PARTITIONING RELEASE MORTALITY IN THE UNDERSIZED RED SNAPPER BYCATCH: COMPARISON OF DEPTH VS. HOOKING EFFECTS

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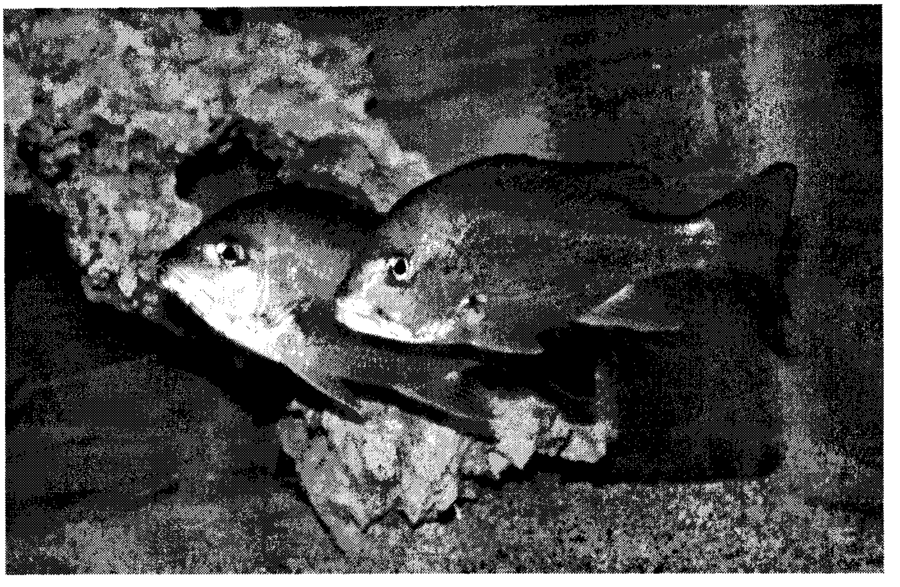

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TABLE OF CONTENTS

Page No.

TABLE OF CONTENTS i

LIST OF FIGURES iii

LIST OF TABLES v

ABSTRACT 1

EXECUTIVE SUMMARY 1

PURPOSE 3
- A. Problem Description 3
- B. Project Objectives 3

APPROACH 3
- A. Work Performed 3
  - Acute Mortality aboard Headboats 3
  - Circle vs J Hook Mortality 4
  - Gear Evaluation 4
  - Fish Tagging 4
  - Fish Collection 5
  - Laboratory Pressure Experiments 5
  - Publicity Campaign 7
  - Tag Lottery 7
  - Circle Hook Lottery 7
- B. Project Management 9

FINDINGS 11
- A. Actual Accomplishments and Findings 11
  - Acute Mortality aboard Headboats 11
  - Circle vs J Hook Mortality 15
  - Discussion and Conclusions 26
    - Acute Mortality 26
    - Circle Hooks 27
    - Predation 28
    - Barotrauma 29
- B. Significant Problems 32
- C. Need for Additional Work 32

TABLE OF CONTENTS, CONTINUED

Page No.

EVALUATION 32
A. Extent to Which the Project Goals and Objectives Were Attained 32
1. Goals and Objectives Attained 32
2. Modifications Made to the Goals and Objectives 33
B. Dissemination of Project Results 34

ACKNOWLEDGMENTS 34

LITERATURE CITED 35

LIST OF FIGURES

Page No.

Figure 1. Hyperbaric chambers with one red snapper in each chamber. .... Page 5

Figure 2. Tagged red snapper in chamber viewed through acrylic view plate. .... Page 6

Figure 3. Circle hook advertisement published in MARFIN funded RFSS newsletter. .. Page 8

Figure 4. The Gemini Queen headboat which fishes out of Panama City, FL. .... Page 12

Figure 5. Acute shipboard mortality partitioned by cause of death (depth-related, hooking, other). Graph shows comparison of red snapper to other target reef fish. ... Page 12

Figure 6. Number of red snapper acute shipboard mortality by depth category. .... Page 13

Figure 7. Red snapper killed by hook injury. .... Page 13

Figure 8. Red snapper killed by hook mortality with macerated liver. .... Page 13

Figure 9. Pooled blood in a red snapper which died as a result of latent hook mortality. Page 14

Figure 10. Canine teeth of a red snapper. .... Page 15

Figure 11. Red grouper dentition. Notice the backward slant of the teeth. .... Page 15

Figure 12. Locations of where red snapper were tagged. .... Page 15

Figure 13. Locations where red snapper were recaptured. .... Page 15

Figure 14. Percent of red snapper tagged/released by participating fishing sector. ..... Page 16

Figure 15. Percent of red snapper recaptured by participating fishing sector. .... Page 16

Figure 16. Number of red snapper measured/tagged/released and measured/released or measured/kept by fishing sector. .... Page 17

Figure 17. Length/frequency histogram of red snapper which were measured/tagged/released and measured/released from October 1, 1990 - December 31, 2003. .... Page 18

LIST OF FIGURES, CONTINUED

Page No.

Figure 18. Number of red snapper tagged and recaptured by distance from shore. Distance from shore in nautical miles. .... Page 19

Figure 19. Red snapper multiple recaptures. .... Page 19

Figure 20. Days of Freedom (DOF) for recaptured red snapper. .... Page 19

Figure 21. Days of Freedom (DOF) for recaptured red grouper. .... Page 19

Figure 22. Number of red snapper tagged by fishing sector and hook type. .... Page 20

Figure 23. Number of red snapper recaptured by fishing sector and hook type. .... Page 20

Figure 24. Percent of red snapper tagged and recaptured by tagging depth for red snapper caught on circle hooks when originally tagged. .... Page 21

Figure 25. Percent of red snapper tagged and recaptured by tagging depth for red snapper caught on J hooks when originally tagged. .... Page 21

Figure 26. Number of red snapper tagged/released by depth and fishing sector. .... Page 22

Figure 27. Total number of red snapper tagging events by depths. .... Page 22

Figure 28. Red snapper recaptures from fish originally tagged at depths shown. ...... Page 23

Figure 29. Actual red snapper recapture depths for all returns. Recaptures without depth data were not included. .... Page 23

Figure 30. Red snapper recaptures plotted by Days of Freedom (DOF) and distance traveled. .... Page 24

Figure 31. Oral stomach protrusion in red snapper decompressed from 61 m (200 ft). . Page 25

Figure 32. Esophageal ring bruise caused by stomach prolapse in red snapper decompressed from 61.0 m (200 ft). .... Page 26

Figure 33. Pressure induced exoptahalmia in red grouper decompressed from 27.4 m (90 ft). .... Page 26

LIST OF FIGURES, CONTINUED

Page No.

Figure 34. Dying red grouper from 42.7 m (140 ft) chamber trial. Note exopthalmia. . Page 26

Figure 35. Bilateral post-cranial hemorrhages in red grouper decompressed from 21.3 m (90 ft). . . . . Page 26

Figure 36. Bottle nose dolphin feeding on undersized red snapper discards from a headboat off Panama City, FL. . . . . Page 28

Figure 37. Bottle nose dolphin taking hooked red snapper (with rod and reel) before the fisher could land it aboard a headboat off Panama City, FL. . . . . Page 28

Figure 38. Stack of commercial reef fish traps. . . . . Page 30

Figure 39. Inflated swimbladder of 670 mm (26 in) red grouper caught in a commercial fish trap at 35.0 m (115 ft). . . . . Page 30

LIST OF TABLES

Page No.

Table 1. Number of red snapper tagged and recaptured by fishing sector. (Number differs from that above because this table includes recaptured fish that were re-released). . . . . Page 17

Table 2. Number of red snapper measured/tagged/released and measured/released by sector. (No recaptures are included in this table; fish with no data type listed are omitted). . . . . Page 17

Table 3. Size range of red snapper measured in the areas tagging occurred. (The number of fish includes recaptured remeasured fish). . . . . Page 18

Table 4. Percent of red snapper tagged and recaptured by tagging depth for red snapper caught on circle hooks when originally tagged. . . . . Page 21

Table 5. Percent of red snapper tagged and recaptured by tagging depth for red snapper caught on J hooks when originally tagged. . . . . Page 22

Table 6. Recaptures of red snapper by size and water depth. . . . . Page 24

Table 7. Red snapper and red grouper mortalities from hyperbaric chamber tests. Data includes the # of mortalities for each depth, % of all fish tested for each species, % of all fish tested at depth by species, and % of all mortalities by depth. . . . . Page 25

Table 8. Acute and delayed mortalities of red snapper and red grouper from hyperbaric chamber tests. . . . . Page 25

Table 9. % of total red snapper bycatch taken by bottlenose dolphins off Panama City, FL. . . . . Page 29

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ABSTRACT

Size limits have long been a cornerstone of fisheries management. The fate of undersized bycatch is a major concern, as discarded fish are subject to a suite of factors contributing to mortality. It is generally assumed that discarded fish do not survive after capture and release. In the Gulf of Mexico and South Atlantic, red snapper, *Lutjanus campechanus*, support important recreational, recreational-for-hire, and commercial fisheries. To examine the impact of two important causes of mortality, hook and depth induced mortality, in the recreational and recreational-for-hire red snapper fisheries, a study to quantify and estimate survival of undersized bycatch was conducted. Data were collected from the hook-and-line recreational and recreational-for-hire reef fish fishing sectors. Shipboard studies to quantify undersized red snapper bycatch were conducted by counting and measuring red snapper caught during fishing trips, mainly off both coasts of Florida. Moribund fish, which suffered acute mortality, were brought to the lab for necropsy to determine cause of death. Acute mortality measurements were one method used, to test the hypothesis that hook and release mortality is greater than depth induced mortality in the recreational-for-hire and recreational fisheries. Undersized red snapper captured at various depth increments (0 -12.2 m, 12.5 - 21.3 m, 21.6 - 30.5 m 30.8 - 61.0 m, and 61.3+ m) were tagged and released by Mote Marine Laboratory (MML) staff and student interns aboard headboats and volunteer taggers (fishers) aboard recreational vessels, charter boats and headboats. Survival of fish caught on circle versus J hooks was compared using tag returns. Laboratory studies to systematically evaluate depth-related capture-release mortality and sub-lethal effects for red snapper in the absence of hooking mortality, were conducted using fish hyperbaric chambers.

EXECUTIVE SUMMARY

Minimum size limits are intended to prevent growth and recruitment overfishing by allowing some portion of fish in a cohort to grow and reproduce at least once before dying of natural or fishing related causes. All fishers must abide by the minimum size regulation and release undersized bycatch regardless of location, water depth, fish condition or predators present. Determining the survival of undersized discards in fisheries, such as the red snapper fishery, is critical as undersized bycatch comprise a significant percentage of the total catch in the red snapper recreational and recreational-for-hire fisheries.

There are a suite of factors which can cause mortality. This study concentrates on the effects of hook damage and depth of capture on mortality of red snapper in the recreational and recreational-for-hire fisheries. The project objectives included 1) testing the hypothesis that hook and release mortality is greater than depth induced mortality for red snapper in the recreational, charter, and headboat fisheries, 2) obtaining catch and release mortality rates by depth through comparison of return rates for red snapper caught using circle versus J hooks aboard headboats, charter boats, and recreational vessels and 3) systematically evaluating through laboratory studies depth-related capture-release mortality and sub-lethal effects for red snapper.

