of stations, and then comparing estimated abundance estimates using a similar point on the survival curve, ie. the number of individuals at time=0 (Y-axis intercept). An adjustment will need to be made if groups of collections to be compared are comprised of different numbers of samples. If using this survival curve technique it is important to have a relatively large number of collections from quite a few locations to reduce sampling variability because the age-frequency distribution determined from only a few collections may be very different from the actual age-frequency distribution of larvae.

Of primary concern is the question of where the captured larvae were spawned. In the northern Gulf during summer months the eggs of most species hatch in approximately 24h. If spawned eggs drift away from an area that we have defined as having a high concentration of rigs within a 24h period, ichthyoplankton samples will not be able to provide information about the spawning adults. Associating larval distributions with bottom habitat where spawning adults are found is uncommon, but recent data suggest that under certain circumstances it may be possible in the northern Gulf.

Some of the non-tidal water currents in the northern Gulf follow the bottom bathymetry, and recent data strongly imply that in these areas captured larvae can be associated with particular bottom substrates where the adults are known to occur: natural reef sites in the northcentral Gulf are generally located in the vicinity of the 40 and 50 fathom isobaths, the direction along which currents tend to flow, and the distribution of larval wenchman snapper in this area follows a swath that generally overlays bottom reef habitat (unpublished info.). Another possible example of an association between the distribution of spawning adults and larvae was found in collections of red snapper larvae collected in July 1992 over the Alabama and west Florida continental shelf; two collections with the highest abundances of red snapper larvae were adjacent to the extensive artificial reef habitat off the Alabama coast.

The usefulness of ichthyoplankton collections taken in the vicinity of oil and gas structures is certainly in question, but this question can be answered quite cheaply; while a research vessel is on station at a rig it would take little time and expense to take an oblique plankton tow with a bongo net. Sorting the plankton collections is the only significant expense, and this could be terminated if results are not positive.

## RECOMMENDATIONS

The second day of the workshop consisted of the SEAMAP Reef Fish Work Group members, presenters, invited guests and other participants discussing all the presented methodologies and formulating some recommendations concerning oil and gas structure sampling. These recommendations will be used by the NMFS and SEAMAP for the development of sampling methodology in the Gulf of Mexico. The following recommendations were developed during those deliberations:

- Separate the study area into three zones: coastal (from shore out to 22 meters in depth); offshore (23 to 80 meters in depth); and blue water (greater than 80 meters in depth);
- Mobile shipboard ascoustic passes on all sides of rig;
- Mobile ROV acoustic passes;
- ROV visual at set depth strata;
- Four-camera array for static visuals at set depth strata;
- Standard water parameters as well as current speed and direction, transmissivity, and PAR;
- Plankton sampling including standard sampling and possible "light trap" samples;
- Laser measurements of target species;
- Collect hard parts for aging studies; and
- Examine historical data bases for baseline information.

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