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The Life History (Age, Growth and Reproduction) of Red Snapper (Lutjanus Campechanus) and Its Affinity for Oil and Gas Platforms.

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THE LIFE HISTORY (AGE, GROWTH AND REPRODUCTION) OF RED SNAPPER (*Lutjanus campechanus*) AND ITS AFFINITY FOR OIL AND GAS PLATFORMS

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by
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ACKNOWLEDGMENTS

"Man cannot conquer new oceans until he has the courage to lose sight of the shore". . . An old Irish saying.

This dissertation is dedicated to its author, Jeffrey Howard Render, who died at sea while conducting research on the life history of red snapper. His untimely death leaves an irreducible void in the hearts of his family and friends. However, Jeff had already contributed significantly to our understanding of red snapper; this document is the essence of his research up until the time of his death.

Jeff would have thanked many people for their help and encouragement during his graduate years. First and foremost, Jeff would have acknowledged the support, dedication, and endless love of his wife, Cynthia, and the love of his children, Hannah and Ian. Also of great importance to Jeff was that his pursuit of education was encouraged and fostered by his loving mother, Margery Louise Render, his father, the late Ronald James Render, and brothers, Michael and Robert Render. Jeff would also have thanked his friends and colleagues (Bruce Thompson, Bob Allen, David Stanley, Jim Tolan, Don Baltz, Rick Shaw, Walter Keithly, Mike Wascom, David Nieland, Marty Beasley, Gary Fitzhugh, Joe Nunn, Stacey Pollard, and Louise Stanley) for their camaraderie and help while he was at Louisiana State University.

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Although Jeff had written most of this dissertation and several chapters had been submitted for publication in scientific journals, the text still required a dedicated effort to put it in the proper format and to tie up loose ends. Jeff and his family sincerely thank Louise Stanley for taking the lead in compiling and editing this dissertation and Carol Fleeger, Kim Fleniken, David Nieland, David Stanley, and Jim Tolan for helping with the various chapters.

We will miss him. . .

Charles A. Wilson, Professor and friend.

Jeff wrote in a letter to our son, Ian, on the day he was born, "Life is not always easy nor kind; yet for the most part, life for most of us is what we make of it. I want for you to follow the path you find in your heart." Jeff followed that path and embraced life fully. To the person whom Jeff admired, respected, and turned to for guidance along that path, many thanks to Dr. Charles "Chuck" A. Wilson, a valued confidant and mentor.

Cynthia Render.

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ABSTRACT

The purpose of this dissertation was to describe the association of red snapper, *Lutjanus campechanus*, with oil and gas platform habitat in the northern Gulf of Mexico.

Ages were estimated using transverse sections of sagittae. Annuli were validated to have formed yearly. Age estimates ranged from less than 1 to 54 years. Von Bertalanffy growth models were significantly different for males and females; females exhibited a faster initial growth rate but achieved a lesser maximum length than did males. The variability in age among individuals of a given length or weight class precluded formulation of age at size keys. Otolith weight provided a more precise estimate of age than did length or weight.

Spawning season commenced in May and extended through September. The presence of multiple oocyte maturation stages within ovaries evidenced a heterochronal spawning pattern. Estimated batch fecundities ranged from 455,919 to 2,096,519 ova and correlated moderately well with fork length. Spawning frequencies were estimated variously as 4.5 days, 5.4 days, and 7.6 days. Fifty percent maturity was achieved in both sexes at 290 mm fork length. All individuals greater than 420 mm fork length were mature.

Red snapper were caught with hook-and-line, treated (control, gas bladder deflation, tagging, tagging with deflation), and released into a holding net for varying lengths of time (24, 30, 36, 48 hours) to assess post-capture mortality. Results indicated an average mortality rate of 20% at 21 m depth, with no significant difference between treatments, or time-in-net. There was a significant difference in mortality between season, and an interaction between season and treatment, with

higher mortalities observed in the summer. Gas bladder deflation did not significantly enhance survival at 21 m.

Behavioral observations of red snapper in association with oil and gas platforms were collected with remotely operated underwater video systems. Schools of small juveniles were most often observed in close association with the platform structure, whereas larger adults were most often observed as solitary individuals. Both the adults and juveniles appeared to partition habitat by selecting different depth locations along the vertical gradient of the structure.

GENERAL INTRODUCTION

Recent increases in commercial and recreational harvests and growing knowledge of red snapper, *Lutjanus campechanus*, life history have raised questions regarding the status of red snapper populations in the western north Atlantic Ocean and Gulf of Mexico. This is consistent with declines in tropical snapper and grouper populations worldwide (Polovina 1984) due to the economic importance of these fishes and their relative ease of exploitation. Advances and reduced costs in bathymetric mapping and electronic "fish finding" technology have increased harvest pressure as habitats suitable for snappers and groupers are now both more easily found and more easily relocated.

The purpose of this dissertation was to describe the association of red snapper with oil and gas platform habitat in the northern Gulf of Mexico. These structures are widely recognized by commercial and recreational fishermen in the northern Gulf as habitats where high concentrations of red snapper are found. Although debate continues within the scientific community as to whether artificial habitats increase or aggregate fish populations, few studies have attempted to describe the functional relationships of these habitats in supplying specific life history requirements to reef oriented species such as red snapper.

Red snapper are distributed on the continental shelf of the Gulf of Mexico and the western north Atlantic Ocean north to Cape Hatteras, North Carolina (Rivas 1966). Although *L. campechanus* has not been reported from the Caribbean Sea, a closely related congeneric species, *L. purpureus*, is widely distributed in the Caribbean and in the Atlantic coastal waters of South America (Moran 1988). A description of red snapper morphology is given in Moran (1988).

Preferred habitats of red snapper include submarine gullies, depressions, coral reefs, rocky outcrops, and gravel bottoms (Stearns 1885). Artificial habitats (e.g., oil and gas platforms, artificial reefs, ship wrecks, pipelines) have also been identified as important red snapper habitats, particularly where they exist in high relief (Sonnier et al. 1976; Stanley 1994). Oil and gas platforms on the continental shelf of the Gulf of Mexico west of the Mississippi River may be of particular significance to the distribution of red snapper. In this area natural hard substrates are limited and the oil and gas structures rise above nepheloid layers which are commonly found in these waters. The species diversity and abundance of reef fish on natural hard substrates in the western Gulf have been shown to be highest where these substrates rise above the nepheloid layer (Rezak et al. 1983; Putt et al. 1986; Dennis and Bright 1988; Rezak et al. 1990).

Previous red snapper age and growth studies have been inconclusive. Investigations have been conducted off the North Carolina coast and Florida (Bortone and Hollingsworth 1980) and, although there is a general feel for longevity and growth, aging methodologies have not been validated. Beamish and McFarlane (1983) emphasized the importance of age validation and warned against the use of unvalidated age estimates in fishery management.

The reproductive biology of red snapper is poorly understood. Other than limited information provided by Moseley (1966) and Futch and Bruger (1976), there is no published information on age and size at maturity, age specific fecundity, spawning frequency, or oocyte development for red snapper in the northern Gulf of Mexico. Grimes (1987) summarized the existing literature on the reproductive biology of all snappers. Although this summary provided an updated comparison of

available information on snapper reproduction, it clearly demonstrated the lack of accurate species specific information.

Recent red snapper fishery management regulations have mandated the release of individuals of less than specified length in both the commercial and recreational fisheries. The questions of behavior and survival of released red snapper have not been adequately addressed, particularly off Louisiana where extremely large numbers of undersized fish are caught and released (Personal Communication - Captain Steve Tomeny, F/V "Southerner", P.O. Box 82483, Baton Rouge, LA 70884). Little is known of why these smaller fish congregate around oil and gas platforms. The success of release practices also remains in question since contact with an individual fish is lost at time of release and return rates in most tagging studies have been low.

There has been considerable debate on the efficacy of deflating the gas bladders of certain fishes by anglers to facilitate their ability to descend to depths rapidly (Sport Fishing Institute 1991). The question has merit since upward and downward movements of physoclistus fishes are limited by Boyle's Law effects on positive or negative buoyancy (Alexander 1967). A central question exists, however, as to whether deflation techniques increase survival of released fishes or simply enable the fishes to submerge and subsequently experience delayed mortality. Gotshall (1964) studied the effect of deflating gas bladders on survival of tagged rockfish (Genus *Sebastodes*). He concluded that deflated rockfish may have suffered greater mortality than non-deflated ones and suggested that more detailed studies on the recoverability of deflated and non-deflated rockfish were needed.

Typical survey methodologies addressing community species composition (Huntsman et al. 1982) have generally proven ineffective around oil and gas platforms within the Gulf of Mexico. Although acoustic technology has been used to effectively estimate density and biomass (Stanley 1994), species composition cannot be independently derived from acoustic data. Further, accurate behavioral observations can only be obtained through survey techniques which are non-destructive and non-obtrusive. Remotely operated underwater video observations around oil and gas platforms can provide both estimates of community composition as well as insights on species behavioral interactions.

CHAPTER I

AGE AND GROWTH RATE ESTIMATION FROM OTOLITHS OF RED SNAPPER (*Lutjanus campechanus*) IN THE NORTHERN GULF OF MEXICO

Introduction

Red snapper, *Lutjanus campechanus* (Family Lutjanidae), is a species of the continental shelves of the Gulf of Mexico and Atlantic Ocean from the Bay of Campeche to Cape Hatteras, North Carolina (Rivas 1966). The species has been a very important component of the past and current commercial and recreational fisheries in the northern Gulf of Mexico (Cato and Prochaska 1976; Moran 1988; Goodyear 1994). However, recent declines in total annual landings and individual mean sizes have prompted the Gulf of Mexico Fishery Management Council to impose regulations restricting harvest of red snapper in the Gulf of Mexico for all user groups to allow stock recovery (Goodyear 1994). Among those data necessary to insure continued responsible management of red snapper are accurate age estimates and distributions, and age-length and age-weight relationships of existing stocks.

Red snapper age and growth studies have been inconclusive. Studies have been conducted off the Atlantic coast and Florida (Nelson and Manooch 1976; Bortone and Hollingsworth 1980) and, although there is a general feel for longevity and growth, aging methodologies have not been validated. Beamish and McFarlane (1983) emphasized the importance of age validation and warned against the use of unvalidated age estimates in management.

Otolith analyses have proven effective in estimating ages of many species, including species from the temperate waters of the northern Gulf of Mexico (Johnson et al. 1983; Barger 1985; Beckman et al. 1989; Beckman et al. 1990). The purposes of this study were to validate the use of otolith (sagittae) sections to generate growth

models, and to determine age at size relationships for red snapper in the northern Gulf of Mexico.

Methods

Otoliths and morphometric data from red snapper (*N* = 1,849) were collected from 1989 to 1993. Specimens were sampled from the commercial red snapper fleet (*N* = 1,057) which operated primarily out of Leeville, Port Fourchon, and Grand Isle, Louisiana; from recreational fishing rodeos and recreational charter boats (*N* = 528) operating in Louisiana and Texas; and from a gas platform (*N* = 264) operated by Mobil Exploration and Production USA, Inc. (West Cameron 352), located approximately 80 km south of Cameron, Louisiana. Data from the gas platform study were used only in growth curve calculations because they included small specimens not available to the commercial or recreational fisheries due to minimum size restrictions.

Specimens were sampled randomly from unsorted catches for the commercial fishery and opportunistically from the recreational fishery. Although red snapper were available during all months, sample sizes were smaller during late fall and early winter (October through December) of some years (Table 1.1). This was due to closures of the commercial fishery as quotas were achieved, and to lower recreational effort during cooler months.

Morphometric measurements (fork length (FL), total length (TL), total weight (TW), and eviscerated body weight (BW)) were generally taken at the various landing sites. Sagittal otoliths from all specimens were excised, placed in labeled vials or envelopes, and transported to our laboratory. Each otolith was subsequently washed

Table 1.1. Numbers of red snapper collected by year and month.

	Month											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	-	-	6	-	-	-	41	10	5	-	-	-
1990	-	-	-	10	-	-	65	6	3	-	-	52
1991	91	75	91	86	88	150	90	170	77	-	-	-
1992	63	103	74	29	87	28	125	56	40	-	-	-
1993	-	-	80	1	12	3	31	2	-	-	-	-

to remove any extraneous tissue and stored either dry or in 100% ethanol. After they were dried, weighed, and embedded in a clear epoxy-resin (Araldite, CIBA-GEIGY), each otolith was sectioned through the core in the transverse plane with a Buehler Isomet low-speed saw. Sections approximately 0.7 mm thick were mounted with clear thermoplastic cement on glass slides, sanded, and polished with alumina micropolish to obtain a smooth, more readable surface.

Examinations of otolith sections were made with a dissecting microscope and transmitted light at 40X to 100X magnification. Counts of annuli (opaque zones) were determined by reading along the medial surface of the transverse section ventral to the sulcus. In most samples annuli were inconsistent in other regions of the otolith section. Otolith sections were rejected if the prepared surface was unreadable due to improper preparation or orientation of the otolith during sectioning. All increment counts were done without knowledge of date of capture or morphometric data. The otolith margin was recorded, when readable, as either opaque (annulus forming) or translucent (during the active growing season) and each was coded for degree of completion following Beckman et al. (1991). Frequency of annulus formation was determined by marginal increment analysis that was modified from Beckman et al. (1991). If one opaque and one translucent zone are formed each year, validation of increments as annual rings is accomplished. Because edges were difficult to interpret, I randomly examined otoliths from each month until 10 otoliths with readable edges were successfully compiled from each month. Readability of these sections was enhanced by manipulating the angle of the section with a microscope attachment that allowed precise orientation of the section; thus improving the ability to discern edge condition.

