A review: pelagic fishes at petroleum platforms in the northern Gulf of Mexico; diversity, interrelationships, and perspectives

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Abstract

Approximately 4,000 petroleum (oil and gas) platforms exist in the northern Gulf of Mexico and form one of the world's most extensive *de facto* artificial reef systems. Collectively, these structures may comprise one of the largest FAD (Fish Aggregating Device) arrays in the world, attracting surface and midwater pelagic fishes. The diverse composition of pelagic fish fauna at NGOM platforms is described and includes valued species such as *Thunnus albacares, Thunnus atlanticus, Coryphaena hippurus, Acanthocybium solandri, Rachycentron canadum, Seriola dumerili, Scomberomorus cavalla*, and *Decapterus punctatus*. Petroleum platforms influence pelagic fishery resources and are an important component of the Gulf's commercial and recreational fishing industries. Reviewed literature revealed a sparsity of fundamental knowledge of densities, temporal and spatial occurrence, and fishing effort/catch rates of pelagic fishes at platforms. The role of Gulf petroleum platforms "as FADs" is examined, possible mechanisms for aggregation are reviewed, and a synopsis of the author's preliminary findings on life history aspects of *A. solandri* and *R. canadum* from platforms is presented. It is proposed that platforms provide opportunities for the study of pelagic species to better understand the life history, ecology, behaviour, and habitat requirements of pelagic fishery resources in the Gulf of Mexico.

Introduction

In the northern Gulf of Mexico (NGOM), coastal and oceanic petroleum (oil and gas) production platforms constitute long-lasting structures (40 years) which attract large assemblages of pelagic fishes and enhance recreational and commercial fishing within the region. Although northern Gulf platforms aggregate a diverse and abundant pelagic fish resource, there is little fundamental knowledge of factors influencing their ability to attract fishes, and information is scant regarding the influence of platforms on pelagic fish populations within the NGOM.

Approximately 4,000 platforms exist in the NGOM, extending from waters off the State of Alabama to Padre Island National Seashore off the State of Texas (Scarborough-Bull & Kendall, 1994) (fig. 1). Of these, 81% occur off Louisiana and 14% off Texas. NGOM platforms supply 25% of the US production of natural gas and 18% of its oil. NGOM States manage petroleum resources that occur within their territorial waters; however, most platforms occur on the outer continental shelf (OCS) within United States territorial waters where the development of petroleum resources is managed by the Minerals Management Service (MMS), an agency of the US Department of the Interior.

