Chapter 5

Oil and Gas Platforms in the Gulf of Mexico: Their Relationship to Fish and Fisheries

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Additional information is available at the end of the chapter

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Abstract

There are over 2300 standing oil and gas platforms in the northern Gulf of Mexico (GOM). It has been argued that platforms provide reef-like habitat that increases the growth and survival rates of fishes by increasing prey availability and affording shelter for protection from predators, provide additional spawning substrate, and by acting as a visual attractant for organisms not otherwise dependent upon hard bottom. Platforms differ from most natural habitats, and from traditional artificial reefs, in that their vertical profile extends upward through the water column into the photic zone and the sea surface. Increased habitat quality on, or immediately around, oil and gas platforms are thought to be derived from increased *in situ* food production associated with encrustation by fouling organisms. In this chapter, we address the issue of how to evaluate the role of artificial reefs by first establishing levels of evaluation for individual fish species found on oil and gas platforms in the GOM. The levels of evaluation relate to the amount and adequacy of the available information, which was populated with an extensive literature and data search. Three levels of assessment are established, analogous to the levels of analysis established National Oceanographic and Atmospheric Administration (NOAA) Fisheries for identification of Essential Fish Habitat. More than 1300 documents, including reports, stock assessments, other gray literature, and papers published in the primary literature, were used to complete this chapter. When available, published literature was the preferred source of information.

Keywords: Gulf of Mexico, oil and gas platforms, fish, fisheries, biomass production

1. Introduction

In the waters of the northern Gulf of Mexico (GOM) there are over 2300 standing oil and gas platforms that together constitute the largest *de facto* artificial reef program in the world

(**Figure 1**). It has been argued that platforms provide reef-like habitat that increases the growth and survival rates of fishes by increasing prey availability, and affording shelter for protection from predators, provide additional spawning substrate, and by acting as a visual attractant for organisms not otherwise dependent upon hard bottom. Platforms differ from most natural habitats, and from traditional artificial reefs, in that their vertical profile extends upward through the water column into the photic zone and the sea surface. Increased habitat quality on, or immediately around, oil and gas platforms are thought to be derived from increased *in situ* food production associated with encrustation by fouling organisms.

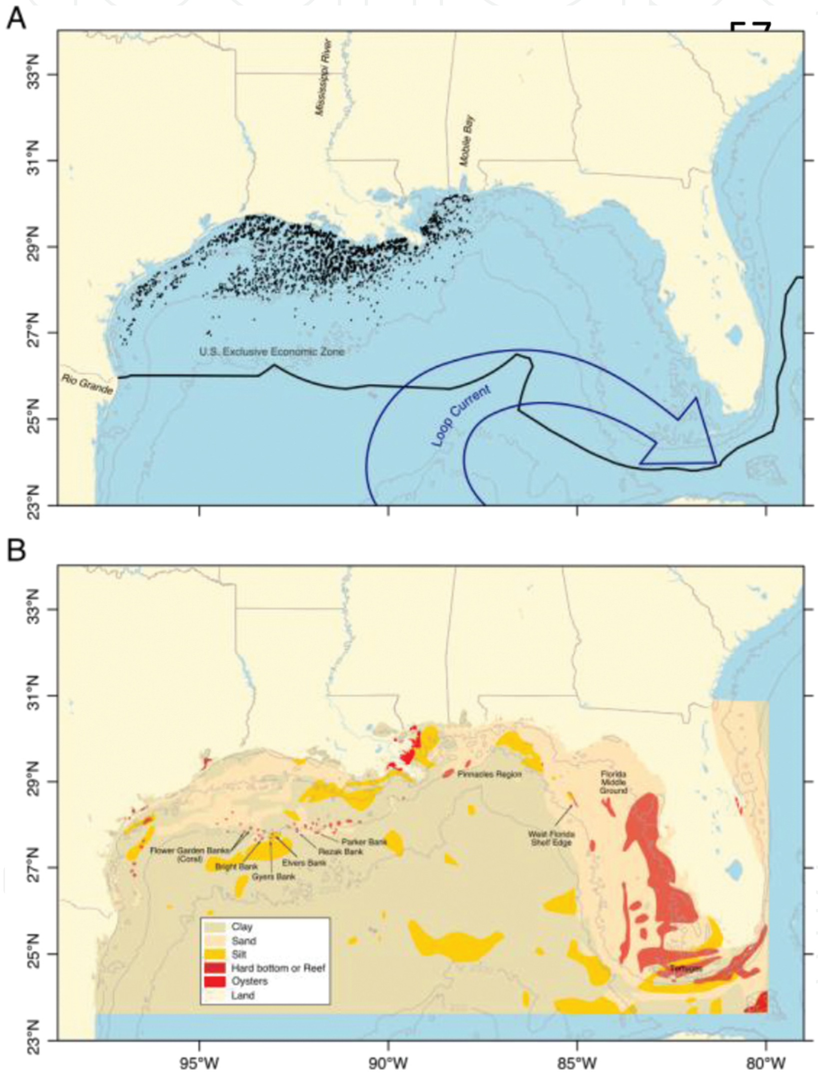

Figure 1. Map of the northern Gulf of Mexico. Panel A depicts oil and gas structures currently in place (black dots), the U.S. exclusive economic zone, and depth contours for 20, 200, and 2000 m. The continental shelf follows the 200-m contour approximately. Panel B (adapted from Gulf of Mexico Fishery Management Council 2005) depicts the primary bottom substrate in the area. Labeled banks were sampled during fishery independent reef fish surveys.

Artificial reefs, such as oil and gas platforms, may be useful tools for fishery managers if they increase reef fish biomass production, but many researchers question whether or not they are a positive influence on fish stock dynamics. If artificial reefs constitute habitat that is otherwise

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limiting for reef-associated fishes, then they may be viable management tools. If they are simply attracting fish, then they may be promoting overfishing. Unfortunately, the extent to which structures have influenced the status of exploited fish stocks, either directly via population production rates or indirectly through changes in fishing mortality rates, is still not well understood. The structures may alter fish populations and communities as a result of altering ecosystem structure and function. The effects on exploited fish stocks could also be detrimental if the high levels of fishing mortality rates do not result in compensatory processes that lead to increases in stock production.

2. Methods

In this chapter, we evaluate the role of artificial reefs by first establishing levels of evaluation for individual fish species found on oil and gas platforms in the GOM. The levels of evaluation are dependent upon the amount and adequacy of the available information, which was populated with an extensive literature and data search. Three levels of assessment are established, analogous to the levels of analysis established National Marine Fisheries Service for identification of Essential Fish Habitat (EFH). More than 1300 documents, including reports, stock assessments, other gray literature, and papers published in the primary literature, were used to complete this chapter. When available, published literature was the preferred source of information.

Level 1–For species about which little process information is known, the evaluation is based simply upon whether the species has been observed in association with platforms or artificial reefs.