Age estimates of red snapper were based on otolith annulus counts and adjusted, if necessary, by edge condition. One year was assigned for each annulus. Based on our studies of red snapper reproduction (Wilson et al. 1994), I assigned a uniform hatching date of July 1 to all specimens in this study. The degree of edge completion was used to adjust ages of certain individuals captured at the same time of year. The otoliths of some specimens collected in the late winter or early spring were nearing completion of a translucent growth zone while others were just beginning formation of a new opaque zone. Ages of the latter fishes were adjusted by - 1 annulus count to prevent erroneously assigning them to an older year-class. Annulus counting error was evaluated between two readers who each independently counted annuli in a subsample of 75 otolith sections. Reproducibility of age estimates was determined using the Coefficient of Variation, Index of Precision (Chang 1982), and Average Percent Error (Beamish and Fournier 1981).

Von Bertalanffy growth equations were fit by nonlinear regression (SAS 1985) for FL and TW in the forms:

$$L_t = L\infty\,[1\text{-}e^{-k(t-to)}]$$

$$W_t = W\infty\,[1\text{-}e^{-k(t-to)}]^b$$

where L_t and W_t are estimated FL and TW, $L\infty$ and $W\infty$ are the FL and TW asymptotes, k is a growth coefficient, t is age in years, t_o is a hypothetical age when FL or TW is zero, and b is the exponent from the length-weight regression. Plots of residuals from regression models were used to test the assumption of normality (Sokal and Rohlf 1981). To test for differences in growth for males and females, a full model, in which sexes were modeled separately, was compared with a reduced

model, in which sexes were grouped. An *F*-test (Ott 1988) was used to test for differences in the models.

Results and Discussion

Morphometric Data

Within the sample population, female red snapper ranged from 170 to 890 mm FL, and from 0.3 to 14.7 kg TW; males from 239 to 878 mm FL and 0.4 to 13.3 kg TW. Specimens of undetermined sex as small as 94 mm and 0.1 kg were collected. Size ranges (FL and TW) by sampling source are presented in Table 1.2.

Fork length frequency distributions of fish samples from the commercial and recreational fisheries are shown in Figure 1.1. The distribution of red snapper in the commercial fishery off Louisiana was dominated by fish ranging from 300 mm to 500 mm in size (78.3%) with a minor peak around 750 to 850 mm. Fish sampled from the recreational fishery showed a bimodal distribution, with peaks at 350 mm and 700 mm. Several factors should be noted relative to the distributions of fork lengths observed from each source. Samples from the commercial fishery were probably most representative of the entire population vulnerable to hook-and-line catch due to relatively large sample size and random harvest; the exception to random harvest was the exclusion of fish under 325 mm FL since 1990. Many of the fish sampled from the recreational fishery were specimens entered in various fishing rodeos conducted along coastal Louisiana. Larger individuals targeted for competition presumably account for the bimodal distribution observed in Figure 1.1.

Regression equations of $\log_{10}$ transformed data were calculated to predict TW from FL, and FL from TW for both males and females. The comparison of

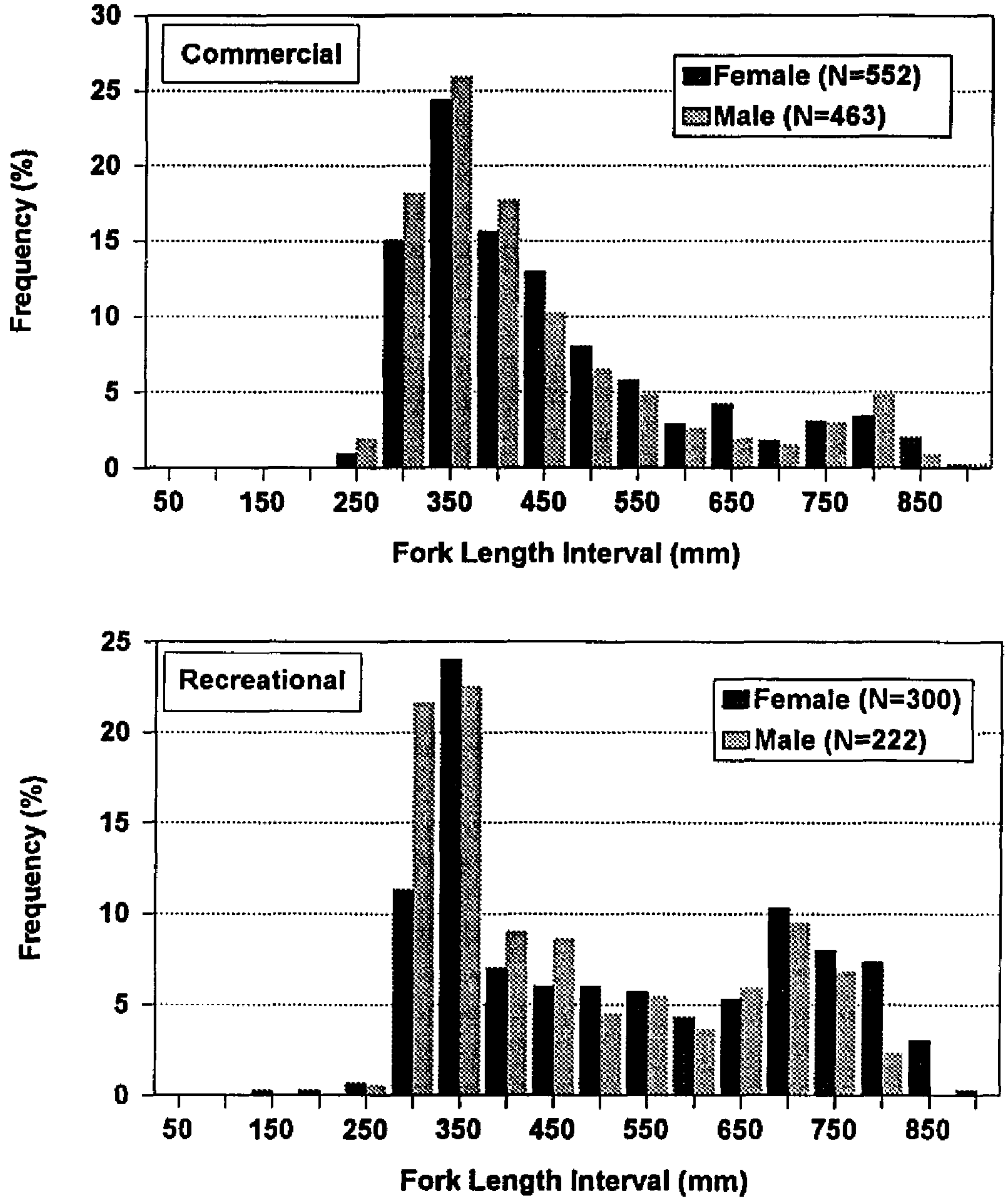


Figure 1.1. Fork length frequency distribution of samples from the commercial and recreational fisheries.

Table 1.2. Size ranges of red snapper by sampling source.

	Fork Length (mm)			Total Weight (kg)		
Source	Mean	Range	*N*	Mean	Range	*N*
Commercial	442	225 - 973	105	1.84	0.20 - 13.35	544
Recreational	493	170 - 890	528	3.61	0.18 - 14.69	465
Petroleum Platform WC 352	264	194 - 425	264	0.38	0.13 - 1.50	207

regression equations between sexes showed no statistical difference ($P < 0.05$); however, females attained a slightly larger size than males. Resultant equations to predict these parameters are:

$$\text{Male TW (kg)} = 2.95 \times 10^{-8} \times (\text{FL (mm)}^{2.92})\ (r^2 = 0.93)$$

$$\text{FL (mm)} = 382.30 \times (\text{TW (kg)}^{0.32})\ (r^2 = 0.93)$$

$$\text{Female TW (kg)} = 1.71 \times 10^{-8} \times (\text{FL (mm)}^{3.01})\ (r^2 = 0.95)$$

$$\text{FL (mm)} = 382.86 \times (\text{TW (kg)}^{0.32})\ (r^2 = 0.95)$$

Conversions between fork length and total length were calculated as follows:

$$\text{FL (mm)} = 0.92\ (\text{TL (mm)}) + 0.53\ (r^2 = 0.98)$$

$$\text{TL (mm)} = 1.07\ (\text{FL (mm)}) + 2.29\ (r^2 = 0.98)$$

Age and Growth Data

Sagittae of red snapper are ovate, laterally compressed and have an indented sulcus on the medial surface. Although one can count increments in whole otoliths from red snapper less than age 5 (Personal Communication - Dr. Stephen Szedlmayer, Auburn University Marine Extension and Research Center, 4170 Commanders Dr., Mobile, Alabama 36688), it is difficult to discern annuli in whole otoliths of older individuals. Thin transverse sections exposed narrow opaque and narrow to broad translucent zones which alternated from the core to the growing edge (Figure 1.2). Marginal increment analysis indicated the formation of a single annulus (opaque zone) per year from November to May (Figure 1.3).

A subsample of 75 otolith sections, read to assess the degree of agreement, aging precision, and average percent error between two readers, produced identical annuli counts in 80% of the otoliths compared. Aging precision was high based on a mean coefficient of variation (V) of 0.031, a mean index of precision (D) of 0.022, and

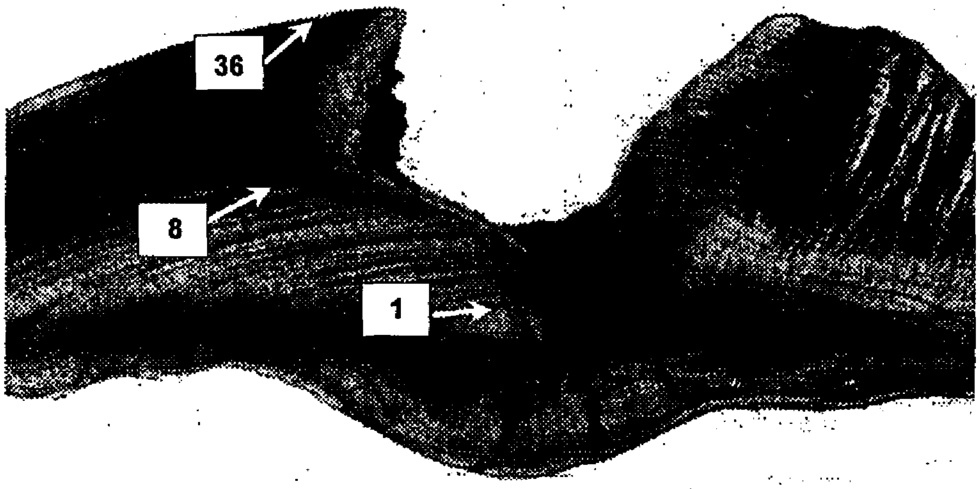


Figure 1.2. Photomicrograph of a transverse section of a red snapper sagitta. Annuli corresponding to years 1, 8, and 36 are indicated.