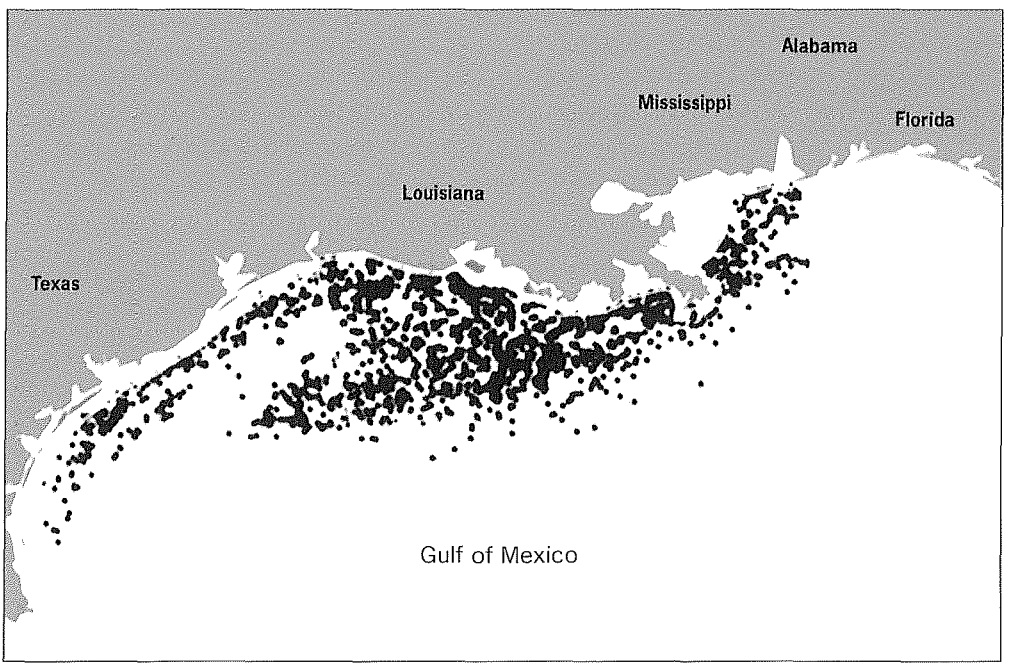


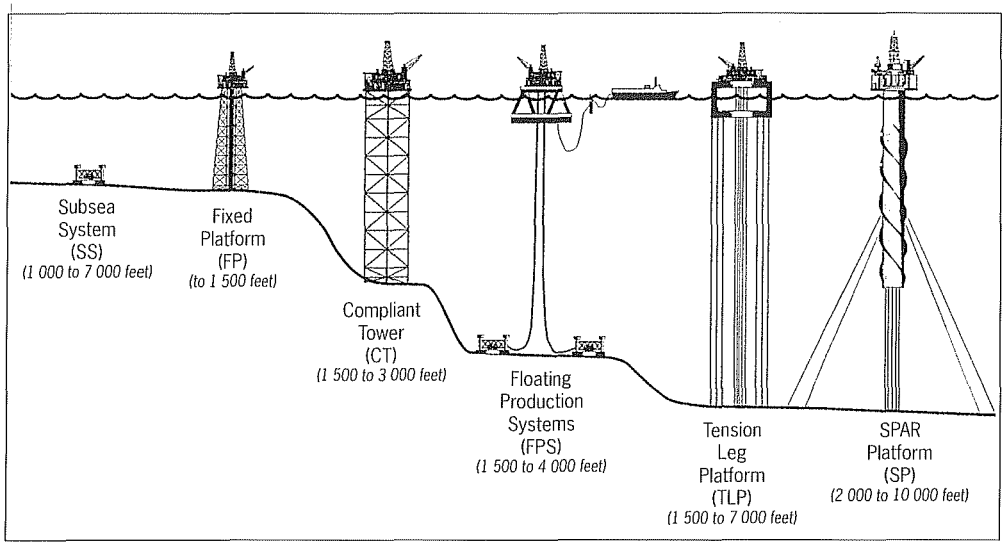
Figure 1
Map of the northern Gulf of Mexico study area showing the general location of 4,000 petroleum platforms. Platforms are designated by black dots.
Source: Ditton & Auyong (1984).

This paper provides, by way of review of the scientific literature and other available sources, information on the pelagic fish fauna associated with NGOM platforms. The diversity and abundance of pelagic fishes at platforms are examined, possible mechanisms for pelagic fish aggregation at platforms and various interrelationships are reviewed, and a synopsis of the authors' research findings on selected life history aspects of two pelagic fishes, wahoo (*Acanthocybium solandri*) and cobia (*Rachycentron canadum*), which associate with NGOM platforms is presented. It is proposed that NGOM petroleum platforms and fish attracting devices (FADs) may function comparably in their attraction of pelagic fishes, and that platforms provide unique opportunities to study the natural history and behaviour of pelagic species.