Level 2–Here we used the conceptual model of Bohnsack [1] (qualitative, **Figure 2**). This conceptual model centers on the attraction vs. production issue, which encompasses much of the debate about the ecological role of artificial reefs (including oil and gas platforms) in a complex and dynamic coastal geography. The difference between Level 1 and Level 2 assessments is the degree of inference at the process level about the species in question, even if the process information (e.g., fishing mortality, site fidelity) is poorly documented. As such, relative knowledge of where a species falls along the continuum of data availability and confidence for several process-related variables provides significant insight into how that species may be affected by platforms. The evaluation presented here is based upon information reported In FishBase® (http://www.fishbase.org/), combined with expert opinion, and is used to provide relative species-specific assessments of: (1) Site fidelity (High, Moderate, Low); (2) Whether or not a directed fishery exists for this species (Yes or No, includes recreational fishing); (3) Whether diet is derived directly from reef habitat (Reef, Benthic, Pelagic); (4) Whether population size is believed to be limited by recruitment or habitat limitation (Habitat limited, Recruitment limited); (5) Type of behavior of adults (Reef, Demersal, Pelagic, Highly Migratory); and, (6) A summary judgment about whether the species is reef or habitat dependent, and the type of habitat on which some dependent species are most often found (e.g., Sargassum, Sea Grass, Hard Bottom).

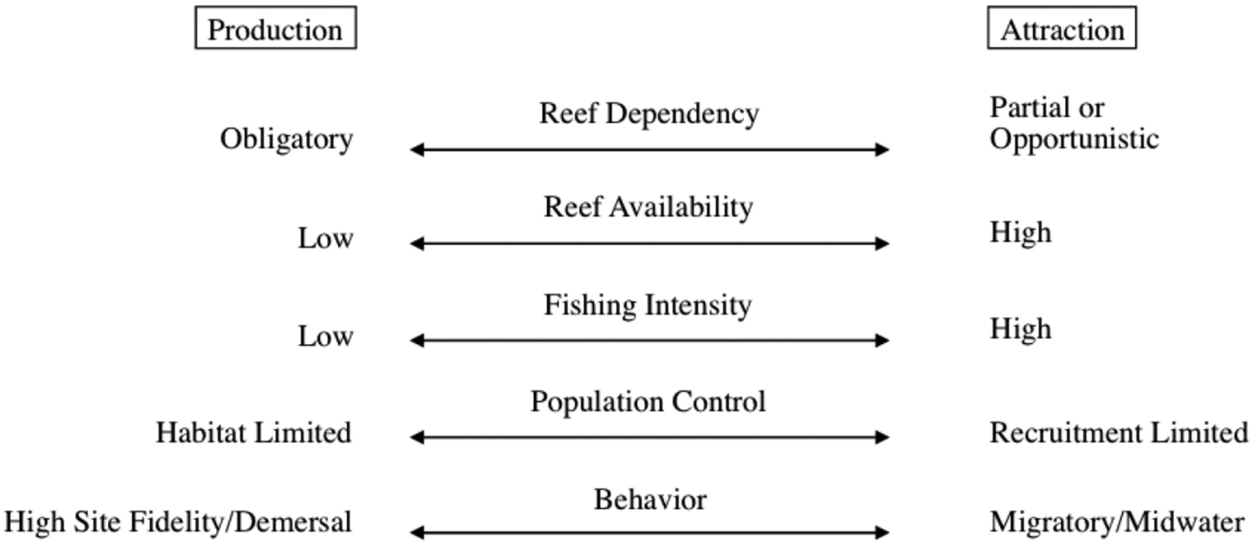

Figure 2. Bohnsack's [1] conceptual model for addressing the role of reefs in fisheries (redrawn from Bull. Mar. Sci. 44: 631–645).

Level 3–Based upon our extensive review of the literature, data for only five species of fishes were deemed sufficient for more complex analysis of estimating production; these are red snapper *Lutjanus campechanus*, blue runner, *Caranx crysos*, sheepshead *Archosargus probatocephalus*, Atlantic spadefish *Chaetodipterus faber*, and bluefish *Pomatomus saltatrix*. As might be expected, these species are abundant around standing platforms in the Gulf of Mexico and have been studied in some detail. Here evaluations are based upon various semi-quantitative or quantitative models found in the published literature.

The first model used in Level 3 evaluations is the semi-quantitative model described in Powers and colleagues [2], which uses the species-specific fish biomass production of a population on a reef (here a platform) weighted by the degree to which growth (biomass production) is attributable to prey resources produced on the reef. The production estimate for each species is multiplied by an index of reef exclusivity (IRE) derived from quantitative diet data. Applying the IRE, annual production (P) of a species attributed to a platform (AP; kg platform^{-1} yr^{-1}) is calculated by:

$$AP_i = IRE_i * P_i \tag{1}$$

where AP is a measure of relative species-specific production attributable to a platform. In the original equation, there was a term for the difference between pre-structure and post-structure biomass, but we are unable to provide pre-structure data because almost all of the platforms on the continental shelf were employed more than 25 years ago. We also believe that an estimate of biomass on a seafloor lacking structure, when compared to biomass after a structure has been constructed, may result in an overestimate of new biomass production because of the likelihood that individuals of many species are simply attracted to standing platforms.

The second method of estimating annual production for Level 3 is an empirical model [3]:

$$P = 0.00051 * B^{0.69} * T^{1.04} \tag{2}$$

where P is production (g dw d^{-1}), B is biomass (kg), and T is temperature (°C). We assumed that g dw = g wet weight * 0.20. The data used to estimate B (g) is based upon data obtained from published literature on biomass, estimated daily somatic production, and ambient water temperature for 62 species of fishes collected from numerous locations in Australia and elsewhere. Temperature data were summarized from several Gulf of Mexico studies on the continental shelf.

The previous and following methods of estimating production require an estimate of biomass on a platform. To make this estimate, we first calculated the simple arithmetic mean number of fish by species on a platform by summing all of the available estimates of numbers observed, based mostly upon visual surveys using scuba diving. In addition to numbers of individuals, length ranges (cm) are also reported for each species.

The third estimate of production for Level 3 is based upon methods described in by Ricker [4] where annual production is estimated by:

$$\hat{P} = \bar{B} * (G) \tag{3}$$

where $\hat{P}$ is biomass production, $\bar{B}$ is annual mean biomass, and G is specific growth rate yr^{-1}. Annual mean biomass is estimated by using:

$$\bar{B} = \frac{B(1 - e^{-(Z-G)})}{Z - G} \text{ when } G > Z \tag{4}$$

$$\bar{B} = \frac{B\,[(e^{(G-Z)} - 1)]}{G - Z} \text{ when } Z > G \tag{5}$$

Where $\bar{B}$ is annual mean biomass, B is biomass per platform in kg, G is specific growth rate yr^{-1}, and Z is specific mortality rate yr^{-1}. In actuality, Z is the sum of F (annual fishing mortality rate) plus M (annual natural mortality rate). In our Level 3 assessment, we ignore F in calculations, but we discuss the implications of this omission in the discussion. Biomass estimates were calculated based upon age and growth relationships reported in the literature from samples collected in the GOM for all species except Atlantic spadefish. For Atlantic spadefish, we used data collected in South Carolina. To estimate length at age, we used the Von Bertalanffy growth model (**Tables 1** and **2**):

$$TL_t = L_\infty(1 - e^{-k(t-t_0)}) \tag{6}$$

Species	MN	SR	ML	AR	B (kg)
Red snapper	1884 (range 905–4632)	25.5–79.1	295.3	2–10	886
Bluefish	1438 (range 282–4000)	45–50	475	1–6	1489
Atlantic spadefish	4177 (range 10 –5323)	10–50	30.0	1–8	2618
Sheepshead	2250 (range 150–17,000)	22–50	360	2–5	1774
Blue runner	6260 (range 427–25,188)	30–36	33.5	2–6	4152

Table 1. Literature values for mean number per platform (MN), size range at platform (SR, cm FL), mean length of individuals observed (ML, cm FL), age range (AR yrs), and biomass per platform (B kg wet wt) for five abundant species of fishes collected from Gulf of Mexico oil and gas platforms.