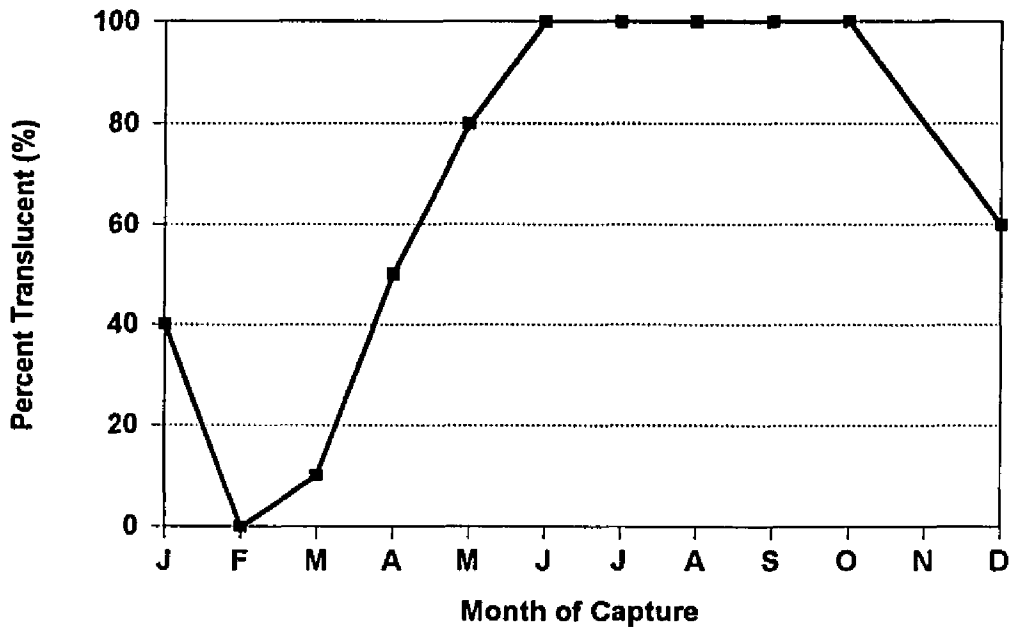


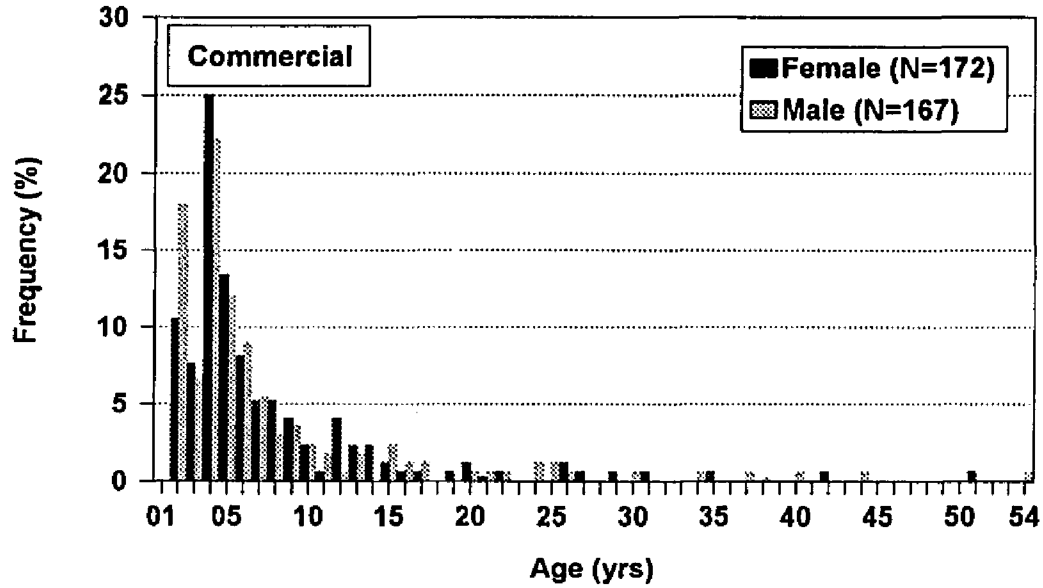
Figure 1.3. Marginal increment analysis indicating the percent frequency of translucent edge presence throughout the year.

an average percent error (APE) of 0.031. The remaining 660 otoliths were read by one reader.

Age distributions of red snapper from the commercial and recreational fisheries are shown in Figure 1.4. It is noteworthy that the commercial population included all specimens aged as 20 years or older. A possible explanation for the difference may be the operational characteristics of each fishery. Recreational red snapper fishermen in Louisiana tend to fish oil and gas platforms close to port of departure due to smaller vessel size and less sophisticated electronic equipment. Prior to the implementation of trip poundage limits (since 1992) commercial red snapper fishing involved extended trips far from port of departure, usually in deeper water (Goodyear 1994). Also, in addition to oil and gas platforms, other substrates including wrecks, pipelines, and other natural structures are commonly fished (Personal Communication - Captain Steve Tomeny, F/V "Southerner", P.O. Box 82483, Baton Rouge, Louisiana 70884). It is possible, therefore, that the red snapper sought in the recreational fishery are more heavily exploited, due to their proximity to port, and thus have a lesser probability of reaching older ages.

It is difficult to compare age distributions generated in this study to those reported in studies that used scale analysis for aging red snapper (Moseley 1966; Wade 1981; Nelson and Manooch 1982). The data from this study show a much greater maximum observed age (53 years) than those reported in the scale studies cited above or other published studies using otoliths (Nelson et al. 1985; Szedlmayer and Shipp 1994) (Table 1.3).

Von Bertalanffy growth curves of FL at age and TW at age for red snapper are shown in Figures 1.5 and 1.6.



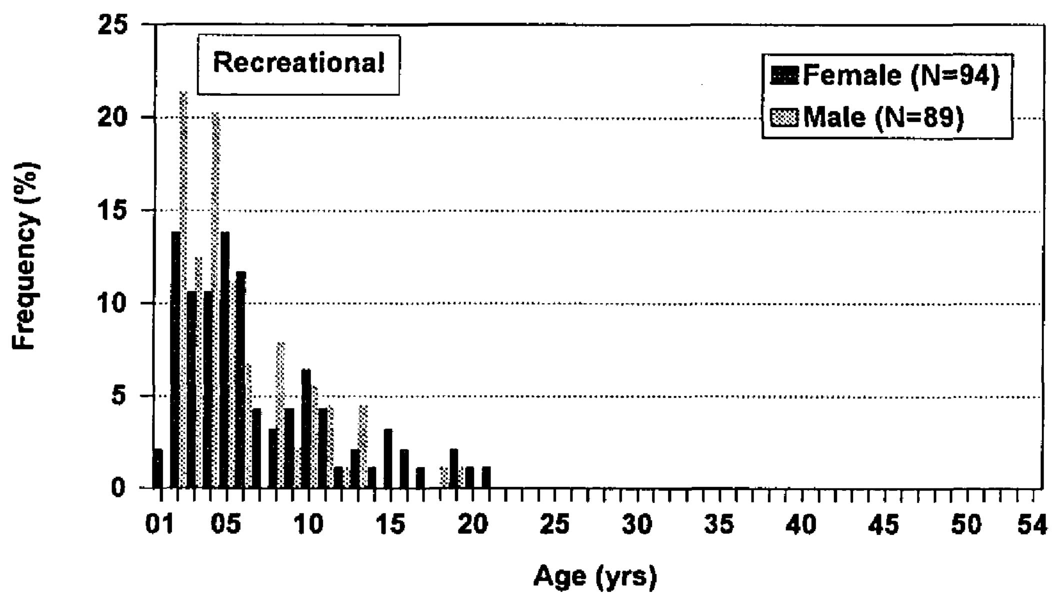


Figure 1.4. Age frequency distribution of samples from the commercial and recreational fisheries.

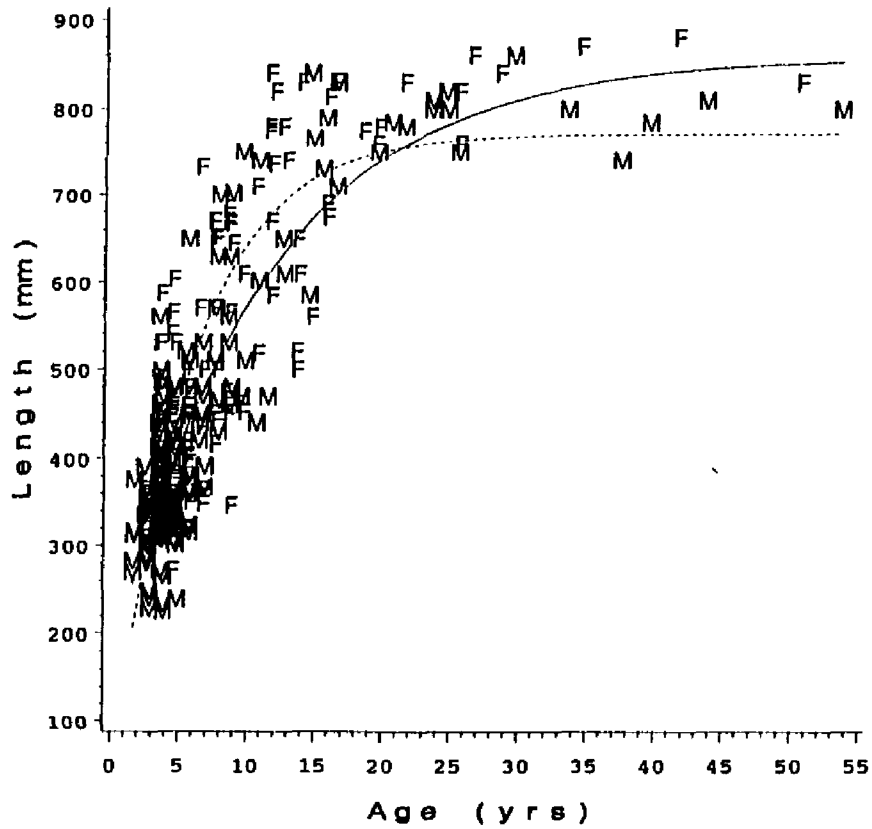


Figure 1.5. Von Bertalanffy growth curve of FL at age for red snapper.

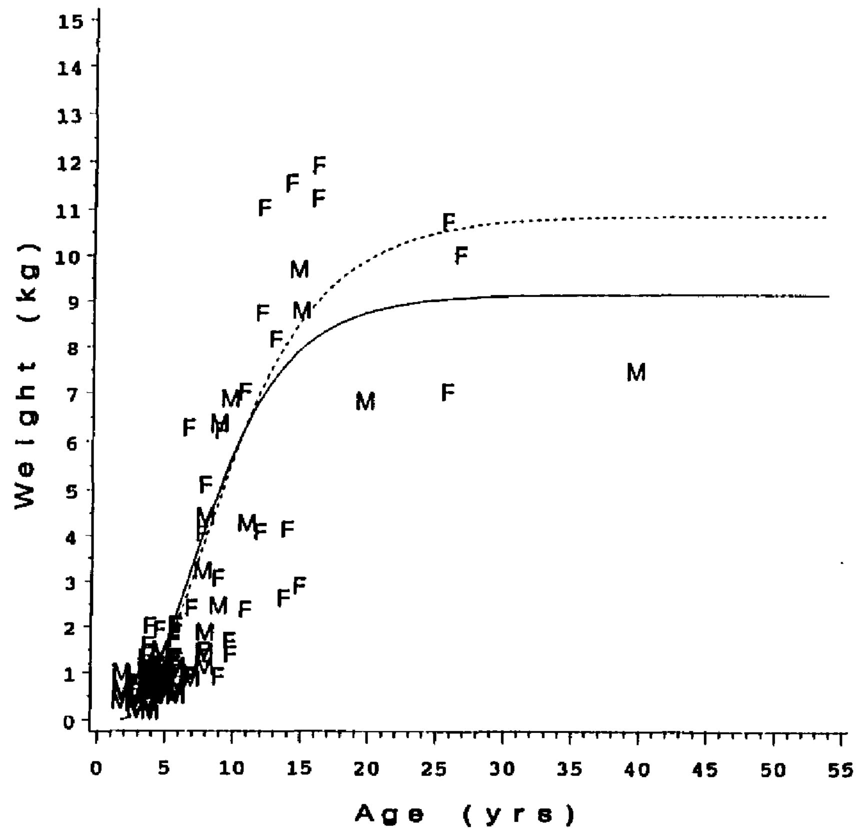


Figure 1.6. Von Bertalanffy growth curve of TW at age for red snapper.

Table 1.3. Estimated maximum age and von Bertalanffy growth parameters. Modified from Manooch (1987).

Area	Method	Maximum Age	L_∞	k	t_0	Source
Gulf of Mexico	S[1]	4+	-	-	-	Moseley 1966
Gulf of Mexico	S	9	-	-	-	Wade 1981
Gulf of Mexico	S, O	13	941 TL	0.17	-0.10	Nelson & Manooch 1982
Southeastern U.S.	S, O	16	975 TL	0.16	0.00	Nelson & Manooch 1982
Gulf of Mexico	O	10	925 TL	0.14	-0.10	Nelson et al. 1985
Gulf of Mexico	O	42	1025 TL	0.15	-	Szedlmayer & Shipp 1994

[1] S = scale, O = otolith

The fork length models are:

$$\text{Female FL (mm)} = 771.59\ [1\text{-}e^{-0.18(t-0.00)}]$$

$$\text{Male FL (mm)} = 858.64\ [1\text{-}e^{-0.09(t+2.21)}]$$

The weight models are:

$$\text{Female TW (kg)} = 10.87\ [1\text{-}e^{-0.19(t-1.33)}]^{3.01}$$

$$\text{Male TW (kg)} = 9.15\ [1\text{-}e^{-0.23(t-1.60)}]^{2.92}$$

The growth curves suggest rapid growth of red snapper to an age of approximately 20 years after which an asymptote is approached. The growth rate predicted in this study is similar to those previously reported for red snapper from the Gulf of Mexico (Nelson and Manooch 1982; Nelson et al. 1985; Szedlmayer and Shipp 1994). An interesting aspect of the fork length at age model is that males are predicted to achieve a greater asymptotic size than females. Among marine teleosts from temperate waters an opposite pattern of growth is generally exhibited (Sandeman 1969; Kimura et al. 1979; Fraidenburg 1980; Beckman et al. 1991).