To obtain data to the support hypothesis #1, fish which died of acute mortality aboard headboats were collected and brought to the Mote Lab for necropsy. Results of necropsies on moribund red snapper showed hook release mortality was greater than all other causes of mortality on red snapper aboard headboats.

Recreational, recreational-for-hire and a few commercial fishers participated in tag and release studies to determine if circle hooks increased survival of red snapper discards over that of J hooked fish and to provide red snapper survival data by depth.

To compliment these field studies on depth, laboratory studies employing fish hyperbaric chambers were used. Since fish were held for a month before the rapid decompression experiments began, any detrimental effects of hooking were eliminated from test results.

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, does not appear to be a problem for bottom-dwelling reef fish such red grouper and red snapper in shallow water. Burns and Restrepo (2000) report that red snapper and red grouper swimbladder ruptures heal within four days for fish captured in shallow water. This study continues that research for red snapper at deeper depths of 42.7 and 61 m (140 and 200 ft).

PURPOSE

A. PROBLEM DESCRIPTION

Red snapper support important commercial and recreational fisheries in both the Gulf of Mexico and South Atlantic. Due to critical management issues concerning this species, it has been targeted for high priority research by NMFS and the Gulf of Mexico and South Atlantic Management Councils. Survival of undersized catch in the fishery is one of the most important of those issues.

B. PROJECT OBJECTIVES

~ To test the hypothesis that hook and release mortality is greater than depth induced mortality for red snapper in the recreational, charter, and headboat fisheries.
~ To obtain catch and release mortality rates by depth through comparison of return rates for red snapper caught using circle versus J hooks aboard headboats, charter boats, and recreational vessels.
~ To systematically evaluate through laboratory studies depth-related capture-release mortality and sub-lethal effects for red snapper.

APPROACH

A. WORK PERFORMED

Task A: Testing the Hypothesis that Hook Release Mortality Is an Even Greater Factor than Depth Induced Mortality for Red Snapper in the Recreational and Recreational-for- Hire Fisheries.

Acute Mortality aboard Headboats:

a. *Specimen collection*: Mote Marine Laboratory staff collected moribund red snapper caught during fishing trips aboard headboats off Panama City, Daytona and St. Augustine, Florida. These fish were quantified and brought back to the lab for necropsy to determine the cause of death.

b. *Fish Necropsy*: Necropsies were performed on the acute mortalities to determine the cause of death. Red snapper acute mortalities were compared to red grouper and vermilion snapper acute mortalities collected under MARFIN project NA17FF2010, entitled, "*Evaluation of the Efficacy of Current Minimum Size Regulations for Selected Reef Fish Based on Release Mortality and Fish Physiology*".

c. *Feeding Videos:* Although not initially a part of this study, captive red snapper were filmed in holding tanks during feeding to document feeding behavior to understand the causes of hook mortality in red snapper. Red grouper were also filmed to document their feeding behavior for comparison between the two species. Results of the study are included in this report as they elucidate some research results on hook mortality.

Task B. Obtaining Catch and Release Mortality Rates by Depth, Comparing Return Rates for Red Snapper Caught Using Circle and J Hooks Aboard Headboats, Charter Boats, and Recreational Vessels.

Circle vs J Hook Mortality: Circle hooks were purchased at a reduced rate from *Eagle Claw*. *Eagle Claw* also donated additional circle hooks for the study. Free circle hooks were sent to any fishers in the recreational and recreational-for-hire reef fish fishing sectors, targeting red snapper, who were willing to participate in the study. Tag returns from red snapper originally captured on circle hooks were added to the MML Reef Fish Tagging database for comparison with those for J hook captured fish.

Gear Evaluation: Some recreational fishers, as well as headboat and charter boat captains and crew, rigged their poles with circle hooks provided by MML; other fishers used with J hooks. All live undersized red snapper caught on either hook type were measured, tagged and released. Tag return rates from fish caught with both hook types were compared.

Fish Tagging: Undersized red snapper were tagged by MML staff, student interns and volunteers, as well as by charter boat and headboat captains and crew, and recreational fishers. Tags and tagging kits, including instructions, were provided by MML. Both large and small tags (for juveniles) were used. Tagging occurred in the same areas already included in MML's Tagging Program.

All red snapper were tagged using single-barbed Hallprint® plastic dart tags inserted at an angle next to the anterior portion of the dorsal fin. These tags have already been used successfully in MML's Reef Fish Tagging Program. Data collected included tagging date, gear type, tag number, time of day, bait used, water depth, fork length in inches, fish condition upon release, amount of time the fish was out of the water, whether or not the abdomen was deflated and the capture location to the nearest 1 degree of latitude and longitude. If fish were vented before release, abdomen deflation was accomplished by use of the abdomen deflation device provided by MML and protocol currently used by MML.

Tag information included tag number and the 1-800 dedicated telephone number at Mote. The telephone was answered personally during work hours and calls regarding tag return information were recorded on weekends, holidays and evenings by the answering machine.

Return data including tag number, date of capture, gear type, bait type, water depth, fork length in inches, capture location, the overall condition of the fish, the condition of the area around the tag insertion site and whether the fish was kept or released, were recorded. Data were entered on a PC computer using Paradox® software. Data were compared among various depths and gear (circle *vs.* J hooks). Some of the data were presented in the MARFIN funded quarterly newsletters (see ***Publicity Campaign***).

Tag returns were monitored to obtain estimates of survival. This evaluation of survivorship was accomplished by comparing results from this study with those of other currently funded MARFIN Mote studies, as well as by integrating the new data into MML's ongoing long term reef fish tagging program (discussion in Schirripa *et al*, 1993 and Wilson and Burns 1996), as these data have proven very reliable (Schirripa and Burns, 1998).

Task C: Laboratory Simulations of Depth Effects Using Fish Hyperbaric Chambers

1. Fish Collection

Undersized red snapper were captured by hook and line aboard headboats and held in 55 gallon coolers or in live wells aboard ship. Fish were transported to the laboratory in 250 gallon tanks supplemented with oxygen. Upon arrival they were treated with a 5-min fresh water/Formalin solution (2 drops 37% Formalin/gallon of water) to remove ectoparasites and gill trematodes. Fish were also dipped on days 7, 14 and 21 after capture to kill ectoparasites that hatched after the first dip. A final dip, on day 28, was done before fish were transferred from the quarantine tanks to the experimental holding tanks. The fish were held in quarantine for one month to identify any health or parasite problems, eliminate the possibility of complications from latent hook mortality and to acclimate the fish to handling and their new surroundings. After quarantine fish were divided into experimental groups and well fed before being placed in the hyperbaric chambers.

2. Laboratory Pressure Experiments

Hyperbaric chambers (described in Wilson and Burns, 1996 and shown as ***Figure 1***), were used in the laboratory to simulate pressure changes that red snapper would experience when being captured from depths of 42.7 m and 61.0 m (140 ft and 200 ft, 63 psi and 90 psi, respectively). Four chambers were used simultaneously, providing 4 replicate tests. Fish were first acclimated to conditions inside the chamber, and then observations of gauge

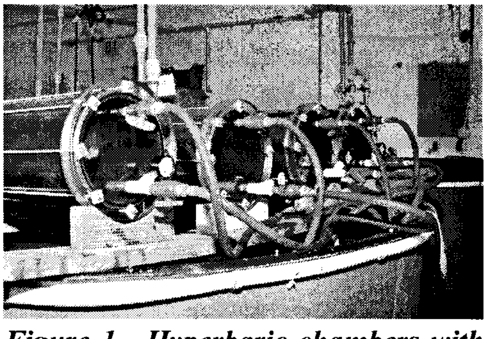


Figure 1. Hyperbaric chambers with one red snapper in each chamber.

pressure and fish behavior/orientation within each chamber were made every 30-min. Observations of fish behavior were made through the acrylic view plate (***Figure 2***).

Figure 2. Tagged red snapper in chamber viewed through acrylic view plate.

Acclimation was confirmed when a fish became neutrally (or nearly neutrally) buoyant, and had gained upright (vertical) orientation in the chamber following its initial tendency to list at the bottom of the chamber, or to lie on its side there. When acclimation was confirmed, the hydrostatic pressure was rapidly decreased (rate approx. 2-3 m/sec or 6-10 ft/sec) to ambient (1 atm), and the fish removed from the chamber. During year one, all chambers were depressurized simultaneously. During year two, each chamber was depressurized individually so that any remaining fish were unaffected by pressure changes during the recompression of each fish. The handling time for each fish was timed with a stopwatch and recorded. Timing began when the pressure gauge reached 0 psi (1 atm ambient) and ended when the fish was released.

Upon removal, fish were vented and put into holding tanks. One fish from each experiment was immediately sacrificed and necropsied to determine the extent of internal trauma sustained from that depth simulation. The remaining fish were placed in holding tanks to heal. A second fish was sacrificed 4 days after removal and a third after 7 days to document healing. During year two, the fourth experimental fish was kept for long term observation. After all the experiments were completed, this last group of fish was moved to the Mote Aquarium, where they are still alive and on display.

During necropsy all major body systems were examined for gross trauma and anomalies. Externally the skin, eyes, and fins of each fish were examined. Internally the gills, heart, liver, spleen, swimbladder, stomach, and urinary bladder were inspected. Observations included position of organs in the body cavity, gross distortion of organ tissues, gas bubbles, ruptures or tears in any tissues, and hemorrhaging and discoloration. A digital still-camera was used to document trauma and anomalies.

During the second year, an additional chamber test was completed to examine acclimation times using a controlled ascent from 42.7 m (140 ft). Red snapper were acclimated to depth as in all other runs, however, depressurization took place in increments allowing acclimation to each new depth (pressure) before continuing. The pressure in the chambers was lowered until the fish showed signs of depth stress (increased buoyancy, downward oriented swimming, bloating) at which time decompression stopped and the pressure was noted. The fish were left at the stopping pressure until they had attained neutral buoyancy again, at which point they were taken to the next stopping pressure and held. This continued in increments until fish were at ambient pressure, at which time they were removed from the chambers. Acclimation times were recorded and necropsies were performed on the fish to assess any damage.

For comparison, red grouper were also used in chamber runs at depths of 21.3, 27.4, and 42.7 m (70, 90, and 140 ft, respectively). A stepwise decompression experiment, identical to that described above for snapper, was also performed on red grouper. In all experiments, identical protocols were used for both red grouper and red snapper experiments.

3. Publicity Campaign

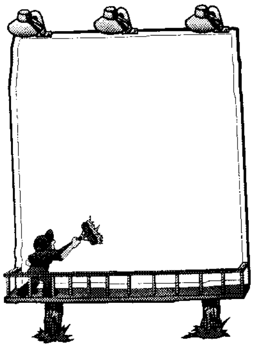
A publicity campaign including MML press releases, presentations at scientific conferences and fishing club meetings and publication of information in various issues of the MARFIN funded Reef Fish Survival Study (RFSS) newsletter, were used to disseminate project objectives and results. Copies of the newsletter were sent to all study participants as well as to fisheries scientists, fishery management agencies, industry representatives, and newspaper "Outdoor" writers and fishing magazine writers, who have requested them.

4. Tag Lottery

At the project's end, a tag lottery was held. The winning tag was chosen from all tags returned. Both the tagger and the person returning the tag each received $100.

5. Circle Hook Lottery

When this project began, volunteer taggers resisted fishing with circle hooks. In an attempt to get taggers to use circle hooks, MML held a red snapper circle hook contest (***Figure 3***). With additional funds from the Board of Directors of the Yamaha Contender Miami Billfish Tournament, MML was able to offer cash prizes for contest winners.



