EVALUATION OF MULTIPLE FACTORS INVOLVED IN RELEASE MORATLITY OF UNDERSIZED RED GROUPER, GAG, RED SNAPPER AND VERMILION SNAPPER

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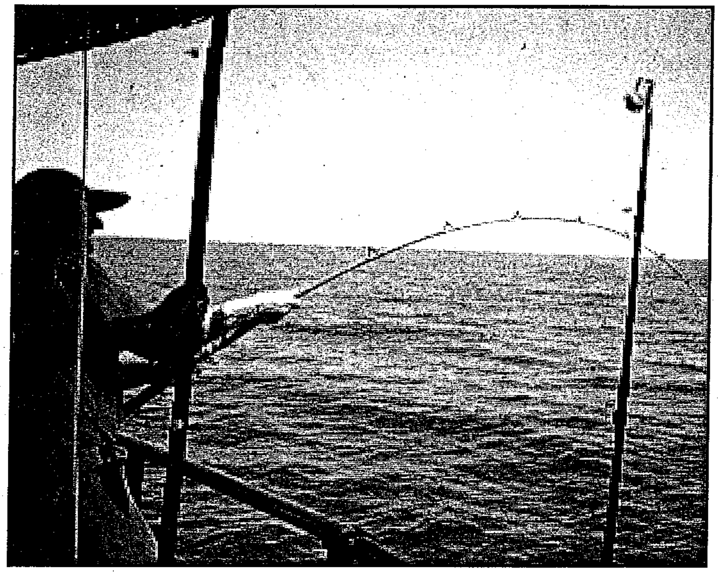

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ABSTRACT

A total of 16,639 fish (5,501 red grouper, 2,295 gag, 4,797 red snapper and 4,046 vermilion snapper) were measured. Of these, 11,105 fish (5,058 red grouper, 1,755 gag, 3,467 red snapper and 825 vermilion snapper) were tagged and released. Five hundred twenty-seven (527) fish (194 red grouper, 119 gag, 208 red snapper and 6 vermilion snapper) were recaptured. Distance traveled and days of freedom were recorded. A subset of 821 fish (376 red grouper, 45 gag, 398 red snapper and 2 vermilion snapper) were double tagged as part of the tag assessment study. Forty (40) fish were recaptured, including 9 red grouper, 6 gag and 25 red snapper. Only 2 recaptured fish lost the external dart tag. Of the 133 acute mortalities of target species which occurred, 93% were red snapper. Of these 56.5% died of hook mortality. Mortality was depth related in gag and red snapper, with red snapper LD50 (lethal depth of capture at which 50% die) being 48.6 m and gag LD50 being 43.7 m . The relationship between depth of capture and mortality was unclear in red grouper and vermilion snapper. Control fish, which were held at a capture depth of 20m for 2 weeks, showed no mortality. Caging and tag-recapture data sets for gag and red snapper were combined to produce a general logit model of depth-related mortality (LD50 = 40.4 m; 99% c.i., 32.8 – 61 m). Aberrations, or the overt signs of swimbladder gas expansion (everted stomach and intestines, and protruding eyes) were depth related to 60 m in all species except for vermilion snapper, which showed no aberrations. The major factor found to increase mortality at depth of capture was surface interval. No relationship between mortality and ascent rate was found.

EXECUTIVE SUMMARY

In this report we studied the effects of capture and release on four species of reef fish: gag, red grouper, red snapper, and vermilion snapper. The multiple objectives of this study include: (1) to evaluate the effects of depth of capture on release mortality by two methods, tag-recapture and caging. (2) To evaluate the effects of hook type on release mortality. (3) To evaluate the effects of gear type and venting on release mortality. (4) To combine tag-recapture and caging mortality estimates for all four species to develop a model of capture-depth-related release mortality. (5) To determine tag shedding rates and effects of tagging on growth in all four species. (6) To obtain movement and migration patterns for all four species in the Gulf of Mexico and south Atlantic regions.

Tag-recapture studies were done from October 1998 to December 2001 in the Gulf of Mexico and south Atlantic regions on headboats, charter boats, recreational vessels, and commercial vessels. Caging studies were done only in the northeastern Gulf of Mexico from 1999 to 2001 in water depths of 20 to 60 m. Fish for caging studies were caught with standard commercial gear (electric reels and circle hooks) by commercial fishermen and put into cages and left *in situ* for about a week before being scored for depth-of-capture related mortality.

Undersize fish predominated in the catches of the Gulf and Atlantic for red grouper (95.8% undersize in the Atlantic and 95.4% in the Gulf), gag (82.8% undersize in the Atlantic and 85.2% in the Gulf), and red snapper (88.4% in the Atlantic and 82.5% in the Gulf). However, vermilion snapper catches were only 25% undersize in the Atlantic and 24% in the Gulf.

The rate of return for tagged vermilion snapper was very low (6/862 = 0.7%), but survival was very high in the caging studies. We therefore propose that predation is a dominant source of mortality for released vermilion snapper. By contrast, 3.8% (194/5058) of the red grouper tagged were recaptured, 6.8% (119/1755) of the gag, and 6% (208/3467) of the red snapper.

Overall, fish caught with circle hooks showed a small but significant ($P<0.05$) increase in recapture rate.

The effects of venting on recapture rates were variable and related to the species. In the three-year (1998 – 2001) data set red grouper showed a significantly greater ($P< 0.0001$) return rate when un-vented. However, no significant difference was detected for gag, or red snapper. In the 10-year data set unvented red grouper still showed a significant recapture rate ($P<0.0001$) and so did red snapper, but gag showed a significant ($P<0.0001$) increase in return rate, but this was only from fish captured in shallow water (0 – 12 m). Because of such a small sample size, vermilion snapper could not be evaluated.

Most of the individuals of gag, red grouper, and red snapper moved less than 2 miles when recaptured.

Caging studies showed positive depth-related release mortality for gag and red snapper, but not for red grouper or vermilion snapper. The experimental LD50 (depth at which 50% of the test fish die) was 43.7m for gag and 48.6m for red snapper. Red grouper mortality remained at about 15% for depths from 35 to 55 m. No significant mortality was observed for vermilion snapper at depths up to 60m.

Mortality at depth was estimated from the tag-recapture data from this study and combined with the mortality data from the caging studies. These combined data were then used with published data to develop a model of depth-specific release mortality for gag and red snapper which gave an LD50 of about 40m (99% c.i., 32.8 – 61.4). The logit model equation for gag and red snapper is: $P=1/(1=EXP(-(-2.3915+0.0592*X)))$, where P is the probability of mortality and X is the depth of capture.

PURPOSE

A. PROBLEM DESCRIPTION

Groupers and snappers support extremely important fisheries along the entire southeast U.S. coast. Fisheries in this region are regulated primarily by minimum size limits, although catch quotas, trip limits and seasonal closures are also used. Minimum size limits are intended to prevent growth and recruitment overfishing by allowing some proportion of fish in a cohort to grow and reproduce at least once before dying of natural or fishing-related causes. Enforcement prohibits the landing of fish below the legal size. This requires undersized fish be released (discarded) at sea. The minimum size rule for regulated reef fish species is in effect over all locations and depths fished, and the rule is applied to recreational and commercial fishers.

Two factors that jointly play an important role in determining the efficacy of size limits are the selectivity of the fishing gear for undersized fish and the survival of undersized discards. Generally, grouper and snapper fisheries that are based on hook-and-line gear catch many small fish, although there is considerable variability in the proportion of undersized catches depending on species, area, season and other factors. The fate of these undersized discards then becomes critical in determining the effectiveness of the minimum size regulation.

Capture by either hook-and-line fishing or trap-fishing, is a rapid process. The result is that swimbladder volume increases proportionally with decreasing pressure (=decreasing depth). For example, a fish at 40 meters experiences a pressure of 5 atmospheres (atm) on the gas in the swimbladder (w/atm for each 10 m depth plus 1 atm pressure at sea level). If the fish is rapidly hauled to 20 m depth where there is only 3 atm pressure on the gas in the swimbladder, the volume of the swimbladder increases to 5/3 67 times) its volume at 40 m. At the surface, at 1 atm pressure, there is only 1/3 original pressure. If no gas is lost from the swimbladder and the swimbladder itself exerts negligible pressure on the contained gas the swimbladder will expand to 5 times its original volume. Of course, if the depth of capture is shallower, the degree of expansion of the swimbladder will be less; at 10 atm depth of capture, the volume will double at the surface. If the depth of capture is greater, say 90 m, the swimbladder at the surface will be about 10 times its volume at the bottom.

Fish exposed to rapid lowering of the ambient pressure exhibit many overt responses related to the expansion of gas in the swimbladder, including eversion of the stomach and intestines, protruding eyes, bubbles under the skin, internal hemorrhage, and a bursting of the swimbladder. The severity of these effects increases with the depth of capture, if all else is held constant. Slow ascent of the captured fish may lessen the severity of the response by allowing the fish to remove gas from the swimbladder; however, it is unrealistic to assume that any fishermen will chance losing the fish by bringing it to the surface slowly.

Bloated fishes with ruptured swimbladders are incapable of rapid return to benthic refugia. Although Wilson and Burns (1996) have shown that red grouper, gag, and scamp can potentially survive this experience in sufficient numbers to justify a minimum size rule if the fish are returned to the bottom, it is apparent that survival has a depth-related component. In addition, discarded bloated, undersized fish stranded at the surface become easy prey for sea birds as well as large piscine predators such as amberjack, barracuda and sharks. This predation is probably sufficient to undermine the conservation goals of a minimum size regulation.

Commercial fishermen must return undersized fish and then continue to fish for enough legal sized fish to make their trip profitable. Charter boat captains and crew must explain the concept of the minimum size law to their clientele as they watch the undersized fish float away. When fishermen and clients of commercial charter boast watch bloated undersized fish float away with what appears to be little chance for survival, it is difficult for them to comply with the minimum size rule.

Because they believe it aids an undersized released fish to immediately descend to its habitat, some recreational and commercial fishers and charter boat captains and crew vent the undersized reef fish they catch.

Although various swimbladder venting methods are used, little research has been conducted concerning survivorship of vented fish (Shasteen and Sheehan, 1997; Parker, 1991). Although venting allows the fish to overcome surface buoyancy to return to the bottom by having a ruptured swimbladder, it does not overcome the buoyancy-control problem. Estimates of survivorship to document swimbladder healing of the interval between swimbladder rupture and healing are important because only then is the fish completely capable of returning to its normal lifestyle. This short interval, a matter of days, (personal observation) does not appear to be a problem for bottom-dwelling reef fish such red grouper and red snapper.

Swimbladder rupture occurs at relatively shallow depths (~23 m, possibly shallower) but healing, in both red grouper and red snapper with swimbladders ruptured, was rapid (Karen Burns, personal observation).

Survival of water-column species found in deep water, such as vermilion snapper, may not be as high. A vermilion snapper with a ruptured swimbladder would be unable to maintain its position in the water column without constantly swimming until its bladder healed. Remaining on the bottom while their bladders heal, even assuming the bladder healing rates are as rapid as those of red snapper and red grouper, subjects them to increased predation risk, because unlike red grouper and red snapper, they would not be returning to their normal habitat but rather the habitat of some of their predators. If vermilion snapper swimbladders rupture and the fish do not survive, that may be the reason that with the exception of one tagging study (Fable 1980), few tagged vermilion snapper have ever been recaptured, especially since they are reported not to migrate.

The acute effects of capture and release on reef fish have been studied by a number of researchers (Collins, 1991; Parker, 1991; Wilson and Burns, 1996; Dixon and Huntsman, 1993). Collins (1991) determined acute mortality in 19 species of reef fish. He observed both the ability of released fish to swim down in the water column and their survival in cages held at the capture depth for 24 hours. Overall survival estimates for all species were 88% at 21 m, 81% at 36 m, and 62% at 46-54 m. Wilson and Burns, (1996) determined potential release mortality in groupers by making ROV observations of captured individuals in cages held at the capture depth for 2 to 8 days. The overall survival at depth of capture was 92.5% at 43 m (142 ft.), 50% at 52 m (170 ft.), and 12.5% at 73 m (240 ft.). Dixon and Huntsman, (1993) observed mortality of captured reef fish at the time of release (= those that could swim down and avoid predation) for all species and under all conditions was 82.7% (range = 72.5% - 92.9%). Parker (1991) caged red snapper at the depths of capture and found that release mortality increased with depth of capture.

In all these studies, there have been no systematic species-specific studies of capture-release mortality relative to depth. This must be done to evaluate incipient lethal levels (i.e., no significant mortality after the observation period) resulting from capture at depth. In addition, sublethal effects (such as blindness), which are lethal or debilitating in the natural environment, were evaluated as well.

Although depth/pressure and related decompression effects are very important factors affecting release mortality of deep-dwelling reef fish, it must be remembered that the depth/pressure effects are superimposed on a suite of release mortality factors that operate independently or interactively with the depth-related factors. The direct physical damage inflicted by fishhooks is the primary factor in this regard. Hook type, type of bait or lure (Clapp and Clark, 1989) may influence location of the hook and associated damage to the fish (Rutledge and Pritchard, 1977; Pelzman, 1978; Loftus, 1986; Payer, Pierce and Pereira, 1989). The type of hook has been shown to be important (McEacheron *et al.*, 1985) and this is particularly pertinent to reef fish, because the potential for damage may be greatly different for circle hooks used by some fishermen, but not all. Even other aspects of tackle and rigging also influence the location of the hook and the associated damage (Weidlen, 1989). Fishing techniques, primarily whether the technique allows the fish to have time to deeply swallow the bait, may greatly increase probability of damage. Additionally, deeply hooked fish may suffer greater mortality because they are often handled longer and more severely during the angler's efforts to remove the hook (Bugley and Shepherd, 1991).

Within various hook-and-line reef fish fisheries, these factors vary by species, locality, and with regard to depth. In some areas, where smaller reef fish are targeted, fishing techniques may employ smaller baits and smaller hooks, which may be more easily deeply swallowed and thus more likely, lead to fatal damage. Fishermen fishing in deeper water are less able to feel a fish take their bait because of the longer length of line (and its associated belly and stretch) and a heavier weight. Thus, it is likely that the incidence of swallowed hooks and severe damage due to deep hooking may be greater when fishers are fishing in deeper water. Overall, the point that must be kept in mind is that, because of many factors that can affect release mortality, a single study in one fishery cannot provide a reasonable estimate of release mortality. The fact that release mortality of a reef fish species has been previously studied does not mean that managers have sufficient information.

Knowledge of the number and percent of reef fish that succumb to immediate mortality is important to management of a species. This was accomplished by recording the number of undersized target species caught on headboats and necropsying dead fish to determine cause of death.

There is no single method or technique that alone can provide all the information needed by resource managers to incorporate reef fish release mortality into their management plans. All techniques applied to data have the strength and weaknesses. For example, studies that estimate survival based on the numbers of fish that swim down at release may underestimate mortality, because some fish may die or be preyed upon shortly after release. Conventional tagging studies can provide some information on longer-term survival, but this information is relative. The fact that a high percentage of tags are returned is indicative of high survival, high fishing pressure, or high site fidelity (enhancing chances of recapture at regularly-fished locations). Similarly, cage studies can systematically evaluate longer-term survival, but artifacts due to damage (skin and fin abrasions, lacerations, and infections) may bias caging studies conducted over periods of many days. Additionally, caging studies eliminate the possibility of predation on fish that are not only weakened by capture and release, but that also, because of swimbladder rupture, may have lost the ability to adjust their buoyancy (Gitschlag and Renaud, 1994).

Conventional tagging study results incorporate these sources of mortality, but again only in a relative sense. The purpose of the suite of studies/components included in this study was to address as many of the sources of release mortality as possible from a multifaceted approach that can give managers more robust estimates of reef fish release mortality.

While determining the effects of hook release and depth induced mortalities on the target species, it was also possible to conduct a tag shedding study, testing the effectiveness of plastic dart tags for research on red grouper, gag, red snapper and vermilion snapper. Although some researchers are not convinced of their value in reef fish research, they have been successful in providing data on three of the target species (red grouper, red snapper and gag; some out for as long as 6 years) in MML's Reef Fish Tagging Program. Tag shedding rates were obtained by double tagging (Hallprint plastic dart tags and PIT tags) some of the undersized target species caught aboard headboats, which participated in this study.

Additional data to come from this study information on movement patterns of the target species.

B. Project Objectives

I. To test the hypothesis that vermilion snapper do not survive release as well as red grouper, gag and red snapper.

II. To test the hypothesis that hook release mortality is far greater than depth induced mortality for red snapper.

III. To obtain catch and release mortality rates by depth and gear for red grouper, gag, red snapper and vermilion snapper.

IV. Systematic evaluation through field and laboratory studies of depth-related capture-release mortality and sublethal effects for reef fish species with a seagrass-associated juvenile stage, and other important reef fishery species.

V. To determine tag shedding rates and effects on growth and survival fish tagged with single barbed dart tags in red grouper, gag, red snapper and vermilion snapper.

VI. To obtain movement and migration patterns for red grouper, gag, red snapper and vermilion snapper in the Gulf of Mexico and South Atlantic.

Approach

A. Work Performed

1. A total of 16,639 fish (5,501 red grouper, 2,295 gag, 4,797 red snapper, and 4,046 vermilion snapper) were measured.

2. A total of 11,105 fish (5,058 red grouper, 1,755 gag, 3,467 red snapper and 825 vermilion snapper) were tagged and released.