Due to the large variability in age at a given FL or TL, size is not a good estimator of red snapper age in individuals older than 5 years. For example, a red snapper greater than 700 mm FL could be from 6 to 54 years old. Otolith weights however, have been shown to correlate well with age in a number of studies (Templeman and Squires 1956; Beamish 1979; Wilson and Dean 1983; Radtke et al. 1985; Reznick et al. 1989; Secor et al. 1989; Beckman et al. 1991) which show that increase in otolith weight is independent of fish growth. Otolith weights of red snapper ranged from 26.8 to 4,800.9 mg for fish aged less than 1 year to 54 years. The relationship between otolith weight and age is shown in Figure 1.7. Linear regressions of age against otolith weight were not significantly different between

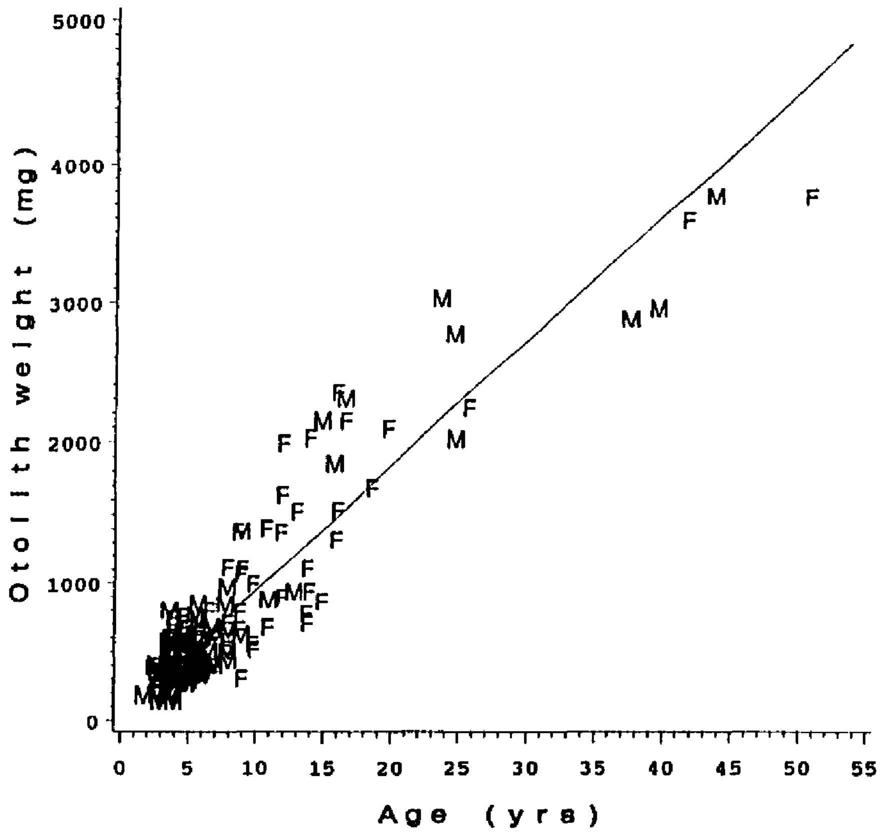


Figure 1.7. Relationship between otolith weight and age.

males and females, therefore I present a single equation to describe this relationship:

$$\text{Age} = 0.00863\ (\text{otolith weight (mg)}) + 0.37 \quad (r^2 = 0.89).$$

Comparison of the three age and growth models presented indicate that otolith weight is the best estimator of age of the morphometric variables considered. To test how well the otolith weight at age model estimated the age distribution of the population, I estimated age distribution from individuals that were not included in the sectioned otolith analyses using the model described above and compared it to the distribution determined from sectioned otolith analyses (Figure 1.8). Comparison of the two distributions using chi square analysis indicated they were not significantly different at $P < 0.05$. Since age at length keys for red snapper have not been entirely adequate for population based modeling (Goodyear 1994), otolith weight at age keys may provide an alternative approach to age estimation of red snapper. Otolith annulus counts remain, however, the most precise method for age estimation.

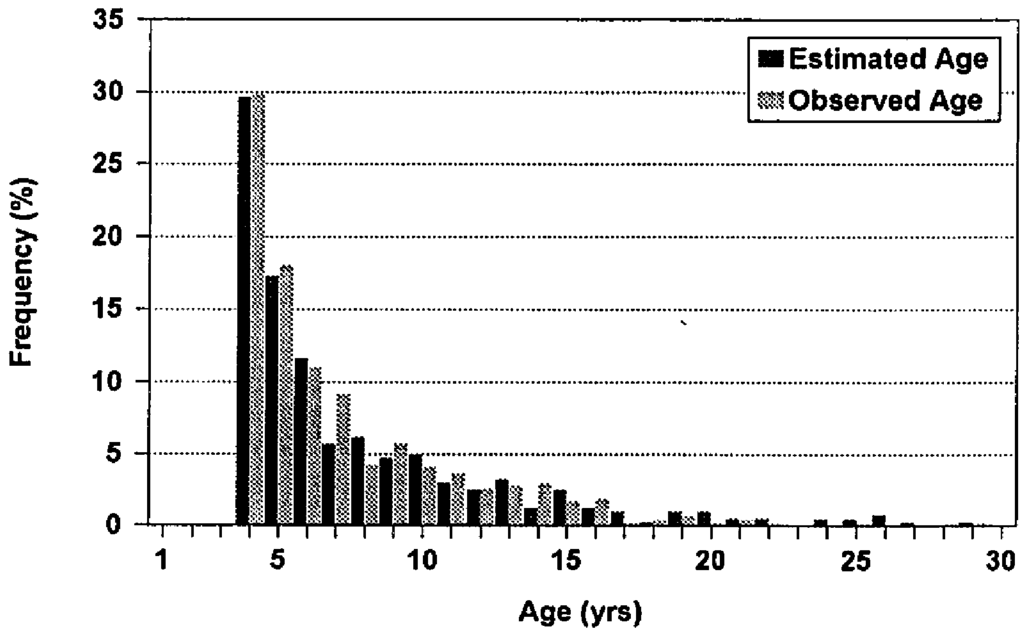


Figure 1.8. Age distribution, estimated from otolith weight, of individuals not included in the sectioned otolith analyses, compared to the distribution determined from sectioned otolith analyses.

CHAPTER II

THE REPRODUCTIVE BIOLOGY OF RED SNAPPER FROM THE NORTHERN GULF OF MEXICO

Introduction

Management of fisheries resources is often hampered by lack of basic life history information. I undertook this study to fill information gaps on the reproductive biology of red snapper, *Lutjanus campechanus.*

Reproductive biology of the family Lutjanidae is generally poorly understood. Grimes (1987) summarized the literature available on the reproductive biology of snappers. Although his summary provides an updated comparison of available biology of the family, he demonstrates the lack of accurate species specific information. Other than limited information provided by Moseley (1966), and Futch and Burger (1976), we are aware of no other published information on age and size at maturity, age and size specific fecundity, spawning frequency, and a general description of oocyte development for red snapper in the northern Gulf of Mexico.

Methods

Red snapper from the northern Gulf of Mexico were sampled monthly (when available) from January 1989 to July 1993. Morphometric data from 1,865 red snapper are included in this report. One thousand and fifty-five specimens were collected from the commercial red snapper fleet which operated primarily out of Leeville, Port Fourchon, and Grand Isle, Louisiana. Data from 528 specimens were collected at various recreational fishing rodeos conducted along coastal Louisiana, and from recreational charter boats operating in Louisiana and Texas. Two hundred and eighty-two specimens were collected from a gas platform operated by Mobil Exploration and Production USA, Inc. (West Cameron 352), located approximately 80 kilometers south of Cameron, Louisiana.

Specimens were sampled randomly if they had not undergone prior sorting by length or weight. Although samples were available during most months, sample sizes were small during late October, November, and December (Table 2.1). Morphometric measurements (fork length, total length, standard length, total weight, and eviscerated body weight) were recorded for all individuals included in the reproductive analysis. Gonads from mature specimens were excised, placed in labeled plastic bags, and put on ice for transport back to the laboratory.

Non-gonadal tissue was removed from gonads prior to weighing to the nearest 0.1 gm. Gonads were then fixed in 10% formalin for a minimum of 2 weeks. Ovaries were subsequently treated as follows for histological analysis: a subsample of ovarian tissue was excised from one of six defined regions (random selection from anterior, medial, and posterior portions of right and left lobes) of the ovary, placed in a tissue cassette, embedded in paraffin, sectioned, stained with Gill hematoxylin and counterstained with eosin (Erickson et al. 1985). Embedding, sectioning, and staining were completed by the LSU School of Veterinary Medicine, Department of Pathology. Upon microscopic examination of the prepared sections, oocytes were classified into one of four oocyte maturation stages (primary growth (PG), cortical alveolar (CA), vitellogenic (V), and hydrated (H)) following Wallace and Selman (1981).

Prior to implementing sampling schemes for oocyte stage of maturity counts and hydrated oocyte counts used in fecundity estimation (discussed below), ANOVA (SAS 1985) was used to determine whether the distributions of oocyte stages were homogeneous among and within ovarian lobes. Six regions (as above) of three ovaries were tested for homogeneity of oocyte counts, and twelve regions (inner and

Table 2.1. Numbers of red snapper collected by year and month.

	Month											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	-	-	6	-	-	-	41	10	5	-	-	-
1990	-	-	-	10	-	-	65	6	3	-	-	52
1991	91	75	91	86	88	150	90	170	77	-	-	-
1992	63	103	74	29	87	28	125	56	40	-	-	-
1993	-	-	80	1	12	3	31	2	-	-	-	-

outer portions of anterior, medial and posterior regions of each lobe of three ovaries were tested for homogeneity in fecundity estimation. There were no significant differences in distributions of either oocyte maturation stages or hydrated oocytes within or between lobes ($P < 0.05$).

A systematic sampling scheme was used to locate microscope fields for oocyte stage counts after randomly selecting a starting point on the ovarian section. All identifiable oocyte stages within a field were counted and classified before moving on to a new field. Movement of the field was inward (from the outer tunica albuginea) along the ovigerous lamellae with realignment along a vertical axis (Weibel 1979). Oocytes were counted if 50% of the cell was visible within the field and it was identifiable to developmental stage. A minimum of 200 oocytes from each slide were counted and numbers were expressed as percentages of the total (Htun-Han 1978; Holdway and Beamish 1985). In addition to oocyte counts, presence or absence of postovulatory follicles (POF) and other unusual histological conditions were noted. Postovulatory follicle terminology follows Hunter and Macewicz (1985).

Batch fecundity was estimated for seven females from three tissue samples randomly selected from among 12 designated regions of ovaries that were visually determined to have hydrated oocytes. Tissue samples (0.050 - 0.150 g) were placed in a 3:7 glycerin:water solution and oocytes gently separated with a stainless steel spatula (Render and Wilson 1992). The number of hydrated oocytes in each sample was counted under a 10X dissecting microscope (Hunter et al. 1985). Total batch fecundity per individual was estimated gravimetrically from the number of hydrated oocytes per sample mass and total wet weight of the ovary.

Spawning frequency (expressed as the average number of days between successive spawning events) was estimated as the inverse of the proportion of females in spawning condition relative to the total number of mature females in a sample (Hunter and Macewicz 1985). Females considered to be in spawning condition were those with either hydrated oocytes indicative of imminent spawning or POF indicative of recent spawning. Based on histological preparations of ovaries from fish sacrificed at known time intervals (13, 24 ,38, or 40 hours) following spawning (provided by Dr. Ed Chesney of Louisiana Universities Marine Consortium), postovulatory follicles were classified as either less than 24 hours old (Day 1) or greater than 24 hours old (Day 2). Spawning frequency was estimated independently for each POF age classification.

Statistical calculation of regression relationships were carried out with standard SAS regression procedures (SAS Institute 1985). Calculation of gonadosomatic indices (GSI) followed Htun-Han (1978):

$$GSI = \frac{\text{gonad weight}}{\text{eviscerated body weight}} \times 100$$

Results

Gonadosomatic indices calculated for both male and female red snapper (Figure 2.1) indicate that gonad development in both sexes begins in March and continues through September. Spawning activity likely occurs from late May through September. Peak GSI values were observed during June through August for both males and females.