2001 Red Snapper Circle Hook Contest New: Grand Prize

Thanks to Ms. Joan Vernon and the other members of the Board of Directors of the Yamaha Contender Miami Billfish Tournament, we have been awarded $1,000 for the Grand Prize of the 2001 Red Snapper Circle Hook Contest. To be eligible follow all of the contest rules.

CONTEST RULES:

- *Grand Prize: Tag the most red snapper,* **all** *of which* **must** *be captured on circle hooks. You may either use your own circle hooks or use the 7/0 or 4/0 circle hooks provided by MML. (In order to be eligible, a minimum of 200 fish must be tagged).*
- *1st Prize: Will go to the fisher who tags the second highest number of red snapper;*
2nd Prize: To the third highest number of red snapper tagged, and;
3rd Prize: To the fourth highest number of red snapper. **All** *which* **must** *be caught on circle hooks.*
- *All red snapper captured by circle hooks* **must** *be tagged (using MML tags) and released.*
- *All data* **must** *be written on MML data sheets (the regular fish tagging data sheets) and sent to MML.*

PRIZES:

GRAND PRIZE: $1,000

1ST PRIZE: $150 2ND PRIZE: $100 3RD PRIZE: $50

The contest will end at the end of red snapper season

To obtain circle hooks and tagging supplies contact us at 800-388-3966

Figure 3. Circle hook advertisement published in MARFIN funded RFSS newsletter.

Task D: Movement and Migration

Although not the primary objective of this study, red snapper movement patterns were noted from tag returns. These data, as well as information on water depth, bathymetry, days of freedom, number of times recaptured, artificial reef locations, seagrass bed and marine sanctuary locations in the Gulf of Mexico and along the Florida East coast, have been put into GIS format. Results from this analysis will be combined with data from other MML MARFIN funded red snapper studies and MML's Reef Fish Tagging Program for comprehensive analysis and publication in a peer reviewed scientific journal.

B. PROJECT MANAGEMENT

Laboratory studies were conducted solely at Mote's Center for Fisheries Enhancement Wet Lab Facility. Field research was conducted offshore in the Gulf of Mexico and South Atlantic. Data analyses were conducted both at Mote Marine Laboratory (MML) and at California State University, Long Beach.

1. Ms. Karen Burns (*MML Staff Scientist/Program Manager of the Fish Biology Program*) served as Principal Investigator and Project Manager. She provided overall supervision of the project ensuring that the work was completed in accordance with the S.O.W. She served as liaison among MML, California State University, Long Beach, NMFS, and the participating fishers. Ms. Burns was responsible for the supervision of the laboratory and field research; writing the reports, and newsletter publication.

2. Dr. Raymond Wilson (*Associate Professor of Biology, Department of Biological Sciences California State University, Long Beach*) served as the Co-Principal Investigator and consultant on this project. Dr. Wilson designed, developed, manufactured, and tested the pressure-retaining system and test chambers that formed the core of the laboratory aspect of this project. He was present during the first experiments to supervise the hyperbaric chamber studies.

3. Mr. Nicholas Parnell (*MML Senior Biologist*) served as Laboratory Coordinator. He supervised and participated in all experimental runs during the last year of the study to ensure replicate integrity. He pressurized and depressurized all of the chambers during the experiments and performed necropsies on all mortalities. Mr. Parnell was also responsible for design and maintenance of the experimental tank systems and capture and transport of live specimens. He also assisted in report writing and newsletter publication.

4. Mr. Jay Sprinkel (*MML Senior Biologist*) served as the data manager for the project. As such, he was responsible for supervising data entry, setting up files and producing graphs and tables for the newsletters, posters, reports and presentations.

5. Mr. Peter Simmons (*MML Staff Biologist*) was responsible for data entry of tag/recapture data, communication with fishers reporting recaptures, supervision of student interns and volunteers, collection of live red snapper for the chamber experiments, fish care and maintenance, filter and system maintenance, chamber set-up, fish observations during chamber experiments, and photodocumentation of fish necropsies during year 2. Mr. Simmons also helped print and distribute the newsletter.

6. Ms. Tanya Merkle (*MML Staff Biologist*) was responsible for ordering supplies, creating the duty roster for shifts during the chamber studies, helping to supervise student interns and volunteers, data entry of fish care maintenance logs, necropsy data and fish observation logs from the chamber experiments. Ms. Merkle also works on formulating articles regarding the project in the RFSS newsletters, as well as reports and presentations. She also helped to collect and maintain the live fish and participated in the fish observations during the chamber experiments during year 2.

7. Ms. Teresa Starks-DeBruler (*MML Staff Biologist*) was responsible for fish collection, care and maintenance of live fish and chamber study fish observations during year 1. Also during year 1, Ms. Starks-DeBruler was responsible for student intern and volunteer instruction and supervision. She also ordered supplies and helped enter data in both the tag/recapture files and the year 1 chamber results.

8. Mr. Matt Thomas (*former MML Staff Biologist*) helped to collect and transport fish to the Lab for the chamber studies during year 1. He participated in making fish observations during the chamber experiments. Mr. Thomas was in charge of the tag/recapture data base and circle hook distribution during the first year of the project.

9. Volunteers:
   a. Dr. Bernard Waxman (*B.S. and D.V.M., Middlesex University*) was the principal person responsible for chamber set up, fish necropsies from both acute mortalities and experimental fish, and fish health during year 1 of the study.

   b. Dr. Daniel Weiner (*M.S. and D.V.M., University of Pennsylvania*) also performed necropsies on experimental fish.

   c. Mr. John Angiolini was involved in hyperbaric chamber set up, recording data during necropsies and in fish care and maintenance during year 1.

   d. Mr. Joseph Mazza volunteered his time to make up and send out circle hooks to participating fishers as well as help with fish care and maintenance.

e. Mr. Roy Francis also volunteered his time to help with fish care and maintenance during year 1 and making and sending out packets with circle hooks to fishers .

f. Ms. Ingeborg Herdegan helped with fish observations during the chamber experiments during year 1. She also translated scientific literature on swimbladder morphology and function from German to English.

g. Mr. Thomas Fuhrer, a polymer chemist from Switzerland, helped with observations during the chamber experiments, while he spent an 8 week sabbatical at Mote during year 2.

10. Recreational, recreational-for-hire and commercial fishers participated in the circle/J hook study, measured, tagged and released fish, reported recaptures and headboat owners allowed MML staff and student interns aboard their vessels to collect and tag fish.

11. Student Interns:
As this research was highly labor intensive, numerous student interns were involved in many of the tasks. Tasks included helping tag and release fish, collect and transport fish to the Lab, fish sanitation and quarantine, fish care and maintenance, and fish observation during chamber experiments. The students who participated in these tasks included:

Lofton Alvarez - Out of Door Academy; Aaron Bevins - Marshall University; Julie Bremner - University of York; Alexander Cameron - Out of Door Academy; Andrew Danks - University of Northern Iowa; Brent Dilts - Emory University; Megan Gallagher - University of Scranton; Gretchen Grotheer - Missouri Southern State; Fiona Higgins - University of Ireland; Ashley Hodges - Booker High School; Danata Janofsky - Lawrence College; Michael Kulik - University of Dayton; Kate Lankin - Wells College; Gordon McDuff - California State University; Andrea Nordholt - University of Tampa; Patrick Schafer - Oakland University; Elise Smith - University of Missouri; Vivian Tang - Brown University.

FINDINGS

A. ACTUAL ACCOMPLISHMENTS AND FINDINGS

Results

Task A: Testing the Hypothesis that Hook Release Mortality Is Greater than Depth Induced Mortality for Red Snapper in the Recreational and Recreational-for-Hire Fisheries

1. Acute Mortality aboard Headboats:
   a. *Specimen collection*: A total of 171 moribund red snapper were collected during fishing trips aboard headboats off Panama City, Daytona and St. Augustine, Florida. Only 20

moribund red grouper and 4 dead vermilion snapper were collected during fishing trips aboard headboats during the same time period (***Figure 4***). Total catches for the three species during these headboat trips were 266 red snapper, 56 red grouper, and 160 vermilion snapper. These numbers include those moribund fish brought to MML for necropsy.

Figure 4. The Gemini Queen headboat which fishes out of Panama City, FL.

b. <u>*Fish necropsy*</u>: All moribund fish were transported to MML for necropsy. ***Figure 5*** shows necropsy results. Mortality was attributed to hook injury, barotrauma, or "other". The other category included improper venting, stress, heat, or unknown.

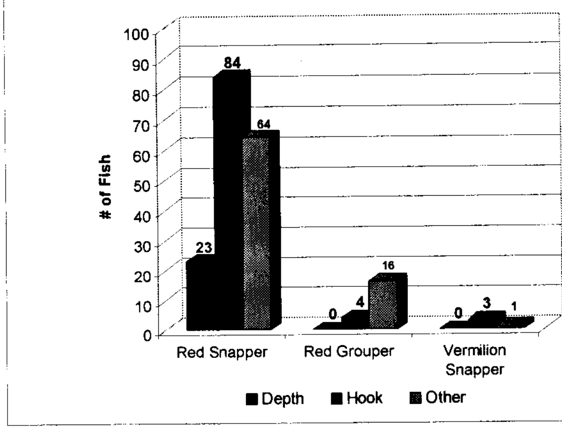


Figure 5. Acute shipboard mortality partitioned by cause of death (depth-related, hooking, other). Graph shows comparison of red snapper to other target reef fish.

Depth-related effects (barotraumas) accounted for 13.5% of red snapper mortality (***Figures 5***). As seen in ***Figure 6***, red snapper mortality was highest (59.1% of all red snapper mortalities) at depths between 27.7 - 42.7 m (91 - 140 ft). Interestingly, hook trauma accounts for the largest portion of mortalities even at these depths (60.4% of all mortalities in this depth category).

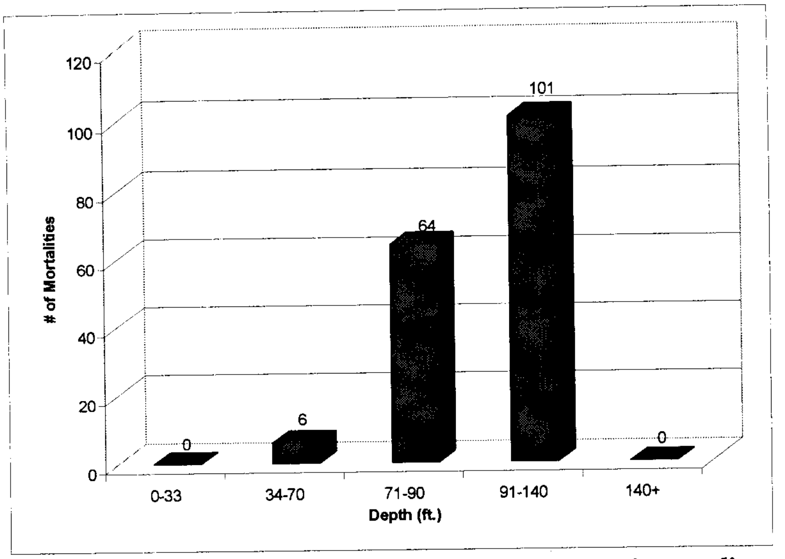


Figure 6. Number of red snapper acute shipboard mortality by depth category.