3. Five hundred twenty one (521) fish, (190 red grouper, 117 gag, 208 red snapper and 6 vermilion snapper) were recaptured.

4. Of the 11,105 fish tagged, 821 (376 red grouper, 45 gag, 398 red snapper and 2 vermilion snapper) were double tagged with an exterior tag, Hallprint plastic dart tag and an internal PIT tag.

5. There were 39 double-tagged fish (9 red grouper, 5 gag and 25 red snapper) recaptured.

6. Necropsies on 133 fish (5 red grouper, 124 red snapper and 4 vermilion snapper) were conducted.

7. Recapture data by hook type and water depth were collected.

8. Eight quarterly newsletters were published and mailed to participating taggers, outdoors writers, and fishery scientists and managers.

9. Eight "Top Tagger" awards of $50 were given to volunteer taggers who tagged the most target species each quarter.

10. Two Tag Lottery awards of $100 for the tagger and $100 for the fisher who returned the tag were awarded.

11. Data on fish movement and site fidelity were collected.

12. Two circle hook contests were run to spark an interest in circle hooks.

13. Results of the research were presented at the MARFIN Conference in Tampa, FL on January 17, 2002.

B PROJECT MANAGEMENT

1. Karen M. Burns, P.I. (Staff Scientist, MML) served as Program Manager. She provided overall supervision of the project, ensuring that work was completed in accordance with the S.O.W. Ms. Burns served as liaison between MML and NMFS and wrote the project reports and newsletters and presented the project results at the MARFIN conference. She made the original arrangements with headboat captains for shipboard fish tagging, acute mortality necropsies at MML and is responsible for quality control of the tagging database, data analyses and dissemination of project results.

2. Christopher C. Koenig, Ph.D., Co-P.I. (FSU, Associate in Research) designed and conducted the depth-related capture-release experiments on commercial fishing vessels, analyzed the data, and prepared a preliminary report to the Gulf of Mexico Fishery Management Council. He also designed and supervised laboratory studies of swimbladder characteristics at FSU.

3. Felicia C. Coleman, Ph.D., Co-P.I. (FSU, Associate in Research) contributed to the project by managing the FSU portion of the budget, design of caging experiments, and analysis of the data. She also helped in arranging trips with commercial fishers.

4. Jay Sprinkel (Senior Biologist, MML) served as Data Manager for the project. He provided the graphs and figures for the project newsletters and the MARFIN presentation. Mr. Sprinkel also prepared the data in NMFS compatible software for the semi-annual reports.

5. Staff Biologists, MML: Tanya M. Chen See, Teresa Starks-DeBruler, Vicki Fritz, Marion Hersey, Peter Simmons III, and Matt Thomas. Ordered field supplies, tagged/released undersized red grouper, gag, red snapper and vermilion snapper aboard headboats off Sarasota, Panama City and St. Augustine, FL. They counted and measured every target species caught aboard the headboats during each fishing trip. The staff biologists conducted the double tagging aboard the headboats at the 3 study locations. They were responsible for data entry and contacting fishers regarding tag returns. They assisted with newsletter production, trained and helped supervise student interns.

6. Kim Churchill (Administrative Assistant, MML) was responsible for the project newsletter production and graphic design. She formatted the newsletter text, photographs, figures, tables, and front page.

7. MML Student Interns: Shannon Bayse, Virginia Tech; Amber Bifoick, University of Rhode Island; Samantha Binion, Emory University; Melissa Booroueng, University of Miami; Jared Chromy, University of South Florida; Gregory Delozier, University of Tennessee; Nancy Nill, Adrian College; Nate Parker, Hampden-Sydney College, Alex Porter, De Pauw University; Brie Sarkisian, Mount Holyoke College; Melanie Simmons, University of Miami; Peter Simmons III, Albion College; Timothy Sippel, Kansas State University; Matthew Thomas, Florida Institute of Technology; Sarah Turner, Clarion University; Danielle Vuncannon, University of North Carolina; Sarah Zapalla, Mary Washington University; Carlos Yanes-Roca, Hull University; Camilo Moro, Universidad del Valle; Diorys Perez, Santo Domingo University; Julie Bremner, University of York; Philip Diamond, Queen Mary & Westerfield University; Daniel Hughes, University of West England; Jochen Menking, University of Bielefield; Leona Lees, Glasgow University; Diego Arana, Universidad de Cadiz; Lisa Blom, Viktor Rydbergs Gymnasium; Ellen Sjölin, Malin Thurell, Enskilda Gymnasiet; and Zeina Joukhader, University of Michigan helped with all aspects of the study. They accompanied MML staff aboard the headboats to measure/tag/release fish. They also helped with computer data entry, photocopying and communicating with fishers regarding tag returns.

8. MML Volunteers: John Angiolini, Bob Eicher, Roy Francis, Ingeborg Herdegen, Joe Mazza, Robert McCracken, Shirley Reynolds, Georgenna Sanderson, Dave Shiplet, Bernie Waxman, and Daniel Weiner. Volunteer veterinarians Dr. Bernie Waxman and Dr. Daniel Weiner conducted the fish necropsies. The other volunteers accompanied MML staff to measure/tag/release fish aboard headboats. They also made the tag applicators, printed, collated and mailed the project newsletter, in addition to putting

together tagging kits to be sent to volunteer taggers. Too numerous to mention are the 370 volunteer taggers who tag/release, and measure target species in locations ranging from offshore southern Georgia coast to Galveston, Texas.

FINDINGS

A. ACTUAL ACCOMPLISHMENTS AND FINDINGS

In order to characterize and assess bycatch impact and release mortality of undersized reef fish on headboats, charter boats, and recreational vessels in the Eastern Gulf of Mexico and South Atlantic, volunteer fishers/taggers were recruited. Some commercial and pier fishers also participated. In addition, MML personnel worked aboard headboats off Madeira Beach, Panama City and St. Augustine, FL. **Figure 1** illustrates the various sectors of the reef fish fishery that participated in this study and the level of their participation. All participants counted and measured all target species (red grouper, gag, red snapper, and vermilion snapper) caught per trip. Both legal and undersized fish were counted and measured.

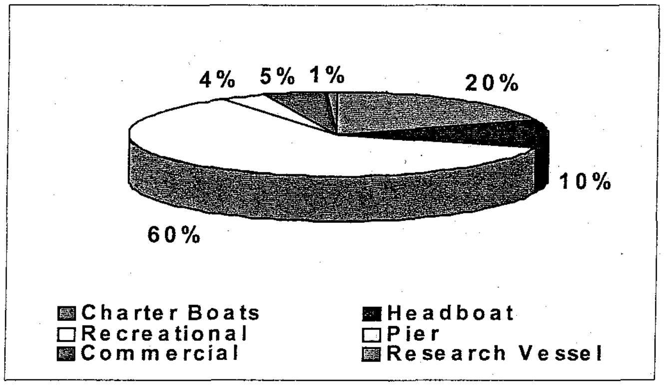

Figure 1. Percentage of taggers broken down by fishing category.

Figures 3 through **5** show the size ranges of the fish caught. For our purposes, the Atlantic extends from southern Georgia to just south of St. Augustine. The central Gulf extends from north of Tampa to South of the Florida Panhandle and the southern Gulf extends from Tampa to Cape Coral, FL. Most fish were caught inshore in waters shallower than 61 meters or 200 feet.

It is important to note that although the size distribution reflects the fish population of the area being fished by the various fishing sectors (mostly recreation-for-hire and recreational), the number of fish is more a factor of where more fishers are participating in the study (effort) rather on fish abundance in the various areas. It is also important to note that these data are merely a small subset of the total number of target species caught in the eastern Gulf of Mexico and Atlantic coast of the state of Florida.

Figure 2 shows the areas where target species were measured and tagged. These figures show all target species, which have been tagged in the area since October 1990. The total number of fish tagged was included in this report because some returns of fish tagged before this study, but returned and reported during the study duration, has been included in project newsletters and study comparison analyses.

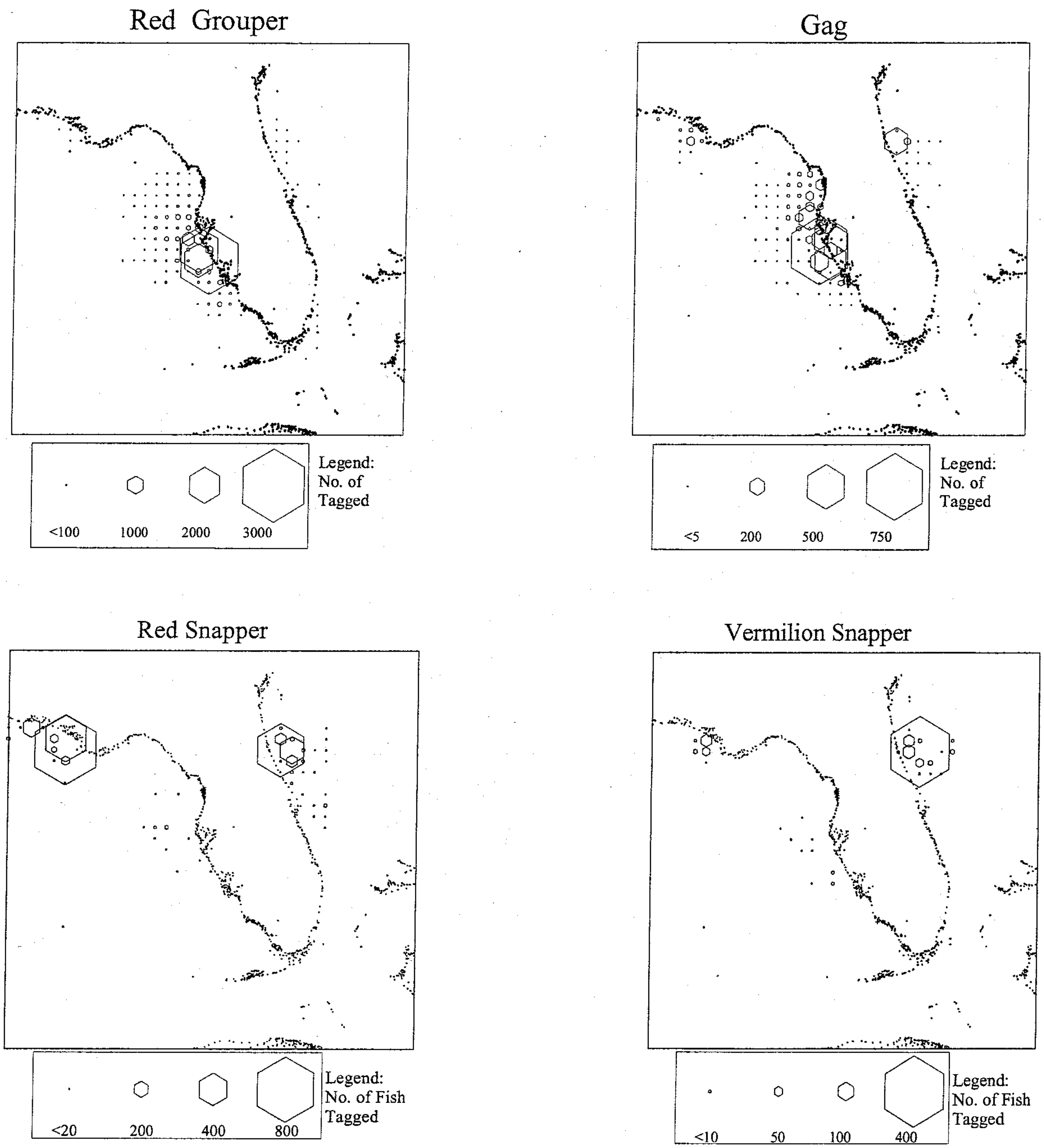

Figure 2. Number and location of red grouper, gag, red snapper, and vermilion snapper tagged/released in the MML Reef Fish Tagging Program database.

Red Grouper

A total of 72 red grouper were measured from the Atlantic versus 5,524 from the Gulf of Mexico. Measurements made by all MML staff, student interns and volunteer taggers (**Figure 1**) were pooled to assemble the following length/frequency histograms. Data are from October 1, 1998 – December 31, 2001. Both legal and undersized fish were counted and measured per trip. The minimum size limit in both the Atlantic and the Gulf for red grouper is 20 inches. In the Atlantic approximately 5.6% of the red grouper caught were legal sized versus 3.8% in the Gulf.

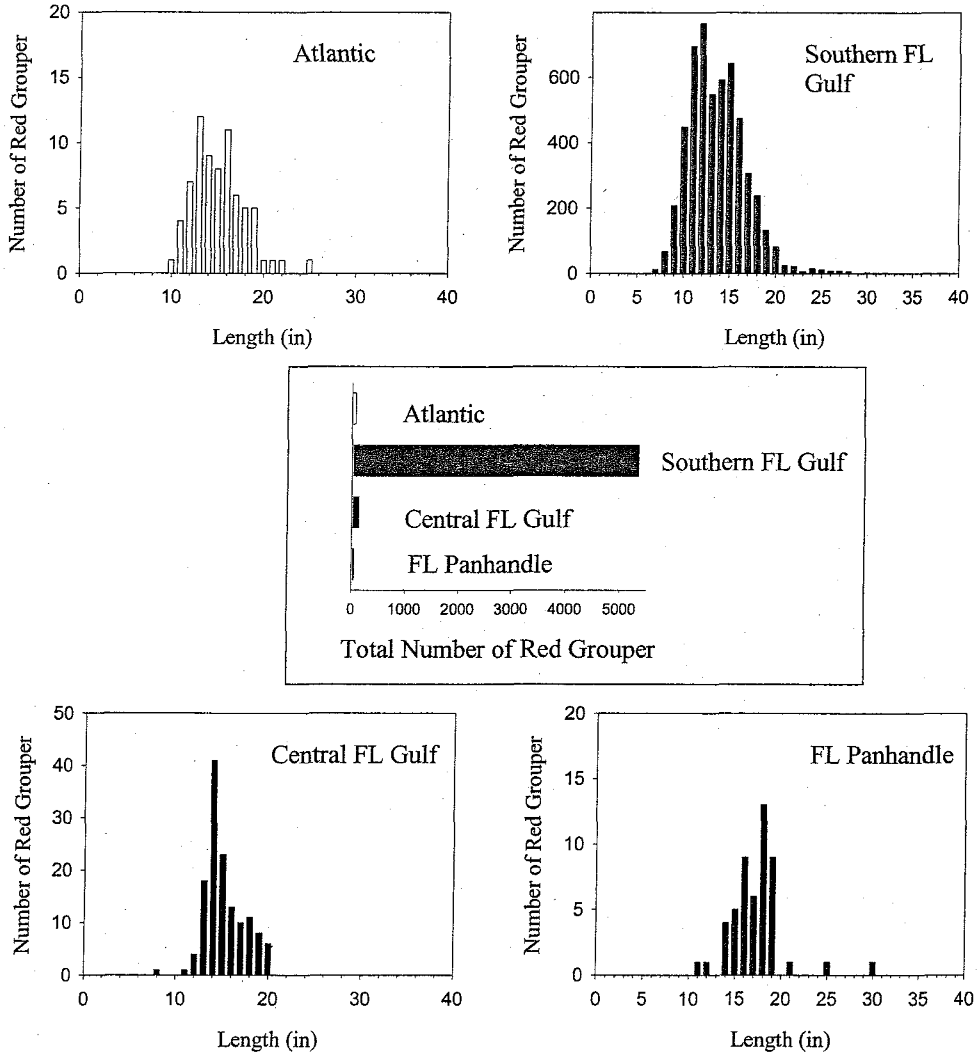

Figure 3. Length/frequency histograms of red grouper measured by MML Staff and student interns aboard headboats and participating fishers from various sectors of the reef fish fishery.

Gag

Gag were also counted and measured per trip by MML staff, student interns and volunteers in the fishing sectors mentioned in **Figure 1**. A total of 462 gags were measured from the Atlantic captures and 1,771 came from the Gulf of Mexico. Legal gag must be 24 inches in the Atlantic and 22 inches in the Gulf. Approximately 11.7% of the Atlantic gags captured and 11.9% of the Gulf gag were legal sized.