Species	T_{max}	G	M	AD	L_∞	K	t_0	a	b	Source
Red snapper	57	0.31 (at T_{max} G=0.05)	0.10 (at T_{max} M=0.07)	2–10	94.1	0.18	–0.55	0.0165	3.03	[5–7]
Blue runner	11	0.39	0.38	2–4	41.2	0.35	–1.17	0.0524	2.690	[8]
Sheepshead	20	0.23	0.22	2–5	41.9 (M)	0.417	–0.901	0.000448	2.88	[9]
					44.7 (F)	0.367	to 1.025	0.000530	2.85	
Atlantic spadefish	8	0.41	0.58	1–8	49.0	0.340	–0.18	0.0927	2.64	[10]
Bluefish	8	0.41	0.58	1–6	94.4	0.18	1.033	–10.02	2.80	[11]

T_{max} = maximum age; M = natural mortality rate; G = specific growth rate (yr); L_∞ (cm TL) is the asymptotic maximum length, K is a constant (the Brody growth coefficient), and t_0 is a constant representing the age (yr) at 0 length. Letters in parentheses following L_∞ indicates sex if males and females were dimorphic. Fish length is converted to wet weight using a length-weight equation with constants a and b. Age distributions of fish (AD) were derived from empirical data for size ranges at age of fishes observed at platforms, except for red snapper that are most abundant from ages 2 to 6 (Wilson and Nieland 2001).

Table 2. Literature values for maximum age, estimated growth and mortality rates, and Von Bertalanffy length-at-age parameters used in production calculations.

where TL_t is total length (TL) at age t, L is the asymptotic TL, k is the Brody growth coefficient, t is age in years, and t_0 is a hypothetical age when TL is zero. Using species-specific versions of this equation, we determined the age range of each species observed on platforms that correspond to the observed length ranges. Length-length relationships available for each species allowed for conversion among total length (TL), fork length and standard length as necessary for consistency among units of length. Length at age was converted to wet weight at age using:

$$TW_i = a * TL^b \tag{7}$$

where TW_i is wet weight in g of species i, TL (cm) and a and b are constants derived for each species. The values for a and b for each species are reported in **Table 3**. Growth (G) is estimated using the equation:

$$G = (\ln W_{t=j} - \ln W_{t-i}) + (t_j - t_i) \tag{8}$$

where G is the specific growth rate in kg yr^{-1}, W is weight in kg and t is time.

Species	Trophic Level (SE)	Diet Composition (source)	IRE	T°C	P_r	P_e	AP_r	AP_e
Red snapper	4.01 ± 0.59	Benthic inverts, demersal fishes, squid, pelagic zooplankton [12–15]	0.05	25.9	306	115	15	6
Blue runner	4.40 ± 0.77	Fish, decapods, hyperid amphipods, chaetognaths, other [[16], FishBase]	0.10	25.9	1627	333	163	33
Sheepshead	3.53 ± 0.53	Portunid crabs, shrimp, barnacles, fish, copepods, bryozoans, amphipods, sargassum [[17], FishBase]	0.90	25.9	410	185	369	167
Atlantic spadefish	3.50 ± 0.47	Sponges and tunicates, cnidarians, worms, ascidicans, plants, benthic inverts, echinoderms, zooplankton (FishBase)	0.95	25.9	987	243	938	231
Bluefish	4.50 ± 0.55	Pelagic and demersal fish and macrocrustaceans (from soft bottoms) [18]	0.01	25.9	561	164	6	2

The index of reef exclusivity (IRE) is an estimate of species utilization of resources associated with platform habitat compared to resources from nearby natural habitat (Powers et al. 2003). The IRE is based upon diet information from the sources provided. Trophic level for each species was obtained from FishBase (http://www.fishbase.org/), T°C is the annual averaged sea surface temperature in degrees centigrade obtained from the NOAA Data Buoy Center for years 2013-2015 and 2005 at SPLL1 (28.87 N, 90.48 W) and MRSL1 (29.44 N, 92.06 W) on the Louisiana Shelf. P_r = annual biomass production in kg $platform^{-1}$ yr^{-1} based upon calculations using Ricker (1975). P_e = annual biomass production in kg $platform^{-1}$ yr^{-1} estimated by using the empirical relationship in Edgar and Shaw (1990). AP_r = IRE*P_r, AP_e = IRE*P_e. Numbers proceeded by * refer to literature resources listed on the table.

Table 3. Estimated relative production attributable to oil and gas platforms (AP).

3. Results

Levels 1 and 2: In total, 246 species of fishes have been reported from oil and gas platforms in the GOM (**Appendix Table 1**, hereafter **ATable 1**). Of these, 33 species are Caribbean expatriates (23 of which are reported to be reef dependent) that occur sporadically in low numbers, and are not believed to contribute to overall stock productivity because their larvae are nearly absent in waters of the northern GOM [17]. One hundred-two species have life history strategies that conclusively exclude them from being reef associated or dependent (N in **ATable 1**), even though these species have been reported in collections of fishes from platforms. Thirty-six species are conclusively considered to be reef dependent (Y in **ATable 1**; note that Y= reef dependent, Y plus habitat descriptor HB, SG, S are habitat dependent on a specified habitat), which here indicates that reef habitat is required for these species to complete their life cycles, or that their diet is almost exclusively derived from the reef [18]. Reef dependent species that are not expatriates are: *Balistes capricus; Cantherhines pullus; Cephalopholis cruentatus; Chaetodipterus faber; Clepticus parrae; Parablennius marmoreus*; and *Xyrichthys novacula*. Thirteen species have life history strategies that appear to preclude reef dependency, or are documented to occur on structured, non-reef habitats, but are listed in FishBase as reef associated. In **ATable 1**, these 13 species are denoted with an N under the Dep category, followed by the habitat type that is reported to be of greatest importance.

The species for which we assigned an N have life history and behavioral characteristics that are qualitatively similar to the attraction end of the Bohnsack's continuum [1]. These species are directly fished or overfished, exhibit low site fidelity, are less or not dependent upon the reef for food, are not dependent upon the reef for completion of their life cycles, and are pelagic and/or migratory, and thus less likely to habitat limited. In contrast, the species for which we assigned a Y in **ATable 1** have life history and behavioral characteristics that are qualitatively more similar to production end of the continuum [1]. These species have relatively high site fidelity, the need for reef or structured habitat to complete the life cycle, and a significant fraction of their diet is comprised primarily of reef-associated prey.