Primary growth stage oocytes (Figure 2.2) were present year-round in all samples examined and were the only stage present from October through

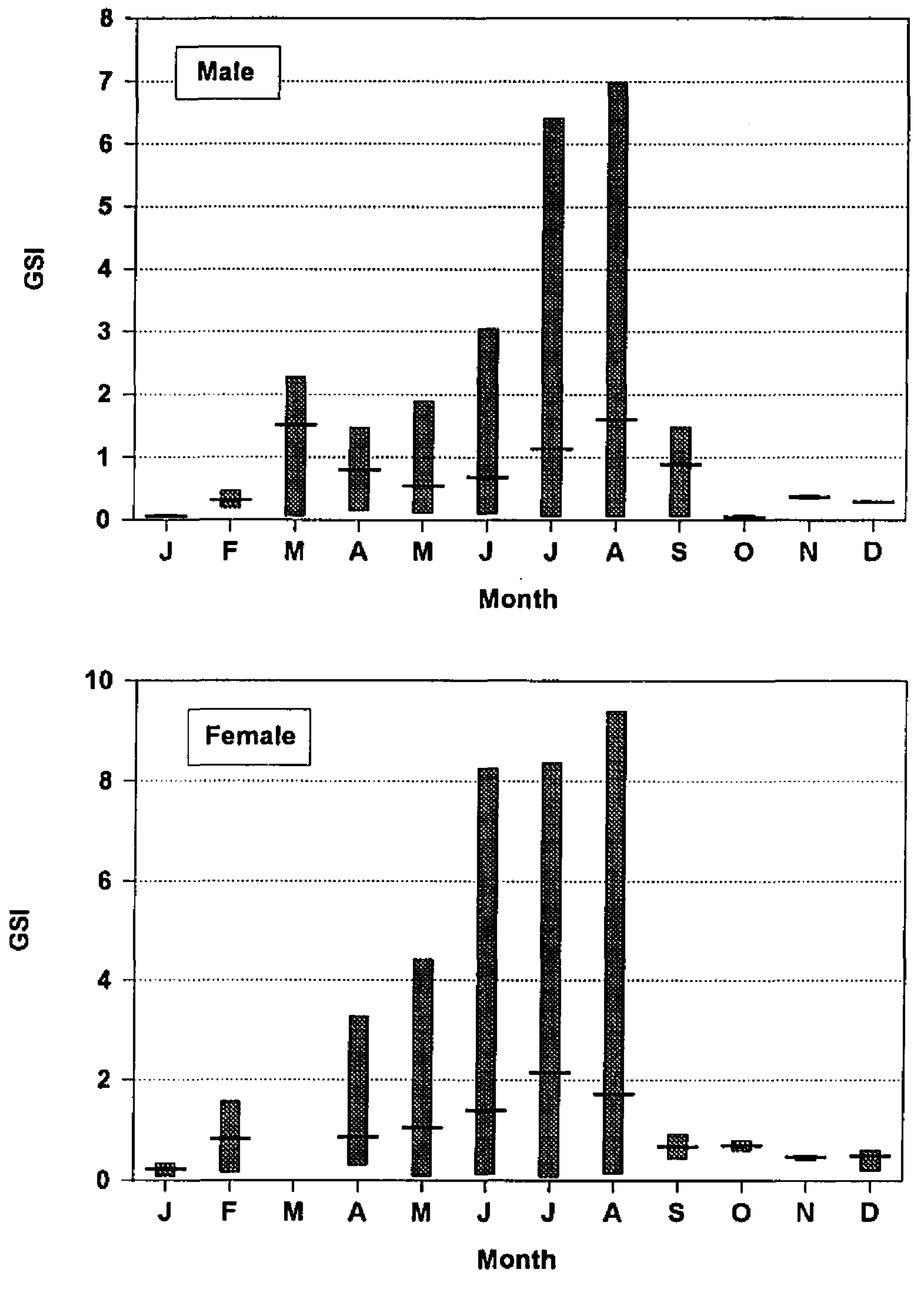


Figure 2.1. Gonadosomatic index values for male and female red snapper.

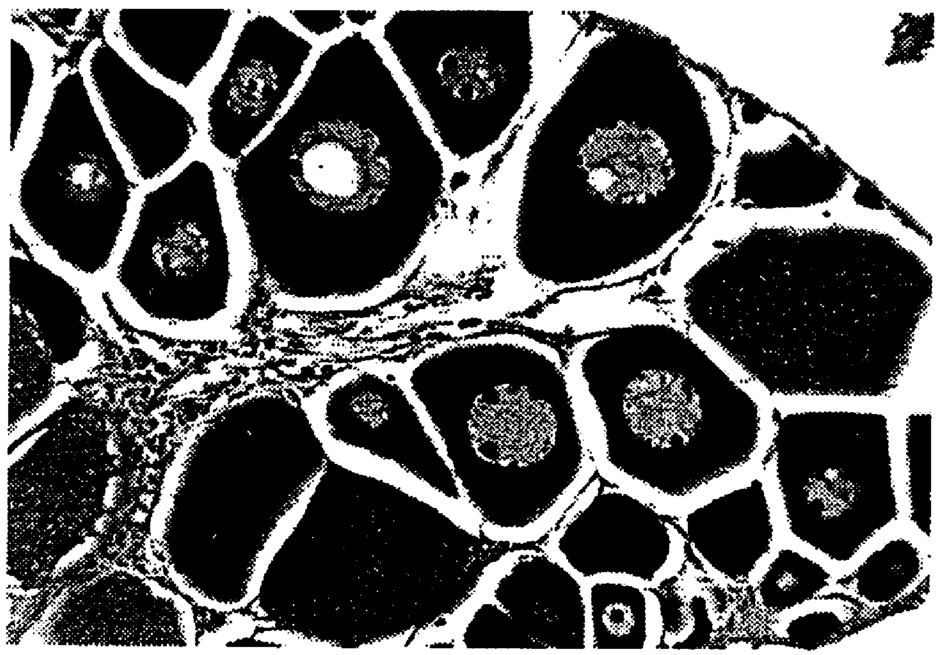


Figure 2.2. Photomicrograph of red snapper ovary showing primary growth oocytes.

March in all years studied (Figure 2.3). Cortical alveolar stage oocytes (Figure 2.4), first observed in March and persisting through October, were less basophilic (indicated by staining characteristics; i.e., basophilic tissues stained purple and acidophilic tissues stained pink) in appearance than primary growth oocytes. Cortical alveolar stage oocytes were characterized by the appearance and proliferation of yolk vesicles. By late May, vitellogenic (Figure 2.4) and hydrated (Figure 2.5) stage oocytes were present indicating near-spawning condition. Vitellogenic oocytes were characterized by an acidophilic cytoplasm and distinct organelle characteristics. Highly acidophilic membrane-bound yolk spheres appeared and proliferated throughout the cell during vitellogenesis. Early hydration was characterized by coalescence of yolk in the cytoplasm and migration of the nucleus toward the animal pole. Intact late stage hydrated oocytes were not observed due to their distortion during histological preparation; however, remnants from late stage hydrated oocytes were easily recognized (Figure 2.5).

The presence of oocytes in all stages of development from April through September is indicative of a batch or heterochronal spawning pattern. Hydrated oocytes, indicative of imminent spawning, and POF (Figure 2.6), indicative of recent ovulation, were present in samples collected from early June through early September indicating a 'season' of actual batch production and egg shedding of approximately 90 days.

Cessation of spawning by mid-September was indicated by atresia of advanced stage oocytes (Hunter and Macewicz 1985). Atretic stages observed in mid-September (Figure 2.7) were associated with rapid decline in ripeness. By

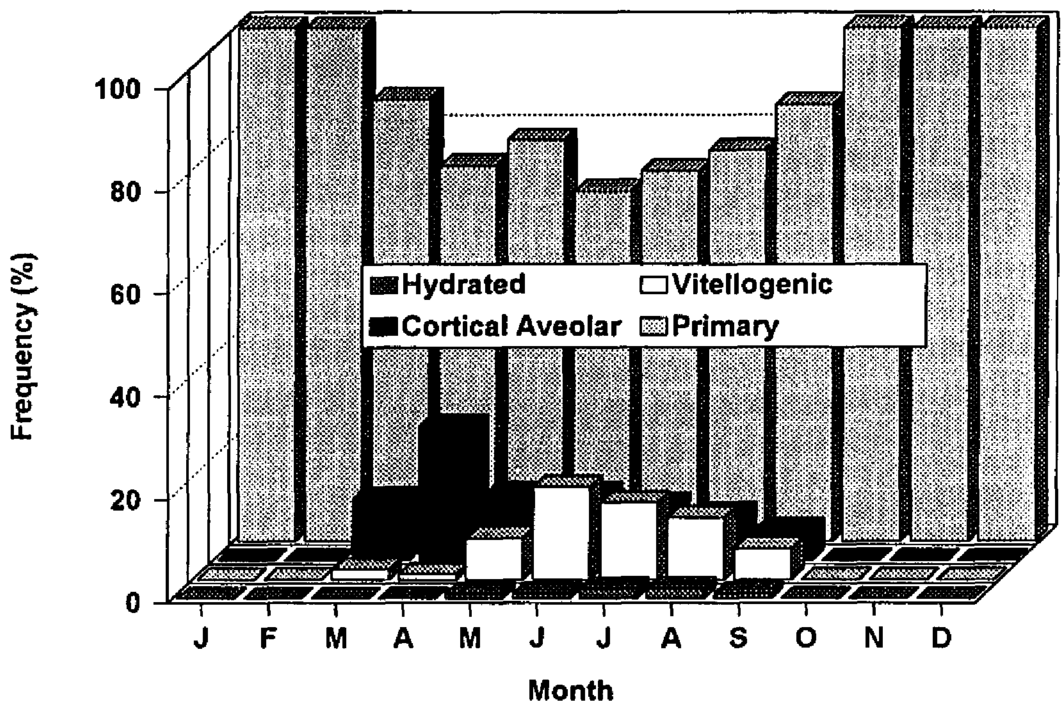


Figure 2.3. Frequency of oocyte stages by month for red snapper.

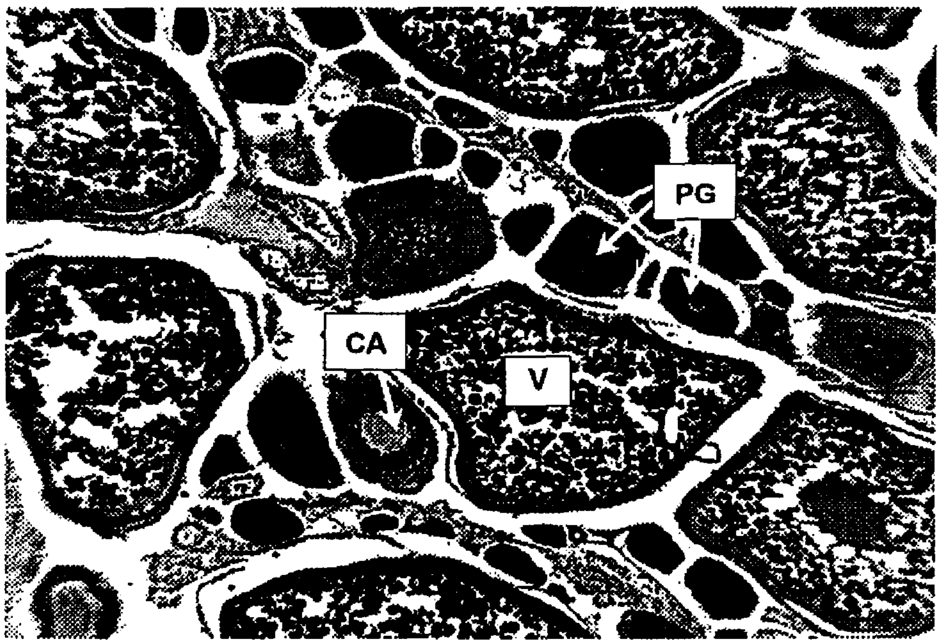


Figure 2.4. Photomicrograph of red snapper ovary showing primary (PG), cortical alveolar (CA), and vitellogenic (V) stage oocytes.

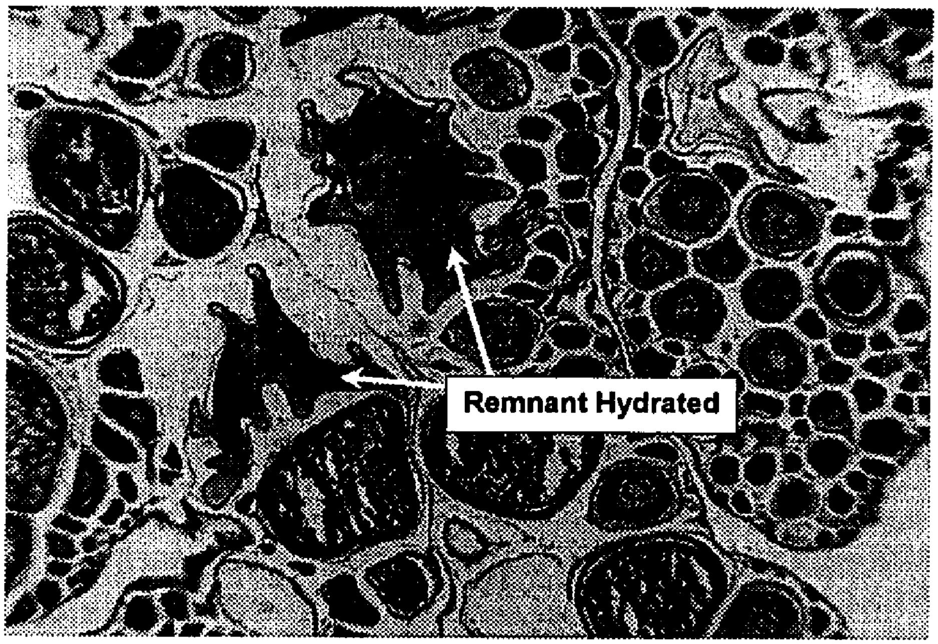


Figure 2.5. Photomicrograph of red snapper ovary showing remnant hydrated stage oocytes.

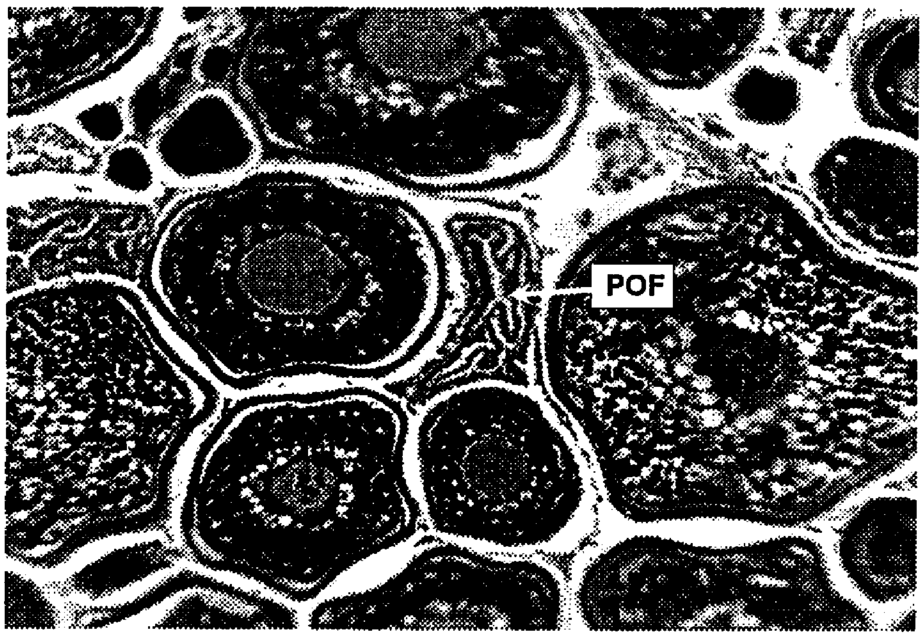


Figure 2.6. Photomicrograph of female red snapper ovary showing post-ovulatory follicle (POF).

