Abstract.–A logbook program was initiated to determine the relative abundance of selected fish species around oil and gas platforms off the Louisiana coast. Logbooks were maintained by 55 anglers and 10 charterboat operators from March 1987 to March 1988. A total of 36,839 fish were caught representing over 46 different species.

Principal component analysis (PCA) grouped the seventeen most abundant species into reef fish, pelagic fish, bluefish–red drum, Atlantic croaker–silver/sand seatrout, and cobia–shark–blue runner associations. Multiple regression analyses were used to compare PCA groupings to physical platform, temporal, geological, and angler characteristic variables and their interactions. Reef fish, Atlantic croaker, and silver/sand seatrout abundances were highest near large, structurally complex platforms in relatively deep water. High spotted seatrout abundances were correlated with small, unmanned oil and gas platforms in shallow water. Pelagic fish, bluefish, red drum, cobia, and shark abundances were not related to the physical parameters of the platforms.

Manuscript accepted 28 September 1990.
Fishery Bulletin, U.S. 89:149–159 (1991).

Factors Affecting the Abundance of Selected Fishes near Oil and Gas Platforms in the Northern Gulf of Mexico*

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Louisiana has long been recognized as having abundant fisheries resources as evidenced by the large number of recreational and commercial fishing opportunities. This is particularly true of its offshore waters which Moore et al. (1970) characterized as having high densities of demersal fishes and Gunter (1963) postulated were the most productive waters on earth based on fishery harvests.

Saltwater sportfishing off Louisiana is concentrated around oil and gas platforms with an estimated 37% of all saltwater angling trips (Witzig 1986) and over 70% of all recreational angling trips in the Exclusive Economic Zone (more than 3 miles from shore) occurring around platforms (Reggio 1987). All of the 3700 oil and gas platforms off the coast of Louisiana are thought to act as artificial reefs and have contributed to Louisiana's designation as a fishing "paradise."

Gallaway (1984) estimated that oil and gas platforms constitute 28% of the known hard substrate off Louisiana and Texas. This is of particular importance off the Louisiana coast since the nearest natural hard bottom habitat is approximately 92 km from shore (Sonnier et al. 1976); therefore, oil and gas platforms provide the only source of hard-bottom habitat close to shore. The continued growth of the offshore oil and gas industry in Louisiana has provided habitat expansion for organisms dependent on hard substrate (Sonnier et al. 1976, Gallaway et al. 1981a, Continental Shelf Associates 1982).

Oil and gas platforms are unique as artificial reefs because they extend throughout the entire water column. Their effects are not confined to benthic and demersal fishes; pelagic fishes also benefit (Gallaway et al. 1981a, Continental Shelf Associates 1982). For example, pelagic baitfish (i.e., round scad *Decaptarus punctatus*, Spanish sardine *Sardinella anchovia*, and scaled sardine *Harengula pensacolae*) often maintain a position from nearsurface to mid-depth within or upcurrent from oil and gas structures feeding on plankton and zooplankton, while large predatory pelagic fishes (i.e., king mackerel and blue runner) are reported to swim from the surface to mid-depth around structures, rarely venturing within the structure (Hastings et al. 1976, Gallaway et al. 1981a).

Although oil and gas structures, like most artificial reefs, are considered to increase production and attract fish, there are few accepted techniques to assess their effectiveness. A method of testing the success or importance of an artificial reef is to track the number of fish caught over time. Due to the complex construction of oil and gas platforms, sampling with traditional fisheries

*Contribution No. LSU-CFI-89-04, Louisiana State University, Coastal Fisheries Institute.

gear (e.g., trawls, gillnets) is difficult at best; therefore, the number of fish caught per angler/hour (CPUE) was used to estimate the relative abundance of fish near oil and gas platforms.

Artificial reefs have been reported to concentrate scattered fishes and/or elevate secondary production by increasing the growth and survival of new individuals. However, few studies have examined the trophodynamics of these systems (Bohnsack and Sutherland 1985). The attraction/production paradigm should not be viewed as a black and white issue, but as a gradient depending upon species, life-history stage, type of artificial reef, etc. (Bohnsack 1989). Many species of fish around oil and gas platforms are trophically independent of the structure (e.g., pelagic fishes), but may use the platform for other purposes (e.g., optical stimulus, shelter, protection from predation, seasonal movements, spawning and orientation) (Gooding and Magnuson 1967, Hunter and Mitchell 1967, Klima and Wickham 1971, Wickham et al. 1973, Gallaway et al. 1981a, Continental Shelf Associates 1982).

