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Impacts of Red Snapper Mortality Associated with the Explosive Removal of Oil and Gas Structures on Stock Assessments of Red Snapper in the Gulf of Mexico

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Abstract.—An average of 96 oil and gas structures are removed with explosives annually from the U.S. Gulf of Mexico. These offshore structures function as artificial reefs attracting a wide variety of marine life, including the commercially and recreationally important red snapper. A multi-year study estimated the mortality of red snapper resulting from the explosive removal of nine platforms at water depths of 14–36 m. Estimated mortality of red snapper due to underwater explosives averaged 515 per platform. Using this value, we estimated the total annual mortality of red snapper resulting from all explosive structure removals in the U.S. Gulf of Mexico. The recent stock assessment for red snapper (Schirripa and Legault 1999) was subsequently recalculated, including this additional source of mortality. Results showed no discernible difference between the two stock assessments, indicating that direct mortality resulting from explosive structure removals was minor compared with other sources of mortality.

Introduction

The first offshore oil and gas platform in the Gulf of Mexico (GOM) was built in 1942 off the coast of Louisiana (Pulsipher et al. 2001). As of 27 January 2003, there were 4,035 oil and gas structures present in federal waters of the GOM (M. Morin, Minerals Management Service, personal communication). Federal regulations[1] require removal of these structures to a minimum depth of 5 m below the sea floor within 1 year of lease termination. From 1989 to 1998, Minerals Management Service (MMS) data (M. Morin, MMS, personal communication) for federal waters indicated that underwater explosives placed beneath the sea floor were used in 64% of all removals (submerged wells not included). The remainder were removed using various mechanical techniques. During the same period, data from the National Marine Fisheries Service (NMFS) Platform Removal Observer Program (PROP) showed that a total of 958 structures were salvaged using explosives with an annual average of 96 structures (G. Gitschlag, NMFS, unpublished data). This includes removals in both federal and state waters. In the most common explosive removal method, charges weighing 18–23 kg are detonated inside the

[1] Oil, Gas, and Sulphur Operations in the Outer Continental Shelf, 30 CFR (250 series).

pilings and well conductors at depths greater than 5 m below the sea floor. After pilings and conductors are severed, the platforms are lifted from the water. Since many structures have numerous pilings and conductors, more than 100 kg of explosives, primarily Composition-B and Composition-4, are often used at each offshore platform removal.

Offshore platforms function as artificial reefs attracting a wide variety of marine life as well as an abundance of anglers (Hastings et al. 1976; Sonnier et al. 1976; Dugas et al. 1979; Gallaway 1980; Gallaway and Martin 1980; Continental Shelf Associates, Inc. 1982; Gallaway and Lewbel 1982; Ditton and Auyong 1984; Witzig 1986; Reggio 1987; Stanley and Wilson 1989; Scarborough-Bull and Kendall 1990; Stanley and Wilson 1990; Rooker et al. 1997). One obvious consequence of using explosives to remove offshore structures is a negative impact on fish. Although offshore platforms have been the subject of scientific study in areas such as fisheries (Stanley and Wilson 1997), biofouling communities (George and Thomas 1979), bird migrations (Russell 1998), mariculture (Clifford 1994), and air quality (Haney and Douglas 1995), there has been no previous attempt to quantify the impacts of explosive platform removal on fish populations.

Of special concern is the red snapper *Lutjanus campechanus*, which occurs at many of these structures. The red snapper stock in the GOM is extremely valuable both commercially and recreationally. Commercial landings data from 1950 to 1999 (NMFS, Fisheries Statistics and Economics Division) show a peak in the 1960s. Approximately 5 million kg of red snapper were commercially harvested at the beginning and end of the decade with an all time high of about 6 million kg reached in 1965. Since that time, stocks declined, and both state and federal management agencies instituted catch limits. Landings reached an all time low in 1991 at 1 million kg. During the remainder of that decade, commercial landings increased to 2.4 million kg in 1997 with a value of approximately US$11 million. The red snapper continues to be the subject of intense government regulation as this species is severely overfished and there are significant problems with the long-term viability of the stock (Goodyear and Phares 1990; Goodyear 1996; Schirripa 1998).

This manuscript describes the first comprehensive study to quantitatively assess impacts of the explosive removal of offshore oil and gas structures on red snapper. Results provide administrators with essential information needed to manage this important natural resource.

Methods

Sampling

Between August 1993 and May 1999, surface and underwater sampling were conducted at nine explosive platform removals to estimate red snapper mortality (Figure 1). Surface sampling alone was performed at one additional platform removal. To accommodate diving operations and reduce costs, explosive removals deeper than 36 m and removals scheduled during the winter weather season from December through April were not included in the study. Platforms shallower than 14 m were excluded because few red snapper were thought to inhabit these areas. Study site selection was also dependent on cooperation from platform owners. Selection of study sites was opportunistic rather than random.