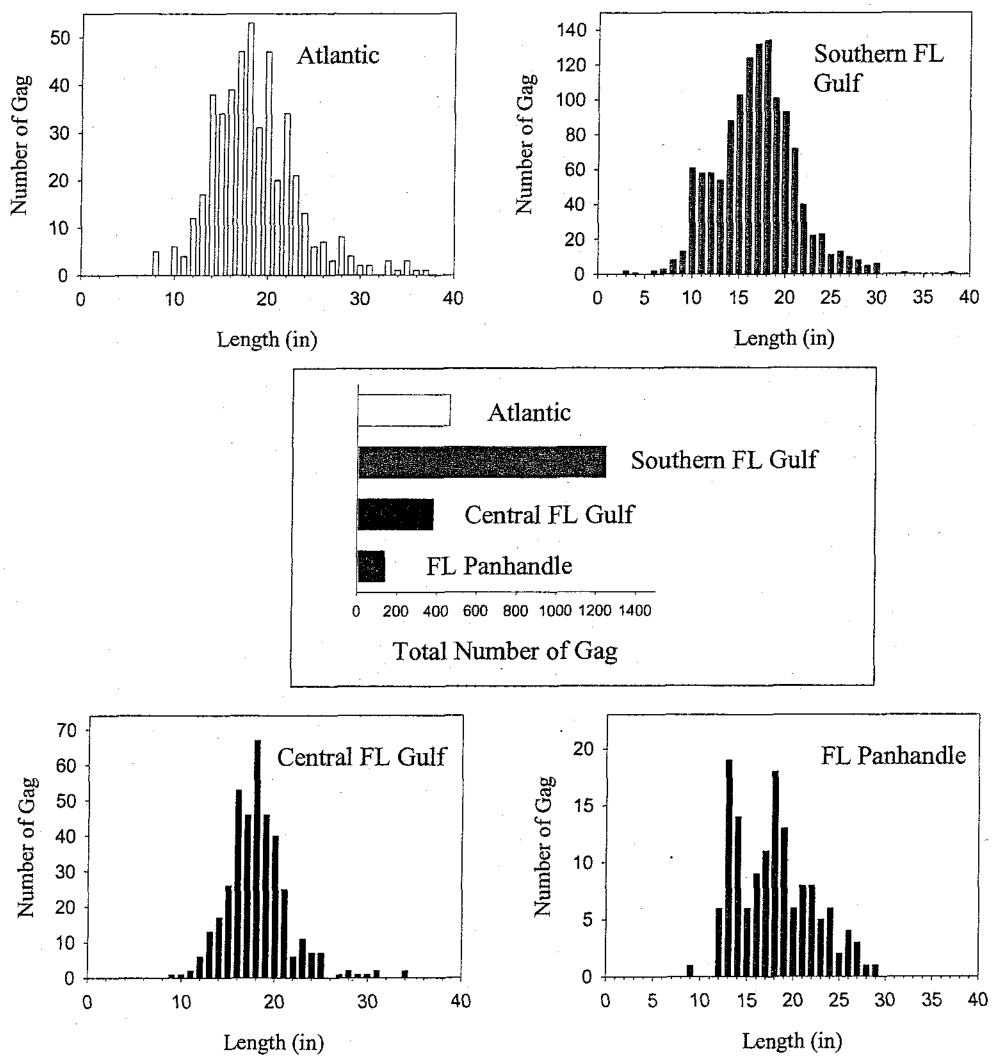

Figure 4. Length/frequency histograms of gag measured by MML Staff and student interns aboard headboats and participating fishers from various sectors of the reef fish fishery.

Red Snapper

MML staff, student interns and volunteers measured 2,660 red snapper in the Gulf and 1694 red snapper in the Atlantic. The size limit for red snapper is 20 inches in the Atlantic and 16 inches in the Gulf. The greatest numbers of red snapper were measured in the Florida Panhandle. Approximately 14.6% of the Gulf captured fish (Panhandle and Madeira Beach) were legal sized versus the 6.9% legal sized fish caught in the Atlantic.

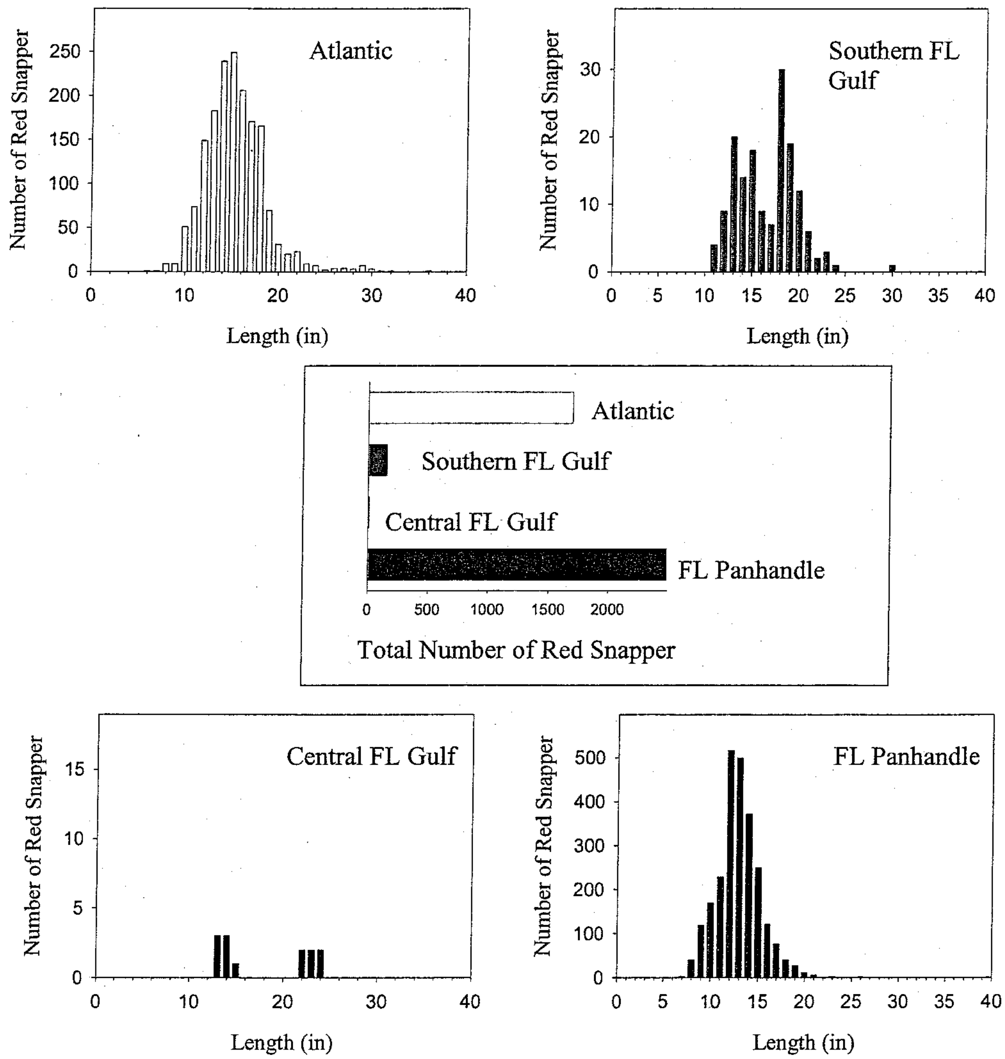

Figure 5. Length/frequency histograms of red snapper measured by MML Staff and student interns aboard headboats and participating fishers from various sectors of the reef fish fishery.

Vermilion Snapper

Both legal and undersized vermilion snapper were counted and measured per trip by MML staff, student interns and volunteers. A total of 956 vermilion snapper were measured in the Atlantic and 760 in the Gulf of Mexico. The size limit for vermilion snapper is 10 inches in both the Atlantic and the Gulf. Size ranges for fish caught off both coasts were similar, as were the percent of legal sized fish. In the Atlantic 75.1% of the catch was legal sized versus 70.7% in the Gulf. Thus, undersized bycatch was much less of a problem for vermilion snapper than for the other three target species.

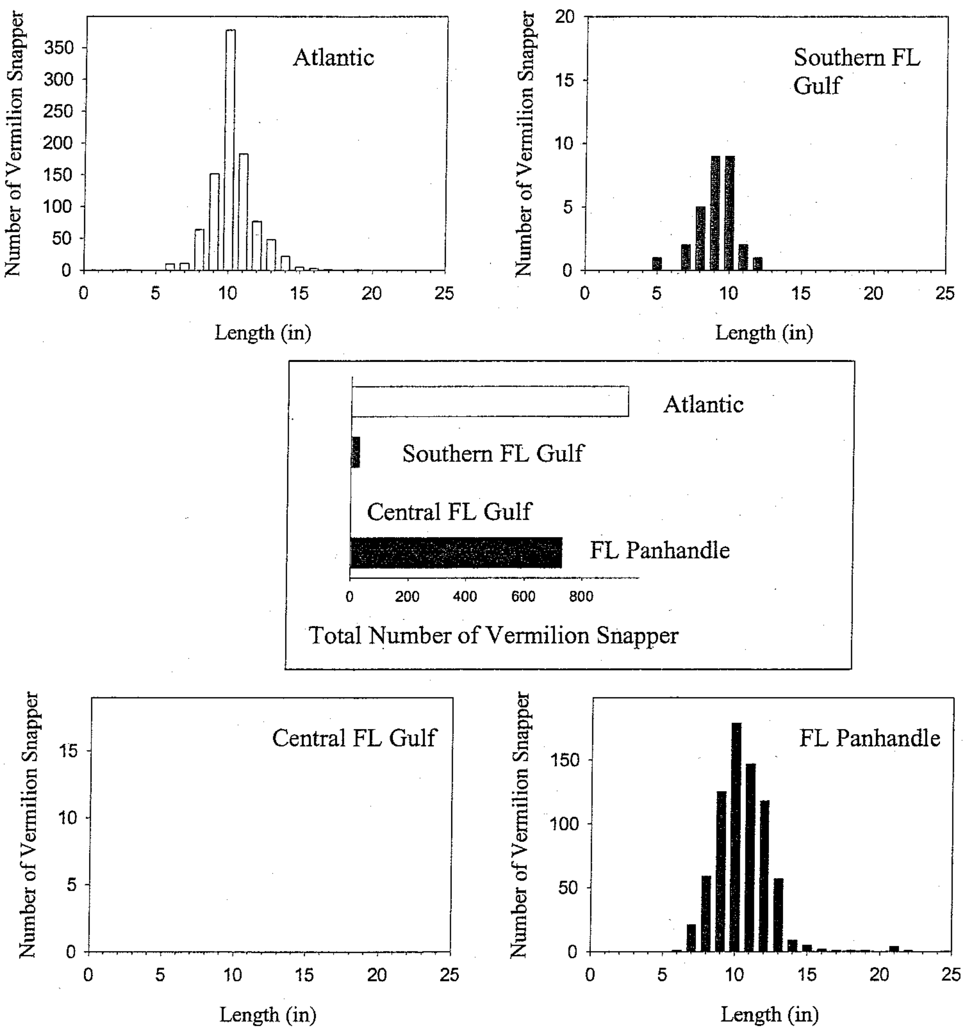

Figure 6. Length/frequency histograms of vermilion snapper measured by MML Staff and student interns aboard headboats and participating fishers from various sectors of the reef fish fishery.

Tables 1-4 show the number of target fish caught in the South Atlantic and the Gulf of Mexico segregated by size during the study. Shaded areas highlight the number of undersized fish caught.

Table 1. Number of red grouper segregated by size measured from the catches of the various fishing sectors.

	Count		Cumulative Percent	
Length (in)	**Atlantic**	**Gulf**	**Atlantic**	**Gulf**
4	**0**	**1**	**0.00**	**0.02**
6	**0**	**2**	**0.00**	**0.05**
7	**0**	**12**	**0.00**	**0.27**
8	**0**	**68**	**0.00**	**1.50**
9	**0**	**209**	**0.00**	**5.29**
10	**1**	**449**	**1.39**	**13.41**
11	**4**	**698**	**6.94**	**26.05**
12	**7**	**770**	**16.67**	**39.99**
13	**12**	**567**	**33.33**	**50.25**
14	**9**	**637**	**45.83**	**61.78**
15	**8**	**671**	**56.94**	**73.93**
16	**11**	**497**	**72.22**	**82.93**
17	**6**	**323**	**80.56**	**88.78**
18	**5**	**262**	**87.50**	**93.52**
19	**5**	**150**	**94.44**	**96.23**
20	1	87	95.83	97.81
21	1	26	97.22	98.28
22	1	22	98.61	98.68
23	0	7	98.61	98.81
24	0	16	98.61	99.09
25	1	13	100.00	99.33
26	0	9	100.00	99.49
27	0	9	100.00	99.66
28	0	7	100.00	99.78
29	0	1	100.00	99.80
30	0	5	100.00	99.89
31	0	2	100.00	99.93
32	0	3	100.00	99.98
38	0	1	100.00	100.00

Table 2. Number of gag segregated by size measured from the catches of the various fishing sectors.

Length (in)	Count Atlantic	Count Gulf	Cumulative Percent Atlantic	Cumulative Percent Gulf
3	**0**	**2**	**0.00**	**0.11**
4	**0**	**1**	**0.00**	**0.17**
6	**0**	**2**	**0.00**	**0.28**
7	**0**	**3**	**0.00**	**0.45**
8	**5**	**8**	**1.08**	**0.90**
9	**0**	**15**	**1.08**	**1.75**
10	**6**	**62**	**2.38**	**5.25**
11	**4**	**60**	**3.25**	**8.64**
12	**12**	**70**	**5.84**	**12.59**
13	**17**	**86**	**9.52**	**17.45**
14	**38**	**119**	**17.75**	**24.17**
15	**34**	**135**	**25.11**	**31.79**
16	**39**	**186**	**33.55**	**42.29**
17	**47**	**189**	**43.72**	**52.96**
18	**53**	**219**	**55.19**	**65.33**
19	**31**	**160**	**61.90**	**74.36**
20	**47**	**139**	**72.08**	**82.21**
21	**20**	**105**	**76.41**	**88.14**
22	**34**	54	**83.77**	91.19
23	**21**	38	**88.31**	93.34
24	13	36	91.13	95.37
25	6	20	92.42	96.50
26	7	17	93.94	97.46
27	3	14	94.59	98.25
28	8	11	96.32	98.87
29	4	7	97.19	99.27
30	2	7	97.62	99.66
31	2	2	98.05	99.77
33	3	1	98.70	99.83
34	1	2	98.92	99.94
35	3	0	99.57	99.94
36	1	0	99.78	99.94
37	1	0	100.00	99.94
38	0	1	100.00	100.00

Table 3. Number of red snapper segregated by size measured from the catches of the various fishing sectors.

	Count		Cumulative Percent	
Length (in)	Atlantic	Gulf	Atlantic	Gulf
6	**1**	**0**	**0.06**	**0.00**
7	**1**	**3**	**0.12**	**0.11**
8	**9**	**40**	**0.65**	**1.62**
9	**9**	**119**	**1.18**	**6.09**
10	**51**	**170**	**4.19**	**12.48**
11	**74**	**233**	**8.56**	**21.24**
12	**149**	**526**	**17.36**	**41.02**
13	**183**	**523**	**28.16**	**60.68**
14	**239**	**389**	**42.27**	**75.30**
15	**249**	**269**	**56.97**	**85.41**
16	**206**	130	**69.13**	90.30
17	**171**	84	**79.22**	93.46
18	**166**	70	**89.02**	96.09
19	**70**	46	**93.15**	97.82
20	31	24	94.98	98.72
21	20	12	96.16	99.17
22	23	5	97.52	99.36
23	9	8	98.05	99.66
24	7	4	98.47	99.81
25	2	1	98.58	99.85
26	4	2	98.82	99.92
27	4	1	99.06	99.96
28	3	0	99.23	99.96
29	7	0	99.65	99.96
30	3	1	99.82	100.00
31	1	0	99.88	100.00
32	1	0	99.94	100.00
36	1	0	100.00	100.00

Table 4. Number of vermilion snapper segregated by size measured from the catches of the various fishing sectors.

	Count		Cumulative Percent	
Length (in)	**Atlantic**	**Gulf**	**Atlantic**	**Gulf**
3	**1**	**0**	**0.10**	**0.00**
5	**0**	**1**	**0.10**	**0.13**
6	**10**	**1**	**1.15**	**0.26**
7	**11**	**23**	**2.30**	**3.29**
8	**64**	**64**	**9.00**	**11.71**
9	**152**	**134**	**24.90**	**29.34**
10	378	188	64.44	54.08
11	183	149	83.58	73.68
12	77	119	91.63	89.34
13	48	57	96.65	96.84
14	22	9	98.95	98.03
15	5	5	99.48	98.68
16	3	2	99.79	98.95
17	1	1	99.90	99.08
18	0	1	99.90	99.21
19	1	1	100.00	99.34
21	0	4	100.00	99.87
22	0	1	100.00	100.00

Table 5 summarizes the number of legal and undersized fish caught during the study. It should be noted that these numbers only reflect the catches by participants in this study at the various study locations show in **Figure 2**. Since these data are only a small subset of all the fish captured in the Atlantic and the Gulf of Mexico, they may not reflect the total ratios of legal to undersized fish in the reef fish recreational and recreation-for-hire catches.

Table 5. Percent of Legal and Undersized Fish Caught in the Atlantic and the Gulf of Mexico.

	Atlantic		Gulf	
	% Legal	% Undersized	% Legal	% Undersized
Red Grouper	6	94	4	96
Gag	12	88	12	88
Red Snapper	7	93	15	85
Vermilion Snapper	75	25	71	29

1. **To test the hypothesis that vermilion snapper do not survive release as well as red grouper, gag and red snapper.**

   During the study, 825 vermilion snapper were tagged and released. Of these, only 6 (0.7%) have been recaptured. All recaptures were from vented fish caught at various depths from 41-200 ft. See **Table 6.**

   These shipboard tag return results were in direct contrast to results obtained during the FSU cage studies. Results from the FSU cage studies showed that of the four target species, vermilion snapper were least susceptible to capture/release mortality. Survival at recapture depths of up to 200 ft. was so high as to prevent the development of a relationship between depth and mortality.

   Mote researchers captured live vermilion snapper and brought them back to the laboratory for study. All fish were vented, dipped for parasites and placed in quarantine tanks for observation. During the first few days all fish rested on the bottom of the tank. Within four days after their swimbladders healed, all fish remained in the water column. After a one-month quarantine period, the fish were put on display in the MML Aquarium.