Factors that may explain the congregation of fish around artificial reefs are poorly known (Grove and Sonu 1983). Some theories on factors influencing the abundance and attraction of fish to artificial reefs include shape and complexity (Hunter and Mitchell 1968, Luckhurst and Luckhurst 1978, Grove and Sonu 1983, Chandler et al. 1985), size of the artificial reef (Hunter and Mitchell 1968, Huntsman 1981, Grove and Sonu 1983, Turner et al. 1969, Rousenfell 1972, Ogawa 1982, Vik 1982), age of the artificial reef and seasonality (Turner et al. 1969, Molles 1978, Stone et al. 1979, Smith 1979, Lukens 1981, Stephens and Zerba 1981). Colonization of natural and artificial reefs did not follow the MacArthur and Wilson (1967) model of species equilibrium for insular biotas according to Smith (1979) and Lukens (1981). They found the strong seasonal effects in the northern Gulf of Mexico produced seasonally stable communities with regular fluctuations in diversity and abundance.

The objective of this study was to determine if a relationship exists between the relative abundance of selected fish species near oil and gas platforms off the Louisiana coast and (1) physical platform variables (e.g., water depth, submerged surface area, volume of water enclosed by the platform, mode of platform operation, platform age), (2) temporal variables (e.g., linear, quadratic, and cubic functions of date), (3) meteorological and geological variables (e.g., air temperature, wind speed and direction, mean sediment size), and (4) angler characteristic variables (e.g., fishing method, boat length, total engine horsepower, presence of electronic fishing aids).

Materials and methods

Between September 1986 and March 1987 we solicited 120 recreational anglers from fishing clubs across Louisiana to maintain logbooks. In addition, 23 of the charterboat operators listed in National Marine Fisheries Service records and Coleman (1984) volunteered to maintain logbooks. Logbook data were collected from March 1987 to March 1988. The design of the logbook and data collected were based on the Lake Erie Angler Diary Program (Sztramko 1986) and logbook criteria outlined by Demory and Golden (1983). Information obtained from the logbooks included: date of trip, number of anglers, oil and gas platform fished, fishing time (not including travel time), fishing method, bait used, and the species and number of fish caught. Due to the difficulty in identification of some fish species, snapper other than red snapper, groupers, sharks, and silver and sand seatrout were classified as other snapper, groupers, sharks, and silver/sand seatrout respectively. Other data acquired from logbook participants included boat length (m), total engine horsepower, and the presence of electronic fishing aids (e.g., LORAN, graph recorders, and echosounders) which assisted in the capture of fish.

We also measured characteristics of the platform, surrounding sediments, and weather which we considered important. Submerged surface area (m^2), volume of water enclosed by the structure (m^3), and the number of legs, wells, and structural crossmembers for each platform utilized by the logbook participants were calculated from drawings and information provided by offshore oil operators. Water depth (m) and age of the structures were supplied by the Minerals Management Service. Surface sediment sizes (μm) adjacent to oil and gas structures were taken from Coleman et al. (1986). Meteorological data, including average daily wind speed (km/hour), direction, and temperature (°C), for the New Orleans International Airport were obtained from the Louisiana State Climatology Office.

To account for seasonal differences in abundance, linear, quadratic, and cubic orthogonal polynomials of the 12 months of the study were used. Orthogonal polynomial contrasts are by definition uncorrelated, thus enabling the unique contribution of the linear, quadratic, or cubic effects of time to be identified.

CPUE was calculated as the number of fish caught per angler per hour of fishing. Prior to any analysis that assumes data normality, the distribution of CPUE data was tested and found not to be normal. Therefore, in order to approximate the normal distribution, the CPUE data were transformed by $\ln(\text{CPUE}+1)$ due to the large number of zero values in the original data (Pennington 1983, 1985).

Two multivariate analysis techniques were utilized to determine the relationships between species abundance and geological, physical, temporal, and meteorological variables. Principal Component Analysis (PCA) was used on the individual fish species as a data-reduction technique. The PCA transforms the original set of variables into a smaller set of orthogonal linear combinations of species that account for a major portion of the variance in the original set (Chatfield and Collins 1980, Dillon and Goldstein 1984). The CPUE data from 17 species or species groups were reduced to 5 principal components (PC's) using the FACTOR procedure (SAS 1985). Only PC loadings greater than 0.35 were considered; although the value of 0.35 is arbitrary, it implies at least 12% of the variance of the species variable was accounted for by the PC. The component scores of the five PC's were used in subsequent multiple-regression analyses.

Stepwise multiple-regression analyses (MRA) were performed with spotted seatrout ln(CPUE + 1) and the component scores of each PC on the angler characteristics, meteorological, temporal, geological, and physical platform data and their interactions (predictor variables) (Table 1). An MRA of the predictor variables and ln(CPUE + 1) of spotted seatrout was treated as a separate analysis because spotted seatrout represented 24.8% and 28.3% of the total number of fish caught by anglers and charterboat operators, respectively (Table 2), and because they did not load positively with the other species in the PCA. The MRA was executed using the STEPWISE procedure with the MAXR option in SAS (1985). Unless otherwise stated, all differences discussed are significant at the $\alpha = 0.01$ level of significance.