Generic description of NGOM platforms

NGOM platforms range in size and complexity from small, single-well operations to large, multi-well edifices of considerable structural complexity. Until recent years, oil and gas drilling activities and subsequent installation of production platforms, occurred from shore to the 200-m depth contour; however, since 1997, 40 platforms have been installed at water depths ranging from 1,000 to 2,300 m and are located more than 250 km from shore (Cranswick & Regg, 1997). As the search for oil and gas extends into the deeper NGOM, platforms in 3,000 m of water may be a reality within the next decade or two. The different types of platforms that are installed at various water depths in the Gulf of Mexico are shown in figure 2. Platforms are stabilized by large vertical supports (legs), a large portion of which is submerged and connected by an assemblage of cross beams. Since conventional platform designs are unfeasible for deep-water structures, they are supported in place by high-tech, innovative mooring systems.

Figure 2
Diagram of the type of petroleum platforms installed at various water depths in the northern Gulf of Mexico.
Source: Cranswick & Regg (1997).



Ecological studies at NGOM platforms: overview

Offshore platforms represent a relatively "new" biological habitat in the northern Gulf which is characterised by a distinctive faunal assemblage and species associations when compared to the surrounding waters and natural habitat (Gallaway & Lewbel, 1982). Early biological surveys conducted at NGOM platforms focused on descriptions of the biofouling community on the vertical supports (Gunter & Geyer, 1955; Pequegnat & Pequegnat, 1968) and benthic fish populations (Perry, 1979).

A review of more recent scientific literature reveals that NGOM platforms as artificial reefs and habitat for reef fishes have been the topic of at least 30 biological studies which primarily investigated the associated demersal or benthic communities.

Research on pelagic fishes at and around platforms has been difficult owing to the complex architecture of platforms, excessive water depths, low visibility, and a lack of applicable scientific sampling gear and methods. However, some information on the association of pelagic fishes with platforms has been acquired from research studies conducted at a few NGOM platforms, which in recent years included diver visual surveys, hydroacoustic surveys, and video recordings from remotely operated vehicles (ROV).

Diversity and abundance of pelagic fishes associated with some NGOM platforms were investigated by Hastings *et al.* (1976), Wilson & Stanley (1991), Gallaway & Lewbel (1982), Reggio (1989) and Stanley & Wilson (1989, 1990, 1995, 1996, 1997). Biological and ecological relationships of pelagic fishes at NGOM platforms were examined by Stanley & Wilson (1995, 1996, 1997), Scarborough-Bull & Kendall (1994). However, long-term scientific assessments of the ecology and interrelationships of pelagic fishes and their aggregations at NGOM platforms are scant. Despite their great numbers and importance to fisheries user groups (Ditton & Auyong, 1984), too few quantitative data exist on the "fisheries value" of NGOM platforms.

Platforms as FADs for pelagic fishes

Associations of tropical and subtropical pelagic fishes with floating objects such as logs, mats of algae (e.g. *Sargassum*), debris, and other flotsam have been widely reported in the literature (see Rountree, 1989 for references). The reasons for the attraction of fishes to floating objects are not fully understood, although availability of food, shelter from predators (Rountree, 1989), and orientation advantages are among the numerous factors that may play important roles.

Numerous economically important tropical and subtropical fisheries have developed as a direct result of fishermen constructing and deploying FADs. These are designed to create artificial habitats and usually float at or near the surface or are suspended in midwater. FADs ostensibly aggregate fish which would otherwise be dispersed over wide expanses of water (Rountree, 1990). The types of FADs, their uses in various regions of the world, and their effectiveness to attract a diverse assemblage of fishes have been the subject of scientific study by various researchers (see Dagorn & Fréon, 1999 for FAD references).

Petroleum platforms in the NGOM also serve as major "aggregation points" for large numbers of fish, and the effects of platforms are not confined to benthic and demersal fish but also extend to pelagic fish which often exhibit high species diversity and typically represent the

greatest fish biomass (Gallaway & Lewbel, 1982). Conventional FADs have not been used to any extent in the NGOM, primarily because platforms are perceived to function as FADs. The submerged portions of all platforms in the NGOM are estimated to provide approximately 12 km^2 of hard substrate (Stanley & Wilson, 1997) and constitute 28% of the known hard-surface habitat off the coasts of Louisiana and Texas (Reggio, 1989). These structures represent the most extensive *de facto* artificial reef system in the world. Do NGOM platforms collectively represent the world's largest *de facto* assemblage of FADs?