Of all the species studied, red snapper suffered the greatest hook mortality. Of 171 moribund red snapper collected, 49.1% succumbed to injuries received during hooking, which is nearly the same percentage (50.9%) as all other sources of mortality combined (***Figure 5***). When compared to total catches per species on these trips (266 for red snapper, 56 for red grouper, and 160 for vermilion snapper) red snapper hook mortalities

Figure 7. Red snapper killed by hook injury.

Figure 8. Red snapper killed by hook mortality with macerated liver.

constituted 31.6% of the total as compared to 7.1% for red grouper and 1.9% for vermilion snapper. If the hook was oriented upward when swallowed it punctured the duct of Cuvier, also known as the anterior cardinal vein (***Figure 7***). If oriented downward it typically punctured or destroyed the liver (***Figure 8***).

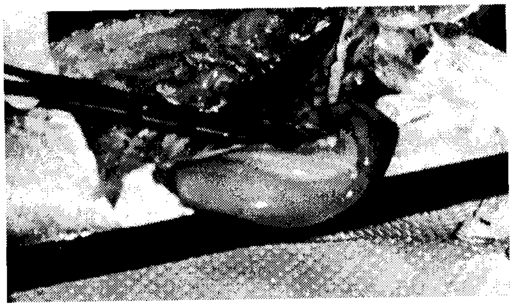


Figure 9. Pooled blood in a red snapper which died as a result of latent hook mortality.

Some red snapper caught on J hooks were brought back to the MML wet lab as experimental animals for the chamber studies and later died of latent hook injuries. The trauma was not immediately apparent. When first caught, and for two days thereafter, the fish appeared healthy. By day three the fish began to lose their bight red color and refused to eat; they died on day five. Necropsies showed that the hook had nicked a vital organ, such that "drop by drop", the fish slowly bled to death. Blood from the nicked vital pooled in the ventral coelom (***Figure 9***).

c. Feeding Videos: Many (672) red grouper, gag, and vermilion snapper were caught during the same fishing trips as were the moribund red snapper. As these undersized fish were in good condition, they were tagged and released. Of these, 32 (4.8%) have been recaptured. Since all these species were caught aboard the same headboats, on the same fishing trips, at the same depth, using the same fishing gear (hook-and-line), bait and by the same fishers, we developed a working hypothesis that differences in hook mortality were due to difference in feeding behavior. To test this, we brought red grouper and red snapper into the laboratory and recorded their feeding behavior on video tape.

A live shrimp was tethered to a diving weight and placed between two cameras facing perpendicular to each other in holding tanks containing either red snapper or red grouper. Color video of both species' feeding behavior was recorded. During review, sections of video were slowed by 50% for better analysis of feeding mechanics.

Although both species are aggressive feeders, the video showed a marked difference in feeding behavior between them. Very often, red snapper take prey (the shrimp) or pieces of the prey into their mouths and quickly chew 2 - 3 times before swallowing. Thus, the prey remains in the mouth for only a brief period. This type of feeding allows only a very small amount of time to set a hook before it is swallowed. That feeding mode appears to be occurring *in situ* as our necropsy results for red snapper mortality caused by J hooks are consistent with injuries so induced.

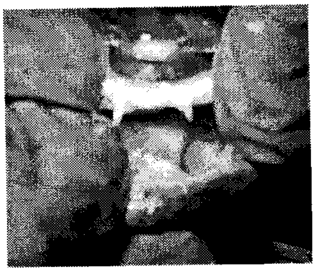


***Figure 10.* Canine teeth of a red snapper.**

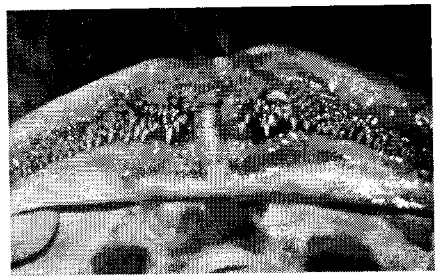


***Figure 11.* Red grouper dentition. Notice the backward slant of the teeth.**

The video observations are also consistent with gut content analyses, which show that red snapper, more often than red grouper, have pieces of prey in their stomachs. It is also consistent with red snapper dentition, shown in ***Figure 10***.

Conversely, red grouper tend to take the entire prey into their mouths and keep it there for awhile before swallowing it whole, if possible for them to do so. Holding the prey longer in the mouth, allows more time to set a J hook before the bait is swallowed.

Red grouper dentition differs from that of the red snapper. ***Figure 11*** shows red grouper dentition. Notice the lack of canine teeth, as seen in red snapper. Note also the way the teeth bend backward for gripping and holding, rather than piercing and slashing.

2. <u>Circle vs J Hook Mortality</u>

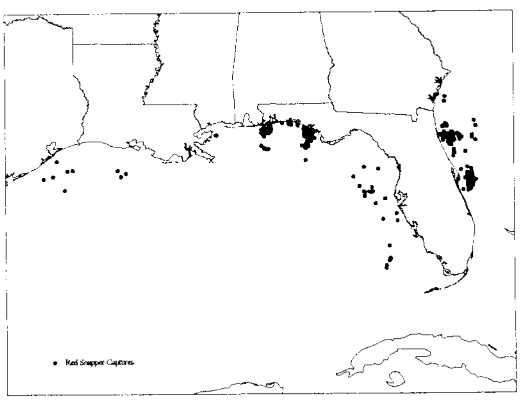


***Figure 12.* Locations of where red snapper were tagged.**

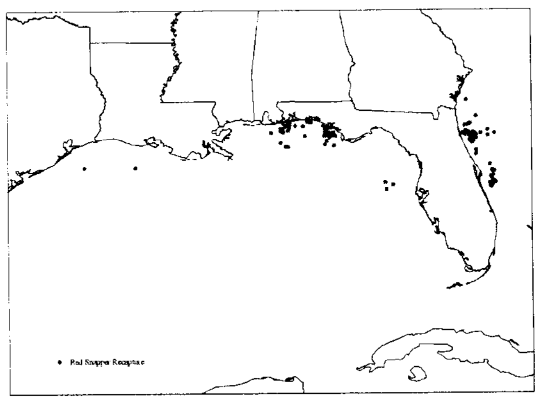


***Figure 13.* Locations where red snapper were recaptured.**

Tagging Results: Since red snapper exhibited very high J hook mortality, we added a circle hook component to the tagging study, comparing survival rates from tag recaptures. To obtain sufficient tag returns of fish captured on circle hooks within the time frame of the project, volunteer taggers from South Georgia to Texas were included in the study. ***Figures 12*** and ***13*** show locations where red snapper were tagged and recaptured.

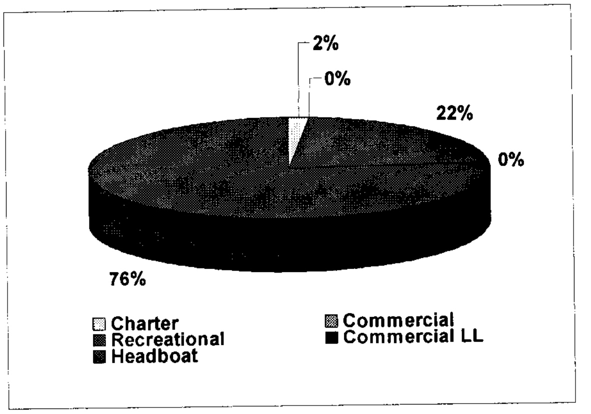


Figure 14. Percent of red snapper tagged/released by participating fishing sector.

Since tag returns can be an effective means of documenting long-term fish survival post-release, an evaluation of survivorship was accomplished by integrating an experimental design into the existing long-term Reef Fish Tagging Program at MML. Data are not representative of the red snapper commercial fishery because most of the data are from the recreational and recreational-for-hire fishing sectors. ***Figure 14*** shows the percentage of fishers in each fishing sector who tagged and released red snapper.

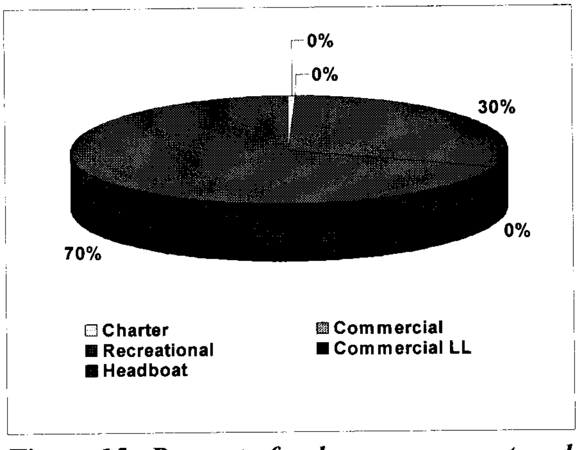


Figure 15. Percent of red snapper recaptured by participating fishing sector.

Most red snapper were tagged aboard headboats by MML staff and student interns. However, red snapper recaptures from headboats appeared to be significantly less than recapture rates from other fishing sectors. This result was due to under reporting of recaptures, rather than lack of recaptures. Only two headboat crews reported recaptures without direct assistance from MML personnel. Some fish tagged aboard headboats were recaptured in other sectors of the fishery (***Figure 15***).

It is important to note that data presented here are from red snapper caught only aboard recreational and recreational-for-hire vessels whose owners participated in the study. They may or may not be representative of the fishery. A few fish were tagged by commercial captains. Although the data are too few to be meaningful, they are included since they were available.

A total of 5,272 red snapper were tagged and released by MML staff and student interns aboard headboats and 83 volunteer taggers from various sectors of the red snapper fishery. Tagged/released fish ranged from 152 - 686 mm (6 - 27 in) FL. Of these, 386 were recaptured. Recaptures ranged from 254 - 965 mm (10 - 38 in) FL. ***Table 1*** shows the number of red snapper tagged and recaptured by sector.

Table 1. Number of red snapper tagged and recaptured by fishing sector. (Number differs from that above because this table includes recaptured fish that were re-released).

Data type	# Tagged	# Recaptured
Charter	85	2
Commercial	10	0
Commercial LL	6	0
Headboat	4143	283
Recreational	1197	123

a. <u>Length /frequency</u>: To determine the magnitude of the undersized bycatch of red snapper, MML staff aboard headboats and participating volunteer recreational and recreational-for-hire taggers were asked to count, measure and record all red snapper (legal and sub-legal) caught per trip (***Table 2*** and ***Figure 16***). Data are from October 1, 1990 - December 31, 2003. Not all taggers participated in the enumeration of red snapper catch per trip.

Table 2. Number of red snapper measured/tagged/released and measured/released by sector. (No recaptures are included in this table; fish with no data type listed are omitted).

Data type	# Tagged	# Measured	Total
Charter	85	106	191
Commercial	10	3	13
Commercial LL	6	0	6
Headboat	4006	1352	5358
Recreational	1124	476	1600

Data collected showed differences in the size of red snapper caught by study participants by area. Areas were divided into four locations - Atlantic (Key Largo to Georgia), South Florida Gulf (Tampa to Florida Bay), Central Florida Gulf (Tampa to Apalachee Bay) and Florida Panhandle and West (Apalachee Bay to Texas).

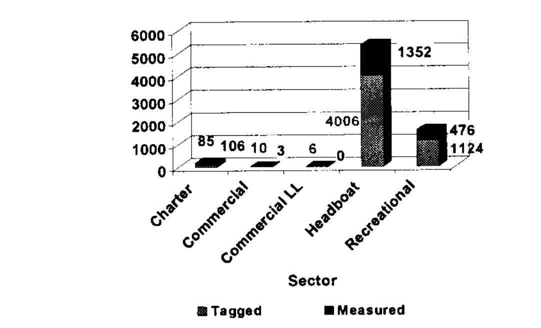


Figure 16. Number of red snapper measured/tagged/released and measured/released or measured/kept by fishing sector.