Table 1

Temporal, meteorological, angler characteristic, physical platform, and geological variables and their interactions used in the multiple regression analysis.

Angler	**Physical**
Fishing method	Structure age
Boat length	Number of crossmembers
Engine horsepower	Number of legs
Presence of echosounder	Number of wells
Presence of LORAN	Water depth
Presence of graph recorder	Submerged surface area
	Volume of water enclosed
Geological	Structure manned
Mean sediment size	Structure in production
	Temporal/meteorological
	Linear date
	Quadratic date
	Cubic date
	Wind speed
Interactions	Wind direction
Boat length × Hp	Air temperature
Quadratic structure age	
Structure age × number of legs	
Structure age × number of crossmembers	
Structure age × submerged surface area	
Number of legs × number of cross members	
Number of legs × number of wells	
Number of legs × enclosed volume	
Number of legs × submerged surface area	
Structure manned × structure in production	
Water depth × volume of water enclosed	
Water depth × submerged surface area	
Submerged surface area × volume of water	

Results

A total of 55 anglers and 10 charterboat operators returned logbooks with usable information, a 45.8% and 43.5% return rate, respectively. The participants fished at 467 different oil and gas platforms a total of 1196 separate times. Anglers fished at platforms on 666 occasions and caught a total of 20,559 fish representing over 46 different species (Table 2). Charterboat operators fished at platforms 530 times and caught a total of 16,280 fish representing over 42 different species (Table 2).

A five-factor PCA explained 45.7% of the variance of the original data set and allowed us to reduce the data from the 17 separate species or species groups into a smaller data set of presumably related species (Table 3). The first factor was defined as a reef fish factor which included high positive loadings for greater amberjack, grey triggerfish, grouper, other snapper and red snapper, and a negative loading for spotted seatrout (Table 3). The pelagic fish factor consisted of positive loadings for dolphin, king mackerel, little tunny and Spanish mackerel, and a negative loading for silver/sand seatrout (Table 3). The third factor was composed of high positive loadings of Atlantic croaker and silver/sand seatrout (Table 3). The fourth factor was composed of high positive loadings of bluefish and red drum (Table 3). The fifth consisted of positive loadings for cobia and sharks, and a high negative loading for blue runner (Table 3). The strongest ecological relationships within a PC existed for reef fish and pelagic fish PC's. These groupings included species with similar life histories, habits, and abundances. The biological relationships between the species in the other PC's were more tenuous; however they did provide information on factors relating to the species relative abundance.

Results of the MRA of ln(CPUE + 1) of spotted seatrout with the predictor variables indicated spotted seatrout abundances were highest near small, nonproducing structures in shallow water. Fourteen

Table 2

Composition of catch around oil and gas platforms of angler and charterboat operator logbook participants, March 1987–March 1988.

	Angler		Charterboat operator	
Species/Group	No. caught	Percent	No. caught	Percent
Atlantic croaker (*Micropogonias undulatus*)	385	1.9	327	2.0
Atlantic spadefish (*Chaetodipterus faber*)	16	0.1	3	0.0
Bearded brotula (*Brotula barbata*)	14	0.1	—	—
Black drum (*Pogonias cromis*)	118	0.6	8	0.0
Blackfin tuna (*Thunnus atlanticus*)	20	0.1	5	0.0
Bluefish (*Pomatomus saltatrix*)	699	3.4	460	2.8
Blue marlin (*Makaira nigricans*)	2	0.0	2	0.0
Blue runner (*Caranx fusus*)	209	1.0	70	0.4
Cobia (*Rachycentron canadum*)	216	1.1	203	1.2
Crevalle jack (*Caranx hippos*)	41	0.2	19	0.1
Cubbyu (*Equetus umbrosus*)	5	0.0	—	—
Dolphin (*Coryphaena hippurus*)	209	1.0	172	1.1
Florida pompano (*Trachinotus carolinus*)	5	0.0	324	2.0
Flounder (*Paralichthys* sp.)	1	0.0	7	0.0
Gafftopsail catfish (*Bagre marinus*)	56	0.3	17	0.1
Great barracuda (*Sphyraena barracuda*)	19	0.1	27	0.2
Greater amberjack (*Seriola dumerili*)	625	3.0	1086	6.7
Grey triggerfish (*Balistes capriscus*)	635	3.1	211	1.3
Grouper (Family: Serranidae)	422	2.1	583	3.6
Grunts (*Haemulon* sp.)	44	0.2	5	0.0
Hake (*Urophycis* sp.)	1	0.0	2	0.0
Hardhead catfish (*Arius felis*)	301	1.5	133	0.8
King mackerel (*Scomberomorus cavalla*)	198	1.0	292	1.8
Ladyfish (*Elops saurus*)	20	0.1	3	0.0
Little tunny (*Euthynnus alletteratus*)	183	0.9	147	0.9
Lookdown (*Selene vomer*)	9	0.0	—	—
Other jacks (*Caranx* sp.)	49	0.2	14	0.1
Other snapper (Family: Lutjanidae)	443	2.2	809	5.0
Pinfish (*Lagodon rhomboides*)	66	0.3	70	0.4
Puffer (Family: Tetraodontidae)	1	0.0	—	—
Rainbow runner (*Elagatis bipinnulata*)	1	0.0	—	—
Rays (Family: Dasyatidae)	1	0.0	1	0.0
Red drum (*Sciaenops ocellatus*)	622	3.0	637	3.9
Red snapper (*Lutjanus campechanus*)	7315	35.6	3977	24.4
Sharks (Order: Selachii)	165	0.8	236	1.4
Sheepshead (*Archosargus probatocephalus*)	31	0.2	4	0.0
Shrimp eel (*Ophichthus* sp.)	—	—	10	0.1
Silver/sand seatrout (*Cynoscion* sp.)	1716	8.3	1407	8.6
Skipjack tuna (*Euthynnus pelamis*)	3	0.0	157	1.0
Spanish mackerel (*Scomberomorus maculatus*)	484	2.4	211	1.3
Spotted seatrout (*Cynoscion nebulosus*)	5108	24.8	4605	28.3
Squirrelfish (*Holocentrus* sp.)	—	—	12	0.1
Tarpon (*Megalops atlanticus*)	3	0.0	1	0.0
Tripletail (*Lobotes surinamensis*)	65	0.3	7	0.0
Wahoo (*Acanthocybium solanderi*)	19	0.1	10	0.1
White spotted soapfish (*Rypticus maculatus*)	9	0.0	—	—
Yellowfin tuna (*Thunnus albacares*)	5	0.0	—	—
Total	20,559		16,280	