Although sampling techniques were refined during the study, the final sampling design is summarized in Figure 2. Fish killed by explosives used during platform removal either floated to the surface or sank to the sea floor. Personnel operating from inflatable boats used dip nets to collect all dead fish that floated to the surface, while divers sampled dead fish that sank to the sea floor. Dives were delayed a minimum of 30 min after detonation to allow time for impacted fish to sink to the bottom.

Two techniques were employed to sample dead fish from the sea floor around the platform: transect lines and circular surveys. Transect lines radiating out from the base of each side of the platform were sampled by divers. Fish were sampled discretely in 25-m increments along the transect line to facilitate calculation of fish density at different distances from the platform (0–25 m, 25–50 m, etc.). One diver was positioned on each side of a transect line. Divers used their outstretched arms to estimate transect width of either 1 or 2 m on each side of the line (2-m or 4-m total width) depending on underwater visibility. Divers collected all fish regardless of species within the prescribed transect width along the entire 100-m line unless otherwise noted (Table 1). The number and length of transect lines sampled varied among platforms due to logistical and safety concerns.

A second technique was also used to assess fish mortality on the sea floor around the platform. At the first study site, Ship Shoal Area, Block 158, Platform C, 44 square frame nets measuring 13.4 m^2 each were deployed on the sea floor within a radius of 100 m around the platform. A buoyed line attached to the frames allowed easy retrieval from a vessel after explo-

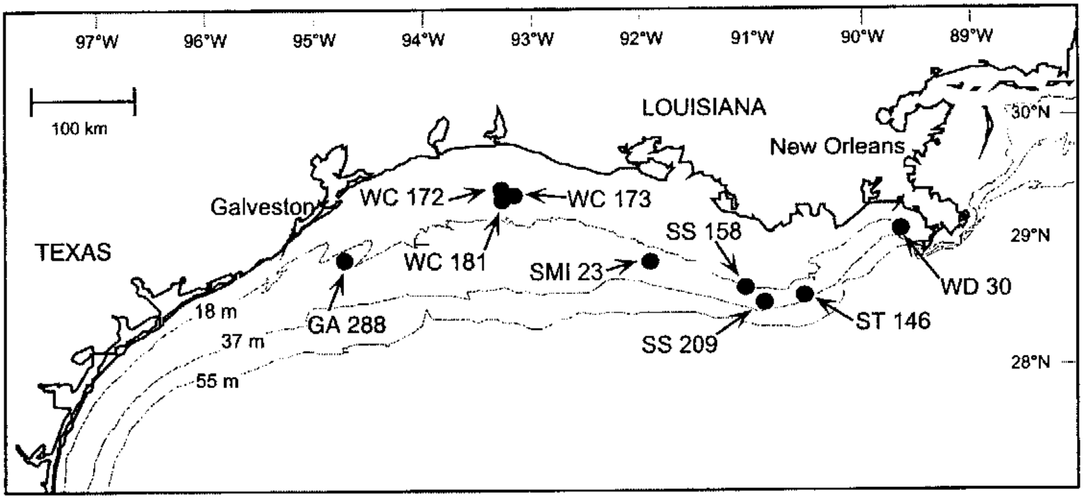

FIGURE 1. Map of study site. Dark circles represent platforms where red snapper mortality was estimated from samples collected at the sea surface and bottom. Abbreviations for platforms follow that used by Minerals Management Service (MMS). The first alphabetic abbreviation indicates the area shown on MMS charts. The following number represents the block within the area, and the last component identifies the particular platform. For example, SMI 23 A-AUX indicates Platform A-Auxiliary in South Marsh Island Area, Block 23. Other area abbreviations are WD for West Delta, ST for South Timbalier, SS for Ship Shoal, WC for West Cameron, and GA for Galveston.