There are numerous species for which expectations about reef dependence are more difficult to describe, even qualitatively. To provide some interpretation, we use both a qualitative assessment relative to the Bohnsack [1] conceptual model, and insight derived from the Level-3 assessments to make comparisons among the reef-associated species in **ATable 1**. Where possible, we identify species that are comparable with respect to ecology, life history, and behavioral characteristics to the Level-3 species. It is fortunate that the latter group is comprised of species that appear to differ significantly in their relative ecological dependence on reefs and, by extension, to platforms. We also consulted additional reference materials to make our determinations [18–24].

In all, 46 species are listed as reef associated (RA in **ATable 1**). Of these, many are known to be pelagic and/or highly migratory. Among this group are several species of jacks (fm. Carangidae, genus *Caranx* (6 species), genus *Seriola* (3 species), *Elagatis bipinnulata, Selar crumenophthalmus, Oligoplites saurus*, and *Trachurus lathami*), mackerels (fm. Scombribdae, *Scomberomorus* (2 species)), clupeids (*Harengula jaguana, Opisthonema oglinum, and Sardinella aurita*), barracudas (genus *Sphyraena* (3 species)), cobia (*Rachycentron canadum)*, and ocean triggerfish (*Canthidermis sufflamen*). Although listed as reef associated in FishBase, they exhibit life history and behavioral characteristics that are more typical of fishes at the attraction end of Bohnsacks continuum, and appear to be most comparable in their use of reefs and platforms to bluefish and/or blue runner. As such, these species may not be significantly dependent upon platforms.

Thirty of the 46 species listed as reef associated (RA) have other habitats listed as primary (fm. Carangidae, mackerels fm. Scombribdae, and clupeiods herrings and anchovies). Many of these species are reported to primarily associate with hard-bottom (HB) habitats (25 species including most of the groupers). This makes sense given the nature of most of the natural reef habitat in the GOM. Other species are reported to associate with sea grass (SG) meadows. Where possible, we have included additional detail in **ATable 1** about primary habitat associations reported for many of the reef-associated species. These primary habitats are consistent with natural habitats reported to occur in the GOM and include reef flats, rocky reefs, coral reefs, oyster reefs, floatsam, shelf-edge banks, offshore rock bottoms, offshore banks, *Oculina* reefs, and structure of all types. This group clearly is the most difficult to assess. We note that the lack of habitat-specific, process-level data makes the following interpretations speculative.

Most of the grouper species reported in **ATable 1** in the genus *Epinephelus*, with the exception of *E. itajara*, and in the genus *Mycteroperca*, with the exception of *M. microlepis*, are managed as a complex in the GOM referred to as the "deep-water groupers." Relatively little is known about the ecology and behavioral characteristics of these species, although they are believed to be long-lived and exhibit relatively low stock productivity [25]. Assessment of the role that platforms play in their life histories would be speculation on our part, but it is likely that association with platforms does not significantly increase their vulnerability to fishing, especially to recreational anglers, given their preferred depth distribution. It also is unlikely that a significant number of platforms are available as habitat for these groupers for the same reason; these fishes are likely to occur only on those structures near or on the shelf-edge banks shown in **Figure 1**. In contrast, *E. itajara*, the goliath grouper, and *M. microlepis*, the gag grouper, are found inshore on a variety of habitats ranging from platforms to artificial reefs, to bridge pilings, piers, docks, seawalls, and other hard structures [26]. Juvenile goliath groupers are most often found in mangroves, which appear to be its primary nursery ground. Goliath groupers are overfished in the US GOM and currently, harvest is limited [27]. They are confined mostly to Florida Bay and the southern portion of the Florida peninsula and the Bay of Campeche where they are harvested in great numbers as juveniles in the GOM, but have been observed occasionally by scuba divers around platforms. As the stock rebuilds and expands northward in the GOM, however, it is plausible that platforms will contain increasing numbers of goliath groupers. The relative role of platforms as sources of stock productivity and fishing mortality should be closely monitored as the goliath grouper stock increases.

Gag groupers are more widely distributed in the GOM, but also are overfished [28]. They are extremely vulnerable to overexploitation because they are haremic as adults, and aggregate to spawn at just a few locations in the northeastern GOM. Juvenile gag groupers are mostly associated with sea grass meadows as nursery areas. To our knowledge, the ecology of gag grouper on platforms has received little study. However, the work of Lindberg and coworkers on the west Florida shelf has demonstrated that the value of artificial reefs as habitat is affected both by size and spatial arrangement of reef modules. The net effect on stock production of reefs is negative when fishing mortality is considered [29, 30]. Despite these results, we caution against drawing inference about the role of platforms as habitat for gag groupers because the aforementioned work was done on relatively small, low-relief, reef modules. Two other species reported as reef-associated in **ATable 1** (*Neoconger mucronatus* and *Ophidion selenops*) also are found in deep waters on or near the shelf edge.

There are several species in **ATable 1** that are reported to be reef-associated, but also occur on a wide variety of habitats including inshore waters, bays, estuaries, and sea grass meadows. Qualitatively, these species have life history and behavioral characteristics that are more similar to those found at the production end of Bohnsack's continuum [1]. These include *Chilomycterus schoepfii, Lagodon rhomboides*, two members of the genus *Opsanus, Sphoeroides spengleri*, two members of the genus *Trachinotus*, and *Stephanolepis hispidus*. This group appears to be most like Atlantic spadefish and sheepshead, for which Level 3 assessments were made.

Similarly, there is another group that qualitatively appears to have life history and behavioral characteristics that are more similar to those found at the production end of the continuum, but also appear to be more restricted in their distribution than the reef-associated group that use many habitats (discussed in the previous paragraph). These more habitat-restricted species are reported to occur in coastal waters, and on shelf-edge banks, but are explicitly identified as not being found on coral reefs. This group includes two members of the genus *Equetus, Gymnothorax nigromarginatus*, two members of the genus *Hypleurochilus*, two members of the genus *Hypsoblennius, Myrophis punctatus, Pseudupeneus maculatus, Saurita normani*, two members of the genus *Syacium, Syngnathus louisianae*, three members of the genus *Synodus*, and the blue phase of *Thalassoma bifasciatum*. Furthermore, blennies are nest builders that depend upon hard substrate. Many members of this group also appear to be most like Atlantic spadefish and sheepshead, for which Level 3 assessments were made.

There are several small, cryptic species listed in **ATable 1** as reef-associated that we believe to be more strongly associated with reefs than the many-habitat and restricted habitat reef-associated species (preceding two paragraphs), and whose life history and behavioral characteristics appear to place them solidly at the production end of Bohnsack's continuum. This group includes *Callionymus bairdi, Coryphopterus punctipectophorus, Ophioblennius atlanticus, Prognathodes aya, Rypticus maculatus*, the yellow phase of *Thalassoma bifasciatum*, and *Trachinocephalus myops*. Although information about the ecology and life history of this group on platforms is lacking, there are no analogues for these among the group for which Level 3 assessments were possible.

In addition, there are several species listed in **ATable 1** as being reef-associated in FishBase, but whose life history and behavioral characteristics (at least qualitatively) do not strongly support placement near either endpoint of Bohnsack's continuum. This group has been reported to occur on a wide variety of natural hard-bottom habitats in the GOM, including platforms, but appear to have only moderate to low site fidelity. Many of these species support directed commercial fisheries, and all appear among the list of species harvested by recreational anglers. This group includes six members of the genus *Lutjanus*, including the red snapper *L. camphechanus* (site fidelity < 1% per year on standing platforms [31]), which is overfished but rebuilding, *Rhomboplites aurorubens, Brotula barbata*, three members of the genus *Centropristis, Haemulon plumierii*, and *Paranthias furcifer*.