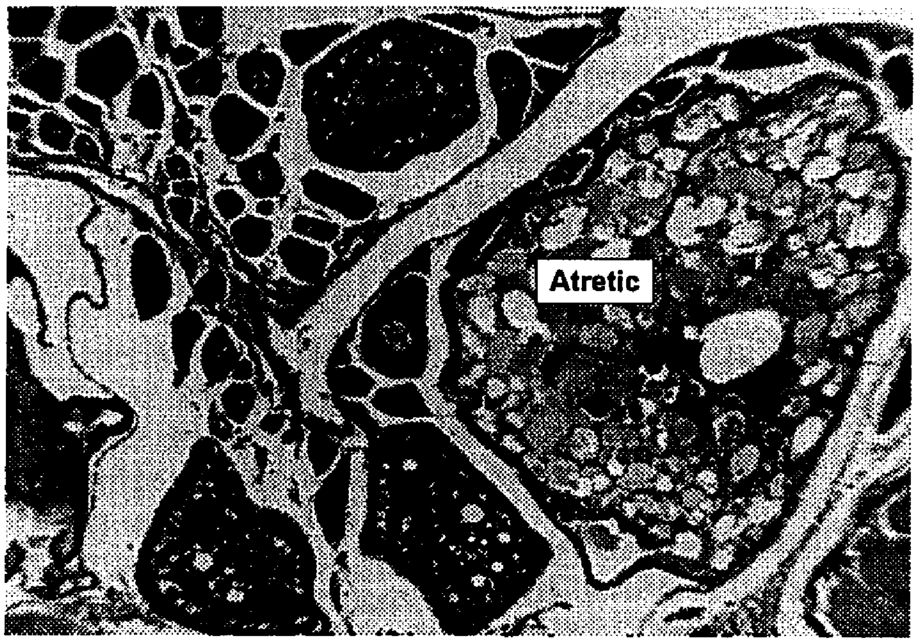


Figure 2.7. Photomicrograph of female red snapper ovary showing atretic follicle.

late September or early October of both years, all yolked oocytes were undergoing alpha atresia.

Batch fecundity was estimated from seven females in hydrated condition. Fecundity estimates correlated moderately well with female size (length and weight) and ranged from 455,919 to 2,096,519 ova per batch for fish ranging from 340 to 850 mm fork length (Figure 2.8).

Based on Day 1 and Day 2 POF, spawning frequency was estimated as 7.6 and 5.4 days, respectively. Estimates based on presence of hydrated oocytes indicated a spawning frequency of 4.5 days. Estimated over a spawning season of approximately 90 days, an individual female has the potential, therefore, to produce from 12 to 20 batches of mature ova per season.

Based on the criteria that maturity is ascribed when 50% of the individuals in a population exhibit gonadogenesis (ovary or testes development), maturity was reached at 290 mm fork length for both males and females (Table 2.2). All males greater than 440 mm and all females greater than 420 mm fork length were mature.

Discussion

The red snapper spawning season in the northern Gulf of Mexico, defined by gonadosomatic indices, corresponded well with that defined by histological results. Onset of development, peak spawning and cessation of reproductive activity were evident in the plot of GSI values over time. Gonadosomatic index values by themselves, however, were not useful for identifying specific events including the periods of egg shedding and batch production. DeVlaming et al. (1982) questioned the validity of GSI values as an index of reproductive activity because the index

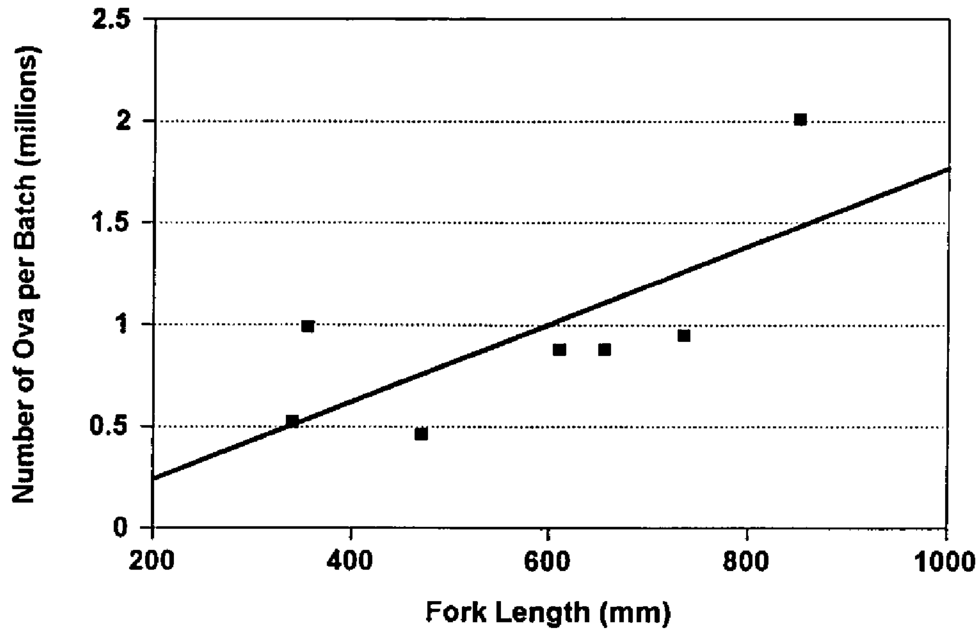


Figure 2.8. The relationship between female red snapper size and batch fecundity.

Table 2.2. Sexual maturity schedule for male and female red snapper.

	Male		Female	
Fork Length (mm)	% Mature	% Immature	% Mature	% Immature
230	0	100	0	100
240	0	100	0	100
250	0	100	25	75
260	0	100	11	89
270	29	71	20	80
280	33	67	43	57
290	62	38	80	20
300	85	15	87	13
310	73	27	87	13

might not accurately allow for body size in a consistent manner for all stages of reproductive development.

Peak spawning in this study was consistent with reports in the literature of summer spawning for red snapper (Bradley and Bryan 1976; Futch and Burger 1976; Collins et al. 1987). There was no evidence of any late fall or winter spawning as reported by Bradley and Bryan (1976).

Spawning frequency estimates were very consistent in our study regardless of the method of calculation (hydrated, Day 1 POF, Day 2 POF). The best estimate, however, was probably generated from hydrated oocytes as there is some intrinsic uncertainty as to the exact age of POF (i.e., whether designated Day 1 or Day 2). Our estimates of spawning frequency and duration of the spawning season agree well with the findings of Collins et al. (1987).

Of the reports in the literature of age at first maturity for male or female red snapper, our results agree well with the estimates of Camber (1995), and Futch and Burger (1976) of maturity at about 290 mm. This size was assigned as age 3 by Futch and Burger and corresponds with our age estimates.

CHAPTER III

HOOK-AND-LINE MORTALITY OF CAUGHT AND RELEASED RED SNAPPER AROUND OIL AND GAS PLATFORM STRUCTURAL HABITAT

Introduction

Red snapper (*Lutjanus campechanus*) are an important commercial and recreational fish species in the northern Gulf of Mexico. Off Louisiana, red snapper comprise a significant portion of the assemblages that are associated with offshore oil and gas production platforms. These platforms serve as 'de facto' artificial reefs in the northern Gulf of Mexico since natural, hard substrate is limited and far from shore. The functional role of oil and gas platforms is speculative; there is little quantitative data on the associated fish assemblages. The question of whether these platforms serve to increase total biomass or merely attract it has been strongly debated (Bohnsack and Sutherland 1985; Munro and Williams 1985; Solonsky 1985; Bohnsack 1987). Regardless, it cannot be debated that the presence of these structures has influenced the distribution of species such as red snapper in the northern Gulf of Mexico. Further, the function of these structures in concentrating red snapper for exploitation is well known by both commercial and recreational fishermen. The red snapper population in the northern Gulf of Mexico was recently characterized by the Reef Fish Assessment Panel as being in a state of "severe overfishing" (Muller 1990). Much of the current dilemma regarding red snapper has been attributed to high mortality rates in young fish. Highest fishing mortality is on age 1 (juvenile) red snapper from shrimp fishery by-catch, followed by age 3 fish from the commercial and recreational fisheries (Muller 1990). Age 1 and age 2 fish are also common in commercial and recreational catches (Personal Communication - Captain Steve Tomeny, F/V "Southerner", P. 0. Box 82483, Baton Rouge, LA 70884), however, they are not observed at the dock due to current size limits. These undersized fish are returned to the water, presumably to recover and grow larger.

Although the effectiveness of release practices as a management tool has been questioned (Sport Fishing Institute 1991), the issue has not been adequately addressed. This is particularly true of physoclistous species like red snapper that must compensate for positive buoyancy caused by rapid hydrostatic pressure change. The problem is especially significant off Louisiana where fishermen report extremely large catches of undersized fish at relatively great depths (15 to 62 m). Little is known about the success of releasing these fish since contact with an individual fish is lost at time of release and return rates in most tagging studies are low. Although the structure and function of gas bladders in physoclistous fish are well studied (Denton 1961; Alexander 1967; Aleev 1969; Alexander 1972) the effect of venting gas from a fish's bladder to enhance survival is not well known. Gotshall (1964) studied the effect of deflating gas bladders on increasing survival of tagged rockfish (Genus *Sebastodes*). He concluded that deflated rockfish may have suffered greater mortality than non-deflated ones, and suggested that more detailed studies on the recoverability between deflated and non-deflated rockfish were needed.

Current and pending regulations on red snapper have made our understanding of survival of hook-and-line caught and released red snapper more critical. Current regulations under the Reef Fishery Management Plan include release by recreational fishermen of red snapper less than 334 mm total length and a bag limit of 5 fish per person per day of red snapper greater than 334 mm. Further restriction on bag limits of red snapper may be implemented based on recommendations from the Reef Fish Assessment Panel and could even involve total closure of the directed fishery for red snapper to allow recovery of the stock (Muller

1990). Understanding survival and mortality relationships of released red snapper will allow more precise calculation of population dynamics statistics and allow formulation of better management strategies, particularly in light of a potential total closure of the directed fishery.

The goal of this study was to estimate mortality of hook-and-line caught and released red snapper captured near oil and gas platforms at a specific depth (21 m), and to explore techniques to increase survival. Specific objectives were:
1) to determine short and long term effect of gas bladder deflation on mortality, and
2) to determine seasonal effects on post-capture mortality.

Methods

The study was conducted on a gas production platform (Mobil West Cameron 352) approximately 80 km south of Cameron, Louisiana from October 1990 through September 1991. The structure was situated in 21 m water depth. Red snapper (N = 282) were caught by hook-and-line, and released into moored vertical holding nets (9 m deep) within the confines of the structure. The holding net design was that of a modified commercial hoop net that was extended to 11 m length (# 15 twine, 2.5 cm square mesh) with a 1.8 m diameter hoop at the mouth. The net was deployed by pulling the bottom of the net with a rope to a shackle attached to the platform 9 m below the surface.

Experimental design included the following treatments: control, gas bladder deflation, tagging, and gas bladder deflation and tagging. Control for the purpose of this paper refers to release into the net with no other treatment. Tagging was included in the treatments since all specimens in the long-term experiments were to be tagged and the additional mortality effects from tagging were unknown. Gas

bladders were deflated by inserting a sterile disposable needle tip (Becton Dicinson & Company, Precision Glide # 20, 4 cm) through the side of the fish at a location under the 4th dorsal spine and directly behind the opercular spine. Tags (Hallprint dart tags) were inserted below the first dorsal fin to hook between the internal support bones (pterygiophores) of that fin. Treatments were designed to test the effects of tagging and gas bladder deflation relative to a control through the following comparisons:

1) tagging versus not tagging,

2) gas bladder deflation versus no deflation, and

3) tagging with gas bladder deflation versus tagging without deflation.

All specimens were caught near the bottom by hook-and-line with typical bottom fishing gear (1.9 m medium action rods, Penn 309 reels, 50 stainless hooks). Bait was typically cut blue runner (*Caranx crysos*), bluefish (*Pomatomus saltatrix*), little tunny (*Euthynnus alletteratus*) or other available species. Following hooking, the fish were brought quickly to the surface, treated, and released into the holding net. Out of water handling time was typically less than I minute and never more than 2 minutes or the specimen was rejected from testing due to excessive handling time.

Mortality was determined for each treatment group following varied time intervals in the net (24 to 48 hours). Sampling was conducted over 4 seasons to allow evaluation of seasonal effects. During each sampling period, at least 20 fish were targeted for each treatment group.