Composition, diversity and abundance

In addition to scientific literature, supplemental (grey) sources of information on pelagic fishes associated with platforms include interviews with recreational fishermen and divers, examination of recreational fishermen's catch, official reports of commercial fishermen, charterboat captains' log books, and captains of petroleum platform supply vessels. Although catches of highly sought-after game fishes at platforms are selective and biased towards larger species because of the hook-and-line gear used, the data are valuable, nonetheless, and would be difficult to obtain otherwise. Available scientific literature (see Ecological studies above) and supplemental sources were consulted to develop a list of pelagic fishes associated with NGOM platforms (see table). The list contains 45 species representing 18 families.

The composition of pelagic fishes at coastal platforms (water depth <20 m) typically differs from that at offshore platforms (water depth 20-64 m) and bluewater platforms (water depth>64 m) (Stanley & Wilson, 1998). Among the pelagics which frequent shallow platforms are *P. saltatrix, R. canadum, C. faber, C. hippos, C. ruber,* and *S. maculatus* (see table). Offshore platforms attract some of the pelagic fishes which also occur at coastal platforms, but *S. mokarran, S. zygaena, S. dumerili, S. rivoliana, E. bipinnulata, S. cavalla, A. solandri, E. alletteratus, B. capriscus* (see table), and an assortment of baitfishes, primarily small clupeids and carangids, are among the species that typically occur at offshore sites (Gallaway & Lewbel, 1982). Bluewater platforms attract some species found at shallower offshore structures, but are defined by large scombrids (tunas, wahoo), istiophorids (blue marlin and white marlin), and vast schools of baitfishes.

Regular fluctuations in diversity and abundance of pelagic fishes at individual platforms appear to be the norm, with higher abundances generally associated with increased water temperatures. Seasonal change in NGOM temperature probably influences migratory patterns of pelagic baitfishes and pelagic predators within the region. Variations in the occurrence of some pelagic species at NGOM platforms suggest a transient relationship with little or no fidelity to a particular platform or group of platforms, a presumption supported by tagging studies (Franks *et al.*, 1991).

Table - Pelagic fishes reported to associate with petroleum platforms in the northern Gulf of Mexico. J = juvenile stage, A = adult stage.

	Life Stage		Life Stage
Carcharhinidae		Carangidae	
Carcharhinus brevipinna	A	*Seriola zonata*	J A
Carcharhinus limbatus	A	*Trachinotus carolinus*	A
Carcharhinus obscurus	A	*Trachurus lathami*	A
Galeocerdo cuvier	A	Coryphaenidae	
Rhizoprionodon terraenovae	J A	*Coryphaena hippurus*	J A
Sphyrnidae		Lobotidae	
Sphyrna mokarran	A	*Lobotes surinamensis*	J A
Sphyrna zygaena	A	Ephippidae	
Elopidae		*Chaetodipterus faber*	J A
Megalops atlanticus	A	Mugilidae	
Clupeidae		*Mugil cephalus*	A
Harengula jaguana	J A	Sphyraenidae	
Sardinella aurita	A	*Sphyraena barracuda*	A
Pomatomidae		Scombridae	
Pomatomus saltatrix	A	*Acanthocybium solandri*	J A
Rachycentridae		*Euthynnus alletteratus*	A
Rachycentron canadum	J A	*Euthynnus pelamis*	J
Echeneidae		*Scomberomorus cavalla*	J A
Echeneis naucrates	A	*Scomberomorus maculatus*	J A
Carangidae		*Thunnus albacares*	A
Caranx fusus	J A	*Thunnus atlanticus*	A
Caranx hippos	J A	*Thunnus thynnus*	A
Caranx latus	A	Istiophoridae	
Caranx lugubris	J A	*Makaira nigricans*	A
Caranx ruber	J A	*Tetrapterus albidus*	A
Decapterus punctatus	J A	Balistidae	
Elagatis bipinnulata	A	*Balistis capriscus*	A
Selene vomer	J A	*Canthidermis sufflamen*	A
Seriola dumerili	J A	Tetraodontidae	
Seriola fasciata	J A	*Lagocephalus laevigatus*	A
Seriola rivoliana	A		