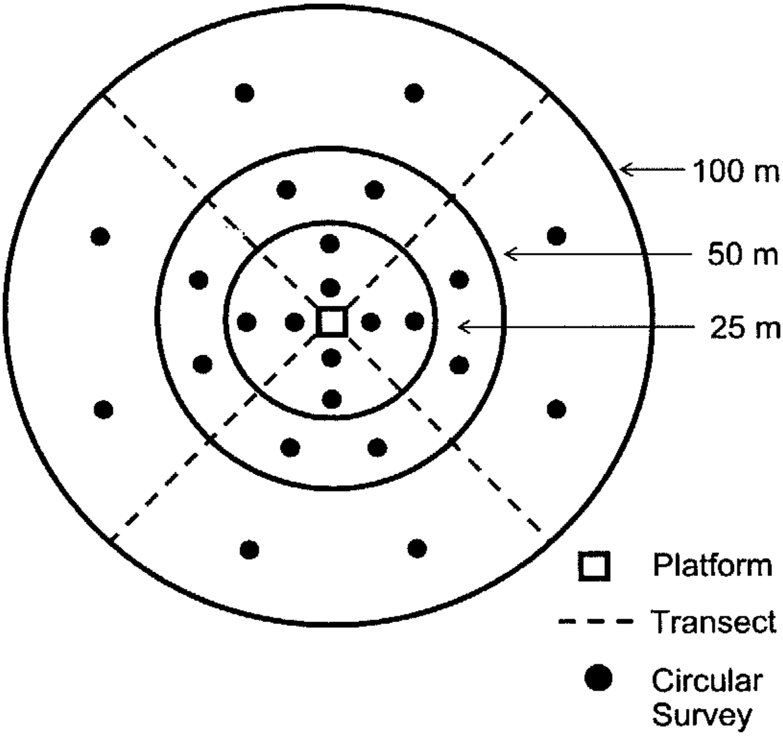

FIGURE 2. Schematic of sampling design showing transect lines and circular surveys. The platform being removed appears as a square in the center of the concentric rings marking distance from the structure.

TABLE 1. Summary of samples collected at each platform including collections at the surface using dip nets and collections from the sea floor beneath and around the platform by divers. Abbreviations for platforms follow those used by Minerals Management Service (MMS). The first alphabetic abbreviation indicates the area shown on MMS charts. The following number represents the block within the area, and the last component identifies the specific platform. For example, SMI 23 A-AUX indicates Platform A-Auxiliary in South Marsh Island Area, Block 23. Other area abbreviations are WD for West Delta, ST for South Timbalier, SS for Ship Shoal, WC for West Cameron, and GA for Galveston. Platforms are listed by water depth from shallowest to deepest.

Platform	Surface collection	Percent of area sampled under platform	Number of circular surveys	Number of transect lines	Length (m) of transect line
WD 30 G	Yes	83	20	4	100
WC 172 CB	Yes	16	23	4	100
WC 173 #5	Yes	14	2	2	100
SS 158 C	Yes	38	N/A[a]	5	60–100
WC 181 CE	Yes	27	24	4	100
GA 288 #18	Yes	14	18	3	100
SMI 23 A-AUX	Yes	22	24	4	100
ST 146 A	Yes	12	13	3	100
SS 209 #3	Yes	22	14	3	50

[a] Forty-four frame nets with a sampling area of 13.4 m^2 each were used at the first study site. At all other sites, circular surveys with a sampling area of 35.3 m^2 each replaced the frame nets.

sives were detonated. At subsequent platform removals, these nets were replaced with circular surveys performed by divers. A 3.35-m-long PVC pipe was laid on the sea floor, and one end was secured to the bottom with a stake. Using the pipe as a distance gauge, divers collected dead fish as they swam the pipe in a circle using the staked end of the pipe as a pivot point. Up to 24 circular surveys encompassing an area of 35.3 m^2 each were sampled within 100 m of each platform. Samples within 25 m of the structure were collected along measured guidelines secured to the base of the platform to guarantee accuracy of sampling distance from the structure and to ensure no overlap between circular and transect surveys. Beyond 25 m, there was little chance of overlap, and a compass and range finder were used to locate sampling sites within selected quadrants around the platform.

A third technique was used to sample dead fish that fell to the sea floor in the footprint area under the platform. Rectangular sampling frames of various designs and dimensions were used. One-inch galvanized pipe frames measuring 3 × 3 m were initially placed beneath the platform prior to detonation of explosives to accommodate potentially large numbers of dead fish sinking from above. These frames featured mesh that could be pursed with a drawstring to prevent fish loss during retrieval to the surface with lift bags. These heavy, cumbersome frames were later replaced with lightweight PVC frames without mesh. Divers manually retrieved fish that fell inside the PVC frames and placed them into mesh bags. When underwater visibility was exceptionally good at West Delta Area, Block 30, Platform G, platform legs themselves were also used to delineate sampling areas on the sea floor.

Mortality Estimates

Data recorded for dead fish collected after the explosion included species identification, total length, and weight. Results refer to fish greater than or equal to 8-cm total length, since this was the minimum size consistently collected by divers. Samples from transect lines and circular surveys were pooled. By dividing the number of red snapper collected in samples by the sample area, density of dead red snapper was calculated for sequential 25-m intervals around the platform out to 100 m (0–25, 25–50, 50–75, and 75–100 m). For each 25-m interval, the ratio of total area of sea floor to sample area was calculated and multiplied by red snapper density to determine estimated fish mortality. Mortality estimates for each 25-m interval were summed to provide a total estimate of red snapper mortality from the sea floor surrounding the platform. The footprint area immediately under the platform was determined mathematically from measurements on platform schematics and measurements made in the field. Areas where well conductors penetrated the sea floor were subtracted from the calculated footprint area to yield the total area under the platform into which dead fish could fall. Samples from the footprint area were pooled, and fish mortality was estimated as described above. Finally, estimated red snapper mortality from the 100-m area surrounding the platform was combined with that from the footprint area and added to the number of mortalities collected at the surface to provide an estimate of total red snapper mortality for each platform.