   In all three instances fish were exposed to handling, yet only the tagged fish appear to have low survival rates. However, one important difference is that in both the cage experiments and laboratory observations, predation was not a factor. In the cage studies, captured fish were held for duration of one week. Previous Mote research has shown that reef fish swimbladders heal in less than four days. Thus all vermilion snappers, whose swimbladders had ruptured during capture, would be healed by the end of the holding period. Upon release, these fish would be able to return directly to their normal habitat in the water column.

   Shipboard tagged vermilion snapper with ruptured swimbladders were immediately returned to the sea. Vented fish would be able to avoid surface predators but would be unable to return to their natural habitat. Fish with ruptured swimbladders would be forced to remain on the bottom for a few days, until their swimbladders healed. While on the bottom, they would be subject to bottom predators. Neither the caged nor laboratory held fish were subject to predators.

   In addition, data from the acute mortality portion of this study showed that vermilion snapper suffered no more hook or rapid decompression mortality than red grouper or gag.

   Results from this study support the hypothesis that vermilion snapper do not survive release as well as red grouper, gag and red snapper. However, it appears that this difference in release survival is due to bottom predation, not hook mortality or rapid decompression. Additional research to test the hypothesis that vermilion snapper do not survive release as well as red grouper, gag and red snapper until their swimbladder heals, due to high vulnerability to benthic predators, needs to be conducted.

2. **To test the hypothesis that hook release mortality is far greater than depth induced mortality for red snapper.**

Necropsy results performed at Mote Marine Laboratory on all moribund target species captured during fishing trips by headboat fishers, revealed that the highest mortality occurred in red snapper. More red snapper died from hook mortality than all other causes combined (**Figure 7**). Other causes included depth, stress, handling, etc. The other major source of mortality for red snapper in this study was improperly vented fish by the crews of some of the headboats who attempted to remove the gas from the fish by sticking a diver's knife up the fish's vent.

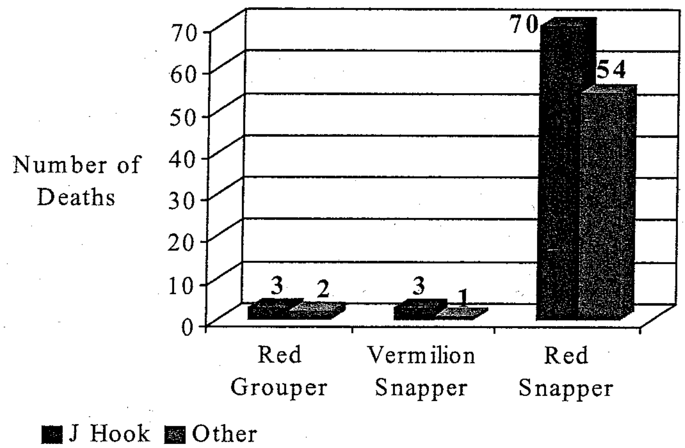

Figure 7. Cause of mortality of target species: J hooks vs. other causes.

Figures 8 and **9** show typical J hook damage of red snapper. Acute J hook mortalities occurred in otherwise healthy, well fed fish. The J hooks penetrated or in some cases, slit the esophagus and then depending on orientation, either macerated the heart or liver. Trauma was so severe that death occurred either as the fish was being landed or a few minutes after landing.

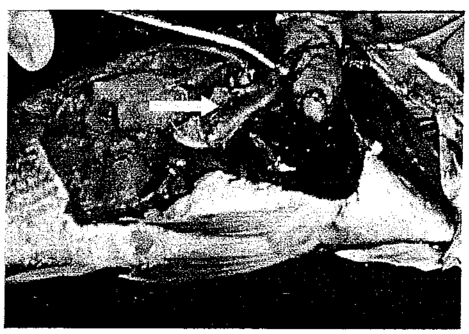

Figure 8. Photo of a healthy, well fed red snapper killed by a J hook.

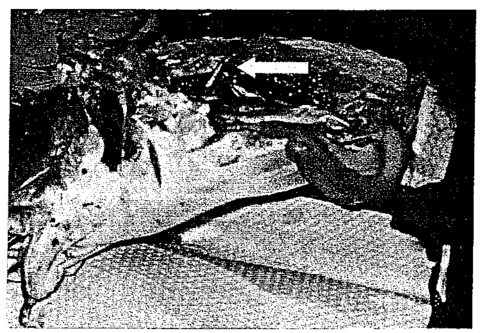

Figure 9. Otherwise healthy red snapper, killed by a J hook.

3. **To obtain catch and release mortality rates by depth and gear for red grouper, gag, red snapper and vermilion snapper.**

<u>Release Mortality</u>

To assess release mortality of the undersized target species, tag returns were used as a measure of survival. Fishers from various sectors of the reef fish fishery tagged and released mostly undersized target species. **Figure 10** shows the percentage of target species tagged by fishers from various sectors of the reef fish fishery. MML staff and student interns tagged fish caught on headboats. The striped section of the pie represents MML effort. The purple section represents efforts by headboat captains and crew. Therefore, the total headboat contribution is the sum of the two sections. **Figure 11** shows the percentage of fish recaptured by the sectors.

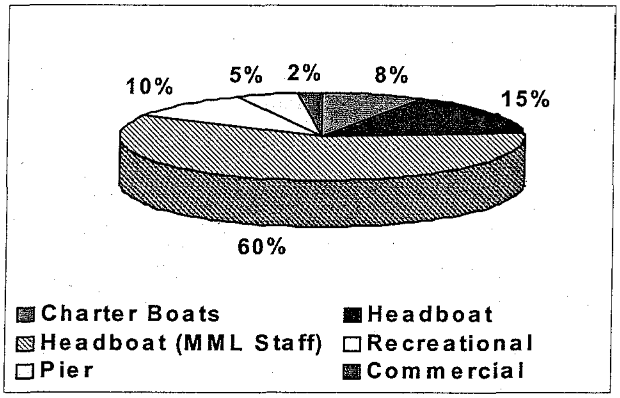

Figure 10. Percentage of fish tagged by fishing category.

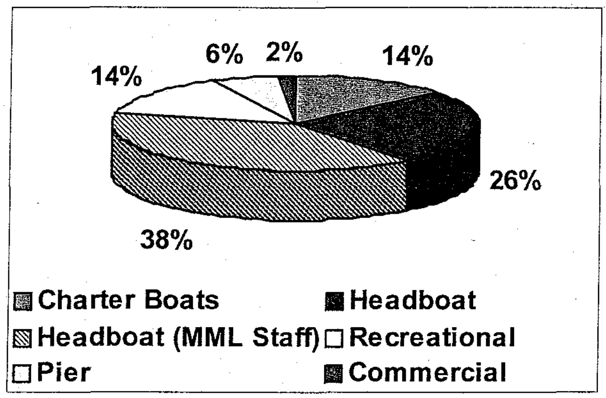

Figure 11. Percentage of reported tag returns by fishing category.

As discussed earlier, return rates for vermilion snapper were negligible. Return rates for the other target species were 3.8% for red grouper, 6.8% for gag, and 6% for red snapper (**Table 6**).

Table 6. Target Fish Tagged/Returned: 10/01/98 through 12/31/01.

Species	Number Tagged	Number Returned	Return Rate
Red Grouper	5058	194	3.8 %
Gag	1755	119	6.8 %
Red Snapper	3467	208	6.0 %
Vermilion Snapper	825	6	.7 %

In addition to single returns, some fish were recaptured multiple times. Fish were recaptured from 2 to 7 times during the study (**Figures 12, 13,** and **14**).

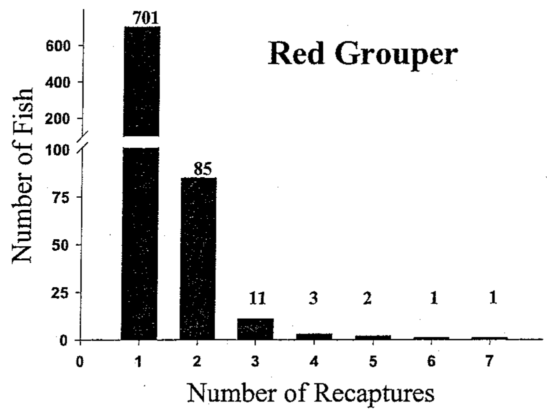

Figure 12. Multiple recaptures of red grouper.

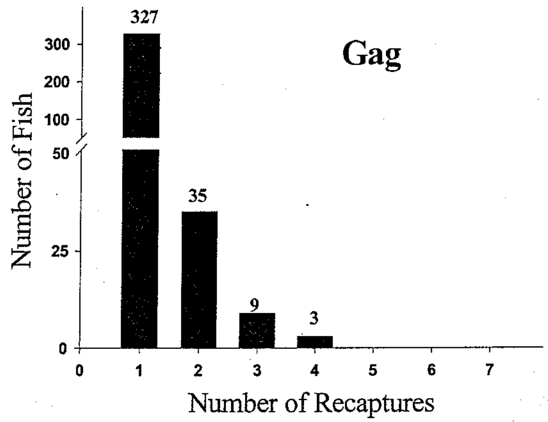

Figure 13. Multiple recaptures of gag.

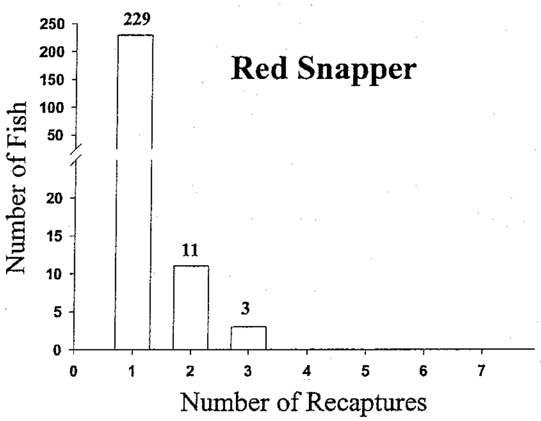

Figure 14. Multiple recaptures of red snapper.

Hook Mortality

It was very difficult getting fishers to use any hook other than J hooks, even when, Mote provided various sizes of kahle and circle hooks for free. After much publicity in the newsletter, various articles in fishing magazines, and two circle hook contests, fishers began to try the kahle and circle hooks. No data on kahle hooks are presented. Fishers disliked them so much, they refused to use them, stating that the kahle hooks caused more injury to fish than J hooks and that they were much more difficult to remove than circle hooks.

The first fish caught, tagged, and released using circle hooks were on 02/10/2000 (red grouper), 02/17/2000 (gag) and 03/28/2000 (red snapper). Due to the small number of returns reported, data should be considered preliminary. Data comparing percent returns have been divided between fish caught in the Atlantic Ocean and the Gulf of Mexico. Comparisons of returns by hook type are from the same time period. Unfortunately, there is a great disparity in the number of fish tagged, which were captured on circle hooks versus those caught on J hooks. Too few fish were tagged in the Atlantic for comparison. See **Table 7**. However, the proportion returned that were caught with circle hooks was significant for red grouper and was significant overall (**Table 7**).

Table 7. Comparison of the Number of Tagged and Recaptured Fish by Hook Type and Area.

	Number Tagged/Returned						Statistical Sign	
	Atlantic		Gulf of Mexico		Total			
Species	**Circle**	**J**	**Circle**	**J**	**Circle**	**J**	**Return**	**P**
Red Grouper	4 / 1	44 / 7	185 / 10	3712/96	189/11	3756/102	Circ>J	< .01
Gag	5 / 0	194 / 23	159 / 4	771 / 34	164/4	965/57	J>Circ	NS
Red Snapper	9 / 0	608 / 67	416 / 28	626 / 9	425/28	1234/76	Circ>J	NS
Total	778	43	0.05527	5955	235	0.039463	Circ>J	< .05

Although far from ideal, a sufficient number of fish per species were tagged in the Gulf of Mexico, to compare tag returns from both hook types. Based on recaptures, more circle hooked red grouper and red snapper survived, however, with so few returns, results should be considered preliminary (**Figures 15, 16,** and **17**).

This research is being continued as part of another MML study funded by MARFIN (Award # NA9700FF0349). Updates based on new data collected will be published in MML's MARFIN funded RFSS, Reef Fish Survival Studies newsletter.

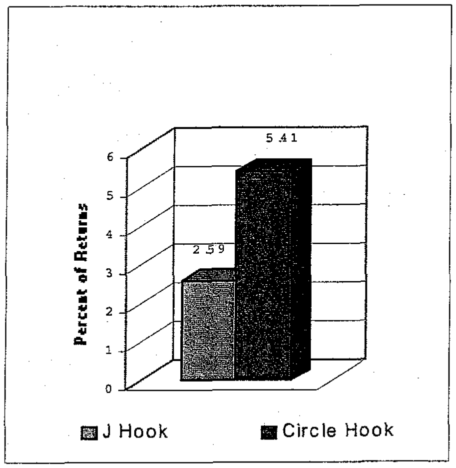

Figure 15. Comparison of tag returns for gag originally caught on J versus circle hook.

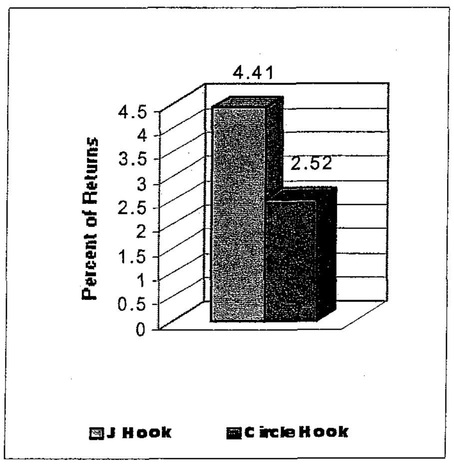

Figure 16. Comparison of tag returns for red snapper originally caught on J versus circle hook.

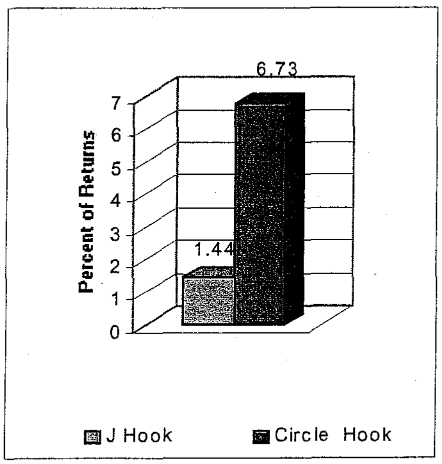

Figure 17. Comparison of tag returns for red grouper originally caught on J versus circle hook.

Although data should be considered preliminary, they show that red grouper and as expected, red snapper benefitted from the use of circle hooks. Once sample sizes increase and become more comparable, results may change for gag.

Depth Mortality

Table 8 shows the number of target species tagged and recaptured by depth category for vented and non-vented fish for the duration of the study. It should be noted that data for the treated (vented) and untreated (not vented) categories are not equal. The reason for this is that much of the data were contributed by fishers, who fished at various depths and decided to vent or not vent their fish. The premise for including fishers in this research is that although scientists might know more about fish physiology and therefore be sure to vent the fish properly, scientists comprise a very small fraction of the user groups. It therefore was more realistic teach the user groups, the proper location to vent and record the results. Unfortunately, due to uneven sample sizes, it makes statistical analyses more difficult.

Two additional reef fish species were added to these analyses, which were not part of the study. The purpose was to show that current data support the result that venting benefits are variable depending on the species. Additional data are being collected and will be presented in the RFSS newsletter supported by MARFIN award NA9700FF0349.

Table 8. Comparison of Recapture Rates for Fish Vented vs. Non-Vented at Various Depths From October 1998 through December 2001.

RED GROUPER	TAGGED VENTED	NOT VENTED	RECAPTURED VENTED	NOT VENTED	RELATIONSHIP	P
0-40 FT	161	216	15	14	Vented > not vented	NS
41-70 FT	2692	1337	67	64	Not vented > vented	< 0.0001
71-100 FT	461	88	18	9	Not vented > vented	< 0.01
101-200 FT	147	32	7	3	Not vented > vented	NS
200 + FT	3	2	0	0	NA	NS
TOTAL	3464	1675	107	90	Not vented > vented	< 0.0001
GAG	**TAGGED**	**NOT**	**RECAPTURED**	**NOT**	**RELATIONSHIP**	**P**
0-40 FT	95	510	3	20	Not vented > vented	NS
41-70 FT	361	512	35	35	Vented > not vented	NS
71-100 FT	157	106	12	14	Not vented > vented	NS
101-200 FT	23	9	3	1	Vented > not vented	NS
200 + FT	1	0	0	0	NA	NS
TOTAL	637	1137	53	70	Vented > not vented	NS

RED SNAPPER	TAGGED VENTED	NOT VENTED	RECAPTURED VENTED	NOT VENTED	RELATIONSHIP	P
0-40 FT	1	5	0	0	NA	NS
41-70 FT	858	98	73	10	Not vented > vented	NS
71-100 FT	1544	243	83	14	Not vented > vented	NS
101-200 FT	723	42	35	2	Vented > not vented	NS
200 + FT	1	0	0	0	NA	NS
Total	3127	388	191	26	Not vent> vent	NS
VERMILION SNAPPER	**TAGGED VENTED**	**NOT VENTED**	**RECAPTURED VENTED**	**NOT VENTED**	**RELATIONSHIP**	**P**
0-40 FT	0	0	0	0	NA	NS
41-70 FT	169	20	1	0	NA	NS
71-100 FT	478	72	3	0	NA	NS
101-200 FT	78	11	2	0	NA	NS
200 + FT	1	0	0	0	NA	NS
Total	762	103	6	0	NA	NS
MANGROVE SNAPPER	**TAGGED VENTED**	**NOT VENTED**	**RECAPTURED VENTED**	**NOT VENTED**	**RELATIONSHIP**	**P**
0-40 FT	732	288	44	8	Vented > not vented	< 0.05
41-70 FT	4	2	0	0	NA	NS
71-100 FT	3	1	0	0	NA	NS
101-200 FT	1	0	0	0	NA	NS
200 + FT	0	0	0	0	NA	NS
Total	740	291	44	8	Vented > not vented	< 0.05
MUTTON SNAPPER	**TAGGED VENTED**	**NOT VENTED**	**RECAPTURED VENTED**	**NOT VENTED**	**RELATIONSHIP**	**P**
0-40 FT	4	1	2	0	NA	NS
41-70 FT	2	1	1	0	NA	NS
71-100 FT	2	0	0	0	NA	NS
101-200 FT	4	1	0	0	NA	NS
200 + FT	0	0	0	0	NA	NS
Total	12	3	3	0	NA	NS

For comparison, tables showing the recaptures of treated (vented) and untreated (not vented) fish from MML's Reef Fish Tagging Program are presented.