The long term effect of gas bladder deflation on survival was investigated using 107 red snapper transferred to a large holding tank at the Aquarium of the Americas in New Orleans, Louisiana. Specimens were transported via ship in a

oxygenated tank to Cameron, Louisiana where they were received by Aquarium personnel for further transport to New Orleans. The specimens were held for 30 to 40 days in a 6.25 m diameter round tank with approximately 34,100 l water capacity. Salinity and temperature were maintained at 32 ppt and 25 degrees °C, respectively. All fish were tagged for identification. Thirty-five of the red snapper had deflated gas bladders, while 72 were tagged only. Mortality rate between the treatment groups (tagged, and tagged and deflated) was monitored by Aquarium personnel.

The effects of treatment, season, and time-in-net on mortality rate were investigated using analysis of variance. Partial residual analysis was used to determine that variance was homogeneous. In some of these comparisons, data were reduced if sample size was insufficient for all of the components in the matrix being compared. For the comparison of treatment effects by season, only data from summer and fall were sufficient among all treatments for comparison. For the comparison of treatment effects by time-in-net, only data from 24 and 48 hours were used. Type III sum of squares were used for the analysis due to unequal number of observations in each subclass. A 0.10 level was considered significant.

Results

The frequency distribution of red snapper tested during this study is shown in Figure 3.1. Minimum size limit for red snapper legally retained by the commercial and recreational fisheries are indicated on the chart. Overall mortality rate during the study averaged 19.7%. No significant variation in mortality rate by treatment, or time-in-net was observed (Table 3.1). I did observe significant variation between season ($P > 0.05$), and the interaction between treatment and season ($P > 0.10$) (Table 3.1, Figures 3.2 and 3.3).

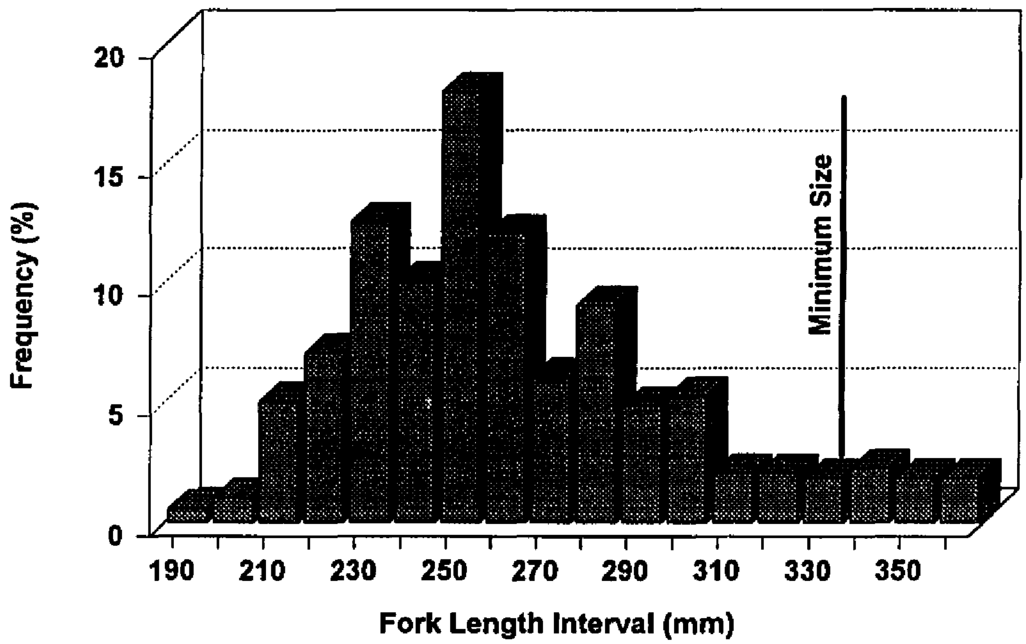


Figure 3.1. Length frequency distribution of red snapper tested during the study. Minimum size limit for red snapper legally retained by the commercial and recreational fisheries is indicated on the chart.

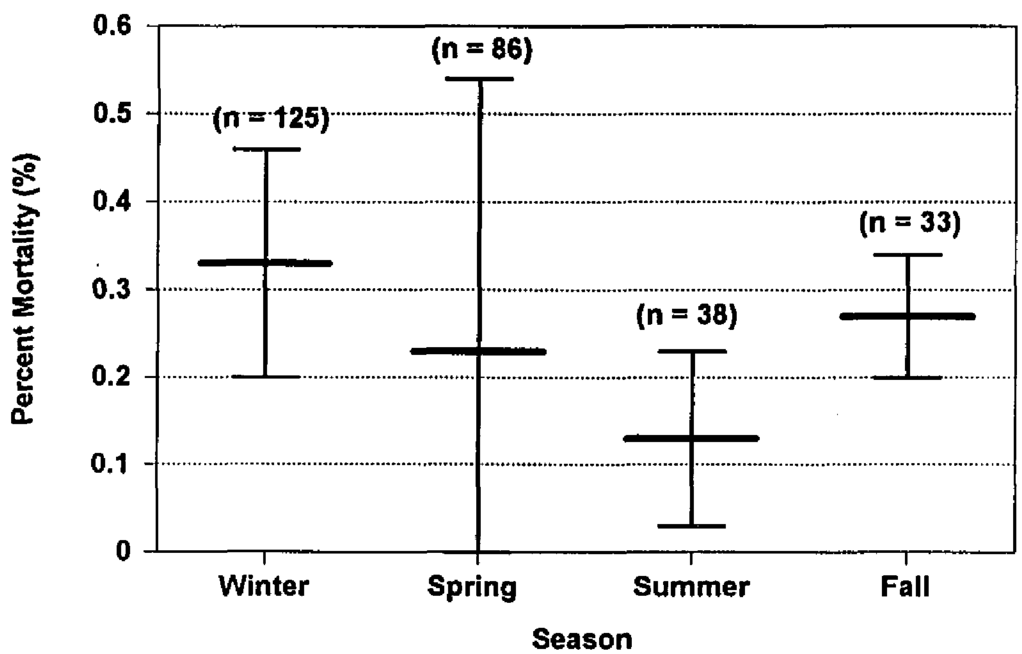


Figure 3.2. Mean percent mortality (± 1 standard deviation) of hook-and-line caught red snapper by season from West Cameron 352 petroleum platform from 1991 and 1992.

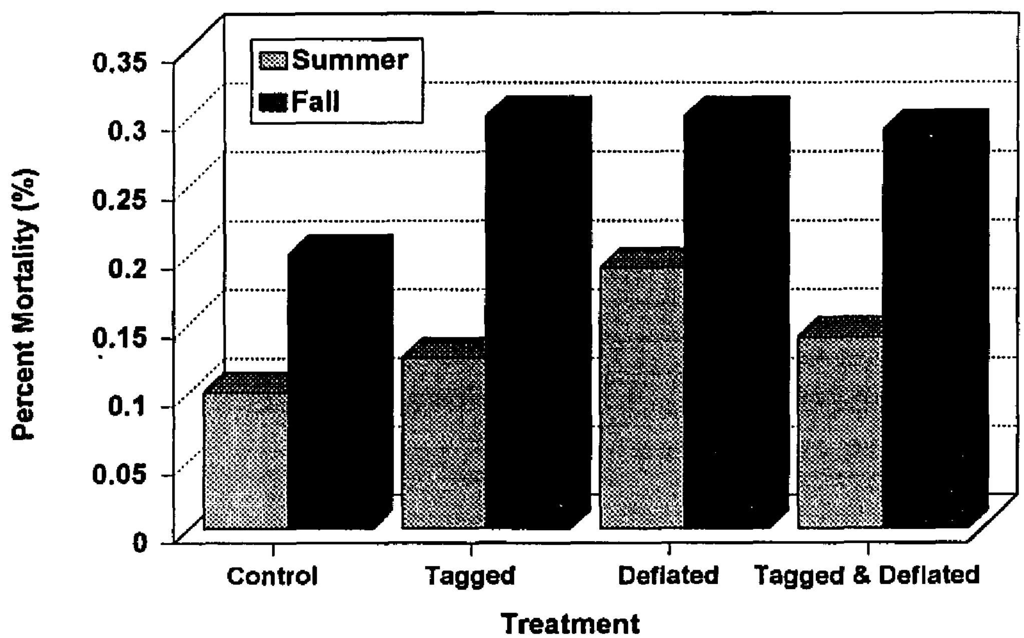


Figure 3.3. Mean percent mortality of hook-and-line caught red snapper by treatment and season from the petroleum platform West Cameron 352 during 1991 and 1992.

Table 3.1. Analysis of variance table testing the effects of treatment, season, time-in-net, and interaction combinations on mortality rates of hook-and-line caught and released red snapper.

Source	df	ss	F-ratio	Model Pr > F
Model	11	0.1826	2.41	0.1708
Error	5	0.0344		

Variable	df	ss	F-ratio	Type III Pr > F
Treatment	2	0.0058	0.43	0.6734
Season	1	0.0773	11.24	0.0203**
Net Time	1	0.0255	3.72	0.1118
Season * Treatment	3	0.0213	1.03	0.4531
Net Time * Treatment	2	0.0723	5.26	0.0589*
Season * Net Time	1	0.0289	4.20	0.0956

** Significant at $P < 0.05$
* Significant at $P < 0.10$

Twenty of the 107 red snapper that were transferred to the Aquarium of the Americas in New Orleans incurred mortality within varied lengths of captivity from the time of transferral (2 to 37 days, $\bar{x}$ = 11.35). Sixty percent of total mortalities occurred within the first week of captivity. Mortality rates between the tagged (18.0%), and tagged and deflated (20.1%) treatment groups were not significantly different ($P >$ 0.05).

Discussion

Based on age data presented by Futch and Bruger (1976), the samples in this study were comprised primarily of age 1, 2 and 3 year classes. The age 2 year class appeared to be most dominant. It is evident based on the length frequency distribution shown in Figure 3.1, that these year classes, particularly year classes 1 and 2, are most significantly impacted by the release regulations in the red snapper fisheries.

Analyses of variance showed no significant mortality differences among treatments, or short term captivity (time-in-net). There were significant differences detected by season and in the interaction between treatment and season, with higher mortality observed in the fall. It is uncertain (because of the lack of data) whether this difference represents a true seasonal pattern. It is plausible that colder sea temperatures in late fall, winter, and early spring may place additional stress on tropical reef species like red snapper.

Gas bladder deflation did not significantly affect survival of red snapper caught at 21 m depth for either the short or long term comparisons. Several factors should be considered, however, when interpreting these results, particularly for fish that were transferred to the Aquarium for the long term experiments. These fish were

held in the net at 9 m for at least 24 hours. This acclimation period would allow some adjustment in buoyancy prior to transfer to the tank for transport (Steen 1970). Secondly, since the tank was highly oxygenated and was without current, the necessity of neutral buoyancy for position maintenance was eliminated. There is evidence based on observation of the fish transferred to the aquarium and ancillary data, that small puncture holes (# 20 hypodermic needle tips) in the gas bladder apparently reseal or repair rapidly. The tissue composition of the gas bladder as described by Fange (1958) indicates elastic properties.

Although deflation techniques may have some significance in enhancing our ability to obtain physoclistous species for aquaria and experimental collections, the fate of deflated specimens released *in situ* is less certain given the harsher environmental conditions that the fish is released into and the fact that return to capture depth would imply negative buoyancy. It is predictable, based on Boyle's Law, that if only a partial amount of the total gas in the bladder is vented (as was usually the case) that a released fish could find neutral buoyancy at some depth between surface and initial capture depth assuming that the gas bladder reseals effectively. The effect of a "compensatory return depth" is unknown. I suspect that for a red snapper caught and released around an oil or gas platform, that the effect would be negligible since the structure of the platform extends throughout the entire water column, and I have observed red snapper at various depths from near surface to bottom when in association with a gas platform. The effect on red snapper caught near the bottom around submerged natural or artificial hard substrate is less predictable, since the structure provided by the substrate may be important for predation shelter (Parrish 1987).

Based on results, gas bladder deflation is unnecessary at catch depths of 21 m or less. The effect of gas bladder deflation on survival beyond the 21 m catch depth can not be extrapolated from this data. I hypothesize that the relationship between depth and mortality may be exponential with depth. Geitchslag (Personal Communication - National Marine Fisheries Service, Galveston Laboratory, 4700 Avenue U, Galveston TX 77551) identified the increased mortality to depth relationship but did not have sufficient data to quantify it. Other factors related to increased hydrostatic pressure change, including internal damage and increased risk of predation because of changed behavior pattern (Gotshall 1964) may influence survival.

CHAPTER IV

REMOTELY OPERATED STATIONARY VIDEO AS A BEHAVIORAL ASSESSMENT TOOL FOR FISH ASSOCIATED WITH OIL AND GAS PLATFORM HABITAT

Introduction

Although progress has been made in our understanding of the life history of fish species occupying reef habitat, little detail is known about the inter- and intra-specific behavior of these species relative to their habitat on any broad scale. Behavioral observations have typically been collected from diver surveys in shallow waters or indirectly obtained from age and growth, food habit, and tagging studies. Although these observations and studies have contributed to our overall knowledge of the life histories of reef oriented species, further work incorporating behavior as a life history component is warranted.