Pelagic species at platforms are represented by juveniles and adults alike, however, there is scant information on seasonal occurrence of various life stages of species or which life stages occur more frequently. Little is known about the size and age composition of pelagic fishes at platforms.

Interrelationships

Very little is known about the interrelationships of fishes at platforms or the interspecific interactions of pelagics within the "platform community". Depending upon the species, pelagics position themselves at varying depths and locations around or near a platform structure. Observations on vertical zonation indicate that smaller species, particularly planktivores, typically maintain a position from nearsurface to mid-depth, closely associate with platform structure, and tend to locate within or slightly upcurrent of the structure (Gallaway *et al.*, 1981).

By positioning themselves upcurrent, plankton feeders can allow the current to bring food to them, wherein a minimum expenditure of energy is required to feed, thereby possibly reducing the amount of food required per individual. Competition for planktonic food may be a determinant of pelagic fish fauna at platforms, i.e., successful or unsuccessful feeding by planktivorous baitfishes such as *Harengula jaguana* might affect attraction and residence time of pelagic predators.
Large, predatory pelagics tend to locate from the surface to middepth and move freely around and away from the platforms as they observe and/or pursue schools of baitfish and smaller pelagic prey. Large pelagics rarely enter the area enclosed by the platform's legs (Gallaway *et al.*, 1981). Just as Marsac & Cayré (1998) observed with FADs, some pelagic predators orient themselves upcurrent of the platform, and the position assumed by predators often matches the distribution of prey when located at a slight distance from the platform. Holland *et al.* (1990) reported that FAD-associated yellowfin tuna might pay an energetics penalty because the forage resource is probably considerably smaller than that available at the perimeters of nearby reefs. There are few natural reefs in the NGOM and only a few scattered natural areas of "high relief", so platforms may represent valuable, albeit opportunistically utilized, foraging sites for tunas and other large pelagics. Tunas may conserve energy at platforms during foraging events by orienting themselves in the current flow and feeding on current-borne prey, as Holland *et al.* (1990) reported for tunas at FADs.

Possible mechanisms of attraction to platforms

Platforms probably redistribute existing pelagic fish biomass within the NGOM. The mechanisms of attraction for pelagic fishes at platforms are poorly understood and have not been fully investigated; however, observations provide some insight into possible elements of attraction. Gallaway & Lewbel (1982) reported that assemblages of platform-associated pelagic fishes appear to be more strongly dictated by the physical factors of the platforms than by biological interrelationships, and, if so, may represent "flexible confederations of species loosely allied by similar environmental requirements or preference". Stanley & Wilson observed relationships of fish abundance and artificial structure were more complex than merely that of attraction to submerged surface area, and suggested that "factors such as natural and temporal variability of species distribution and abundance interacting with physical platform variables and water depth possibly determine overall species abundance".
Pelagic fishes appear to be attracted to artificial structure in greatest numbers when the structure extends a considerable distance above the bottom or even reach the surface, as do petroleum platforms. Baitfishes are thought to be attracted to vertically oriented objects for orientation, enhanced predator avoidance, and the potential increase in feeding (Rountree, 1990), and, in fact, the structural physical barriers created

by deeper-water platforms rising from the seafloor possibly create nutrient upwelling and thus potentially highly productive waters which might attract planktivores. The abundance of some pelagic predators at platforms may be directly correlated with prey availability, wherein predators accumulate in the vicinity of prey by means of "area restricted searching" behaviour (Bohnsack, 1989) which facilitates avoiding unproductive foraging areas. Large pelagics such as tunas and billfishes are gregarious roamers which are believed to be minimally dependent upon resident and small transient pelagics at platforms as food, and even though an individual platform might not provide a supply of prey to support feeding requirements of an entire school of tunas, an array of closely aligned platforms might provide for an ample foraging base.