It is important to remember that size differences in the MML database may be an artifact of our volunteer taggers fishing sites and habits and may not accurately reflect the red snapper populations in the areas sampled in the Gulf of Mexico and the Florida east coast. ***Table 3*** shows the size range of red snapper caught in the four different locations.

Table 3. Size range of red snapper measured in the areas tagging occurred. (The number of fish includes recaptured remeasured fish).

Area	Size (in)	# of Fish
Atlantic	6.0-23.0	2335
Central FL Gulf	13.0-27.0	23
FL Panhandle & West	7.25-26.0	3094
South FL Gulf	10.5-25.0	82

Fish measurements for all four years were used to construct length/frequency histograms of pooled data for measured/tagged/released, measured/released, and measured/kept red snapper by area. Areas include the four locations mentioned above (***Figure 17***). In the Gulf of Mexico, legal size for red snapper is 406 mm (16 in), not the 559 mm (22 in) size limit in the South Atlantic.

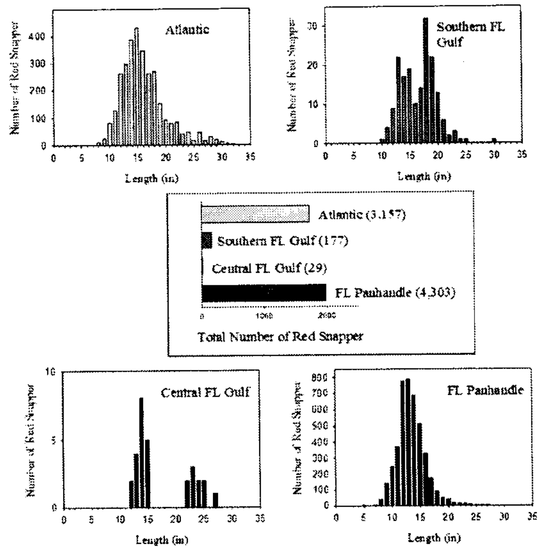


Figure 17. Length/frequency histogram of red snapper which were measured/tagged/released and measured/released from October 1, 1990 - December 31, 2003.

b. <u>*Tagging Results*</u>: As previously mentioned, from 1/01/90 through 12/31/03, a total of 5,272 red snapper were tagged and 386 red snapper were recaptured (***Figure 18***). Of the 386 recaptures, 25 fish were recaptured multiple times, so recapture events totaled 410 (***Figure 19***). The number of fish shown in each category of ***Figure 19*** are unique. The 20 fish caught twice are not included in the group of one time recaptures. Red snapper shown as being recaptured three times are not represented in either of the previous groups in the graph.

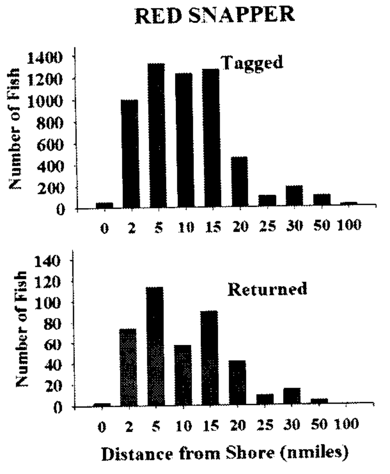


Figure 18. Number of red snapper tagged and recaptured by distance from shore. Distance from shore in nautical miles.

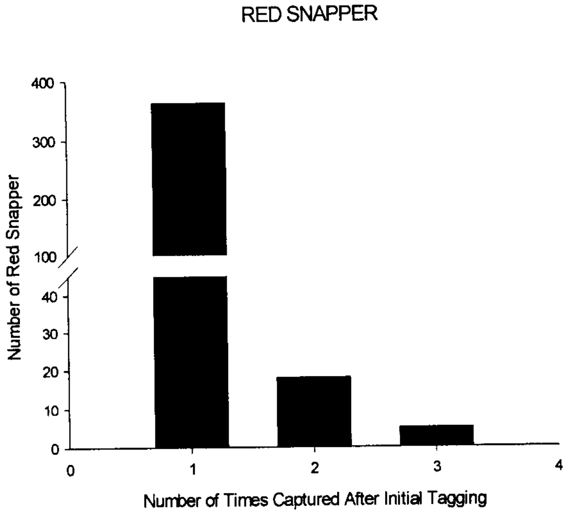


Figure 19. Red snapper multiple recaptures.

c. <u>Days of Freedom</u>: Red snapper exhibited more Days of Freedom (DOF) than other species of reef fish in the MML Reef Fish Tagging Program. Many red snapper were at large for 161 - 640 days (***Figure 20***). This shift in DOF from the more normal distribution seen in red grouper (***Figure 21***) is probably the result of the red snapper closed season.

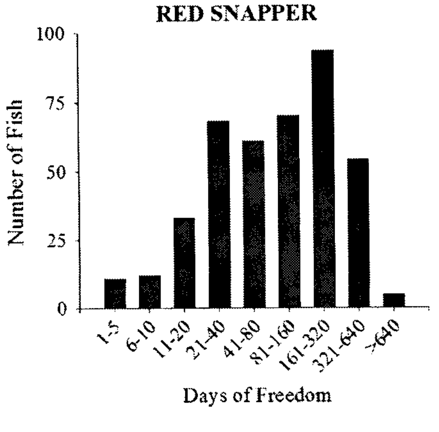


Figure 20. Days of Freedom (DOF) for recaptured red snapper.

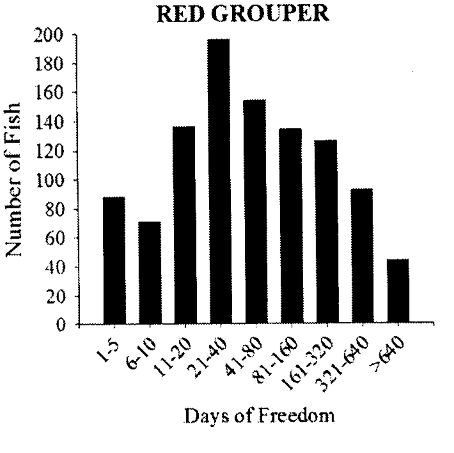


Figure 21. Days of Freedom (DOF) for recaptured red grouper.

d. Red snapper tag returns by hook type and depth:

Fishers from all sectors were asked to measure, tag and release equal numbers of red snapper caught on three different hook types. Hook types included J, kahle, and circle hooks. Most fishers refused to use the kahle hooks, so the study was changed to be a comparison of circle versus J hooks.

Most red snapper were tagged and released aboard headboats and recreational vessels. The 10 fish tagged by the commercial sector were caught on 2 vessels, 4 fish were caught on hook-and-line, the other 6 on electronic rod and reel. ***Figures 22*** and ***23*** shows the number of fish tagged and recaptured by sector and hook type. ***Figure 23*** does not represent the total number of red snapper tagged and released (5,272) because fish (174) caught on kahle hooks, and those where fishers failed to report hook type, are not included.

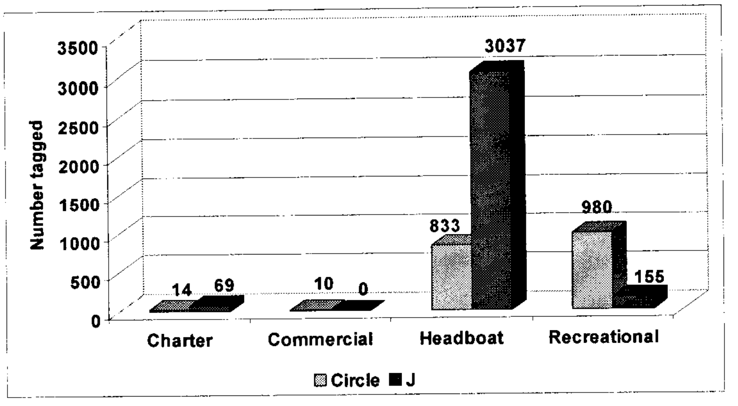


Figure 22. Number of red snapper tagged by fishing sector and hook type.

Most red snapper recaptures were made by headboat and recreational fishers. Returns from both sectors showed, fish originally caught on J hooks to have a slightly better recapture rate that those initially caught on circle hooks. Recapture rates for red snapper initially caught on circle and J hooks from headboats were 5.5% and 7.2%, respectively. For fish recaptured

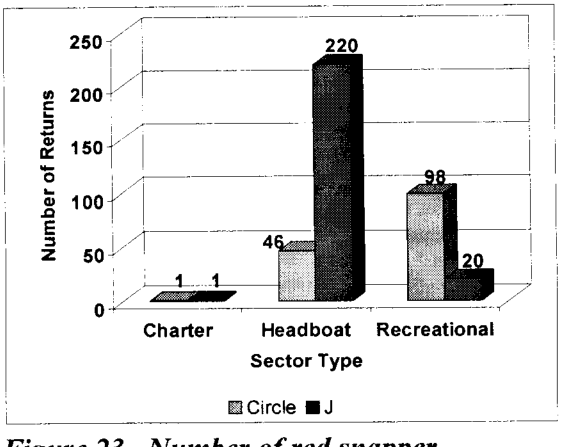


Figure 23. Number of red snapper recaptured by fishing sector and hook type.

by recreational fishers, 10% were initially caught on circle hooks, while 12.9% were from J hooks (***Figures 24*** and ***25***).

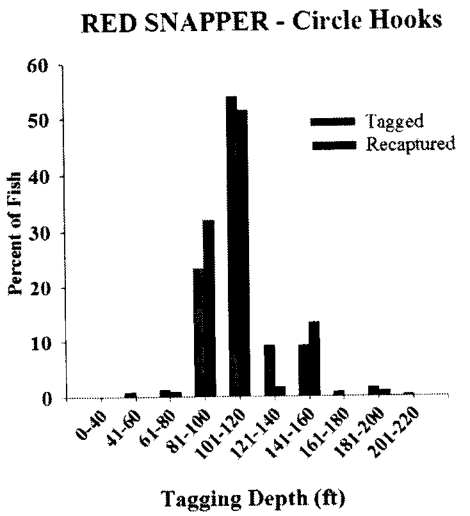


Figure 24. Percent of red snapper tagged and recaptured by tagging depth for red snapper caught on circle hooks when originally tagged.

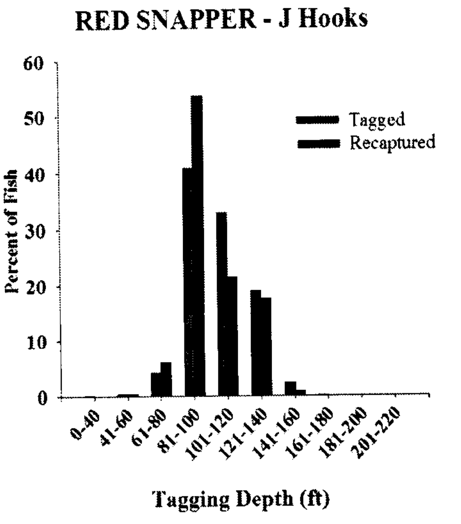


Figure 25. Percent of red snapper tagged and recaptured by tagging depth for red snapper caught on J hooks when originally tagged.