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Of this group only the red snapper, and to some degree *R. aurorubens*, have been reasonably well studied, but almost all of the work on adults of these two species that has focused on recruits to platforms or has been done on small, low-relief, artificial reefs in the northeastern GOM. Similar to the results reported by Linberg and coworkers for gag grouper [29, 30], studies of red snapper indicate that the value of artificial reefs as habitat is affected both by size and spatial arrangement of reef modules, and that the net effect on stock production of reefs is negative when fishing mortality is considered [32, 33]. In addition, diet studies in the northeastern GOM indicate that adult red snapper rely very little on prey derived explicitly from reef habitats, whether collected on artificial [source 2 in **Table 3**] or natural reefs [34]. Despite these results, we caution against drawing inference about the role of platforms as habitat for red snapper given that much of the work has been done on relatively small, low-relief, reef modules. More recently, Simonsen and colleagues [15] compared diets of red snapper on standing platforms, toppled platforms, and on the natural reefs in the western GOM. They found that diets on both of the platform types were less diverse and provided less nutrition than diets on natural reefs. In addition, members of my laboratory and I [35] recently found that natural reefs offer a wider diversity of prey items, and reef-dependent prey species were found only in the diets at the natural reefs. Red Snapper at the natural reefs were on and above the reef, while feeding at the artificial reefs was predominantly on the surrounding seafloor and provided less caloric intake. Natural reefs found in the northwestern GOM appear to offer better habitat quality with regard to prey resources for red snapper compared to artificial reefs (standing and toppled platforms), a difference that should be taken into account as part of management decisions.

The other lutjanids in this group are much less abundant than red and vermilion snapper. Vermilion snapper, *Rhomboplites aurorubens* was overfished as recently as 2010, but the stock has recovered sufficiently to be considered rebuilt [36]. Of the remaining lutjanids reported in **ATable 1**, the dog snapper *L. jocu* is likely to be the most strongly reef associated, as is the creole fish, *Paranthias furcifer*. We believe the remainder of the species in this group to be reef-associated rather than dependent. This group as a whole is most similar to red snapper among the Level 3 species.

Level 3 Results: Sufficient life history information was available for five species to conduct a Level 3 analysis: red snapper, blue runner, sheepshead, Atlantic spadefish, and bluefish. **Tables 1** and **2** provide data and their sources used in the calculations.

Calculated estimates of biomass production per year per platform using Rickers's method ranged from 306 kg platform^{-1} by sheepshead to 1627 kg platform^{-1} for blue runner (**Table 3**). Estimates using an empirical approach [3] were consistent in pattern, but averaged less than half of the values derived from Ricker's [4] method (**Table 3**). This difference was largely because we estimated specific growth rates (G) for each species over a period that was shorter than their reported life span. For red snapper, blue runner, and sheepshead, the age classes we used were those in which high growth occurred during that period of their life cycle. Biomass production in the Ricker's method is sensitive to the ratio of G/Z i.e., specific growth rate and natural mortality rate, and the ratio is close to, or less than, one for all, but red snapper (**Table 3**). When the ratio is less than one, there is a net loss in population biomass. It is also important to note that the often highly productive pre-recruit period was not included in our calculations, which could have a large effect on the overall production estimates.

The results from the Powers [2] model showed that annual production for each species was dependent upon the index of reef exclusivity (**Table 3**). Species for which platforms provide only a small fraction of prey resources (e.g., red snapper, blue fish, and blue runner) are less dependent upon reefs compared to species such as Atlantic spadefish and sheepshead that depend heavily upon the fouling community on platform legs for food. Low annual production values for red snapper, bluefish, and blue runner also imply that platforms are more likely attracting individuals from surrounding natural habitats rather than producing new population biomass. These finding are consistent with recent diet studies of red snapper, and point out the sensitivity of production estimates to subtle changes in the G/Z ratio that are not considered in the less complex methods [2, 3].

4. Final Thoughts and Red Snapper

The most controversial fishery in U.S. waters of the GOM is for northern red snapper *Lutjanus campechanus*, which collapsed in the late 1980s when stock biomass became too low to be fished commercially in almost half of the stock's former range (east of the Mississippi River). Red snapper management began in earnest in 1989, and the stock now is showing strong signs of recovery. More information about the history of red snapper management is available elsewhere [37–39] but the conflict among competing stakeholders has made stock recovery and sustainable fishing especially difficult to achieve.

Like the examples described by Hilborn [40], a 'faith-based fisheries' argument has been used to defer effective management of red snapper, and consequently has greatly strained the relationships among science, management, and stakeholders in the GOM. It has been argued that mass deployment of artificial reefs has substantially increased productivity of the red snapper stock. The premise is that artificial reefs have transformed less desirable fish biomass into red snapper biomass at locations on the shelf where the latter was not previously abundant [41]. The specifics of this argument were elucidated in a management perspective [42] which postulated that oil and gas platforms that began appearing in the western GOM in the late 1940s function secondarily as large artificial reefs, as well as a myriad of other artificial reef structures in the northcentral and eastern GOM since the 1970s, has enhanced biomass production of red snapper. True, results of the last benchmark stock assessment for red snapper [7] indicate that recruitment and stock productivity may have increased since the late 1980s. However, several other possible causes for this putative increase have been identified beyond artificial reef deployment [39]. The perspective [42] speaks to none of the other possible (more likely?) causes for change and further claims that red snapper were not present in the northwestern GOM until oil and gas platforms began being deployed offshore in the early 1940s. They disregard considerable information showing that a well-established red snapper fishery in the northwestern GOM began as early as 1892 [43].

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The arrows in **Figure 3** indicate when artificial reefs began to be deployed in large numbers relative to the estimated spawning stock biomass of red snapper. These deployments took the form of oil and gas platforms in the western GOM and all manner of materials in the east. In both cases, there is no obvious indication that artificial habitats have increased spawning stock biomass because overfishing was occurring until only recently, and changed in response to strong year classes. The artificial reef argument put forth in the perspective is simply not supported by the available information.