significant predictor variables explained 42.2% of the variance contained in spotted seatrout ln(CPUE + 1) (Table 4). Water depth had the highest partial correlation coefficient (r^2) and a negative regression coefficient (Table 4), indicating that spotted seatrout were more prevalent in shallow water. Regression coefficients were negative for submerged surface area × volume of water enclosed, submerged surface area,

Table 3

Common factor analysis using principal component analysis for the first five factors of ln(CPUE + 1) for the 17 most frequently caught species by logbook participants, March 1987–March 1988. Loadings below 0.35 are marked with a dash.

	Principal component				
Species/Group	Reef fish	Pelagic fish	Atlantic croaker Silver/sand seatrout	Bluefish Red drum	Cobia Bluerunner Shark
Atlantic croaker	—	—	0.755	—	—
Bluefish	—	—	—	0.766	—
Bluerunner	—	—	—	—	−0.681
Cobia	—	—	—	—	0.379
Dolphin	—	0.406	—	—	—
Greater amberjack	0.664	—	—	—	—
Grey triggerfish	0.515	—	—	—	—
Grouper	0.691	—	—	—	—
King mackerel	—	0.636	—	—	—
Little tunny	—	0.600	—	—	—
Other snapper	0.582	—	—	—	—
Red drum	—	—	—	0.589	—
Red snapper	0.613	—	—	—	—
Sharks	—	—	—	—	0.350
Silver/sand seatrout	—	−0.401	0.671	—	—
Spanish mackerel	—	0.600	—	—	—
Spotted seatrout	−0.474	—	—	—	—
Eigenvalue	2.248	1.691	1.448	1.235	1.141
Proportion of variance explained	0.134	0.103	0.082	0.073	0.065
Cumulative variance explained	0.134	0.236	0.319	0.392	0.457

Table 4

Significant variables of a multiple regression of spotted seatrout ln(CPUE + 1) from logbook participants, March 1987–March 1988, based on physical, temporal, geological, meteorological, and angler characteristic variables and their interactions.

Variable	b value	Partial r^2
Water depth	−0.03	0.230
Surface area × volume	-1.1×10^{-8}	0.168
Water depth × volume	1.6×10^{-7}	0.162
Water depth × surface area	2.2×10^{-6}	0.132
Number of legs	0.01	0.060
Surface area	-5.7×10^{-5}	0.038
Echosounder presence	−0.21	0.037
Fishing method	−0.26	0.033
Quadratic data	−0.01	0.025
Boat length	0.08	0.017
LORAN presence	−0.17	0.012
Engine horsepower	-7.2×10^{-4}	0.008
Structure in production	−0.14	0.006
Number of legs × wells	-2.7×10^{-4}	0.006
Number of wells	—	N.S.
Volume	—	N.S.
Intercept	0.93	
Model r^2	0.42	

N.S. = not significant at the 1% level.

number of legs × number of wells, and whether the structure was in production; and coefficients were positive for the number of legs, water depth × submerged surface area, and water depth × volume of water enclosed. Since the regression coefficients were negative for water depth, fishing method, quadratic date, boat horsepower, and the presence of LORAN and echosounder, catch rates of spotted seatrout were highest while bottom-fishing by relatively small vessels without sophisticated electronics. Based on the plot of the sum of the linear and quadratic components of month, spotted seatrout were most abundant in the late spring and early summer (Fig. 1).