Comparison of red snapper recaptures from fish caught on both circle and J hooks, then tagged and released at various depths, showed no apparent difference in the number of tagged and recaptured fish returned by depth category for that hook type (***Tables 4*** and ***5***). Because the numbers of fish tagged and released by hook type were different, recaptures are expressed as percentages.

Table 4. Percent of red snapper tagged and recaptured by tagging depth for red snapper caught on circle hooks when originally tagged.

Depth	**# Tagged**	**# Returned**	**% Returned**
0-40	15	0	0.00
41-70	92	3	3.26
71-100	1345	123	9.14
101-200	384	20	5.21

Table 5. Percent of red snapper tagged and recaptured by tagging depth for red snapper caught on J hooks when originally tagged.

Depth	# Tagged	# Returned	% Returned
0-40	17	1	5.88
41-70	1089	115	10.56
71-100	1510	85	5.63
101-200	721	43	5.96

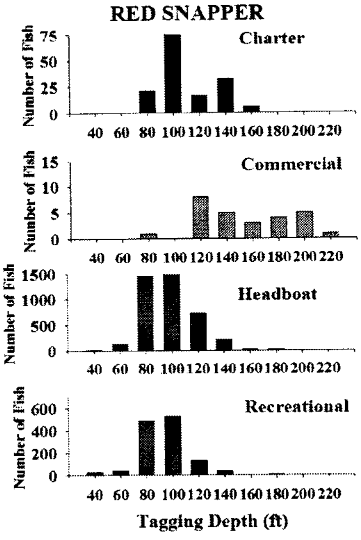


Figure 26. Number of red snapper tagged/released by depth and fishing sector.

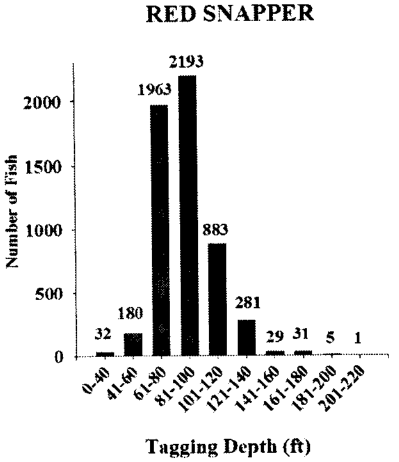


Figure 27. Total number of red snapper tagging events by depths.

Red snapper tagged releases and recaptures were plotted by depth. By and large, study participants from all sectors (***Figure 26***) fished in waters deeper than 12.2 m (40 ft). Most fish were tagged between 18.6 and 36.6 m (61 and 120 ft). ***Figure 27*** shows the number of red snapper tagging events by depth for all sectors. Tagging events include multiple returns where fish are recaptured and re-released. Multiple returns explain why graphs or tables showing the number of events is greater than those showing the number of actual fish tagged. All tagging data are pooled in ***Figure 27***. Most red snapper were tagged at depths ranging from 18.6 - 36.6 m (61 - 120 ft).

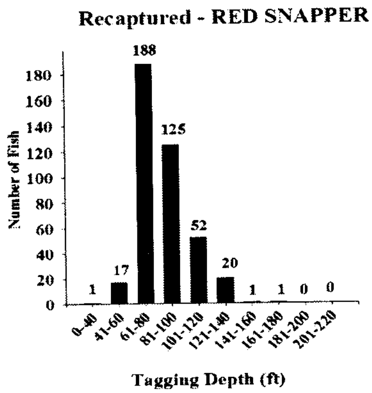


Figure 28. ***Red snapper recaptures from fish originally tagged at depths shown.***

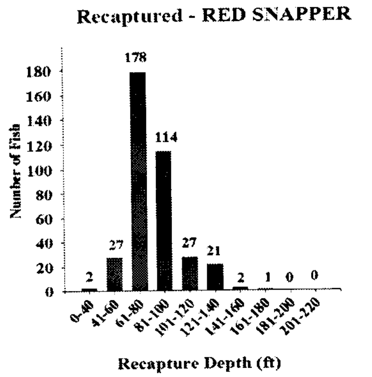


Figure 29. ***Actual red snapper recapture depths for all returns. Recaptures without depth data were not included.***

Figure 28 shows the number of red snapper (events) which were recaptured from red snapper tagged in the tagging depth categories shown in ***Figure 27***. Fish were not necessarily recaptured at that same depth. Data show that more red snapper (9.6% or 188 recapture events from the original 1963 tagging events) recaptures were from fish tagged at depths between 18.6 - 24.4 m (61 - 80 ft). Recaptures from the original tagging depths from ***Figure 27*** were 3% at 0 - 12.2m (0 - 40 ft), 9.4% at 12.5 - 18.3 m (41 - 60 ft), 9.6% at 18.6 - 24.4 m (61 - 80 ft), 5.7% at 24.7 - 30.5 m (81- 100 ft), 5.9% at 30.8 - 36.6 m (101-120 ft), 7.1% at 36.9 - 42.7 m (121 - 140 ft), 3.4% at 43.0 - 48.8 m (141 - 160 ft) and 3.2% at 49.0 - 54.9 m (161-180 ft).

Actual recaptures by depth are shown in ***Figure 29***. There are a few less fish in ***Figure 29*** than in ***Figure 28***, because recaptures without depth of recapture, were not included. Similar to the recaptures in ***Figure 28***, actual recaptures were greater in shallow depths than at deeper depths, however, ***Figure 29*** shows differences in recaptures which can only be accounted for by fish movement.

Most (3,402) red snapper tagged and released ranged in size from 304.8 - 381 mm (12 -15 in) SL. However, a greater percentage of larger fish (406.4 mm, 16 in SL, or greater) was recaptured. Average tagging and recapture depths were approximately the same for all sizes (***Table 6***).

Table 6. Recaptures of red snapper by size and water depth.

Size					Depth					
					Range		Average Tag Depth		Average Recapture Depth	
(mm)	(in)	# Tagged	# Recaptured	% Recaptured	(m)	(ft)	(m)	(ft)	(m)	(ft)
<304.8	<12	1204	39	3.24	6.7-41.1	22-135	26.7	87.5	26.2	86
>=304.8, < 406.4	>=12, <16	3402	236	6.94	3.7-56.4	12-185	27	88.6	26.2	85.9
>=406.4	>=16	1145	130	11.35	3.7-69.5	12-228	27.7	90.92	25.3	83.1

d. Red Snapper Movements: DOF did not necessarily correlate with distance traveled (***Figure 30***). In ***Figure 30***, the x-axis is in nautical miles. Since fishers report tagging or recapture locations to the nearest minute of latitude and longitude, and based on our proximity to the equator, the definition of movement used in this report is at least 1 minute or 1 nautical mile.

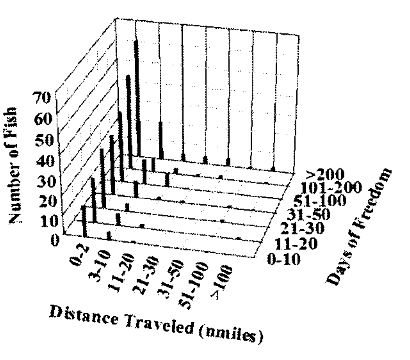


Figure 30. Red snapper recaptures plotted by Days of Freedom (DOF) and distance traveled.

Many red snapper exhibited poor long-term site fidelity, with 56.6% of recaptured fish caught at least 1 nautical mile (1.9 km) from the original tagging site. Fish of all sizes moved and distance traveled was not correlated with a particular size. Data from this project combined with additional data from the MML's Reef Fish Tagging Program database are currently being put into GIS format for analyses of fish movement with size, season, bottom type, bathymetry, artificial reef and sanctuary locations, and possible travel directions and corridors. Results will be published in a peer reviewed scientific journal.

Task B: Laboratory Simulations of Depth Effects Using Fish Hyperbaric Chambers

Over the course of the study, red grouper exhibited higher susceptibility to barotrauma mortality than red snapper. Although similar percentages of red snapper (39%) and red grouper (40%) died from decompression injuries, significant differences between species were apparent (***Table 7***). Mortality for red snapper was 40% for fish decompressed from 42.7 m (140 ft) and 45% for fish from 61.0 m (200 ft). For red grouper 75% of the fish tested at 42.7 m (140 ft) died. Red grouper mortality at 42.7 m was so high that no 61.0 m (200 ft) replicates were attempted. In addition, red grouper exhibited 50% mortality at 27.4 m (90 ft) while red snapper had 0% mortality in other laboratory trials at this depth (Joakim Malmgren, personal communication). Acute mortality in red grouper accounted for 100% of all red grouper mortality, while only 71% of red snapper mortality was acute (***Table 8***).

Table 7. Red snapper and red grouper mortalities from hyperbaric chamber tests. Data includes the # of mortalities for each depth, % of all fish tested for each species, % of all fish tested at depth by species, and % of all mortalities by depth.

		Depth m (ft)				
		21.3 (70)	27.4 (90)	42.7 (140)	61.0 (200)	% of species
Red snapper	# of mortalities	-	-	8	9	39.0
	% by depth	-	-	40.0	45.0	-
	% of all RS mortalities	-	-	47.1	53.0	-
Red grouper	# of mortalities	-	2	6	-	40.0
	% by depth	-	50.0	75.0	-	-
	% of all RG mortalities	-	25.0	75.0	-	-

Table 8. Acute and delayed mortalities of red snapper and red grouper from hyperbaric chamber tests.

	Acute	Delayed	Total mortalities	% acute	% delayed
Red snapper	12	5	17	71.0	29.0
Red grouper	8	0	8	100.0	0.0

When red snapper were removed from the chambers they exhibited different signs of distress and behavior than red grouper. Red snapper exhibited distended abdomens, prolapsed intestines, and oral stomach protrusion upon rapid depressurization (***Figure 31***). The eversion of the stomach from the mouth produced an interesting ring-like bruise in both species. The doubling over of the esophagus caused capillaries in the esophagus to burst, resulting in the bruise seen in ***Figure 32***. In addition to the aforementioned signs, red grouper also showed bilateral pressure-induced exophthalmia (***Figures 33*** and ***34***). This condition was unique to red grouper throughout the course of this experiment. Upon venting and release into the holding/recovery tank most of the red snapper remained upright on the bottom and behaved normally. In contrast, red grouper

Figure 31. Oral stomach protrusion in red snapper decompressed from 61.0 m (200 ft).

Figure 32. Esophageal ring bruise caused by stomach prolapse in red snapper decompressed from 61.0 m (200 ft).

(especially from 42.7 m or 140 ft) dove straight down, bounced off the tank bottom and slowly floated to the surface where they eventually died (***Figure 34***). Internally drastic differences existed as well. Ruptured swimbladders were found in all fish decompressed from 42.7 m (140 ft) or deeper. Some visceral displacement and torsion was found in red snapper, especially from 61.0 m (200 ft), however, very little hemorrhaging was ever detected. In red grouper hemorrhaging was abundant, even in fish decompressed from 27.4 m (90 ft). This hemorrhaging included bilateral clots in the post-cranial area and thoracic cavity (***Figure 35***). Overall, necropsy results for red grouper showed much more traumatic injury than in red snapper. Swimbladder ruptures were found to be healed within 4 days after chamber removal. Even extensive ruptures were found healed over, and swimbladders functional, in both species within this time period.

Figure 33. Pressure induced exoptahalmia in red grouper decompressed from 27.4 m (90 ft).