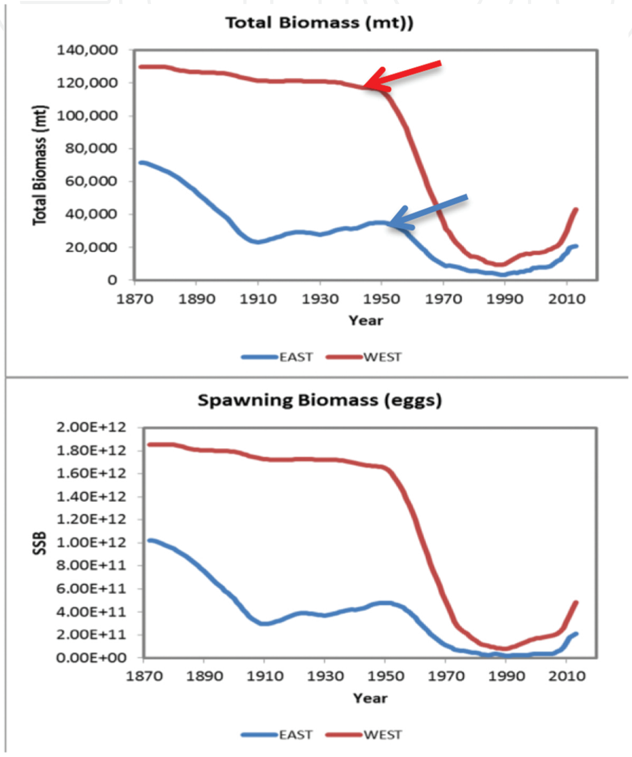

Figure 3. Model estimated spawning stock biomass in the eastern (blue line) and western (red line) US GOM of Mexico. Spawning stock biomass is the estimated weight of all mature females in each region of the GOM. The arrows indicate the year when oil and platforms (red arrow, 1942) and artificial reefs (blue arrow, 1950) began to be deployed in each area (The estimate is taken from the 2015 update of and is the most recent benchmark assessment for red snapper). The recent upturn in biomass is attributable to two relatively strong years classes produced in 2004 and 2006; this is the first time this has occurred over the ~30 year history of red snapper management.

We recognize that the stock assessment process for red snapper and other reef-associated species is controversial and sometimes difficult to understand, so in this chapter we have used simple models using a few parameters, to make our case. In **Table 3** our results indicate that oil and gas platforms produce new red snapper biomass. However, even if only small increase in Z in the Ricker based method of estimation [4] is added (i.e., as fishing mortality (Z=F + M)), the production outcome for red snapper turns negative. We provided tables that include procedural details for readers that wish to see how we estimated production of red snapper on oil and gas platforms. It is entirely plausible that oil and gas platforms make some reef-associated species, including red snapper, more vulnerable to fishing. Our analysis does not address spatial variation in demographic rates due to the intrinsic habitat quality of essential fish habitat or artificial reefs at scales smaller than regional e.g., between Alabama, Louisiana, and Texas.

This is not a blanket recrimination of artificial reefs and artificial reef programs. There are clear examples in the literature where artificial reefs benefit fishes and ecosystems in which they have been employed. Good examples are where artificial reefs are used to mitigate for loss or injury to natural reefs, or used to reduce destructive diving and fishing pressure on natural reefs [44–47], to name a few.

Still, the debate about whether artificial habitats attract red snapper from nearby natural habitats or actually enhance production of new biomass (i.e., the attraction vs. production debate) has been called meaningless and unresolvable [40]. This subject often is debated in broad form for all reef-associated species and, as such, may be un-resolvable in the broader context—this issue has mostly been tried in the court of public opinion. However, a more quantitative approach is tractable for a well studies species like red snapper, although difficult due to the scale and complexity of needed studies [48].

Besides red snapper, many reef-associated species that are found on oil and gas platforms and highlighted in red in **ATable 1** are overfished. The role that these structures play in the population dynamics of these species is unknown. Careful consideration and enumeration of potential positive and negative impacts of man-made habitats on dynamic coastal geographies on continental shelves should be made before such habitats are constructed.

Appendices

Taxa	SF	DF	Diet	PC	Behavior	Dep.
Abudefduf saxatilis	H	N	R	R?	R, D	Y
Abudefduf taurus	H	N	R	R?	R, D	Y
Acanthocybium solandri	L	Y	P	R	P, HM	N
Acanthurus chirurgus	H	N	R	R	R, D	Y
Acanthurus coeruleus	H	N	R	R?	R, D	Y
Achirus lineatus	L	N	B	R	D	N
Albula vulpes	L	Y	B	R	D	N
Aluterus schoepfii	H	N	R, B	R?	R, D	Y
Aluterus scriptus	H	N	R, B	R?	R, D	Y
Amblycirrhitus pinos	H	N	R, B	R?	R, D	Y
Anchoa cubana	L	N	P	R	P	N
Anchoa hepsetus	L	N	P	R	P	N
Anchoa mitchilli	L	N	P	R	P	N

Taxa	SF	DF	Diet	PC	Behavior	Dep.
Anchoa nasuta	L	N	P	R	P	N
Anchoviella perfasciata	L	N	P	R	P	N
Ancylopsetta dilecta	L	N	B	R	D	N
Ancylopsetta ommata	L	Y	B	R	D	N
Antennarius ocellatus	H	N	R, B	H	R, D	Y
Apogon maculatus	H	N	R, B	R?	R, D	Y
Apogon pseudomaculatus	H	N	R, B	R?	R,	Y
Archosargus probatocephalus	M	Y	R, B	R	R, D	RA
Ariomma regulus	L	N	B	R	P	S
Arius felis	L	N	B	R	D	N
Bagre marinus	L	Y	B, P	R	D	N
Bairdiella chrysoura	L	N	B, P	R	D	N
Balistes capriscus	H	Y	R, B	H	R, D	Y
Bodianus rufus	H	Y	R, P	R?	R, P	Y
Bollmannia communis	L	N	B	R	D	N
Bregmaceros cantori	L	N	B	R	D	N
Brevoortia patronus	L	Y	P	R	P	N
Brotula barbata	L	N	B	R	D	RA (juv)
Callionymus bairdi	M?	N	B?	R?	D	RA, SG
Cantherhines pullus	H	N	B	H?	R, D (adults, juv=P)	Y (adults)
Canthidermis sufflamen	L	N	P	R	D, P	N, SG, RA
Canthigaster rostrata	H?	N	B	H?	R, D	Y?, RA & SG
Caranx bartholomaei	L	N	P	R	HM	RA
Caranx crysos	L	N	P	R	P	RA
Caranx hippos	L	N	P	R	P	RA
Caranx latus	L	N	P	R	P	RA
Caranx lugubris	L	N	P	R	P	RA
Caranx ruber	L	N	P	R	P	RA
Carcharhinus plumbeus	L	Y	P	R	P, HM	N
Caulolatilus intermedius	L	Y	P, B	R	D	N
Centropristis melana	M?	Y	P, B	R	D	RA
Centropristis ocyurus	M?	N	B	R	R, D	HB

Taxa	SF	DF	Diet	PC	Behavior	Dep.
Centropristis philadelphica	M?	N	B	R	P, D	HB
Cephalopholis cruentatus	H	N	P	H?	R, D	Y
Chaetodipterus faber	H	N	B, P	R	P, P	Y?
Chaetodon ocellatus	H	N	R	H?	R, D	Y
Chaetodon sedentarius	H	N	R	H?	R, D	Y
Cheilopogon cyanopterus	L	N	P	R	P	N
Cheilopogon furcatus	L	N	P	R	P	N
Chilomycterus schoepfii	M	N	B	R	D	RA, SG
Chlorophthalmus agassizi	L	N	B	R	D	N
Chloroscombrus chrysurus	L	N	P	R	P	N
Chromis enchrysura	H	N	P	H	D	Y
Chromis mutilineata	H	N	R	H	D	Y
Chromis scotti	H	N	R	H	D	Y
Citharichthys spilopterus	L	Y	B	R	D	N
Clepticus parrae	H	N	P	H	D, P	Y
Coryphaena equiselis	L	Y	P	R	P, HM	N
Coryphaena hippurus	L	Y	P	R	P, HM	N
Coryphopterus punctipectophorus	M	N	?	R	D	RA
Cubiceps pauciradiatus	L	N	P	R	P	N
Cyclopsetta chittendeni	L	Y	B	R	D	N
Cyclopsetta fimbriata	L	Y	?	R	D	N
Cyclothone braueri	L	N	P	R	P	N
Cynoscion arenarius	L	Y	P	R	P	N
Cynoscion nebulosus	L	Y	P	R	P	N, RA
Cynoscion nothus	L	Y	P	R	P	N, RA
Decapterus punctatus	L	Y	P	R	P, D	N
Decodon puellaris	H?	N	R?	H	D	Y, HB
Dermatolepis inermis	H	Y?*	R, P	H?	D	RA, HB
Diplectrum bivittatum	L	N	B	R	D	N
Diplectrum formosum	L	N	P	R	D	SG, HB
Diplogrammus pauciradiatus	H	N	B	R	D	SG
Diplophos taenia	L	N	P	R	P	N
Diplodus holbrooki	L	N	B	R	D	N, SG
Dormitator maculatus	L	N	P	R	D	N