FADs possess "attractive or effective ranges" (Hunter & Mitchell, 1967) depending on design, composition, size, type and textural condition of structural materials, color and odor, and similar factors might apply to platforms. Cayré (1991), Holland *et al.* (1990), and others reported the optimum minimal horizontal distance between FADs as 18 km to avoid overlapping the attraction potential and the respective radii of influence with neighbouring ones. Optimum distance may also depend on the available biomass within a given area. The overall radius of influence for large pelagics at platforms is unknown, however, offshore recreational fishermen often catch tunas and marlins within 5 km of platforms. Although, some large pelagic fish typically orient themselves upcurrent of platforms, others may not. Commercial longliners tend to make their tuna "sets" at distances 3 km downcurrent from platforms, primarily to avoid entanglement of their drifting gear with platform support structures.

Hypotheses on the associative behaviour of pelagic fishes are discussed by Fréon & Misund (1999) and provide enlightened insight into possible mechanism of attraction to structure. Some proposed mechanisms for attraction to artificial structure seem to conflict. For example, increased shelter and survival imply reduced predation, and yet, additional food and increased predator feeding efficiency suggest higher predation rates and increased prey mortality (Bohnsack, 1989). Fish attraction behaviour presumably evolved because of some selective advantage, e.g., faster growth, increased survival, and reproduction (Bohnsack, 1989). So, do platforms (and FADs) provide cues beyond the evolutionary experience of pelagic fishes and elicit responses that are not necessarily adaptive? Do pelagic fishes at platforms face higher mortality from natural predators... and fishermen?

Platforms and FADs: some principal factors in common

- Create artificial habitat at or near the surface and in midwater;
- High taxonomic diversity and abundance of pelagic fishes relative to the surrounding waters;
- Attract similar families of fishes; attract resident and transient pelagic fishes;

- Influence regional pelagic fisheries; important component of pelagic fishing industries;
- Significantly increase fishermen catch, decrease fishermen search time, lower fuel consumption;
- Provide opportunities to study the natural history and biology of pelagic fishes.

Platforms and pelagic fisheries

Offshore energy development in the NGOM has been recognized as having a significant positive effect on offshore recreational and commercial hook-and-line fishing within the area. Linton (1994) reported the number of platforms in the NGOM doubled during the 1980s while both the number of species and total amount of finfish landed from the NGOM tripled during the same period. In the United States, the utilization of offshore platforms as fishing sites is greatest in the NGOM (Ditton & Auyong, 1984; Reggio, 1987), and platforms attract a variety of commercial fishing gears (electric bottom rigs, hook-and-line, handlines, etc.) and recreational hook-and-line fishing methods (trolling, drift fishing, casting, etc.).
Several pelagic species, particularly carangids and scombrids, are the main target species of NGOM commercial and recreational fisheries, and platforms concentrate available fish into a smaller geographic area, potentially making them more accessible to fishermen. Over 40% of the US marine recreational fishing catch come from the Gulf of Mexico, and a large portion of that, including pelagic species, come from the NGOM (Ditton & Auyong, 1984). Platforms function to serve an expanding recreational fishing industry that has ever-increasing importance for the economies of States bordering the NGOM. Studies are needed to improve the base of information on the harvest of pelagic species at platforms as related to ecological and socio-economic aspects of the pelagic fishery.