Table 9. Comparison of Recapture Rates for Fish Vented vs. Non-Vented at Various Depths From 1990 through February 2002.

RED GROUPER	TAGGED VENTED	NOT VENTED	RECAPTURED VENTED	NOT VENTED	RELATIONSHIP	P
0-40 FT	229	608	35	111	Not vented > vented	NS
41-70 FT	3761	3035	175	244	Vented > not vented	<0.0001
71-100 FT	1056	761	105	101	Vented > not vented	NS
101-200 FT	696	101	63	12	Not vented > vented	NS
200 + FT	42	5	2	0	NA	NS
Total	5784	3756	380	468	Not vented > vented	< 0.0001
GAG	**TAGGED**	**NOT**	**RECAPTURED**	**NOT**	**RELATIONSHIP**	**P**
0-40 FT	154	1195	9	6	Vented > not vented	< 0.0001
41-70 FT	866	1235	92	115	Vented > not vented	NS
71-100 FT	396	304	51	38	Vented > not vented	NS
101-200 FT	95	30	14	5	Not vented > vented	NS
200 + FT	21	7	0	0	NA	NS
Total	1532	2771	166	164	Vented > not vented	< 0.0001
RED SNAPPER	**TAGGED VENTED**	**NOT VENTED**	**RECAPTURED VENTED**	**NOT VENTED**	**RELATIONSHIP**	**P**
0-40 FT	1	5	0	0	NA	NS
41-70 FT	394	112	76	13	Vented > not vented	NS
71-100 FT	1617	304	87	29	Not vented > vented	< 0.01
101-200 FT	6785	86	40	8	Not vented > vented	< 0.0001
200 + FT	6	2	0	0	NA	NS
Total	8803	509	203	50	Not vented > vented	<0.0001
VERMILION SNAPPER	**TAGGED VENTED**	**NOT VENTED**	**RECAPTURED VENTED**	**NOT VENTED**	**RELATIONSHIP**	**P**
0-40 FT	0	0	0	0	NA	NS
41-70 FT	170	20	1	0	NA	NS
71-100 FT	490	77	3	0	NA	NS
101-200 FT	88	20	2	0	NA	NS
200 + FT	1	0	0	0	NA	NS
Total	749	117	6	0	NA	NS

MANGROVE SNAPPER	TAGGED VENTED	NOT VENTED	RECAPTURED VENTED	NOT VENTED	RELATIONSHIP	P
0-40 FT	732	288	44	8	Vented > not vented	< 0.05
41-70 FT	4	2	0	0	NA	NS
71-100 FT	3	1	0	0	NA	NS
101-200 FT	1	0	0	0	NA	NS
200 + FT	0	0	0	0	NA	NS
Total	740	291	44	8	Vented > not vented	< 0.05
MUTTON SNAPPER	**TAGGED VENTED**	**NOT VENTED**	**RECAPTURED VENTED**	**NOT VENTED**	**RELATIONSHIP**	**P**
0-40 FT	4	1	2	0	NA	NS
41-70 FT	2	1	1	0	NA	NS
71-100 FT	2	0	0	0	NA	NS
101-200 FT	4	1	0	0	NA	NS
200 + FT	0	0	0	0	NA	NS
Total	12	3	3	0	NA	NS

The statistical comparison of return rates from vented versus unvented fish shows species-specific differences. Both red grouper and red snapper showed a statistically significant higher return rate if the fish were unvented. This was even true for red snapper caught in relatively deep water (70 – 200 ft.). However, gag and mangrove snapper showed just the opposite response to venting, significantly higher return rates were observed from vented fish, but all the significant differences were observed in fish captured from shallow water. There were not enough data to evaluate vermilion snapper and mutton snapper.

Figure 18 is a graphic presentation of the data of returned fish by depth for the target species. The first column represents the data collected during the study. The second column is data collected from October 31, 1990 – December 31, 2001.

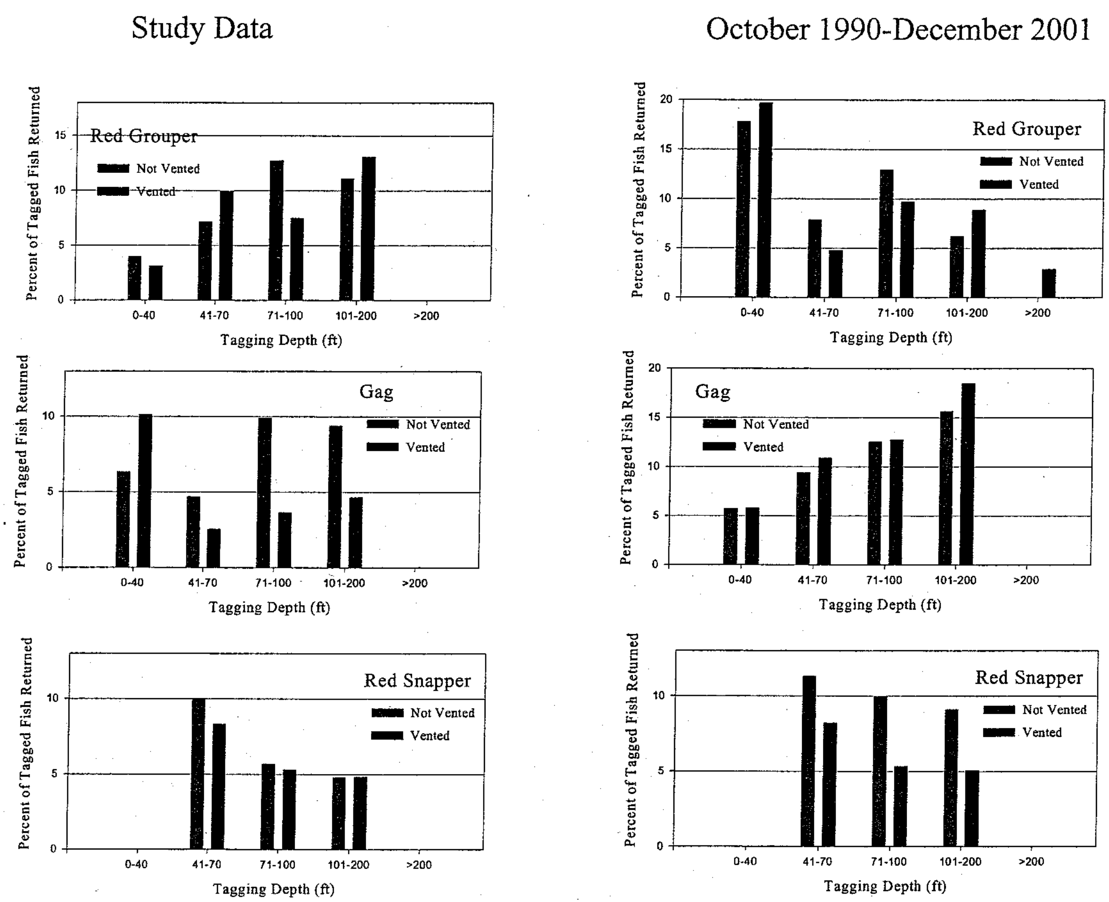

Figure 18. Percent of returns of target species by depth for not vented and vented fish.

4. **Systematic evaluation of depth-related capture-release mortality and sublethal effects for red grouper, gag, red snapper, and vermilion snapper.**

<u>Background</u>

Several experimental studies have shown that capture-release mortality of undersize reef fish increases with depth of capture (e.g., Wilson and Burns 1996, Gitschlag and Renaud 1994). Fish with enclosed swimbladders experience swimbladder rupture and possibly hemorrhage when hauled from high ambient pressure environments (deep water) to low ambient pressure environments (the surface).

Both tag-recapture studies and caging experiments may produce biased results in the estimation of depth-related release mortality. For unbiased estimates, the probability of recapture of released fish should be equal (i.e., equal catchability or random selection among tagged fish) and there should be no bias in tag reporting. Unequal catchability results if (1) fish have an increased or decreased susceptibility to recapture that varies over the capture area, (2) released fish have unequal opportunity to be recaptured (e.g., fishers fish less frequently in areas where the preponderance of fish are undersize or the fish move to relatively unfished or heavily fished places after release.) Unequal catchability would result in biased estimates of survival. Unfortunately, the assumption of equal catchability cannot be tested for single-time tag-recapture data.

A bias may also result from the caging experiments because the cage environment produces artifacts that would not be present in the natural environment. Such artifacts may either increase or decrease rates of mortality. If confinement in cages is stressful to the fish, increased rates of depth-specific mortality may result. On the other hand, if the cages protect the fish from predators during their recovery period, an increase in survival would result. The cages would also force gas-bloated fish back to the bottom whereas they might otherwise die at the surface. The goal of the combined tag-recapture study and the caging study was to gain as unbiased a view as possible of the effects of depth of capture on release mortality. Thus, we combine the results of both methods in an attempt to gain a more reliable view of capture depth-related mortality.

In addition to the factors mentioned above that would produce biased estimates of depth-specific capture-release mortality, there are factors related to fish condition and handling that could modify the observed depth-specific mortality. For a particular species these factors include capture methods (e.g., hook type and fishing gear), handling of the fish prior to release (e.g., venting, time on deck, hook removal method, etc.), condition of the fish upon capture (e.g., fighting time, size, damage due to impacts with the bottom, etc.), pelagic or benthic predators in the release environment, and various environmental factors (e.g., thermoclines, haloclines, variations in dissolved oxygen, etc.). Also, the swimbladder may be inflated to varying degrees in fish of the same species in the same region, depending on their recent history (e.g., feeding high in the water column relative to feeding on the bottom.) Because the degree of swimbladder inflation (or pressure relative to the surface pressure) is the single most important factor in defining impacts on the fish, rates of mortality could be strongly modified by variation in swimbladder inflation.

The goal of the overall project is to gain accurate estimates of the impact of depth-specific capture on red grouper, red snapper, gag, and vermilion snapper. The objectives of this caging study are: (1) to quantitatively determine the relationship between depth of capture and release mortality in gag, red grouper, red snapper, and vermilion snapper, (2) to identify and quantify the most important modifying factors to depth-related capture-release mortality.

Materials and Methods

Locations -

All depth-related capture-release mortality studies were done south of Apalachicola and Caribelle Florida in the northeastern Gulf of Mexico.

Sampling Times -

All capture-release experiments were performed from 1999 through 2001. Tests were done in April and May (N = 445) and July and August (N = 146). Most summer experiments resulted in lost data because sharks, which are plentiful off Apalachicola in the summer, damaged most of the cages and ruined the experiments. Experiments could not be run in the winter because of the poor and variable weather conditions at that time in north Florida. Most of the information is therefore derived from sampling that was done in April and May.

Methods -

We chartered commercial fishing vessels for most of the experiments but also chartered a larger vessel, the private research vessel REEF I, when commercial vessels were not available. However, in all cases the fish were caught by commercial fishermen using standard commercial gear (electric reels) with circle hooks. They selected the sites within the specified depth range and did virtually all of the fishing. We selected relatively small (< 50 cm) red snapper, red grouper, gag and vermilion snapper from the catch for our experiments. Of a total of 591 fish caught, 108 had to be excluded from the study because of lost cages, shark attacks on cages, and gill and gut hooking (exclusively caused by J hooks, which were abandoned early in the study). Also, 100 vermilion snapper were excluded from the study because we were too shallow to observe depth-related mortality.

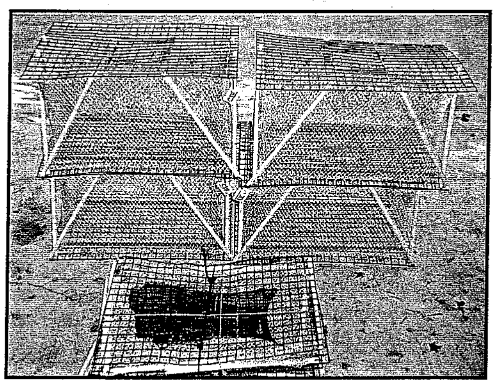

Figure 19. Collapsible cages used in caging experiments; the four cages in the background collapse to the size of the four in the foreground.

Upon capture fish were measured, examined for overt signs of capture-related abnormalities, put into numbered cages, and lowered to the bottom. The experimental fish in cages were left on the bottom at the capture site from 5 to 8 days then retrieved and evaluated for mortality and condition. The number of fish per cage varied from 1 to 6, depending on the abundance of the catch. Electric reels were used on all but one trip, but the ascent rate (time from hook-up to the surface) was recorded at least several times during each trip and varied from about 1 to 2 m/sec.

Collapsible cages (92 cm length x 61 cm width x 46 cm high [3 ft x 2 ft x 1.5 ft]) were designed and built so that we could carry about 50 on board commercial vessels (**Figure 19**). In the collapsed position, the cages were 92 cm x 61 cm x 4.5 cm. Thus, ten collapsed cages occupied the same space occupied by one erected cage. Cage tops and bottoms were constructed of heavy gage plastic coated wire with 2-inch square mesh; sides were composed of ¾ inch mesh nylon shrimp netting. Slotted ½ inch PVC pipes were used for supports, and the bottoms were weighted with 90 cm lengths of ½ inch rebar.

Early in the study we found that fish were gut and gill hooked much more frequently with standard hooks than with circle hooks, so we used only circle hooks for the rest of the study which eliminated the problem. We excluded all gut and gill hooked fish from the study because chances of their survival were often near zero regardless of the depth of capture.

When fish were captured they were immediately measured and examined for aberrations (symptoms of internal gas expansion) such as everted stomachs, everted intestines, and protruding eyes, and then put into floating cages. On several occasions we temporarily placed the fish into tanks with flowing seawater until we could deploy the cages. Thus, depending on conditions such as capture rate and sea state the fish would remain at the surface in flowing seawater for variable lengths of time until we could return them to the bottom. Surface interval varied depending on the conditions of capture (mean = 7.2 min, SE = 0.41 min, range = 1 – 45 min).

To control for the experimental conditions of caging we captured fish at 20 m (two sites at 18 and 23 m deep) and returned them to the bottom in cages within 33 minutes of capture (surface interval (min): mean = 8.7, SE = 2.0, range = 2 – 33). We then periodically checked their condition on the bottom using SCUBA gear at 1 day, 7 days, and 13 days. At control depths we captured 14 gag, 4 red grouper, 4 red snapper, but no vermilion snapper. The number of fish per cage varied from 1 to 5 (5 cages with single fish, 4 cages with 4 fish each, and 1 cage with 5 fish.) Twenty meters was assumed to be a non-lethal depth and there were no capture-related aberrations (everted stomach or intestine, or protruding eyes) in the control fish.

We estimated that an experimental caging duration of 1 week (5 to 8 days, depending on sea conditions) was optimum because of several observations.

2. We determined that reef fish could tolerate at least twice this time in the cages without any overt signs of stress.

3. Other studies (e.g., Gitschlag and Renaud 1994) have shown that although most of the mortality takes place in the first 24 hours, it doesn't plateau until several days later.

4. Standard bioassay protocols (e.g., Hewlett and Plackett 1979) call for 4 day exposures or 4 day response times to reach incipient lethal levels (time limit beyond which no significant mortality occurs). For these reasons we believe that 1-week exposure times are the most efficient in evaluating depth-related release mortality.

5. The capture depth at which swimbladder rupture occurs was determined by examining the swimbladder of captured fish. Rate of healing of ruptured swimbladders was estimated by examining surviving fish after retrieval of cages. We also examined healing rate of the stomach after puncturing the everted stomach as it protruded from the mouth, an often-used method by commercial fishermen to vent the fish.

Data Analysis

The appropriate statistical regression model for bivariate dependent variables (such as percent mortality) is logit or probit analysis. Both types of analyses give very similar results (Hewlett and Plackett 1979) so the mathematically simpler of the two, logit analysis, was chosen for the statistical evaluation of all bivariate data.