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Taxa	SF	DF	Diet	PC	Behavior	Dep.
			(omnivore)			
Echeneis naucrates	L	N	P	R	P	N, RA
Echeneis neucratoides	L	N	P	R	P	N
Echiophis intertinctus	L	N	B	R	D	N
Elagatis bipinnulata	M	Y	P	R	P, HM	RA
Elops saurus	L	N	P	R	P	N
Engraulis eurystole	L	N	P	R	P	N
Engyophrys senta	L?	N?	?	R	D	N?
Epinephelus adscensionis	H	Y?*	R, P, B	H	D	Y, HB
Epinephelus itajara	M	Y	R, P, B	R	D	RA
Epinephelus morio	M	Y	R, B	R	D	RA, HB
Epinephelus nigritus	M	N (closed)	R, P, B	R	D	RA, HP
Epinephelus niveatus	M	Y*	P, B	R	D	RA, HB
Equetus iwamotoi	M?	N	B	R?	D	RA?
Equetus lanceolatus	M	N	B	R?	D	RA?
Etropus crossotus	L	N	B	R	D	N
Etrumeus teres	L	N	P	R	P	N
Euthynnus alletteratus	L	N	P	R	P, HM	N, RA
Foetorepus agassizi	L	N	B	R	D	N
Ginglymostoma cirratum	M?	N	B	R	D (sometimes found on coral reefs)	N, SG
Gobiesox strumosus	M?	N	B	R	D	N, SG, HB (common on oyster reefs)
Gobionellus oceanicus	L	N	B?	R	D	N
Gymnothorax nigromarginatus	H	N	P, B	R?	D	
Haemulon aurolineatum	H	N	P, B	R	D	Y?, SG, HB
Haemulon plumierii	M	Y	P, B	R	D	
Halichoeres bivittatus	H	N	P, B	H?	D	Y, HB
Halieutichthys aculeatus	L	N	B?	R	D	N
Harengula jaguana	M	N	P, B	R	P	RA
Holacanthus bermudensis	H	N	B	R?	D	Y
Holocanthus ciliaris	H	N	B	R?	D	Y

Taxa	**SF**	**DF**	**Diet**	**PC**	**Behavior**	**Dep.**
Holocanthus tricolor	H	N	B	R?	D	Y, RA
Holocentrus ascensionis	H	N	B	R?	D	Y
Hoplunnis macrura	L?	N	B?	R?	D	N?, RA
Hyperoglyphe perciformis	L	N	P	R	P	N
Hypleurochilus geminatus	H	N	B?	H (nest-builder)	D	RA, HB
Hypleurochilus multifilis	H	N	B?	H (nest-builder)	D	RA, HB
Hypsoblennius hentz	H	N	B?	H (nest-builder)	D	RA, HB (common on oyster reefs)
Hypsoblennius invemar	H	N	B	H (nest-builder)	D	RA, HB
Hypsoblennius ionthas	H	N	B?	H (nest-builder)	D	RA, HB
Ioglossus calliurus	L	N	P	R	D	N
Katsuwonus pelamis	L	Y	P	R	P (associated with objects drifting at surface)	N?
Kyphosus incisor	M?	N	P? (plants, including Sargassum)	R	P	Y?, HB. S
Kyphosus sectatrix	M?	N	P, B	R	P	Y?, HB, S

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Taxa	SF	DF	Diet	PC	Behavior	Dep.
		(plants, including Sargassum, some benthic crustaceans)				
Lachnolaimus maximus	M?	Y	B	R	D	Y?, HB
Lactophrys quadricornis	L	N	B	R	D	SG
Lagodon rhomboides	M	N	B	R	D	RA, SG, HB
Larimus fasciatus	L	N	B	R	D	N
Leiostomus xanthurus	L	Y	B	R	D	N
Lepophidium profundorum	L	N	B	R	D	N
Lepophidium staurophor	L	N	?	R	D	N
					(deep water)	
Lestrolepis intermedia	L	N	?	R	P	N
					(bathypelagic)	
Lobotes surinamensis	M	Y	P, B	R	P	RA
					(often found associated with flotsam)	
Lutjanus apodus	M	Y	P, B	R	D	RA
Lutjanus campechanus	M	Y	P, B	R	D, P	RA, HB
Lutjanus griseus	M	Y	P	R	P	RA
Lutjanus jocu	M	Y	R, P, B	R	P	RA, HB
Lutjanus synagris	M	Y	R, P, B	R	D	RA, HB
Lutjanus vivanus	M	Y	R, P, B	R	D	RA, HB
					(common on shelf-edge banks)	
Magnisudis atlantica	L	N	P	R	P	N
					(bathypelagic)	
Makaira nigricans	L	Y	P	R	P, HM	N
Megalops atlanticus	L	Y	P	R	P	N, RA
Membras martinica	L	N	P	R	P	N
Microdesmus lanceolatus	L	N	B?	R	D	N?
Microdesmus longipinnis	L	N	B?	R	D	N
Micropogonias undulatus	L	Y	B	R	D	N
Monolene sessilicauda	L	N	B	R	D	N
					(bathydemersal)	
Mugil cephalus	L	Y	B	R	P	N
			(plants)			
Mugil curema	L	Y	B	R	P	N

Taxa	SF	DF	Diet	PC	Behavior	Dep.
Mullus auratus	L	N	B	R	D	N
Mycteroperca microlepis	M	Y	P	R	P, D	RA, SG, HB
					adults offshore on rocky bottoms)	
Mycteroperca phenax	M	Y*	R, P	R	D	RA, HB
				(high-relief rocky bottoms, often found on Oculina reefs)		
Mycteroperca rubra	M	Y*	R, P, B	R	D	RA, HB
						(rocky and sandy bottoms)
Mycteroperca venenosa	M	Y*	R, P	R	P, D	RA
					(rocky and coral reefs, shelf-edge banks in GOM)	
Myrophis punctatus	L	N	B?	R	D	RA, SG
Neoconger mucronatus	M	N	B	R	D	RA (offshore banks)
Ocyurus chrysurus	M	Y	R, P, B	R	P	RA (mostly coral reefs)
Ogcocephalus declivirostris	L	N	B?	R	D	N, HB
Ogcocephalus radiatus	L	N	B?	R	D	N, HB
Oligoplites saurus	L	N	P, B	R	P	RA
Ophichthus gomesii	L	N	B	R	D	N
					(common on shrimp grounds)	
Ophidion nocomis	L	N	B?	R	D	N
					(uncommon, shallow sandy bays)	
Ophidion robinsi	L?	N	B?	R?	D	N
(rare)						
Ophidion selenops	M?	N	B?	R?	D	RA
(uncommon)						
Ophioblennius atlanticus	H	N	B	H	D	RA
			(plants)			(rocky reefs and corals)
Opisthognathus aurifrons	H	N	R, P	R?	D	Y?
Opisthognathus lonchurus	H	N	R?	R?	D	Y?
Opsanus beta	M	N	B	H?	D	RA, SG