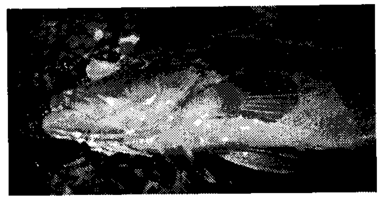


Figure 34. Dying red grouper from 42.7 m (140 ft) chamber trial. Note exopthalmia.

Figure 35. Bilateral post-cranial hemorrhages in red grouper decompressed from 21.3 m (90 ft).

Red snapper which survived decompression from 42.7 m (140 ft) were found to aggressively feed within 4 hrs of chamber removal. Surviving red grouper from the same depths showed no interest in food for 12 – 24 hrs, however, red grouper from 27.4 m and 21.3 m (90 and 70 ft) fed within 2 hrs of removal. Both red grouper and red snapper used in controlled acclimatization tests fed within 1 – 2 hrs of removal from chambers.

Both red snapper and red grouper had 0% mortality in trials with controlled acclimatized ascents. Four pressure increments were used for red snapper (63, 40, 25, and 15 psi) while red grouper required five stops (63, 50, 35, 20, and 5 psi). Despite the need for an extra stop the red grouper spent less cumulative time (76.5 hrs) being acclimated than red snapper (104 hrs). Handling time averaged 51 sec (standard deviation 21.9 sec) for all trials and all chambers. At times fish became hung up on the chamber doors, resulting in longer handling/struggle times. Times ranged from 9 – 103 sec.

<u>Discussion and Conclusions</u>

<u>Acute Mortality</u>:
Although red snapper mortalities were highest in the 27.7 – 42.7 m (91 – 140 ft) depth category the largest portion of mortality (59.1%) here was caused by hook trauma (***Figure 6***). This depth category also contains the largest number of fish caught and therefore would

logically exhibit higher mortality levels. In addition, hooking injuries killed 31.6% of the total catch of red snapper on these headboat trips. Overall, hooking injuries were found to account for the largest overall percentage of red snapper mortalities (***Figure 5***). Koenig (2001) reported that gut and gill hooked fish were not used in their study because the probability of survival of such a fish was essentially zero, regardless of capture depth. It is evident from these results that hooking has a much larger impact on red snapper survival than depth related effects.

Comparison of acute mortality between species was elusive. Too few red grouper and vermilion snapper were captured to arrive at solid conclusions for these species. Although a small number of red grouper and vermilion snapper were collected, those fish that were necropsied did not show obvious signs of hook mortality as were seen in red snapper. Comparing overall mortality rates between the species we see that a total of 64.3% of the total red snapper catch died, much greater than the 35.7% of red grouper and 2.5% of vermilion snapper that died. Based on the results of Koenig (2001), and our findings in the laboratory, it seems that depth-related trauma has a much more significant effect on red grouper than red snapper. However, hooking injuries are much more detrimental in red snapper. With a larger acute mortality data set for red grouper and vermilion snapper these effects may be more apparent.

Circle Hooks:
Some researchers have reported increased survival for various species caught on circle hooks, including juvenile bluefin tuna, striped bass, Atlantic and Pacific sailfish, yellowfin tuna, and Pacific halibut (Falterman and Graves, 2002; Lukacovic and Uphoff, 2002; Prince *et al*, 2002; Skomal *et al*, 2002; and Trumble *et al*, 2002). Results from our study agree with those of Zimmerman and Bochenek (2002) and Malchoff *et al* (2002), who both worked on summer flounder, and reported that circle hooks were not more effective than J hooks in reducing hooking.

Cooke and Suski (2004), wrote "Though much of the current literature shows the benefits from using circle hooks, the data are somewhat limited, and, in many cases, are somewhat conflicting". Although their meta-analysis showed that, for the most part, circle hooks reduced hooking mortality rates by approximately 50% versus J hooks, they also reported that some studies attributed increased tissue damage to circle hooks.

In addition, circle hooks vary by whether or not the hook is offset and by the degree of offset. Malchoff *et al* (2002) reported that in their summer flounder study, "hook offset may have negated the normal "jaw hooking only" pattern normally seen with circle hooks. This is corroborated in the sailfish fishery where highly offset circle hooks were associated with significantly more deep hooking than minor offset (4%) and nonoffset hooks (Prince *et al*, 2002)". Although circle hooks in our study were not offset, there were slightly more red snapper recaptures from fish initially caught on J hooks. This, in spite of the fact that J hook mortality was the leading cause of mortality of red snapper in our study. Red snapper might be a species, like summer flounder, where circle hooks do not provide increased survival over J hooks (Jon Lucy, Virginia Institute of Marine Science, personal communication). On the other hand, it must be noted that in our study, although we issued only 4/0, non-offset circle hooks, it is likely that some fishers may have used their own circle hooks which could vary in both size and offset, or that the hooks were offset by hand. Before any management decisions are implemented, a controlled, scientific study with equal sample sizes and treatments and depths should be undertaken to truly determine if circle hooks enhance survival in red snapper.

Predation:

A confounding factor was realized while tagging and collecting red snapper for this project. Predation events by bottlenose dolphins (*Tursiops truncatus*) on undersized recreational bycatch were observed by Mote Marine Laboratory staff during bycatch quantification. While on two separate tagging trips (April 2003) aboard headboats in Panama City, FL, MML staff witnessed selective predation on undersized red snapper discards (***Figure 36***). Confirmed takes constituted 6.5% and 2.9% of the total red snapper bycatch for each trip respectively. Probable takes amounted to 21.7% and 20.0% respectively (***Table 9***). "Confirmed takes" constituted those in which the observer directly witnessed consumption of the fish by a dolphin. If an observer saw a dolphin turn towards a released fish and pursue it out of sight then a "probable take" was recorded. The dolphins were seen to take some other species, such as sand perch (*Diplectrum formosum*) and gulf flounder (*Paralichthys albigutta*), but they seemed to prefer red snapper. Gray triggerfish (*Balistes capriscus*) were mouthed at times but never consumed. Released gag (*Mycteroperca microlepis*) and red grouper (*Epinephelus morio*) were visually inspected but otherwise ignored by dolphins. During one trip the dolphins were very bold and aggressive, to the point of taking red snapper that were still hooked (***Figure 37***). Although the dolphin was not hooked, the fisherman holding the rod was nearly pulled overboard before the 80 lb. test monofilament line finally snapped.

Figure 36. Bottle nose dolphin feeding on undersized red snapper discards from a headboat off Panama City, FL.

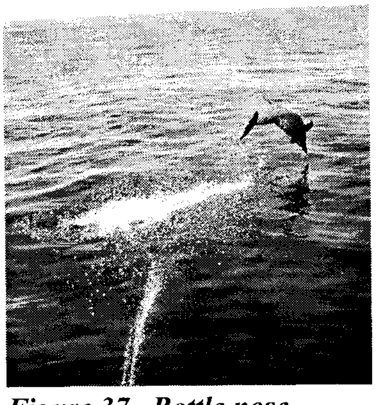


Figure 37. Bottle nose dolphin taking hooked red snapper (with rod and reel) before the fisher could land it aboard a headboat off Panama City, FL.

Table 9. % of total red snapper bycatch taken by bottlenose dolphins off Panama City, FL.

	Percent of bycatch	
	4/2/2003	4/16/2003
Confirmed* red snapper takes	6.5%	2.9%
Probable** red snapper takes	21.7%	20.0%

* confirmed takes were actually witnessed by MML staff.
**probable takes are those in which dolphins turned and pursued released fish but predation was not witnessed.

The dolphins responsible for the observed predation were not solitary animals. In both cases a pod of between 3 and 6 dolphins converged on the boat and exhibited this behavior. At least one individual was present during both trips, being identified by unique scarring on the dorsal fin. In addition, in both cases at least one mother-calf pair was present, suggesting that young bottlenose dolphins could be learning this behavior as part of their normal feeding activity. The dolphins participating in this activity seem to have learned to follow people with fish around the boat until the fish is released. This then negates the act of catching fish on one side of the boat and releasing on the other, which several people attempted to do. Although dolphin predation on red snapper bycatch was only observed in one area it has been reported by fishermen in Madeira Beach and St. Augustine, FL, as well as other popular fishing spots. If this activity turns out to be geographically widespread, and if 20% or more of undersized discards are being taken by predators, serious steps may need to be taken to address this problem in future management decisions.

Barotrauma:

1. Shipboard Mortality/Recapture

Most red snapper were recaptured at depths ranging from 18.6 - 30.5 m (61 - 100 ft). These were also the same depths where most fish were initially tagged. Recaptures dropped steeply at 30.8 -36.6 m (101 - 120 ft), but small numbers of fish continued to be recaptured to depths of 53.3 m (175 ft). Unfortunately, little can be said regarding these deep recaptures, except that they occurred, since the sample size for fish tagged deeper than 42 m (140 ft) is so small. In addition, the physiological trauma that phystoclistic fish species experience during ascent from deeper water appears to involve other factors which may modify the extent of damage experienced from rapid changes in pressure. Koenig (2001) found a significant "direct and strong relationship between depth-related mortality and surface interval". Another relationship may be due to physiological changes related to the amount of physical activity (how much the fish struggles) during ascent from depth.

In our study, all fish caught on hook-and-line at depths ranging 21.3- 42.7 m (70 - 140 ft), suffered from swimbladder rupture. The extent of apparent bloating and other capture related abnormalities increased by depth. However, fish caught in commercial fish traps (***Figure 38***) at similar depths, do not usually experience this damage (trap fishers, personal communication). To photodocument this, 10 red grouper were purchased from commercial reef fish trap fishers. ***Figure 39*** is a photograph of an inflated red grouper swimbladder from this group, which was originally captured in a trap at 35.0 m (115 ft).

Figure 38. Stack of commercial reef fish traps.

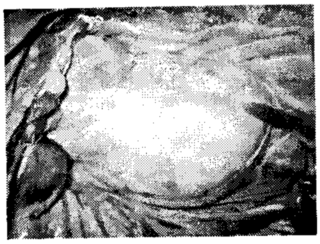


Figure 39. Inflated swimbladder of 670 mm (26 in) red grouper caught in a commercial fish trap at 35.0 m (115 ft).

2. Laboratory: Fish hyperbaric chambers

Hyperbaric chamber tests indicated 60% survival of red snapper at 42.7 m (140 ft). Our results are supported by Gitschlag and Renaud (1994) who reported 56% survival of red snapper at depths of 37 – 40 m (121.4 and 131.2 ft), and Koenig (2001) who reported 50% survival at 36 m (118.1 ft). We also found 55% survival at 61.0 m (200 ft) as compared to previous findings of 60% survival at 50 m (164 ft) (Gitschlag and Renaud, 1994). Although our trials did not include shallow depths (<30 m) for red snapper other studies have found no mortality at 21.3 and 27.4 m (70 and 90 ft) (pers. observation). In addition, Koenig (2001) reported that 20.0 m (65.6 feet) was non-lethal to red snapper (no everted stomachs, etc.). In our study, there were no effects of handling time on survival, however, the average handling time (51.2 sec) during year two may have been too low to realize any effects. Koenig (2001) found surface interval (analogous to handling time) to be strongly related to mortality. The surface intervals ranged from 3 – 18 min, far longer than our range (9 – 103 sec) during year two. However, during year one, longer handling time (3 - 10 min) was probably responsible for the more variable survival observed at 42.7 m (140 ft) and 61.0 m (200 ft) and this does agree with Koenig's results.