Multiple-regression analysis suggested reef fish were most abundant near large complex structures at intermediate water depths (Fig. 2). Ten significant predictor variables accounted for 35.2% of the variance in the reef fish factor (Table 5). The regression coefficients of water depth, volume of water enclosed, and the interactions of submerged surface area × volume of water enclosed, and the number of legs × number of crossmembers were positive, while negative regression coefficients were observed of the interactions of water depth × volume of water enclosed, and water

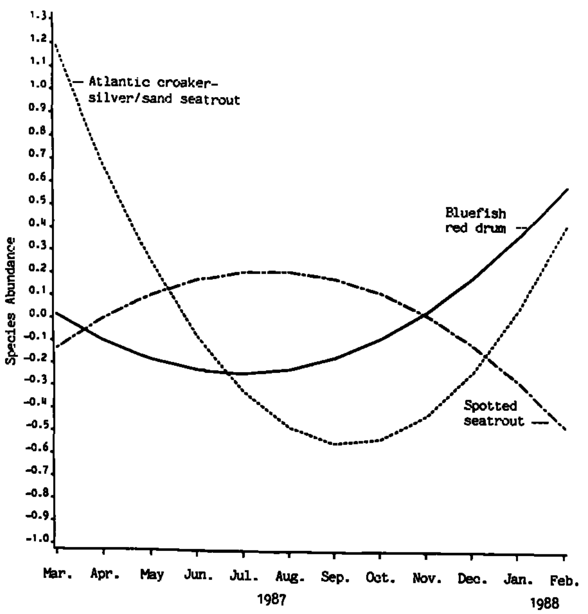

Figure 1
Calculated values of Atlantic croaker–silver/sand seatrout, bluefish–red drum, and spotted seatrout abundance on orthogonal of month from multiple regressions.

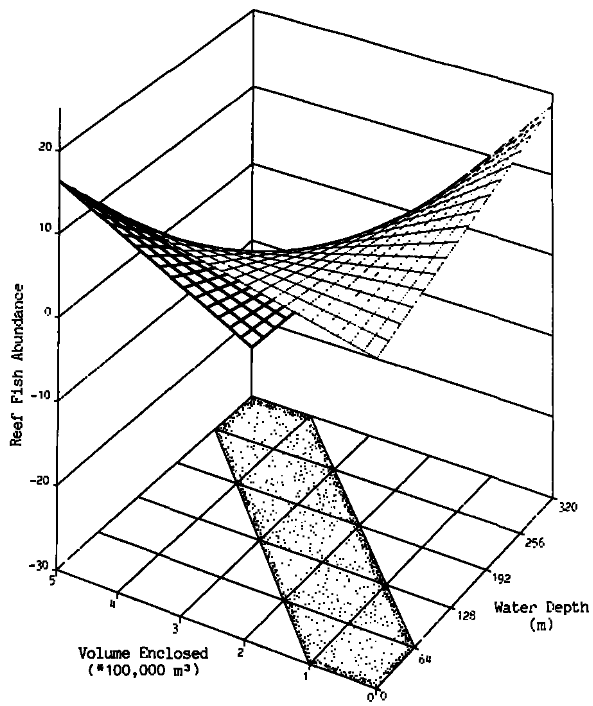

Figure 2
Response surface plot of water depth, volume of water enclosed by oil and gas platforms, and reef fish abundance from the multiple regression of principal component scores for catch data from logbook participants. Note: stippled area represents realistic values of volume of water enclosed at various depths for oil and gas platforms.

depth × submerged surface area (Table 5). Platform age did not affect the abundance of reef fish as evidenced by the negative regression coefficient for quadratic age of the platform (Table 5). Angler characteristics were not good predictors of reef fish catches, with only the presence of graph recorders and fishing method being significant (Table 5). Since the regression coefficient of fishing method was negative, reef fish catches were highest while bottom fishing.

Catches of pelagic fish were higher while trolling in relatively small, well-equipped vessels near large unmanned structures in intermediate water depths (Fig. 3). Retention of 10 significant predictor variables accounted for 31.5% of variance in the pelagic fish factor (Table 5). Regression coefficients for fishing method, LORAN presence, linear date, submerged surface area, water depth, and the interaction of submerged surface area and volume of water enclosed were positive from the MRA, while negative regression coefficients were found for the interactions of structure manned × structure in production, water depth × submerged surface area, and water depth × volume of water enclosed and boat length (Table 5).