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Taxa	SF	DF	Diet	PC	Behavior	Dep.
					`	(common on oyster reefs)
Opsanus pardus	M	N	B	H?	D	RA, HB
Orthopristis chrysoptera	L	N	P, B	R	D	N
Parablennius marmoreus	H	N	B (mostly algae)	H	D	Y
Paralichthys albigutta	L	Y	P, B	R	D	N, HB
Paralichthys lethostigma	L	Y	P, B	R	D	N
Paranthias furcifer	H	N	P	R	P	RA, HB (coral reefs, hard bottoms)
Pareques umbrosus	L	N	B	R	D	N
Parexocoetus brachypterus	L	N	P	R	P	N
Peprilus alepidotus	L	N	P?	R	P (bathypelagic)	N
Peprilus burti	L	Y	P	R	P, D (benthopelagic)	N
Pogonias chromis	L	Y	B	R	D	N
Polydactylus octonemus	L	N	B	R	D	N
Pomacanthus paru	H	N	R, B	R?	D	Y
Pomatomus saltatrix	L	Y	P	R	P	N
Pontinus longispinis	L	N	B	R	D	N
Priacanthus arenatus	H	N	R, P, B	R?	D	Y
Prionotus roseus	L	N	B	R	D	N
Pristipomoides aquilonaris	L	N	P (small fishes)	R	D	N
Prognathodes aya	H	N	R?	H	D	HB (offshore banks)
Pseudupeneus maculatus	M?	N	B	R?	D	RA, HB
Rachycentron canadum	M	Y	P, B	R	P (found associated with structure of all types)	RA
Raja eglanteria	L	N	B	R	D	N
Remora remora	H?	N	P	R	P	RA?

Taxa	**SF**	**DF**	**Diet**	**PC**	**Behavior**	**Dep.**
						(usually attached to sharks, turtles)
Rhomboplites aurorubens	M	Y	P, B	R	P	RA, HB (HB on shelf-edge)
Robia legula	L	N	P	R	P (bathypelagic)	N
Ruvettus pretiosus	L	N	P, B	R	P (bathypelagic)	N
Rypticus maculatus	M?	N	B	R	D	RA?
Sardinella aurita	L	Y	P	R	P	RA
Saurida brasiliensis	L	N	P (nekton)	R	D	N
Saurida normani	M	N	P	R	D	RA
Saurida suspicio		L		N	P	R
Scartella cristata	H	N	R, B	H	D	Y
Schedophilus medusophagus (GOM record is doubtful)	L	N	P	R	P	N
Sciaenops ocellatus	L	Y	P, B	R	D, P	N
Scomber japonicus	L	Y	P	R	P, HM	N
Scomberomorus cavalla	L	Y	P	R	P, HM	RA
Scomberomorus maculatusL	Y	P	R	P, HM		RA
Scorpaena brasiliensis	L	N	B	R	D	HB
Selar crumenophthalmus	L	N	P	R	P	RA
Selene setapinnis	L	N	P, B	R	P (benthopelagic)	N
Selene vomer	L	N	P, B	R	P	N
Seriola dumerilii	M	Y	P	R	P, HM	RA
Seriola fasciata	M	Y	P	R	P, HM	RA
Seriola rivoliana	M	Y	P	R	P, HM	RA
Seriola zonata	M	Y	P	R	P, HM	N
Serranus subligarius	L	N	B	R	D	N
Sphoeroides parvus	L	N	B	R	D	N

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Taxa	SF	DF	Diet	PC	Behavior	Dep.
Sphoeroides spengleri	L	N	B	R	D	RA (SG, reef flats)
Sphyraena barracuda	M	Y	P	R	P	RA, SG
Sphyraena borealis	M	N	P	R	P	RA
Sphyraena guachancho	L	N	P	R	P	N
Stegastes partitus	H	N	R, B	R?	D	Y
Stegastes variabilis	H	N	R, B	R?	D	Y
Stellifer lanceolatus	L	N	B	R	D	N
Stenotomus caprinus	L	N	B	R	D	N
Stephanolepis hispidus	H?	N	B	R?	P, D	RA
Syacium gunteri	M	N	B, P	R	D	RA
Syacium papillosum	M	N	B	R	D	RA
Symphurus civitatium	L	N	B?	R	D	N
Syngnathus louisianae	H	N	P	R	D	RA
Synodus foetens	L	N	B	R	D	HB
Synodus poeyi	L	N	B	R	D	RA, HB
Synodus synodus	M	N	P (nekton)	R	D	RA, HB
Tetragonurus atlanticus	L	N	P (jellyfish)	R	P	N
Thalassoma bifasciatum	H	N	R, B	R	D	RA, SG
Thunnus albacares	L	Y	P	R	P, HM	N, RA
Thunnus atlanticus	L	Y	P	R	P, HM	N, RA
Thunnus thynnus	L	Y	P	R	P, HM	N
Trachinocephalus myops	M	N	B, P	R	D	RA, HB
Trachinotus carolinus	L	Y	B, P	R	D (benthopelagic)	N
Trachinotus falcatus	M	Y	B	R	D	RA
Trachinotus goodei	M	Y	B, P	R	P (benthopelagic)	RA
Trachurus lathami	M	Y	P	R	P (minor, bait)	RA
Trichiurus lepturus	L	Y	P, B	R	P, D	N
Trichopsetta ventralis	L	Y	B	R	D	N

Taxa	SF	DF	Diet	PC	Behavior	Dep.
Trinectes maculatus	L	N	B	R	D	N
Upeneus parvus	L	N	P, B	R	D	N
		(zoobenthos, small fishes)				
Urophycis floridana	L	N	B, P	R	D	N
Vinciquerria nimbaria	L	N	P	R	P	N
					(bathypelagic)	
Xyrichtys novacula	H	N	B	H?	D	Y?

Appendix Table 1. Fish taxa reported to occur on Gulf of Mexico oil and gas platforms: SF=Site Fidelity (High, Moderate, Low); DF = Directed Fishery (Yes or No, includes recreational fishing); Diet (Reef, Benthic, Pelagic); PC = Population Control (Habitat limited, Recruitment limited; Behavior (Reef, Demersal, Pelagic, Highly Migratory); Dep = Reef or Habitat Dependent (Yes, No, Reef Associated, Sargassum, Sea Grass, Hard Bottom). Red highlight = overfished; Yellow highlight = Caribbean expatriate.

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