Statistical Analysis

Total lengths of red snapper collected in our study were pooled with those from the NMFS PROP and partitioned by depth. Since sample size was very large, length data were not subjected to rigorous testing for normality and homogeneity of variance prior to testing with analysis of variance (ANOVA) in keeping with the Central Limit Theorem. Two sample *t*-tests were then used to determine differences between depth zones.

Development of Data Set for Stock Assessment

Mortality of red snapper resulting from the explosive removal of nine platforms was estimated based on sample collections. Mean mortality of red snapper per platform was then calculated and multiplied by the mean annual number of explosive structure removals for 1989–1998. This included all types of permanent, offshore oil and gas structures: caisson, submerged well, flare pile, and platform. This yielded an estimate of the number of red snapper killed during explosive removals annually. However, estimates of both number and size of red snapper were needed to perform a new stock assessment. Although mortality estimates were available from only nine explosive platform removals in the current study, information on size of dead, floating red snapper collected at explosive structure removals was available from the NMFS PROP. Red snapper lengths from the NMFS PROP were combined with those from the current study. This strengthened the study by contributing an additional 13,522 red snapper lengths for a total of 16,505 collected at 116 explosive structure removals. PROP data includes only surface collections of dead fish. Any potential bias resulting from the use of PROP data are believed to be small because of the small difference in mean total length of only 2.6 cm for red snapper collected at the surface versus sea floor in our study.

Red snapper lengths to be used in a new stock assessment analysis (after Schirripa and Legault 1999) were compiled as follows. Since no red snapper in the PROP data were collected at depths less than 7 m, structures shallower than this were assumed to have no red snapper mortality. Due to a significant difference ($P < 0.00$) in red snapper size by depth (Table 2), length records were sorted into two groups by water depth (7–20 m and >30 m versus 20–30 m) as were counts of explosive structure removals. Estimated annual red snapper mortality per structure, as determined in our study, was multiplied by the 10-year (1989–1998) average annual number of explosive structure removals (from NMFS PROP) in each of these two depth zones to yield an estimate of red snapper mortality for each zone. The records of red snapper lengths in each depth zone were then expanded by replication to equal the number of estimated mortalities for each zone. Data from the two depth zones were then pooled and used in the new stock assessment.

Red Snapper Stock Assessment Methodology

There is inherent uncertainty in estimating red snapper mortality for an annual average of 96 explosive structure removals based on a sample size of nine platforms that were nonrandomly selected and sampled

TABLE 2. Summary of statistical analysis of red snapper total length (TL) by platform depth for combined data from the NMFS Platform Removal Observer Program (1989–1998) and our study. An asterisk denotes significant difference.

Statistical procedure	Depth (m) groupings	N	Test statistic	P
ANOVA	<20, 20–30, >30	16,505	$F = 120.8$	0.000*
t-test	<20, 20–30	7,976	$t = 11.5$	0.000*
	<20, >30	10,898	$t = 1.0$	0.295
	20–30, >30	14,136	$t = 14.8$	0.000*

over 6 years. The authors felt that doubling the mortality estimate of red snapper should encompass these uncertainties and simulate an upper limit of potential impacts. Consequently, the stock assessment analysis was performed with the doubled mortality estimate. Length frequencies of red snapper were converted to age frequencies using Table 1 of Schirripa and Legault (1999), a recent red snapper stock assessment analysis. The additional mortality at age implied by the doubled estimate was added to each year of the annual fishing induced mortality at age estimated from other sources: commercial, recreational, discard mortality, and bycatch. The stock assessment analysis in Schirripa and Legault (1999) was then repeated using this new mortality at age for each year.

In conjunction with the red snapper stock assessment analysis, management benchmarks and population characteristics were recalculated. These included fishing mortality rate at which the slope of the yield-per-recruit curve is one-tenth of what it is at the origin ($F_{0.1}$); fishing mortality rate that maximizes yield-per-recruit (F_{MAX}); fishing mortality rate which reduces spawning potential ratio to 20%, 30%, and 40% of what it would be with no fishing ($F_{20\%SPR}$, $F_{30\%SPR}$, $F_{40\%SPR}$); fishing mortality rate that would eventually produce maximum sustainable yield (F_{MSY}); and the most recent estimate of fishing mortality rate (for 1998, F1998). Additionally, Maximum Sustainable Yield (MSY), the biomass that would support the taking of MSY (B_{MSY}), and the spawning stock in number of eggs that would support MSY (SS_{MSY}) were also recalculated. Results were compared to the recent red snapper stock assessment (Schirripa and Legault 1999).