Red grouper appeared to be much more susceptible to depth-related trauma than red snapper. In 42.7 m trials, we found only 25% survival in red grouper as compared to 60% survival in red snapper. Only 50% of red grouper survived from depths of 27.4 m (90 ft), however, 100% survived from 21.3 m (70 ft). The physical effects of rapid decompression on red grouper were much more evident in necropsies. Of particular interest was the presence of massive visceral hemorrhaging and bilateral cranial clots (see ***Figure 35***). These injuries were not found in red snapper, even those from 61.0 m. Red grouper also exhibited exophthalmia, from all depths except

21.3 m. In cases of exophthalmia gas was actually present behind the eyeball. The source of the gas was uncertain, however, the volume seemed to be too great to be accounted for by dissolved gas in tissues. Red snapper may be less prone to exophthalmia due to physical differences. Grouper eyes normally protrude much farther than those of snapper which may increase vulnerability to exophthalmia. Differences in depth-related trauma between the two species may also be related to swimbladder volume. Red grouper, being a more heavy-bodied fish, appear to have larger swimbladders as compared to red snapper. Thus, when the bladder bursts more gas may be released into the ventral coelom, increasing the amount of damage to the fish.

The ring-like esophageal bruise was an interesting and important finding (see ***Figure 32***). This bruise can be used to diagnose stomach distension in fish which are examined several days after the pressure event occurs. The magnitude of a depth-related trauma can also be assessed based on the ring since only stomach eversion into the oral cavity produces it. Also, using this landmark it may be possible to determine if a live fish has previously had pressure-related stresses, without having to sacrifice the animal.

No mortality was seen in either species during slow decompression runs. Red grouper took less total time to acclimate and decompress (76.5 hrs) from 42.7 m than red snapper (104 hrs). However, red snapper required four incremental pressure changes while red grouper required five. Also, red snapper were depressurized in nearly equal increments (39, 37, and 40% decreases from previous pressure) while red grouper increments differed (20, 30, 43, and 75%). Time to initial acclimatization (42.7 m, 63 psi) was much shorter for red snapper (52 hrs) than red grouper (71 hrs). Although red snapper required more time to reacclimatize after each pressure decrease they were able to handle larger changes than the grouper.

Overall, red snapper appeared to be much less affected by rapid decompression than red grouper. In addition to survival from depth results, and physical necropsy findings, red snapper recovered more quickly than red grouper. After only four hours red snapper decompressed from 42.7 m (140 ft) fed aggressively on live shrimp. Many of these fish had everted stomachs protruding from their mouths upon removal from the chambers, however, after a short period of time they were ready to feed. Red grouper from the same depths needed much longer to return to normal feeding activity (12 – 24 hrs). This difference in feeding activity following simulated catch and release (hyperbaric chamber runs) is important when considering delayed mortality from fishing activities. The cumulative effects of stress from decompression may have a larger impact on long-term red grouper survival following catch and release events.

B. SIGNIFICANT PROBLEMS

There were a number of problems encountered during the time period of this research. Some problems included difficulties in fish collection due to hurricanes, tropical storms, and weather fronts, a local power outage in the middle of the night which resulted in the death of all captive fish and overcoming resistance and convincing fishers to try circle hooks when fishing for red snapper. A major difficulty was having our research facilities moved to a new building just after year 1 experiments. The new facility was not ready on time and when we needed it because the Florida Power Company was 6 months late in getting electricity to the building, thereby resulting in our need to request a no cost extension. The final difficulty encountered was that the state collection permit needed for obtaining undersized red snapper for the chamber experiments was not processed by the state of Florida for more than 5 months from when the application was submitted. By the time the permit arrived, the Gulf of Mexico and South Atlantic water temperature was too warm in the shallow waters. The few fish caught, which had not moved to cooler deeper water, died after captured from exposure to the warm air temperature. Since red snapper could not be collected, the project had to be extended a second time.

C. NEED FOR ADDITIONAL WORK

Comparing results between hook versus depth-induced mortality rates for red snapper and red grouper, and the mechanisms responsible for the differences, demonstrated that the response of a fish to those factors depends not only on gear type, but also on the species. Feeding behavior, anatomy and physiology vary among species. Thus, each species of interest needs to be evaluated independently with respect to management options.

Additional work also needs to be done to evaluate survival from depth by various gear types. Fish caught on hook and line experience trauma different from fish caught in commercial fish traps which experience pressure changes differently from hook captured fish (see ***Figure 39***). Circle hooks vary not only by size but also by the angle of offset of the hook from the shank, which can provide different survival results.

EVALUATION

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

1. Goals and Objectives Attained

   Objective 1. To test the hypothesis that hook release mortality is an even greater factor than depth induced mortality for red snapper in the recreational, charter and headboat fisheries.

   The first objective was met for headboat mortalities. Acute mortality data obtained for red snapper and other reef fish captured during regular fishing trips aboard various headboats, showed that red snapper have a much greater susceptibility to acute J hook mortality than red grouper, vermilion snapper. Necropsies performed on moribund red snapper showed hook trauma killed 49% of all mortalities, which was almost as much as all other sources of mortality combined.

Since recreational and charter fishers had to discard all undersized fish, alive or dead, they were unable to provide MML staff with acute mortalities. Due to the number of tagging locations and the number of MML staff could not be on all these vessels. Headboats were targeted because they provided the opportunity for the most fish caught per trip. Direct measurements of hook mortality via necropsy of moribund fish could not be accomplished from recreational and charter vessels.

Objective 2. To obtain catch and release mortality rates by depth comparing return rates for red snapper caught using circle and J hooks aboard headboats, charter boats, and recreational vessels.

The second objective was accomplished. Data showed a slight difference in survival (return rates) for red snapper caught on J hooks versus the type of circle hook (no offset) used in the study. Data on survival at depths fished by participants were obtained. However, a controlled scientific study with equal sample sizes, treatments and depths, should be conducted before any management decisions are made.

Objective 3. To systematically evaluate through laboratory studies depth-related capture-release mortality and sub-lethal effects for red snapper.

The third objective was accomplished. Data collected from fish in hyperbaric chambers, free of hook mortality, agreed with data from project shipboard tag/return analyses for this project and those of other researchers. In addition, red grouper data were included for comparison.

2. <u>Modifications Made to the Goals and Objectives</u>

In the initial proposal, comparison of three different hook types was proposed. This was not possible. Fishers were unwilling to use kahle or circle hooks for the first year of the study. After the circle hook contest, circle hooks were being popularized in fishing magazines and at fishing clinics, etc., so some fishers began to use the circle hooks provided by MML. A few fishers tried the kahle hooks, but didn't like them. Due to the unpopularity of the kahle hooks, the study was modified to compare circle and J hooks. Results of analyses of red snapper and red grouper feeding videos, not part of this study, were included in this report.

B. DISSEMINATION OF PROJECT RESULTS

Project results were disseminated by presentations (Annual American Fisheries Society Meeting, Quebec, Canada, August 10-14, 2003 and the 15th Annual MARFIN Conference, Biloxi, MS, December 3-4, 2003). They are also disseminated in this report. Some of the results were published in Mote's Center for Fisheries Enhancement Fish Biology Program's Reef Fish Survival Studies (RFSS) newsletters (published quarterly with MARFIN funds). Some results are also available on the Fish Biology Program's website. Finally, results will be combined with those from identical research on red grouper to serve as part of Karen Burns' doctoral dissertation, from which a manuscript by Karen Burns, Raymond Wilson, Ph.D. and Nicholas Parnell, will be submitted later this year for publication in the scientific journal *North American Journal of Fisheries Management*.

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LITERATURE CITED

Burns, K.M. and V. Restrepo. 2002. Survival of Reef Fish after Rapid Depressurization: Field and Laboratory Studies. Pages 148-151 *in* J.A. Lucy and A.L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries Society, Symposium 30, Bethesda, Maryland.

Cooke, S.J. and C.D. Suski. 2004. Are circle hooks an effective tool for conserving marine and freshwater recreational catch-and-release fisheries? Aquatic Conserv: Mar. Freshw. Ecosyst. 14:000-000, 28 pages.

Falterman, Brett and John E. Graves. 2002. A Preliminary Comparison of the Relative Mortality and Hooking Efficiency of Circle and Straight Shank ("J") Hooks Used in the Pelagic Longline Industry. 2002. Pages 80-87 *in* J.A. Lucy and A.L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries society, Symposium 30, Bethesda, Maryland.

Koenig, Christopher. 2001. Preliminary results of depth-related capture-release mortality of dominant reef fish in the eastern Gulf of Mexico. Special report to the Gulf of Mexico Fishery Management Council.

Lucy, Jon A. and Michael D. Arendt. 2002. Short-Term Hook Release Mortality in Chesapeake Bay's Recreational Tautog Fishery. Pages 114-117 *in* J.A. Lucy and A.L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries society, Symposium 30, Bethesda, Maryland.

Lukacovic, Rudolph and James H. Uphoff. 2002. Hook Location, Fish Size, and Season as Factors Influencing Catch-and-Release Mortality of Striped Bass Caught with Bait in Chesapeake Bay. Pages 97-100 *in* J.A. Lucy and A.L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries society, Symposium 30, Bethesda, Maryland.

Malchoff, Mark H., Jeff Gearhart, Jon Lucy, and Patrick J. Sullivan. 2002. The Influence of Hook Type, Hook Wound Location, and Other Variables Associated with Post Catch-and-Release Mortality in the U.S. Summer Flounder Recreational Fishery. Pages 101-105 *in* J.A. Lucy and A.L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries society, Symposium 30, Bethesda, Maryland.

Prince, Eric D., Mauricio Ortiz, and Arietta Venizelos. 2002. A Comparison of Circle Hook and "J" Hook Performance in Recreational Catch-and-Release Fisheries for Billfish. Pages 66-79 *in* J.A. Lucy and A.L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries society, Symposium 30, Bethesda, Maryland.

Schirripa, M.J. and K.M. Burns. 1998. Estimates of growth based on hard-part analyses and release-recapture for three reef fish species in the eastern Gulf of Mexico. *Bull. Mar. Sci.*, in press.

Schirripa, M.J, K. Burns and J.A. Bohnsack. 1993. Reef fish release survival based on tag and recovery data. SEFC, Miami Laboratory, Contribution No. MIA 92/93, 34 pp.

Skomal, Gregory B., Bradford C. Chase, and Eric D. Prince. 2002. A Comparison of Circle Hook and Straight Hook Performance in Recreational Fisheries for Juvenile Atlantic Bluefin Tuna. 2002. Pages 57-65 *in* J.A. Lucy and A.L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries society, Symposium 30, Bethesda, Maryland.

Trumble, Robert J. and Stephen M. Kaimmer, and Gregg H. Williams. 2002. Review of the Methods Used to Estimate, Reduce, and Manage Bycatch Mortality of Pacific Halibut in the Commercial Longline Groundfish Fisheries of the Northeast Pacific. Pages 88-96 *in* J.A. Lucy and A.L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries society, Symposium 30, Bethesda, Maryland.

Wilson, R.R. and K.M. Burns. 1996. Potential survival of released groupers caught deeper than 40 m based on shipboard and *in situ* observations, and tag-recapture data. *Bull. Mar. Sci.* 5(1): 234-247.

Zimmerman, Steven R. And Eleanor A. Bochenek. 2002. Evaluation of the Effecxtiveness of Circle Hooks in New Jersey's Recreational Summer Flounder Fishery. Pages 106-109 *in* J.A. Lucy and A.L. Studholme, editors. Catch and release in marine recreational fisheries. American Fisheries society, Symposium 30, Bethesda, Maryland.