Platforms as research opportunities

Studies of pelagic fishes at platforms can provide valuable information about their natural history, behaviour, and habitat requirements and on relationships between pelagic species and the platform environment. However, until repeated quantitative studies are performed, fisheries information associated with platforms will be of a qualitative nature. Platforms provide the opportunity for the collection of small pelagic species (and juveniles) rarely caught in conventional ichthyoplankton nets and could serve as "tools" for conducting controlled experiments in the pelagic environment. Platforms are of a long duration, and by conducting on-site, long-term studies, more can be learned about the associations of fishes with platforms, and the fisheries values of platforms. For the past ten years, the author has conducted life history research on cobia, *Rachycentron canadum*, a large migratory pelagic species which supports a valuable fishery throughout the Gulf of Mexico. Cobia

exhibit a strong attraction for platforms, and the majority of specimens used in the author's studies of age and growth (Franks *et al.*, 2000), reproduction (Lotz *et al.*, 1996; Biesiot *et al.*, 1994), and feeding habits (Meyer & Franks, 1996) were captured at NGOM platforms. Also, numerous cobia were tag-released at NGOM platforms during studies of cobia migratory behaviour (Franks *et al.*, 1991). Research findings revealed that cobia utilize platforms as prime feeding sites and probably spawn in offshore waters of the NGOM (some possibly at platforms). Seasonal fidelity to individual platforms and specific groups of platforms was demonstrated by a few recaptured tagged fish, and, in fact, captures of tagged as well as non-tagged specimens suggest that some members of the population may not migrate at all and remain as year-round residents at deep-water NGOM platforms (Howse *et al.*, 1992; Lotz *et al.*, 1996).

Life history studies recently initiated by the author and colleagues on wahoo, *Acanthocybium solandri*, from the NGOM (Brown-Peterson *et al.*, 2000; Franks *et al.*, 2000) rely heavily upon specimens caught at or near platforms by fishermen. Although research findings are preliminary, they suggest that wahoo are rapid growers, mature by two years of age, and spawn during summer months in the NGOM. Wahoo are attracted to offshore and bluewater platforms for purposes of foraging and as possible pre/post spawning-event meeting sites.

Although ongoing studies continue to expand the scientific base of information on cobia and wahoo from the Western Central Atlantic Ocean, the biology and behaviour of both species are not well understood. Cobia and wahoo are mentioned here to emphasize the value of platforms as prime locations for the collection and study of some of the large pelagic species within NGOM waters, and to underscore the need for additional studies of the underlying biology of aggregations of pelagic fishes around platforms. Continued studies of these two species at platforms will provide information useful in their management as highly valued pelagic fishery resources.

Suggested research on pelagic fishes at platforms could include:

- Mechanism of attraction/association; studies of species diversity, abundance, and behaviour;
- Importance of physical gradients to pelagic fish orientation and distribution;
- Trophic relationships and energy flow; biological assessments; new bio-survey techniques;
- Magnitude of bio-impacts in the presence of natural variations.

Research at NGOM platforms might elucidate the following:

- How dependent upon platforms are pelagic fishes; what are the interspecific relationships?
- What is the importance of platforms to ecological productivity and pelagic fish diversity in the NGOM?

- How do platforms modify dynamics of the "pelagic fish system" in which they are placed?
- What is the influence of platforms on juvenile pelagics and on the recruitment of juveniles?
- Are specific year-classes of pelagics attracted to platforms?
- Are platforms pelagic fishery enhancement tools, or tools to enhance fish harvest, or both?
- What is the role of platforms in sustainable development of pelagic fisheries in the NGOM?

Conclusion

Although scientific studies have provided information on pelagic fishes at NGOM platforms, the need exists for a greater understanding of the biological, ecological and socio-economic (including human dimensions) aspects of pelagic fish-platform relationships. Continued study of pelagic fishes at platforms will expand the base of scientific knowledge of pelagic fish resources within the Gulf of Mexico and may provide information useful to those involved in the study of FADs as components of pelagic fisheries in tropical and subtropical oceans. Conversely, results of scientific investigations of relationships between FADs and pelagic species have relevance to the study of NGOM pelagic fish-platform associations.

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