Results and Discussion

No red snapper were collected in samples beyond 50 m from any platform. Per platform mortality estimates for red snapper ranged from 24 to 1,193 (Table 3) with a mean of 515, standard error of 111, and 95% confidence level of 255. The annual estimated mortality of red snapper resulting from explosive structure removals was 41,200. Double this value or 82,400 was used in the stock assessment to provide a simulated upper limit of mortality. The resulting age-frequency graph (Figure 3) indicated a modal age of 2.

Results designed to evaluate an upper limit of purported impacts (doubling of mortality estimate) were compared to a recent red snapper stock assessment by Schirripa and Legault (1999). Graphics comparing red snapper stock assessments with and without mortality from explosive structure removals are shown in Figure 4. Plots show red snapper abundance by fish age for three representative years. The two plotted lines in each graph are virtually indistinguishable indicating little discernible difference between assessments with and without impacts from explosive platform removals. Differences were well within the statistical estimation variances for the original assessment (see Schirripa and Legault 1999). The additional mortality from explosive removals altered management benchmarks slightly (Table 4) with fishing mortality and MSY benchmarks decreasing 3% or less and stock size benchmarks increasing less than 1%. Present management strategy of the Gulf of Mexico Fishery Management Council is robust to

TABLE 3. Estimated total mortality of red snapper *Lutjanus campechanus* by platform, depth, structure age, weight of explosives used, month and year of removal. Abbreviations for platforms follow those used by Minerals Management Service (MMS). The first alphabetic abbreviation indicates the area shown on MMS charts and the following number represents the block within the area where the platform is located.

Platform	WD30	WC172	WC173	SS158	WC181	GA288	SMI23	ST146	SS209
Mortality	24	498	709	296	709	487	1,193	298	418
Depth (m)	14	15	15	17	18	23	25	28	32
Platform age (year)	39	23	19	12	17	31	33	16	37
Explosives (kg)	290[a]	136	95	136	172	95	73	113	113
Month removed	Jul	Aug	Sept	Jul	Jul	May	Aug	May	Jul
Year removed	1994	1994	1995	1993	1995	1995	1995	1998	1999

[a] Values represent total weight of explosives used on first day detonations occurred. On subsequent days, additional explosives were used at four locations: WD30 - 472 kg, SS158 - 23 kg, GA288 - 18 kg, and ST146 - 45 kg. Only surface collection of fish occurred on subsequent days when explosives were used.

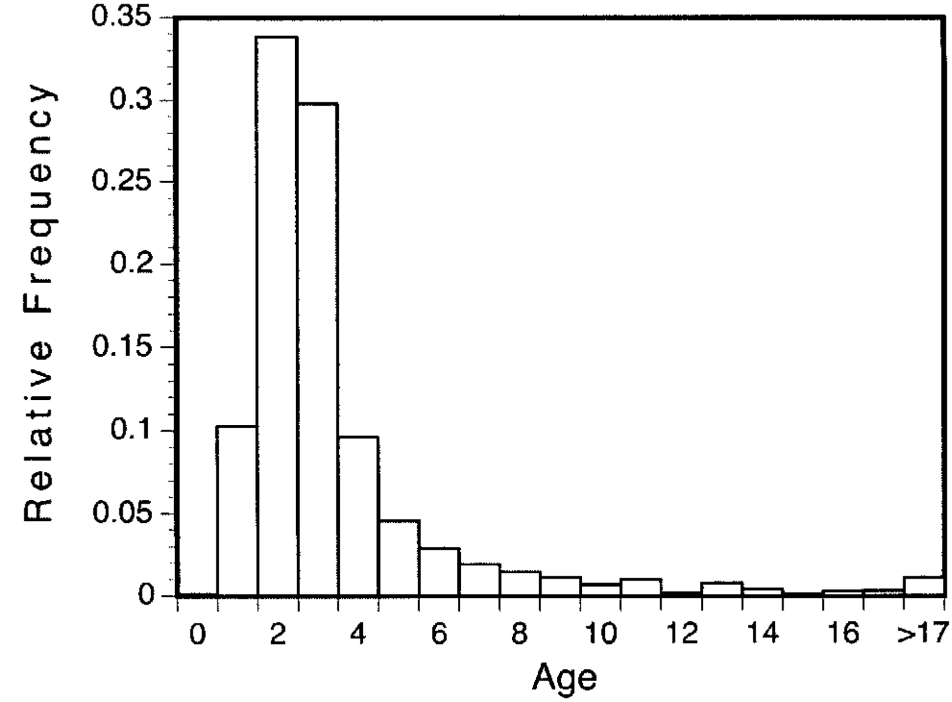

FIGURE 3. Estimated age frequency (years) of annual red snapper mortality resulting from explosive structure removals. Length-frequencies from the current study combined with those from surface fish collections from the NMFS Platform Removal Observer Program (1989–1998) were converted to age frequencies using Table 1 of Schirripa and Legault (1999).

these changes in benchmarks (i.e. the recovery strategy would function approximately the same with or without inclusion of mortality from platform removals). Recall that these results reference the doubled estimate of red snapper mortality, and actual impacts are likely to be less.