In the caging experiments the proportion surviving at the various test depths was used directly in the analysis of depth-related mortality, however, it was necessary to estimate mortality from the proportion recaptured in the tag-recapture studies. The relationship between capture depth and mortality was estimated in the tag-recapture data by assuming that mortality was zero at capture depths shallower than 20 m. (This assumption was based on our control experiment, **Table 10**).

Mortality was estimated directly from the data by first estimating the probability of surviving at the various depths (i.e., p recaptured/p max), then subtracting that probability from 1 to get probability of dying at the various depths. That probability was then multiplied by the total number captured at each depth to get an estimate of numbers dying at each depth interval (depth intervals were 10 m; midpoints were plotted). Capture- depth interval is the independent variable, with the probability of dying at those depths the dependent variable (labeled % mortality). The total number caught at each depth interval was the weighting factor in the logit regression. The 95% and/or 99% confidence intervals were also calculated, plotted, and tabulated.

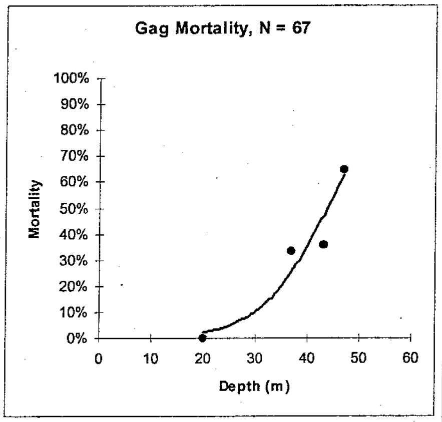

Figure 20 . A logit regression of mortality at depth of capture for gag grouper.

Results

Controls - All control fish survived and were in good condition upon retrieval (**Table 10**).

Table 10. Experimental control conditions.

Species	Depth of capture (m)	N	Time in cage	Condition
Gag	30	14	13 days	excellent
Red snapper	20	4	13 days	excellent
Red snapper	20	4	7 days	excellent

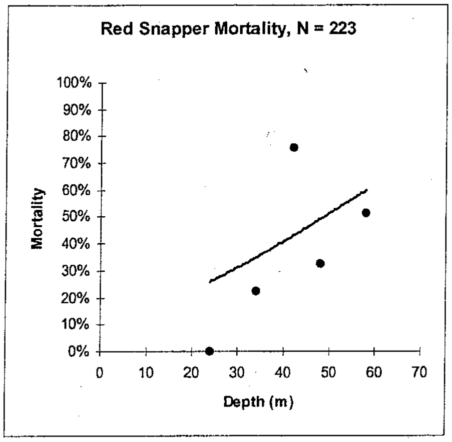

Figure 21. A logit regression of mortality at depth of capture for red snapper caging studies.

Mortality (Caging Studies) - Capture-release mortality was strongly related to depth of capture in gag and red snapper, but not so strongly related in red grouper or vermilion snapper, at least within the depth ranges observed (20 to 60 m). At depths of 50 – 100 m we had difficulty finding small fish for our tests because there is a positive relationship between depth and size in all four species tested. **Figures 20** and **21** show the depth-mortality relationship for gag and red snapper, respectively. The LD50 (capture depth at which 50% die) is the best single indicator of effect of depth of capture or any other dose-like effect because variability is least at the 50 % response point.

The LD50 for gag was 43.7 m, and the LD50 for red snapper was 48.6 m, but the two estimates are not significantly different. The variation about these estimates is very high because of intrinsic variation due to multiple factors effecting mortality and also because the sample sizes were relatively small. An LD50 could not be calculated for either red grouper or vermilion snapper because a clear depth-related pattern of mortality was not observed (**Figure 22**). Red grouper mortality increased to about 15 % mortality at 35 m capture depth and remained at that level out to 55 m. Vermilion snapper showed a similar low response.

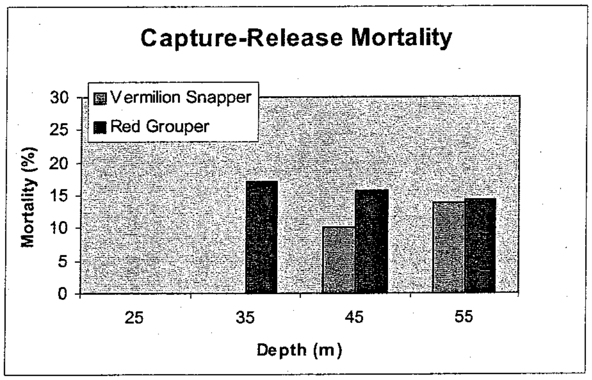

Figure 22. Logit regression of depth of capture mortality for vermilion snapper (N=94) and red grouper (N=71).

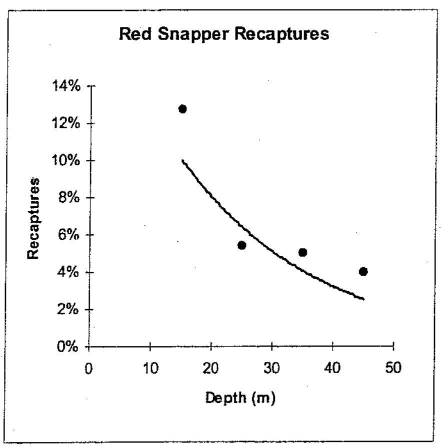

Figure 23. Red snapper recaptures relative to depth of capture.

Mortality (estimates from tag-recapture studies) - Our recaptures were variably related to depth in all species except red snapper. Gag and red grouper showed a positive percent recapture with depth up to 40 m. However there was a clear decrease in recaptures with depth in red snapper (**Figure 23**).

Mortality (tag-recapture studies and caging studies combined) - The caging studies indicate that the LD50 for red snapper and gag is between 40 to 50 m. The aberration incidence EC50 (depth at which 50% are effected; see below) is also close to this depth interval. Our original intent was to combine the caging data with the tag-recapture data to provide the 'best' estimate of depth-related capture-release.

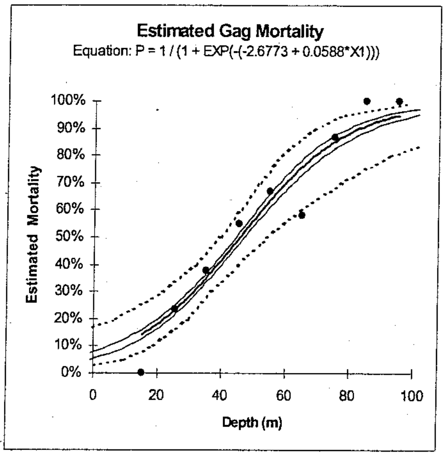

Figure 24. Logit regression of gag depth-related mortality estimated from tag-recapture data from McGovern et al. (in press).

mortality. However, because all of our estimates of mortality are from captures shallower than 60 m, which is just above the LD50, we need a model to anchor our estimates at greater depths. A data set from McGovern et al. (in press) provides such a model for comparison of our mortality data. In that paper commercial fishers in the south Atlantic region captured, tagged, and released 3,876 gag from depths of 10 to 95 m over a 5 year period (1995 to 1999). These fish were of all sizes, ranging from 230 to 1190 mm TL. With the assumption that no mortality occurs at depths shallower than 20 m, the estimated capture-related morality from McGovern et al. (in press) is presented in **Figure 24**. The LD50 of this data set is 45.5 m with 99% confidence limits of 39.6 m to 54.3 m. This LD50) is very close to the value derived from the gag caging study, 43.7 m.

Figure 25 shows our caging and tag-recapture results for gag only pooled with the McGovern et al. data set and recalculated with the logit model. The LD50 for this data set is 47.2 m with 99% confidence limits of 40.7 m and 59.2 m. Red snapper depth-related mortality was not significantly different from that of gag, so it was pooled with the gag data set and recalculated to yield **Figure 26**. The LD50 of the combined gag and red snapper data is 40.4 m with 99% confidence limits of 32.8 m and 61.4 m. The concordance between these various data sets lends support to the contention that the LD50 for gag and red snapper lies between 40 and 50 m. **Tables 11, 12,** and **13** tabulate the probabilities of mortality at the various depths corresponding to **Figures 24, 25,** and **26,** respectively.

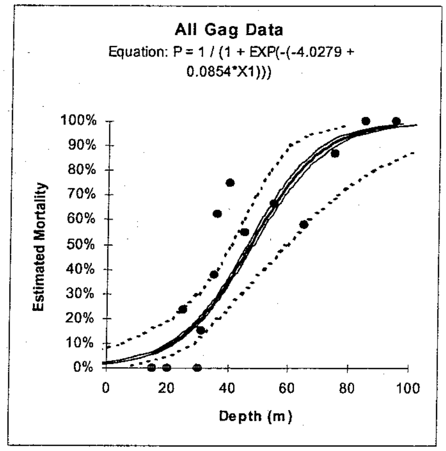

Figure 25. Gag capture-depth-related mortality estimated from tag-recapture data from McGovern et al. (in press) and tag-recapture and caging studies in this report.

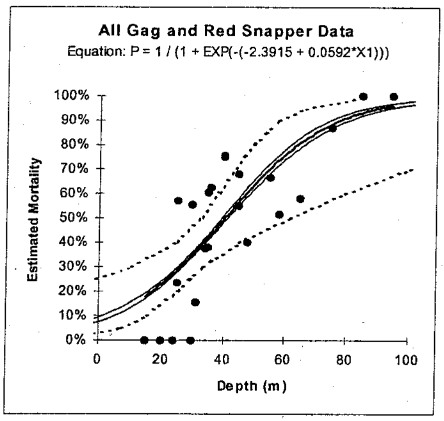

Figure 26. Capture-depth-related mortality for gag and red snapper combined. Data from McGovern et al. (in press) and tag-recapture and caging experiments from this report.

Aberrations - We found that swimbladders of gag, red snapper and red grouper would rupture at between 30 and 40 m depth of capture. The rupture would release swimbladder gas into the body cavity and would often cause eversion of the stomach, eyes, and/or intestines. Capture depth-related aberrations showed a clear increase with depth for red snapper (**Figure 27**), red grouper (**Figure 28**), and

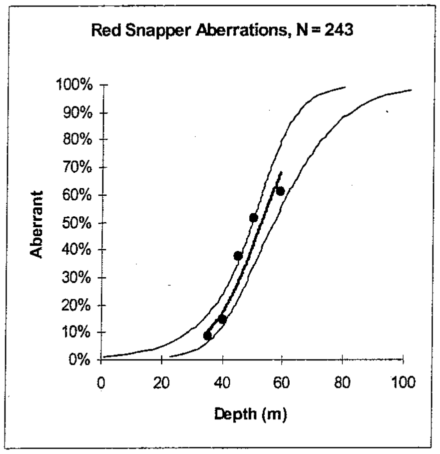

Figure 27. Capture depth-related increase in aberrations in red snapper. Curvilinear lines define 95% confidence intervals.

gag (**Figure 29**), but aberrations were rarely observed in vermilion snapper in capture depths up to 65 m (1 aberration observed in 85 fish captured from 40 to 65 m). Variation in the expression of aberrations was much less that of mortality. The aberration ED50s (capture depth at which 50% of the fish showed aberrations) for red snapper was 52.8 m with 95% confidence limits of 49.9 m and 56.9 m (N = 243). The ED50 for red grouper was 45.5 m with 95% confidence limits of 39.8 m and 54.9 m (N = 67). The ED50 for gag was 47.0 m (N = 59).

Modifying factors - Characteristics of the fish or experimental conditions that have a significant effect on the relationship between depth of capture and mortality are called modifying factors.

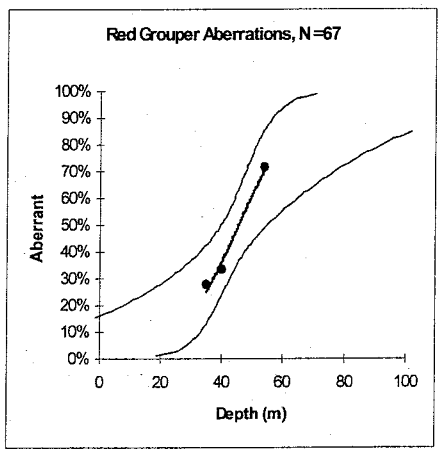

Figure 28. Capture depth-related increase in aberrations in red grouper. Curvilinear lines define 95% confidence intervals.

Modifying factors thought to be most important are: fish size, cage density (number of fish per cage), surface interval (time at the surface in flowing seawater), and ascent rate (speed with which the fish is hauled to the surface [m/sec]).

The relationship between size and mortality for red grouper and red snapper caught at 40 m and 35 m showed a slight positive relationship, suggesting that, all else being equal, larger fish are more susceptible to capture-release than smaller fish. However the relationship for each species is not significant ($P > 0.05$).

At 35 m capture depth the relationship between mortality and the number of fish per cage (cage density) is not significant. However, at 40 m capture depth, the relationship is significant. And there was a significant relationship between surface interval and mortality at 40 m depth of capture. Ascent rate within the experimental limits showed no relationship to mortality.

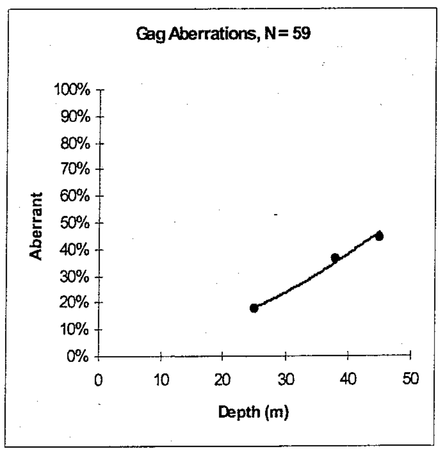

Figure 29. Capture depth-related increase in aberrations in gag. Curvilinear lines define 95% confidence intervals.

Discussion

Mortality and Aberrations -

The relationship between depth of capture and release mortality is clear for red snapper and gag, but not clear for red grouper and vermilion snapper. Similar depth-related mortality has been shown for red snapper by other researchers. For example, Gitschlag and Renaud (1994) showed a surface release survival of red snapper to be about 56 % at depths of 37 to 40 m, but they stated that these estimates should be thought of as "maximum survival rates" because all fish observed actively swimming down were recorded as survivors. Additionally, they observed survival of about 60% at 50 m capture depth, which is very similar to the overall model of depth-related mortality in which the LD50 lies between 40 and 50 m. Their observations of a 51% aberration incidence at 50 m capture depth is also very close to our observations of 52.8 m ED50 (i.e., 50% aberration incidence at 52.8 m). Therefore, we feel confident that our results are comparable to published studies.

The incidence of aberrations showed a similar, but less variable response than mortality in all fishes tested except vermilion snapper. In that species we saw virtually no aberrations. One of us (CCK) has observed vermilion snapper directly on the reef. They often school over the reef rather than on the bottom like demersal species. They are, therefore, not like the other three species we tested. They are also smaller. The data suggests that they are relatively insensitive to depth-related effects, at least over the range of depths we worked in. Future studies should evaluate their capture-depth mortality in depths greater than 50 m.

Our capture depth-related mortality of red grouper was also similar to that of Wilson and Burns (1996). They observed a 91% survival rate at 44 m capture depth when fish were returned to the capture depths for several days in cages. We found that red grouper mortality was about 15% at 46 m (**Figure 28**). However, we carried out experiments on red grouper to 55 m and saw no increase in mortality. If red grouper responded similarly to gag and red snapper in capture depth mortality, we should have observed an increase in mortality at 55 m. All gag died in Wilson and Burns' experiment, but capture depths were greater than 50 m. The LD50 in the gag model we developed was 47.2 m (**Figure 29**).

We used the gag tag-recapture data of McGovern et al. (in press) to provide a model for the comparison of our tag-recapture and caging studies. Their data set is unique in that it provides estimates of mortality from zero to 100%. Our difficulty was in capturing enough small fish in deep water (50 – 100 m) to provide estimates at the upper end of the capture-depth-mortality curve to assemble the total relationship between capture depth and mortality. We believe that the model presented in **Figure 26**, which was developed from our pooled data, is reasonable for both gag and red snapper. We chose not to include red grouper and vermilion snapper in this model because their response to capture was quantitatively different. The response of these two species to capture and release should be studied further in depths of 50 to 100 m.

Modifying Factors -

Surface Interval - A significant finding in our study is the direct relationship between depth-related mortality and surface interval. In our control experiment where the depth of capture was about 20 m, all fish survived regardless of the variable surface interval (**Table 10**). But at 40 m depth of capture mortality ranged from 20% for a 3 minute surface interval to 100% for an 18 minute surface interval. Thus, time at the surface is strongly related to mortality at greater capture depths, even though the fish are held in flowing seawater. Although the mechanism for the increased mortality is unknown, it is possible that the high intra-body pressure relative to ambient is an important factor in the relationship between surface interval and mortality. It is possible that the internal pressure affects circulation. If the venous system and the sinus venosus of the heart are collapsed from the higher internal pressure, blood would be restricted from returning to the heart and circulation would decrease. If such a mechanism operates, then even good gill ventilation would be inadequate to deliver sufficient oxygen to the tissues because circulation is inhibited, and the fish would essentially suffocate. These data suggest that the quicker the fish are released and return to the bottom, the better are their chances of survival. Future studies of capture depth-related mortality should evaluate this phenomenon further.