Highest abundances of Atlantic croaker and silver/sand seatrout were found near small, manned platforms in deep water. Angler characteristic variables had little influence on their catch rates. Eight significant predictor variables explained 18.4% of the Atlantic croaker–silver/sand seatrout factor (Table 5). Temporal variables (quadratic date and linear date) had the highest partial r^2 values (Table 5) and indicated Atlantic croaker–silver/sand seatrout were most abundant in the early spring (Fig. 1). Positive regression coefficients were found for water depth and the interaction of structure manned × structure in production, and negative regression coefficients were found for volume of water enclosed and structure age × submerged surface area. LORAN presence and fishing method were the only significant angler characteristic variables retained in MRA (Table 5).

Based on MRA results, highest catches of bluefish and red drum occurred while trolling from late winter to early spring near platforms with complex construction. Retention of five significant predictor variables explained 14.5% of the variance in the bluefish–red drum factor (Table 5). The positive regression coefficient and the high partial r^2 (Table 5) for the interac-

Table 5

Significant variables of multiple regressions of reef fish, pelagic fish, Atlantic croaker-silver/sand seatrout, bluefish-red drum, and blue runner-shark-cobia principal-component scores from logbook participants, March 1987–March 1988, based on physical, temporal, geological, meteorological, and angler characteristic variables and their interactions.

	Reef fish		Pelagic fish		Atlantic croaker–silver/sand seatrout		Bluefish–red drum		Blue runner–shark–cobia	
Variables	b value	Partial r^2	b value	Partial r^2	b value	Partial r^2	b value	Partial r^2	b value	Partial r^2
Water depth	0.04	0.17	0.02	0.03	0.01	0.01	—	—	−0.01	0.04
Surface area × volume	1.6×10^{-9}	0.12	1.1×10^{-9}	0.05	—	—	—	—	—	—
Water depth × volume	-3.2×10^{-7}	0.08	-1.1×10^{-7}	0.04	—	—	—	—	—	—
Water depth × surface area	-2.3×10^{-6}	0.06	-1.8×10^{-6}	0.04	—	—	—	—	—	—
Number of legs	−0.01	0.01	−0.01	0.04	—	—	—	—	—	—
Surface area	—	—	5.5×10^{-5}	0.02	—	—	—	—	2.4×10^{-5}	0.02
Echosounder	—	—	—	—	—	—	−0.19	0.01	−0.21	0.01
Fishing method	−0.51	0.06	1.13	0.20	0.35	0.02	0.45	0.04	−0.39	0.03
Quadratic date	—	—	—	—	0.02	0.08	0.01	0.01	—	—
Boat length	—	—	−0.07	0.03	—	—	—	—	—	—
LORAN presence	—	—	0.43	0.04	−0.33	0.02	—	—	—	—
Number of legs × crossmembers	2.5×10^{-5}	0.02	—	—	—	—	1.9×10^{-5}	0.08	—	—
Graph recorder	−0.23	0.02	—	—	—	—	0.23	0.01	0.17	0.01
Quadratic age of platform	-2.8×10^{-6}	0.01	—	—	—	—	—	—	—	—
Volume	1.8×10^{-5}	0.01	—	—	-3.5×10^{-6}	0.01	—	—	—	—
Linear date	—	—	0.04	0.03	0.04	0.03	—	—	−0.02	0.01
Structure manned × production	—	—	−0.14	0.01	0.11	0.01	—	—	—	—
Age × surface area	—	—	—	—	-2.4×10^{-7}	0.01	—	—	—	—
Intercept	−0.51		−0.11		−0.11		0.45		0.31	
Model r^2	0.35		0.32		0.18		0.15		0.12	

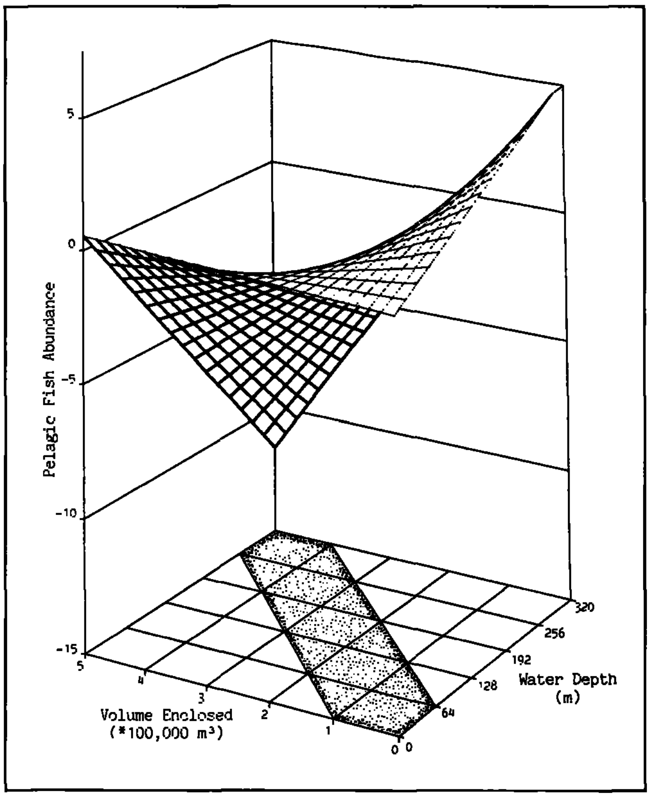

Figure 3

Response surface plot of water depth, volume of water enclosed by oil and gas platforms, and pelagic fish abundance from the multiple regression of principal component scores for catch data from logbook participants. Note: stippled area represents realistic values of volume of water enclosed at various depths for oil and gas platforms.