Red snapper mortality from explosive structure removals was compared to other sources of mortality. The doubled red snapper mortality estimate resulting from explosive structure removals was divided by the combined mortality from commercial and recreational fishing, release mortality, and bycatch for each age-class and year. This provided the percent contribution from explosive structure removals relative to other sources of mortality used in the stock assessment. When values of these proportions were averaged by age-class, results showed that mortality from explosive structure removals represented the following percentage of other combined mortality: 1% or less for ages 0, 1, 3, 4, and 14; 1–5% for ages 5, 6, 11, and 15+; 5–10% for ages 2, 7, 8, 9, and 13; and 10–13% for ages 10 and 12.

Note that our study addressed direct impacts of explosive structure removals on red snapper mortality and did not address issues related to potential habitat loss resulting from the removal of these artificial reefs. Since red snapper are severely overfished, habitat availability is certainly not the primary factor restricting current stock size.

Sources of Error and Potential Factors Influencing Fish Mortality at Explosive Structure Removals

The primary source of error in our estimation of red snapper mortality at explosive platform removals over a 10-year period (1989–1999) relates to sampling. Estimates based on a sample size of nine platforms that were nonrandomly selected and sampled over 6 years were used to predict red snapper mortality at an annual average of 96 explosive structure removals. Since sampling effort was not equal between years, potential differences in red snapper recruitment and stock size between years would pose an additional source of error. Higher mortality would theoretically

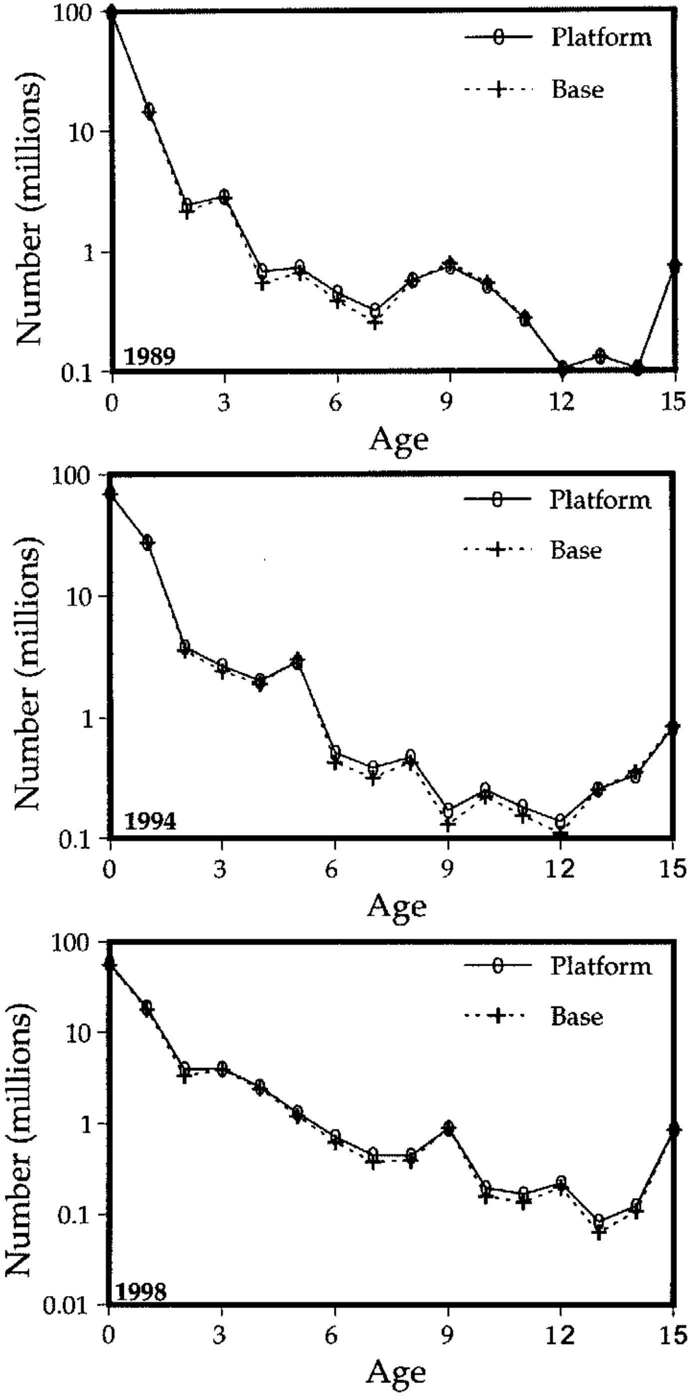

FIGURE 4. Comparison of red snapper stock assessments with (Platform) and without (Base) mortality from explosive structure removals. Refitted estimation models (Platform) used double the estimated mortality of red snapper to simulate an upper limit of potential impacts. Graphs plot number of red snapper by fish age (years) for three representative years. The two plotted lines in each graph are virtually indistinguishable indicating little discernible effect from explosive platform removals.