Ascent rate - There was no clear relationship between ascent rate and mortality at 40 m capture depth. However, we did not evaluate a wide range of ascent rates and used electric reels almost exclusively. Some authors (e.g., Gitschlag and Renaud 1994) suggest that ascent rates have a significant influence on depth-related capture-release mortality. However, we know of no experiments that explicitly test that idea. As discussed earlier, the main effect on fish hauled to the surface is the expansion of swimbladder gas. This is a problem in fish with a physoclistis swimbladder (no connection with the outside), such as those used in this study. Some fish species such as the salmonids have a physostomous swimbladder (connection with the mouth via the esophagus), and the gas in these fish can be released through control of a sphincter. Physoclistous fish, when hauled to the surface, experience an embolism, not the bends like divers experience if they are forced to the surface without adequate decompression. The physoclistous fish must re-dissolve the gas back into the blood and expel it at the gills (or use it at the tissues since most of it is oxygen). This is a very slow process, taking on the order of hours. Physostomous fish, on the other hand, can be hauled to the surface from depths as great as 50 m and exhibit no capture-depth-related mortality (Loftus *et al.*, 1988). Because of the slow rate of gas reduction in physoclistis fish, it is doubtful that ascent rates with standard hook and line gear would affect capture depth survival rates, and clearly, no fisher is willing to wait hours for a physoclistis fish to reduce the gas in its swimbladder before bringing it to the surface.

Table 11. Logit regression of gag tag-recapture data from McGovern et al. (in press).
Model equation: P = 1 / (1 + EXP(-(-2.6773 + 0.0588*X1)))

Probability	Depth (X1)	Lower 99%	Upper 99%
0.01	-32.6036	-86.8774	-10.5236
0.05	-4.5413	-38.1708	9.4795
0.10	8.1617	-16.3153	18.7270
0.20	21.9479	6.9313	29.2355
0.30	31.1111	21.5093	37.0933
0.40	38.6224	31.9457	45.0482
0.50	**45.5155**	**39.5978**	**54.2736**
0.60	52.4086	45.8425	64.9065
0.70	59.9199	51.8858	77.2546
0.80	69.0831	58.8094	92.7667
0.90	**82.8693**	**68.8585**	**116.4727**
0.95	95.5723	77.9554	138.4787
0.99	123.6346	97.8420	187.3020

Table 12. Logit regression of McGovern et al. data and
Tag-recapture and caging data on gag from this report.
Model equation: P = 1 / (1 + EXP(-(-4.0279 + 0.0854*X1)))

Probability	Depth (X1)	Lower 99%	Upper 99%
0.01	-6.6415	-45.2474	8.1188
0.05	12.6864	-9.9285	22.0172
0.10	21.4356	5.6176	28.7503
0.20	30.9308	21.3776	37.1693
0.30	37.2419	30.2686	44.3492
0.40	42.4154	36.1655	51.6262
0.50	**47.1630**	**40.6941**	**59.1871**
0.60	51.9106	44.7195	67.2512
0.70	57.0840	48.7915	76.3531
0.80	63.3952	53.5207	87.6948
0.90	**72.8904**	**60.3875**	**105.0069**
0.95	81.6396	66.5818	121.0919
0.99	100.9675	80.0644	156.8266

Table 13. Logit regression of McGovern et al. data on gag and tag-recapture and caging data on gag and red snapper from this report.
Model equation: $P = 1 / (1 + EXP(-(-2.3915 + 0.0592*X1)))$

Probability	Depth (X1)	Lower 99%	Upper 99%
0.01	-37.1999	-166.4170	-9.5233
0.05	-9.3344	-86.6724	7.7623
0.10	3.2795	-50.8370	15.8497
0.20	16.9690	-12.7214	25.4021
0.30	26.0679	10.6314	33.7326
0.40	33.5266	24.9567	45.3791
0.50	**40.3713**	**32.8079**	**61.3620**
0.60	47.2161	38.4036	79.6003
0.70	54.6748	43.6652	100.3104
0.80	63.7737	49.6520	126.0070
0.90	**77.4632**	**58.3156**	**165.0114**
0.95	90.0770	66.1456	201.1042
0.99	117.9426	83.2424	281.0376

5. To determine tag shedding rates and effects on growth and survival of fish tagged with single barbed dart tags in red grouper, gag, red snapper and vermilion snapper.

A total of 823 fish were double tagged, 379 red grouper, 45 gag, and 399 red snapper. Only 2 vermilion snapper were double tagged because of the poor recapture rate.

Of the 823 fish that were double tagged, 40 were recaptured. These included 9 red grouper, 6 gag, and 25 red snapper. For recaptured fish, Days of Freedom (DOF) ranged from 5-443 days and tagging depth ranged from 44-138 feet. Of the 40 fish recaptured, only 2 (5%) had shed the Hallprint dart tag. The two fish included a red snapper, which had been out for 110 days and a gag with 366 DOF. See **Tables 14, 15,** and, **16.**

Since only 4.9% of the double tagged fish have been recaptured, the double tagging work is being continued as part of a new MARFIN project, award number NA17FF2010. However, based on the preliminary data of a 95% retention rate for the Hallprint dart tags, it appears that these tags, when properly inserted and not eaten by triggerfish, have a very low shedding rate and should be recommended for tagging large reef fish.

Table 14. Return Data for Double Tagged Red Grouper.

Area	Tag (ft)	Tag Length (in)	Return Depth (ft)	Return Length (in)	DOF*	Movement (mi)
Sarasota	44	9.00	42	9.00	6	1
Sarasota	45	11.50	47	12.25	57	N/A
Venice	50	12.00	50	12.00	11	N/A
Venice	50	12.50	50	N/A	11	1
Venice	53	10.50	55	10.50	7	N/A
Sarasota	54	13.00	N/A	14.25	119	4
Sarasota	54	17.00	55	18.00	119	4
Venice	61	11.00	60	11.50	35	1
Venice	74	18.00	75	18.00	5	1

** DOF = Days of Freedom*

Table 15. Return Data for Double Tagged Gag.

Area	Tag (ft)	Tag (in)	Return Depth (ft)	Return Length (in)	DOF*	Movement (mi)
Venice	48	15.00	50	15.00	7	1
Sarasota	49	14.25	43	15.00	105	0
Venice	53	15.50	53	16.00	73	0
Venice	53	16.25	55	16.50	27	0
Sarasota	55	16.50	125	N/A	366	N/A
Panama City	104	13	100	18.50	439	1

**DOF = Days of Freedom*

Table 16. Return Data for Double Tagged Red Snapper.

Area	Tag (ft)	Tag (in)	Return Depth (ft)	Return Length (in)	DOF*	Movement (mi)
St. Augustine	63	11.25	78	14.00	188	N/A
St. Augustine	63	16.50	63	16.50	19	0
St. Augustine	63	17.50	63	N/A	59	0
St. Andrew's	65	12.75	65	N/A	198	0
St. Augustine	65	10.50	65	10.75	26	N/A
St. Augustine	70	10.00	70	N/A	11	0
St. Augustine	70	11.00	70	N/A	30	0
St. Augustine	70	11.50	70	N/A	122	0
St. Augustine	70	14.00	62	14.00	21	0
St. Augustine	70	16.00	68	N/A	108	0
Jacksonville	75	11.25	78	14.00	231	0
Jacksonville	75	12.00	75	N/A	110	0
Jacksonville	80	14.00	65	15.00	52	N/A
Panama City	98	13.50	100	16.00	281	N/A
Tarpon Springs	98	17.50	96	17.50	30	0
St. Augustine	103	17.00	110	22.00	443	1
Panama City	110	13.00	98.5	14.50	327	1
Panama City	110	14.50	111	15.00	57	1
Panama City	111	14.75	90	16.00	188	0
Panama City	111	14.75	90	16.50	188	0
Panama City	111	18.00	111	21.00	170	0
Panama City	114	14.50	119	16.00	316	0
Panama City	116	14.25	3	16.00	179	N/A
Panama City	116	16.25	116	20.00	170	0
Dunedin	138	16.00	140	17.00	70	0

** DOF = Days of Freedom*

6. To obtain movement and migration patterns for red grouper, gag, red snapper and vermilion snapper in the Gulf of Mexico and South Atlantic.

As was previously mentioned the study produced insufficient data from vermilion snapper. Therefore, only results for red grouper, gag, and red snapper are presented.

Although some red grouper, gag, and red snapper exhibit site fidelity over time, data collected show, that at least some fish in all size ranges represented in the study, (>12 in. to

>18 in.), in both the Gulf of Mexico and the Atlantic, moved anywhere from 2 to 100 miles from their original capture sites.

Tables 17 and **19** show the number and percentage (**Tables 18** and **20**) of red grouper, gag, and red snapper recaptured by size range and the distance traveled from their original tagging location. Data for Atlantic and the Gulf caught fish are presented.

It should be noted that the number of fish tagged and recaptured in each size range is not equal, nor is the number of fish tagged and recaptured in the Gulf and Atlantic. In addition, the numbers of fish tagged and recaptured per species are not the same. Therefore, these data do not in any way imply that more fish travel in the Gulf than in the South Atlantic. The data merely show that target fish of all sizes susceptible to hook and line fishing can and do travel.

Table 17. Distance traveled (in miles) of recaptured red grouper, gag, and red snapper, sorted by size and distance traveled during the study period (10/01/98-12/31/2001).

		Gulf of Mexico					Atlantic Ocean		
Length (in)	**Distance (mi)**	**Red Grouper**	**Gag**	**Red Snapper**	**Length (in)**	**Distance (mi)**	**Red Grouper**	**Gag**	**Red Snapper**
<=12	**0**	14	3	4	<=12	**0**	1	0	11
	1-2	18	4	5		**1-2**	0	1	6
	3-10	2	2	2		**3-10**	0	2	0
	11-20	1	0	1		**11-20**	0	0	1
	21-30	0	0	0		**21-30**	0	0	0
	31-50	0	0	0		**31-50**	0	0	0
	51-100	0	0	0		**51-100**	0	0	1
	>100	1	0	0		**>100**	0	0	0
Total		**36**	**9**	**12**	**Total**		**1**	**3**	**19**
>12, <=18	**0**	70	25	28	>12, <=18	**0**	1	18	42
	1-2	21	9	16		**1-2**	0	9	31
	3-10	28	6	6		**3-10**	1	7	15
	11-20	9	0	2		**11-20**	1	0	8
	21-30	1	0	0		**21-30**	0	0	2
	31-50	4	0	0		**31-50**	1	0	3
	51-100	2	2	1		**51-100**	0	0	1
	>100	1	0	2		**>100**	0	0	1
Total		**136**	**42**	**55**	**Total**		**4**	**34**	**103**
>18	**0**	6	8	1	>18	**0**	1	10	1
	1-2	4	3	0		**1-2**	0	9	2
	3-10	2	2	1		**3-10**	1	1	1
	11-20	0	0	0		**11-20**	0	1	0
	21-30	0	1	0		**21-30**	0	0	0
	31-50	0	0	0		**31-50**	0	0	0
	51-100	0	0	0		**51-100**	0	0	0
	>100	0	1	0		**>100**	0	0	0
Total		**12**	**15**	**2**	**Total**		**2**	**21**	**4**
Total Fish Movement		**184**	**66**	**69**	**Total Fish Movement**		**7**	**58**	**126**

Table 18. Percentage of target species which traveled 0 to >100 miles from the original tagging site during the study period (10/01/98-12/31/2001).

		Gulf of Mexico					Atlantic Ocean		
Length (in)	**Distance (mi)**	**Red Grouper**	**Gag**	**Red Snapper**	**Length (in)**	**Distance (mi)**	**Red Grouper**	**Gag**	**Red Snapper**
<=12	**0**	38.9%	33.3%	33.3%	**<=12**	**0**	100.0%	0.0%	57.9%
	1-2	50.0%	44.4%	41.7%		**1-2**	0.0%	33.3%	31.6%
	3-10	5.6%	22.2%	16.7%		**3-10**	0.0%	66.7%	0.0%
	11-20	2.8%	0.0%	8.3%		**11-20**	0.0%	0.0%	5.3%
	21-30	0.0%	0.0%	0.0%		**21-30**	0.0%	0.0%	0.0%
	31-50	0.0%	0.0%	0.0%		**31-50**	0.0%	0.0%	0.0%
	51-100	0.0%	0.0%	0.0%		**51-100**	0.0%	0.0%	5.3%
	>100	2.8%	0.0%	0.0%		**>100**	0.0%	0.0%	0.0%
>12, <=18	**0**	51.5%	59.5%	50.9%	**>12, <=18**	**0**	25.0%	52.9%	40.8%
	1-2	15.4%	21.4%	29.1%		**1-2**	0.0%	26.5%	30.1%
	3-10	20.6%	14.3%	10.9%		**3-10**	25.0%	20.6%	14.6%
	11-20	6.6%	0.0%	3.6%		**11-20**	25.0%	0.0%	7.8%
	21-30	1.0%	0.0%	0.0%		**21-30**	0.0%	0.0%	1.9%
	31-50	2.9%	0.0%	0.0%		**31-50**	25.0%	0.0%	2.9%
	51-100	1.5%	4.8%	1.8%		**51-100**	0.0%	0.0%	1.0%
	>100	1.0%	0.0%	3.6%		**>100**	0.0%	0.0%	1.0%
>18	**0**	50.0%	53.3%	50.0%	**>18**	**0**	100.0%	0.0%	57.9%
	1-2	33.3%	20.0%	0.0%		**1-2**	0.0%	33.3%	31.6%
	3-10	16.7%	13.3%	50.0%		**3-10**	0.0%	66.7%	0.0%
	11-20	0.0%	0.0%	0.0%		**11-20**	0.0%	0.0%	5.3%
	21-30	0.0%	6.7%	0.0%		**21-30**	0.0%	0.0%	0.0%
	31-50	0.0%	0.0%	0.0%		**31-50**	0.0%	0.0%	0.0%
	51-100	0.0%	0.0%	0.0%		**51-100**	0.0%	0.0%	5.3%
	>100	0.0%	6.7%	0.0%		**>100**	0.0%	0.0%	0.0%

Table 19. Distance traveled (in miles) of recaptured red grouper, gag and red snapper, sorted by size and distance traveled during MML's Reef Fish Tagging Study (10/01/90-12/31/2001).

		Gulf of Mexico					Atlantic Ocean		
Length (in)	Distance (mi)	Red Grouper	Gag	Red Snapper	Length (in)	Distance (mi)	Red Groupe	Gag	Red Snapper
<=12	0	60	13	12	<=12	0	1	0	11
	1-2	31	9	5		1-2	0	1	6
	3-10	9	7	4		3-10	0	2	0
	11-20	3	0	3		11-20	0	0	1
	21-30	2	0	2		21-30	0	0	0
	31-50	1	0	2		31-50	0	0	0
	51-100	2	1	0		51-100	0	0	1
	>100	1	0	0		>100	0	0	0
Total		**109**	**30**	**28**	**Total**		**1**	**3**	**19**
>12, <=18	0	306	115	35	>12, <=18	0	1	18	45
	1-2	139	69	16		1-2	0	10	31
	3-10	97	33	7		3-10	1	8	16
	11-20	33	10	3		11-20	1	0	8
	21-30	11	2	2		21-30	0	0	3
	31-50	17	4	0		31-50	1	0	3
	51-100	18	8	1		51-100	0	1	1
	>100	2	2	2		>100	0	0	1
Total		**623**	**243**	**66**	**Total**		**4**	**37**	**108**
>18	0	55	30	1	>18	0	2	10	4
	1-2	24	10	0		1-2	0	9	3
	3-10	18	15	1		3-10	1	2	1
	11-20	4	0	0		11-20	0	1	0
	21-30	0	2	0		21-30	0	0	0
	31-50	8	2	0		31-50	0	0	0
	51-100	5	0	0		51-100	0	0	0
	>100	1	1	0		>100	0	0	0
Total		**115**	**60**	**2**	**Total**		**3**	**22**	**8**
Total Fish Movement		**847**	**333**	**96**	**Total Fish Movement**		8	**62**	**135**

Table 20. Percentage of target species, which traveled 0 to >100 miles from the original tagging site MML's Reef Fish Tagging Study (10/01/90-12/31/2001).