tion of the number of legs × number of crossmembers indicated that bluefish and red drum were most abundant near platforms with complex construction. Based on the plot of the orthogonal components of month, bluefish and red drum catch rates were highest in the early spring and late winter (Fig. 1). A positive regression coefficient for fishing method and negative regression coefficients for the presence of echosounders and graph recorders (Table 5) indicated that highest catches of bluefish and red drum occurred while trolling and that sophisticated electronic equipment did not increase catch rates.

Shark and cobia catches were highest while bottom fishing in the spring near large platforms in shallow water. The MRA with six significant predictor variables accounted for 11.5% of the variance in the shark–cobia factor (Table 5). The negative regression coefficient for water depth and positive regression coefficient for submerged surface area (Table 5) provide evidence that shark and cobia abundances were highest in shallow waters near large structures. Highest catches of shark and cobia occurred while bottom fishing in the spring, based on the negative regression coefficient for fishing method and linear date (Table 5). Conflicting results on the presence of electronic gear were found with a positive regression coefficient for presence of graph recorders and a negative regression coefficient for the presence of echo sounders (Table 5).

Discussion

Anglers and charterboat operators utilized the entire range of sizes and operational types of platforms available off the coast of Louisiana (single-well caissons, steel template platforms, and mobile semisubmersible drilling platforms), although certain trends in platform size utilization and fishing method were evident. Nearshore fishermen most often fished at the small structures (i.e., caissons) in shallow water (i.e., <10 m), while offshore bottom-fishing and trolling fishermen fished near much larger steel template platforms in deeper water (i.e., >30 m). Charterboat operators had larger vessels and were able to fish in deeper waters and farther offshore than anglers.

Anglers and charterboat operators caught a total of 36,839 fish representing at least 46 different species, providing evidence for the high diversity of fish around the oil and gas platforms. Fishes caught ranged from relatively common and highly desirable species such as spotted seatrout and red snapper to relatively rare fishes such as hake, bearded brotula, and squirrel fish. Highly sought-after gamefish such as tarpon, blue marlin, king mackerel, and yellowfin tuna were also caught. Catches by angling are selective and biased towards larger species because of the hook-and-line gear utilized, and usually only carnivorous species are susceptible to the gear. Consequently species not susceptible to angling were not represented (Grimes et al. 1982).

The associations of fish identified by the reef fish and pelagic fish PC's were in agreement with fish classification systems using direct observation around natural and artificial reefs in the Gulf of Mexico by Starck (1968) and Lukens (1981). This confirms that these groupings have an ecological basis, and were not an artifact of the sampling or analysis techniques.

Factors affecting the abundances of fish

Physical platform variables Generally, the highest abundances of spotted seatrout were found in shallow water (i.e., <10 m) around small, non-producing platforms such as caissons. These results were expected, as this estuarine-dependent species (Johnson and Seaman 1982) would likely have its highest abundances in shallow water near estuaries.

Our results suggest that reef fish, Atlantic croaker, and silver/sand seatrout abundances increased with size and complexity of the artificial reef, agreeing with past studies (Turner et al. 1969, Grove and Sonu 1983). However, an optimal artificial reef size occurred for reef fish based on the response surface plot of water depth, volume enclosed, and fish abundance as highest reef-fish abundances occurred at intermediate depths (i.e., 70–100 m) near relatively large platforms (i.e., mean volume enclosed 150,000–250,000 m^3). The optimal size range of oil and gas platforms acting as artificial reefs was significantly larger than the optimal artificial reef sizes reported in past studies. This difference could be due to the open construction and lack of interstitial spaces on oil and gas platforms which may not be as efficient at attracting or increasing secondary production of fish as the large rubble or prefabricated artificial reef units on which past estimates were calculated. Also, oil and gas platforms extend throughout the entire water column, and because many reef fish are demersal, a large portion of the platform may not be suitable reef-fish habitat. Reef-fish abundances were lowest at the largest platforms in extremely deep water, probably because the water depths exceeded the preferred ranges for these species.

Physical platform variables were not important predictor variables of pelagic fish abundance. Our results are consistent with Wickham et al. (1973) and Grove and Sonu (1983) who concluded that pelagic fishes respond to the visual attraction of artificial reefs and not to the overall size or surface area.