TABLE 4. Changes in red snapper management benchmarks between standard assessment without inclusion of mortality from explosive structure removals and new assessment including double the estimated mortality resulting from explosive structure removals (1989–1998 data). Data were doubled to represent an upper limit of potential impacts.

Management benchmarks	Standard assessment without platform mortality included	New assessment with platform mortality included	Percent change
$F_{0.1}$ [a]	0.096	0.093	−3.04
F_{MAX} [b]	0.125	0.121	−3.03
$F_{20\%SPR}$ [c]	0.169	0.165	−2.78
$F_{30\%SPR}$ [d]	0.126	0.122	−2.80
$F_{40\%SPR}$ [e]	0.095	0.093	−2.83
F_{msy} [f]	0.118	0.115	−2.99
$F_{current}$ [g]	0.474	0.444	−6.32
MSY[h] (million kg)	48.99	48.15	−1.71
B_{MSY} [i] (million kg)	1,782.76	1,787.29	0.25
SS_{MSY} [j] (million kg)	7.76E+09	7.78E+09	0.22

[a] Fishing mortality rate at which the slope of the yield-per-recruit curve is one tenth of what it is at the origin.
[b] Fishing mortality rate that maximizes yield-per-recruit.
[c] Fishing mortality rate which reduces spawning potential ratio to 20% of what it would be with no fishing.
[d] Fishing mortality rate which reduces spawning potential ratio to 30% of what it would be with no fishing.
[e] Fishing mortality rate which reduces spawning potential ratio to 40% of what it would be with no fishing.
[f] Fishing mortality rate that would eventually produce maximum sustainable yield.
[g] Most recent estimate of fishing mortality rate (for 1998, F1998).
[h] Maximum sustainable yield.
[i] Biomass that would support the taking of MSY.
[j] Spawning stock in number of eggs that would support MSY.

occur in years when stock size was larger. A similar error exists for years (1989–1992 and 1996) where red snapper lengths from PROP data were used in the stock assessment and no explosive platform removals were sampled in our study. To account for these and other errors, our estimated red snapper mortality was doubled to simulate an upper limit of potential impacts from explosive structure removals. Stock assessment analysis was then performed on this doubled value.

There are many factors that may influence the pressure wave and, hence, the impact resulting from detonation of explosives placed inside platform legs and well conductors at a depth of at least 5 m beneath the sea floor. These include, but are not limited to, the weight and type of explosive used, depth at which explosive charges are placed, sediment characteristics, water depth, density layers within the water column, and thickness and other physical properties of the steel legs and conductors. Explosives used in structure removals nearly always have the capacity to cause massive fish kills. Also, any factor affecting red snapper abundance within close proximity to offshore structures may affect the number of red snapper at risk during explosive removals. Stanley and Wilson (1996) describe a local area of influence of approximately 16 m around platforms where highest fish densities occur with fish density decreasing rapidly at greater distances. Note that our sampling distances from platforms far exceeded 16 m. Potential factors affecting fish distribution at platforms include structure age, water depth, platform size, and season in which the structure was removed.

Platform Age

Platform age was probably not a factor influencing red snapper mortality in the current study. Colonization of newly installed platforms occurs quite rapidly, and mature fish assemblages can be anticipated at all but the very youngest platforms. Lukens (1981) reported full colonization of GOM artificial reefs can occur within 15 months. Stanley and Wilson (1991) also found that structure age was not a significant factor in explaining fish abundance at platforms. Generally, it is the older platforms that are removed. Relatively few very young platforms are salvaged.

It should be noted that Platform A-Auxiliary in South Marsh Island Area, Block 23 was the last platform remaining from a complex of three platforms. Although the other two platforms were removed with explosives 2 years earlier, this remaining platform accounted for the highest estimated red snapper mortality in our study.