		Gulf of Mexico					Atlantic Ocean		
Length (in)	Distance (mi)	Red Grouper	Gag	Red Snapper	Length (in)	Distance (mi)	Red Grouper	Gag	Red Snapper
<=12	0	55.0%	43.3%	42.9%	<=12	0	100.0%	0.0%	57.9%
	1-2	28.4%	30.0%	17.9%		1-2	0.0%	33.3%	31.6%
	3-10	8.3%	23.3%	14.3%		3-10	0.0%	66.7%	0.0%
	11-20	2.8%	0.0%	10.7%		11-20	0.0%	0.0%	5.3%
	21-30	1.8%	0.0%	7.1%		21-30	0.0%	0.0%	0.0%
	31-50	1%	0.0%	7.1%		31-50	0.0%	0.0%	0.0%
	51-100	1.8%	3.3%	0.0%		51-100	0.0%	0.0%	5.3%
	>100	1%	0.0%	0.0%		>100	0.0%	0.0%	0.0%
>12,	0	25.0%	48.6%	41.7%	>12, <=18	0	25.0%	48.6%	41.7%
	1-2	0.0%	27.0%	28.7%		1-2	0.0%	27.0%	28.7%
	3-10	25.0%	21.6%	14.8%		3-10	25.0%	21.6%	14.8%
	11-20	25.0%	0.0%	7.4%		11-20	25.0%	0.0%	7.4%
	21-30	0.0%	0.0%	2.8%		21-30	0.0%	0.0%	2.8%
	31-50	25.0%	0.0%	2.8%		31-50	25.0%	0.0%	2.8%
	51-100	0.0%	2.7%	1%		51-100	0.0%	2.7%	1.0%
	>100	0.0%	0.0%	1%		>100	0.0%	0.0%	1.0%
>18	0	47.8%	50.0%	50.0%	>18	0	66.7%	45.5%	50.0%
	1-2	20.9%	16.7%	0.0%		1-2	0.0%	40.9%	37.5%
	3-10	15.7%	25.0%	50.0%		3-10	33.3%	9.1%	12.5%
	11-20	3.5%	0.0%	0.0%		11-20	0.0%	4.5%	0.0%
	21-30	0.0%	3.3%	0.0%		21-30	0.0%	0.0%	0.0%
	31-50	7.0%	3.3%	0.0%		31-50	0.0%	0.0%	0.0%
	51-100	4.3%	0.0%	0.0%		51-100	0.0%	0.0%	0.0%
	>100	1%	1.7%	0.0%		>100	0.0%	0.0%	0.0%

Figures 30-32 show the number of red grouper, gag and red snapper, which moved greater than or equal to 2 miles from the original tag, capture site. The graphs also show the Days of Freedom (DOF) associated with these movements. All illustrated data are from tag recaptures. The graphs are based on data from MML's entire Reef Fish database (October 1990-current), not just the study period (October 1, 1998 – December 31, 2001).

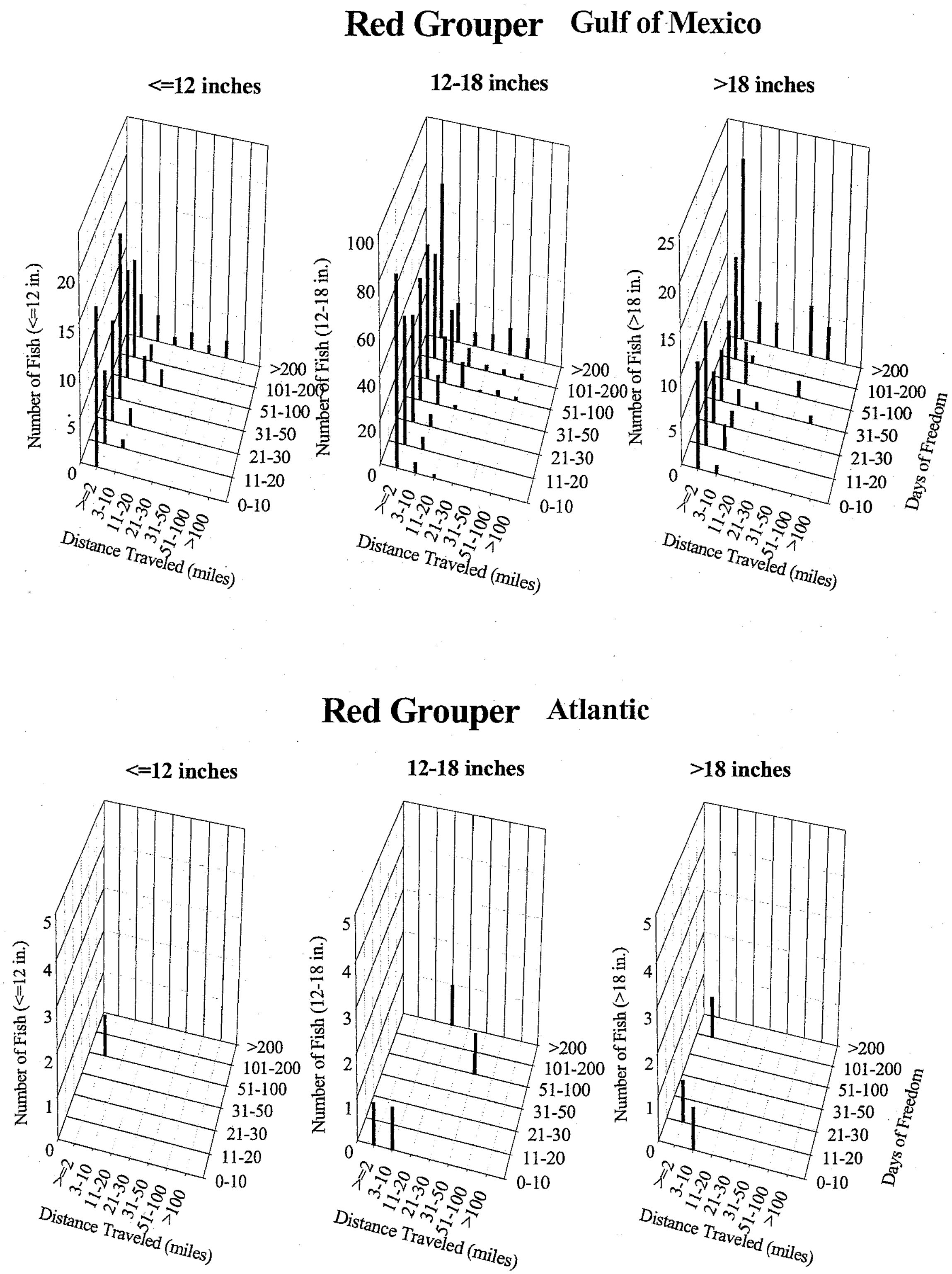

Figure 30. Number of red grouper that moved from their original tagging site in the Gulf of Mexico and South Atlantic.

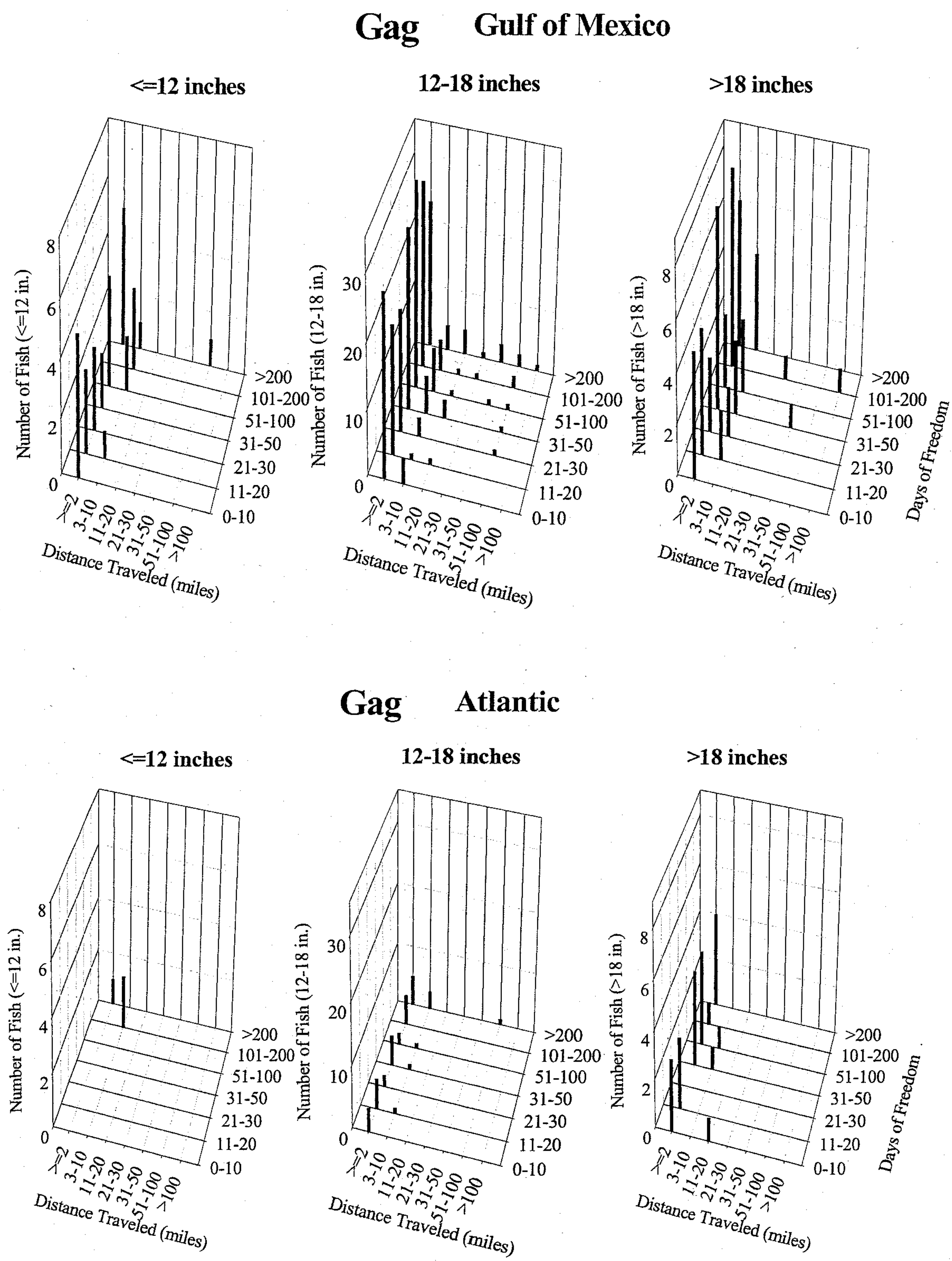

Figure 31. Number of gag that moved from their original tagging site in the Gulf of Mexico and South Atlantic.

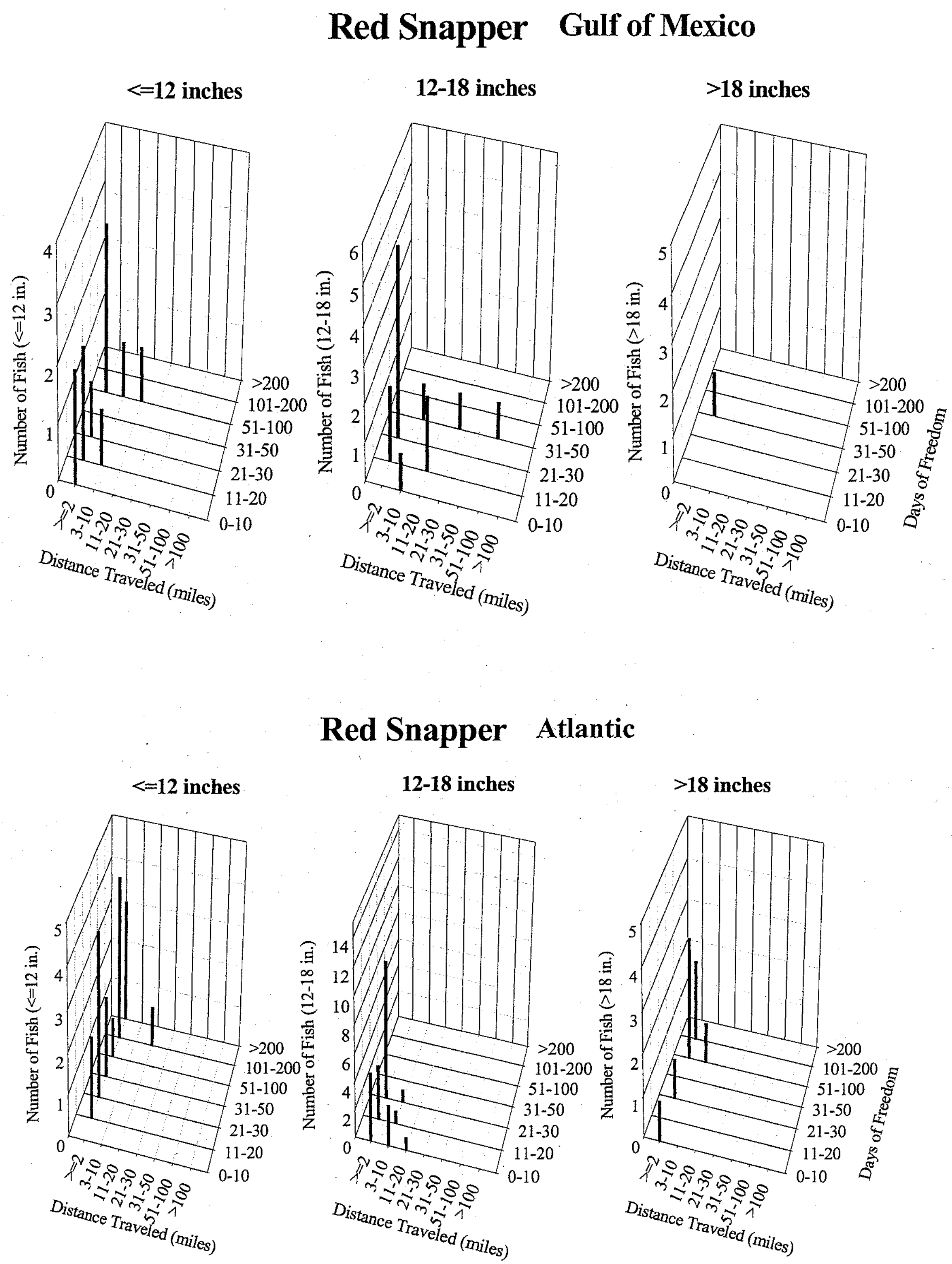

Figure 32. Number of red snapper that moved from their original tagging site in the Gulf of Mexico and South Atlantic.

A. SIGNIFICANT PROBLEMS

1. Originally scheduled for 2 years, the project had to be extended to 3 years to complete all the fieldwork, which was interrupted, by numerous weather fronts and hurricanes at the study sites.

2. It was difficult to get fishers to use the circle and kahle hooks. They didn't like the kahle hooks. We had to obtain additional outside funds from the Yamaha Contender Miami Billfish Tournament to offer prize money to create a circle hook contest to get fishers to use the circle hooks.

B. NEED FOR ADDITIONAL WORK

1. Field studies need to be conducted to determine the predation rate on released vermilion snapper.
2. Additional fish need to be double tagged to evaluate Hallprint tag shedding rates.
3. Additional research on survival rates between circle and J hooks needs to be conducted.

EVALUATION

A. EXTENT TO WHICH THE PROJECT GOALS AND OBJECTIVES WERE ATTAINED

1. Goals and Objectives Attained

Most of the project goals and objectives have been completely attained. Two objectives, the tag shedding study and the hook research require additional data for proper statistical analyses. These two objectives are being addressed as part of another MARFIN, funded project, award number NA17FF2010. The additional time (2 years) gained by adding these objectives to MML's newly funded MARFIN, will accomplish these objectives.

2. Modifications Made to the Goals and Objectives

Originally, the objective of the hook mortality study was to provide data comparing reef fish survival using three hook types, J, circle, and kahle. Fishers disliked the kahle hooks and refused to use them. The study was changed to compare just two hook types, J and circle hooks.

B. DISSEMINATION OF PROJECT RESULTS

Project results have been disseminated to NMFS, biologists, fishery managers, sports and outdoors writers, 370 participating fishers, and the Wright & McGill Tackle Company through quarterly newsletters. See **Table 21**. The newsletters contained text, figures, and tables describing the results obtained each quarter.

Table 21. Categories of the Newsletter Recipients

Fishery Managers
Department of Agriculture and Fisheries – Bermuda; Florida Fish and Wildlife Conservation Commission; Gulf of Mexico Management Council; and Gulf States Marine Fisheries Commission
States
Alabama; California; Colorado; Florida; Georgia; Louisiana; Maine; Massachusetts; Mississippi; New Jersey; North Carolina; South Carolina; Texas; Vermont; Virginia; and Washington D.C.
Writers
Florida Mariner; Miami Herald; Orlando Sentinel; and St. Petersburg Times
Countries
Australia; Bermuda; Japan; Scotland; and Spain
NMFS
NMFS – Panama City Lab; NMFS – Pescagoula; NMFS Southeast Fisheries Science Center; NMFS – Pacific Recreational Fisheries Coordinator NOAA/NMFS – Miami Lab; and NOAA/NMFS – Office of Habitat Conservation;
Non-NMFS
California State University, Long Beach; CCAR/University of Maine; Florida State University; Florida State University Marine Lab; Gulf Coast Research Laboratory; University of Massachusetts; University of North Carolina, Wilmington; University of Southern Mississippi; and West Australia Marine Research Labs
Agencies
Billfish Foundation – Ft. Lauderdale; Centro Oceanografica de Baleares – Spain; Department of Commerce/NOAA – Washington, D.C.; Florida Marine Research Institute; Florida Sea Grant; Georgia DNR; Marine Advisory Service, Virginia Institute of Marine Science; Miami-Dade County Extension Service; Ocean Research Institute, University of Tokyo; Ponce de Leon Port Authority; South Carolina DNR; Southeast Fishery Center, Mississippi; and Texas Parks and Wildlife

Results were sent to NMFS in the form of semi-annual reports. Raw data collected were also sent to NMFS with the semi-annual reports. Final project results were presented at the MARFIN Conference on January 17, 2002 in Tampa, FL.

Results will also be disseminated in this final report. Final reports were sent to NMFS, FSU, the Gulf of Mexico Fishery Management Council, the Florida Fish & Wildlife Conservation Commission, and the MML library.

Highlights of some of the final results will also be posted on MML's Fisheries Biology website. To find the link, go to www.mote.org, click on Research and choose Center for Fisheries Enhancement. Scroll down to where the three programs within the Center are listed and click on Fisheries Biology Program.

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