Bluefish, red drum, cobia, and shark abundances were highest around large, structurally complex platforms. These species were probably not trophically dependent on the structures, but were attracted to platforms by an optical stimulus as reported by Wickham et al. (1973) for cobia.

Age of the structure was not a significant factor in explaining fish composition or abundance around oil and gas platforms. Therefore it appears that the species-equilibrium model, which suggests that the number of species present and their abundances increase rapidly over a colonization period eventually stabilizing (MacArthur and Wilson 1967), was not applicable, or that the platforms may have been fully colonized at the start of the study and we were sampling after species stabilization occurred. The latter explanation seems most likely, because the age of platforms in our study ranged from 8 months to 30 years, and full colonization of artificial reefs in the northern Gulf of Mexico can occur in as little as 15 months (Lukens 1981).

Seasonal variation Season was an important factor affecting the abundances of fish around oil and gas platforms. Smith (1979) and Lukens (1981) reported large fluctuations in species composition and abundance around natural and artificial reefs in the northern Gulf of Mexico, and based on our results this would include fish populations around oil and gas platforms off the Louisiana coast.

The apparent higher abundances of spotted seatrout in the spring and summer may be a result of a temperature-induced increase in feeding rate and/or the aggregation of the fish into spawning schools (Johnson and Seaman 1982).

The increase in pelagic fish catches from winter through fall indicated that abundance may have been related to water temperature. This is consistent with the findings by Fable et al. (1981), as they found that the charterboat catches of king mackerel and other pelagic species in the northeast Gulf of Mexico increased with water temperature.

Lassuy (1983) reported that Atlantic croaker abundance was highest in the spring and summer, while Sutter and McIlwain (1982) reported silver/sand seatrout abundance to be highest in the winter and spring. This may explain the apparent conflicts in the results from the MRA with respect to seasonal abundances of these two species. Silver/sand seatrout may have been abundant in the winter and spring, and Atlantic croaker in the spring and summer. However, when these species were grouped the seasonal abundance results explained only silver/sand seatrout and not the entire group.

Our results, along with those of others (Gallaway et al. 1981b, Reagan 1982) provided evidence that bluefish and red drum were seasonal transients with highest abundances from fall through spring. Shark and cobia abundances appeared to be highest in the spring and decreased thereafter.

Angler characteristic variables Overall, fishing power was not equal because fishermen with larger vessels and engines had access to deeper water, and fishermen with sophisticated electronics could more easily locate fish. Because reef fish, Atlantic croaker, and silver/sand seatrout are found in deep water, anglers with large vessels and engines had the highest catches for these species, while cobia, sharks, and pelagic species were more frequently caught by vessels having sophisticated electronics. Since spotted seatrout were found in shallow water, large vessels or sophisticated electronics did not increase spotted seatrout catches.

Geological and meteorological variables Geological and meteorological variables were not significant predictors of fish abundance around oil and gas platforms. Meteorological variables were probably not important because fishermen generally fish only in good weather, consequently catch rates during poor weather conditions were not reported.

Conclusions

The physical construction of oil and gas platforms precludes sampling of the associated sportfish populations using traditional methods (e.g., gillnets, trawls). Based on the results of this logbook program, the collection of CPUE data over long periods of time may be an effective technique of monitoring the fish populations susceptible to angling associated with artificial reefs. Although the data supplied by the logbooks is an index of relative abundance of fish susceptible to angling and is biased towards larger individuals, it provides a valuable source of data which is otherwise difficult to obtain.

With the advent of the "Rigs to Reefs" initiative in Louisiana, biological criteria to determine where to locate retired oil and gas platforms as artificial reefs was needed. Information derived from this study suggests that optimal artificial reef configurations exist, but vary depending on the species. To effectively site artificial reefs for reef fish, Atlantic croaker, and silver/sand seatrout there should be large complex platforms at intermediate depths; for pelagic species artificial reef size is not a factor, although they should again be placed at intermediate depths. Optimal siting of artificial reefs for spotted seatrout should include small structures in shallow water. Gallaway and Lewbel (1982) suggested that abundances of some species were directly proportional to the submerged surface area of oil and gas platforms. We believe that the relationship between fish abundances and artificial reefs is much more complex, with other factors, such as natural and temporal variability of species distribution and abundance interacting with physical platform variables and water depth to determine overall species abundances.

Acknowledgments

The authors thank the 55 anglers and 10 charterboat operators for maintaining logbooks; the oil and gas operators for providing information and drawings on the platforms; Mr. Villere Reggio, Minerals Management Service, for additional platform information; Louisiana State Climatology Office for meteorological data; Drs. James Geaghan and Gary Shaffer for statistical assistance; Dr. Linda Jones and two anonymous reviewers for critical review of the manuscript and improving its contents. This study was part of a Master's thesis by David R. Stanley and was supported by the Department of Marine Sciences, LSU; the Louisiana Artificial Reef Initiative; and Dupont Inc. Educational Aid Program.

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