Water Depth

Attempts have been made to characterize fish assemblages at platforms by water depth. Based on observations at some 20 platforms off Louisiana and 18 off Texas, Gallaway and Lewbel (1982) suggested three depth zones of fish assemblages at platforms: the coastal zone ranged from 0 to 30 m, the offshore zone from 30 to 60 m, and the bluewater zone deeper than 60 m. These depth ranges are, of course, general in nature and gradual, rather than acute, changes in fish assemblages can be expected in transitional depths. Water depths at our nine study sites ranged from 14 to 32 m and corresponded to the shallowest zone described above. Fish assemblages in deeper zones will be different than those found in our study. Although red snapper are known to occur in all zones, the population of red snapper per platform in deeper zones may vary from that of the shallow zone of our study.

NMFS PROP data from 1989 to 1998 showed that 33% (319) of explosive structure removals occurred in 14–32 m, the depth range in our study, while 43% (420) were in shallower water and 24% (228) in deeper water. Recall that no red snapper were reported in the NMFS PROP data in depths less than 7 m, and only two dozen mortalities were estimated at our shallowest study site. Although our experimental design would have benefited from sampling at platform removals deeper than 32 m, these depths only accounted for 24% of the total explosive structure removals. Also, anecdotal reports of thousands of dead red snapper floating up at "deep" water platform removals, though likely true, are probably not a common occurrence. During 1989–1998, an annual average of five platforms and three submerged wells were removed with explosives in the bluewater zone deeper than 60 m (NMFS PROP data). Although bluewater platforms will have to be removed at some time in the future, they currently represent a minor portion of explosive structure removals.

Season

A discussion of seasonal affects on our results must consider both red snapper abundance and frequency of explosive platform removals. During 1987–1998, 61% of explosive removals occurred from May through September, 24% from October to December, and 15% from January through April (NMFS PROP). Our study was conducted during May, July, August, and September, months with high levels of explosive removals. Seasonal changes in fish abundance are well documented for the GOM (Moseley 1966; Bradley and Bryan 1975; Gallaway 1980; Fable et al. 1981; Lukens 1981; Reagan 1985; Sutter and McIlwain 1987; Stanley and Wilson 1991). In the northern GOM, the most dramatic differences in fish abundance are generally found between summer and winter. Any seasonal differences in fish distribution during summer and fall should be much less dramatic than in winter and, consequently, is probably a relatively minor factor affecting our results. However, large differences in fish abundance can occur not only between seasons, but also on a monthly basis. Fish population size at offshore platforms was observed to vary by a factor of up to five from month to month (Stanley and Wilson 1996, 1997). This information combined with our observations indicates that the size of fish populations, at least in certain cases, can vary considerably between similar platforms as well as at the same platform over relatively short time periods.

Platform Size

There are a wide variety of offshore structures ranging from single pile caissons and submerged wells to individual platforms with dozens of legs to complexes of interconnected platforms with hundreds of legs and well conductors penetrating the sea floor. During 1989–1998, 70% of all explosive structure removals involved platforms (NMFS PROP). Although platforms come in a variety of sizes, there was little diversity among platforms in the current study. All but one had four pilings with 0–6 well conductors. The exception was a 39-year-old platform with 24 pilings and 14 well conductors located in 14 m of water. This platform had both the largest size and the smallest estimated red snapper mortality of the nine structures studied.

There is conflicting information available on the relationship between structure size and fish abundance. Gallaway and Lewbel (1982) reported that abundance of Atlantic spadefish was directly proportional to platform size. Ogawa et al. (1977) and Rousenfell (1972) also found that fish abundance was directly correlated with reef size. In contrast, Stanley and Wilson (2000) reported that structure size affected fish density with higher density at mid-size platforms. Anecdotal information provided to the first author by a professional snapper fisherman indicated that one of his largest catches occurred at a submerged structure about the size of a barrel. Structure size alone probably does not determine fish abundance at offshore platforms. Due to a paucity of quantitative evidence to the contrary, when estimating total red snapper mortality at explosive removals throughout the entire U.S. GOM, we assumed that there was no difference due to structure size.

Assessing Future Impacts on Red Snapper (1999–2023)

The procedures described above provide an analysis for the period 1989–1998 and can be used to assess the current status of the red snapper stock. However, a recent forecast for 1999–2023 estimates the number of annual structure removals (both mechanical and explosive) in federal waters to increase to 186 (Pulsipher et al. 2001). Using the current ratio for explosive to nonexplosive removals and state to federal removals, this value was adjusted to yield an estimated annual average of 129 explosive structure removals in both state and federal waters combined for 1999–2023. This is an increase from an annual average of 96 explosive structure removals for 1989–1998. If red snapper mortality is equal at all structure types, these increased removals would yield a projected annual mortality at explosive structure removals of 66,400 red snapper for 1999–2023. Although this is approximately one and one-half times the 41,200 annual estimate for 1989–1998, it is still less than the 82,400, which represents double the annual 1989–1998 estimate used in our stock assessment. Assuming other influencing factors remain constant and removal forecasts are accurate, the impact of the projected increase in average annual explosive structure removals is not expected to be distinguishable from benchmarks.

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