Oil and gas platforms serve as important artificial reefs in the northern Gulf of Mexico since natural hard bottom substrate is typically limited and far from shore. The significance of artificial structures as habitat for reef fish species populations has been strongly debated in terms of whether these structures enhance populations by creating habitat or whether populations are simply redistributed (Bohnsack and Sutherland 1985; Munro and Williams 1985; Solonsky 1985; Bohnsack 1987). Regardless, it cannot be debated that the presence of these structures has influenced the distribution of reef fish in the northern Gulf of Mexico. Platform habitat along the continental shelf in the northern Gulf of Mexico west of the Mississippi River may be of particular importance to the distribution of reef fish populations since these structures rise above the nepheloid layer common in this area. The distribution and abundance of reef fish on natural hard bottom features in the western Gulf has been shown to be strongly influenced by the depth of those features relative to the nepheloid layer (Rezak et al. 1983; Putt et al. 1986; Dennis and Bright 1988; Rezak et al. 1990) with reef fish species diversity and abundance higher above the

nepheloid layer. Although oil and gas platform habitat in the northern Gulf is considered to be important, little quantitative data exists to describe it.

Oil and gas platform habitat is generally difficult to characterize in terms of species abundance and composition due to the vertical nature of the habitat, depth and structural complexity. Since platform habitat is represented in three dimensions, fish species can be distributed in patterns and depth strata not normally observed on natural hard substrates (Figure 4.1). Stanley (1994) found that in general, fish concentrate within 16 m of oil platforms and may vary spatially with depth and side of a given platform. In addition, he observed that overall fish abundance associated with a given structure could vary widely on a relatively short temporal scale (one month) and suggested that platforms represent a "non-equilibrium" system.

Investigations of sampling methodologies to survey the fishes that aggregate on or over live bottom, ledges, outcrops, banks, mud lumps, sink holes, rocks, and oil and gas platforms have been conducted by the National Marine Fisheries Service, and university and state scientists (Huntsman et al. 1982). Collection (fishing) gears used have included bottom longlines, gill nets, traps, and power assisted handlines (Haynes 1988). In general though, these gears have proven ineffective around oil and gas platform structures. Fisheries acoustic technology has been used successfully around these structures to enumerate fish density and estimate biomass (Stanley 1994), however species composition cannot be independently derived from acoustic data.

Underwater video techniques have evolved rapidly in recent years due to advancements in electronic technology that have resulted in miniaturization of components. Remotely operated underwater video systems offer several

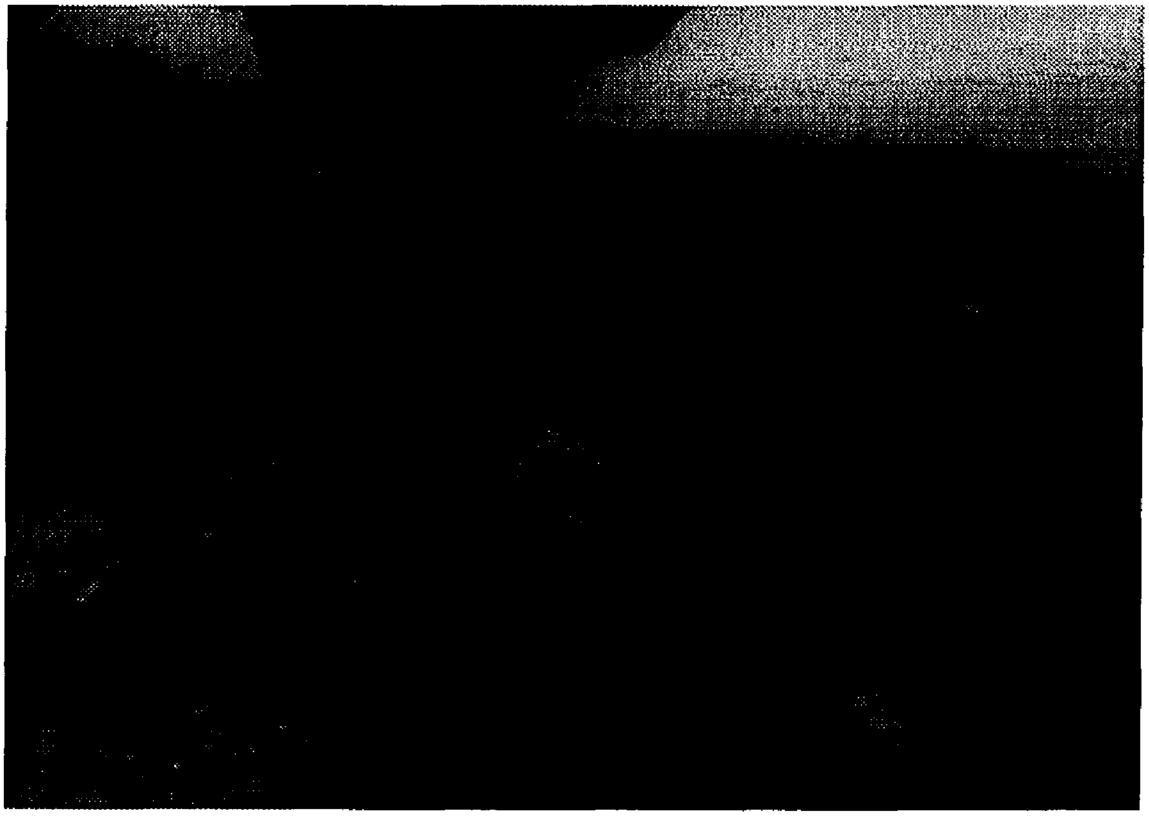


Figure 4.1. Red snapper associated with platform habitat at Mobil West Cameron 352.

advantages over traditional sampling gear including in that they:

1) are non-destructive,

2) are non-obtrusive (i.e., do not effect normal behavior of individuals observed),

3) have greater depth and time capabilities than diver surveys, and

4) are relatively inexpensive.

The purpose of this study was to utilize remotely operated video systems to observe red snapper, *Lutjanus campechanus,* around oil and gas platform habitat, and discuss how qualitative behavioral data may be integrated into our understanding of the life histories of various reef associated species.

Methods

The study site was a gas platform owned by Mobil Exploration and Production U.S., Incorporated (West Cameron 352), located approximately 80 km south of Cameron, Louisiana, in 21 m water depth. The video system employed was designed by Fuhrman Diversified, 2912 Bayport Blvd., Seabrook, Texas, and consisted of a low lux (0.1) black and white video camera encased in a waterproof housing (100 m depth maximum) (Figure 4.2).

Power input and video output were designed to operate with coaxial cable, and thus data could be seen in real time and/or recorded on tape for later analysis and processing. The camera housing was mounted on a weighted sled and the system could be deployed and lowered at different locations and depths around the platform. A separate line was attached to the sled to control direction of view and to keep the camera and sled from rotating with the current. Following data collection, tapes were returned to Louisiana State University for processing. Video data were viewed and observations on behavior were recorded. Observations noted included

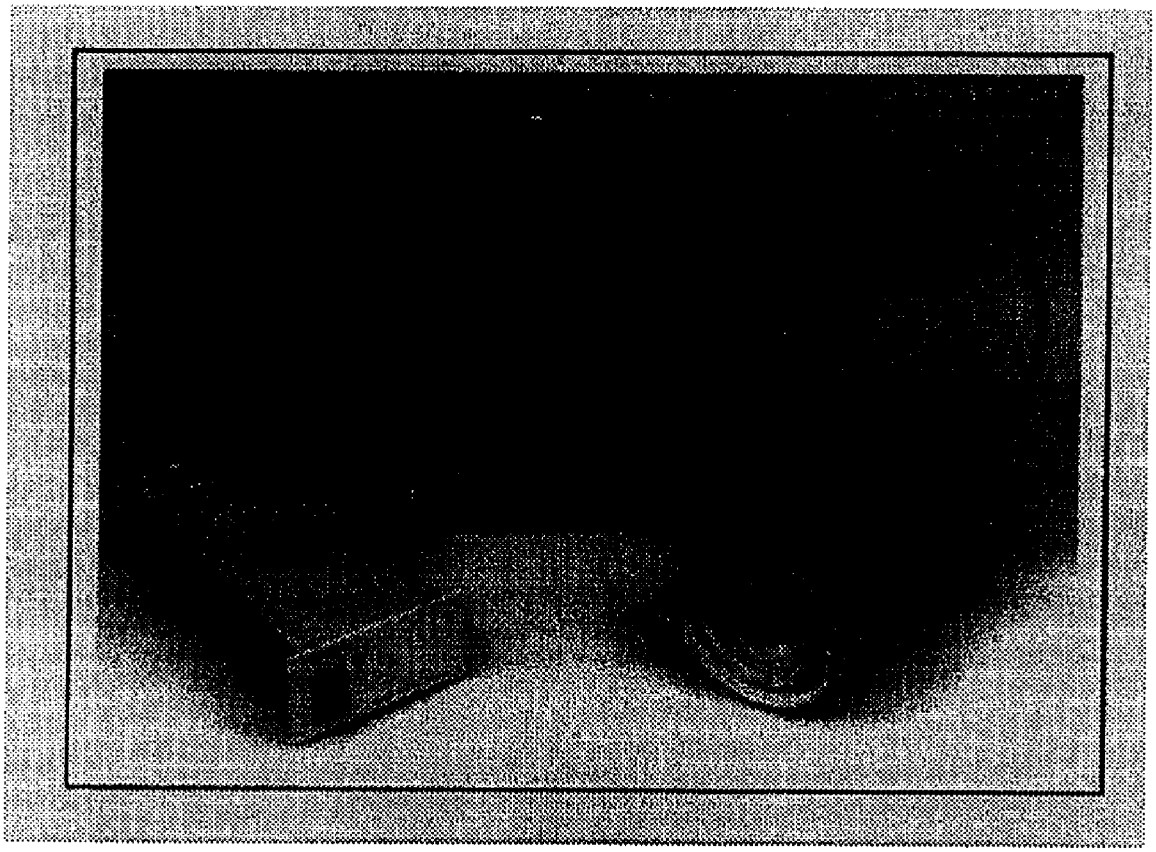


Figure 4.2. Video system designed by Fuhrman Diversified.

depth, number of individuals, position relative to structure, orientation, feeding, inter- and intra-specific interactions, and other notable events.

Results and Discussion

Approximately 40 hours of video data were collected from May 1992 through October 1992. Most of the data collected were observations of large schools (30 to over 100) of small juvenile red snapper (180 to 300 mm). Though less frequent, larger adult size individuals (>300 mm) were also observed. Video analysis of the behavioral patterns of red snapper in relation to platform habitat produced several general observations. Red snapper do not appear to be a "bottom fish" when associated with platform habitat. Juveniles were almost always observed in schools in close association with platform structure (i.e., rig legs, cross beams), whereas adults tended to be solitary or in small groups, and did not appear to be obligate to structure based on their movement patterns. Additionally, adult and juvenile red snapper appeared to partition habitat by selecting different depth locations along the vertical gradient.

Although these data are qualitative in nature, the patterns observed are still useful for hypothesis development and ultimately quantitative hypothesis testing. For example, the results suggest that juvenile and adult red snapper occupy shared platform habitat differently both in affinity for physical structure and in vertical distribution. I presume that structural affinity by juveniles is related to predation risk since the physical structure of the platform habitat may provide refuge from large predators (Werner and Gilliam 1984). Large fish are generally less vulnerable to predation than smaller conspecifics (Schmitt and Holbrook 1984; Osenberg and Mittlebach 1989) resulting in the opportunity for larger fish to expand niche width.

Mueller et al. (1994) noted that change in body size during ontogeny is associated with the outcome of intraspecific social interactions for most reef fish. Older, larger fish, for example, may have a more diverse diet than younger fish due to greater foraging flexibility, decreased vulnerability to predators, and superior prey location and handling experience. A combination of these dynamics (and others) may explain the observed partitioning of platform habitat between adults and juvenile red snapper.

In summary, video data and qualitative analysis can be a useful tool for preliminary investigation of fish behavior. Observation of inter- and intra-specific behaviors can and should lead to the development of quantitative methodology and experimentation for describing behavior in these complex and difficult environments. The challenge is to design experiments which lead to comprehensive, detailed understanding of fish life history and the dynamic interactions which occur within and among species relative to the habitat they occupy.

EPILOGUE

The Research Efforts of Jeffrey Howard Render

The preceding document provides critical life history information that will be used in the management of red snapper in the Gulf of Mexico and along the north Atlantic coast. The age, growth and reproductive information will be used directly in establishing standing stock biomass and year per recruit estimates that are developed by the National Marine Fisheries Service for making management recommendations. The Gulf of Mexico Fishery Management Council uses such recommendations to set seasons and harvest levels for this species. All of Dr. Jeffrey Render's data have been provided to the National Marine Fisheries Service and have been incorporated into management plans that are currently under debate.

Jeff has opened the door to a better understanding of hook-and-line mortality and associated behavior of red snapper. This information is also critical in making management decisions, because many of the red snapper that are caught and released by commercial and recreational fishermen are undersized. One prevailing question has been, "what is the survival of fish that are brought up from depth and released back into the ocean?" Jeff's data have proven that survival is relatively high for red snapper caught at depths to 21 m, although he hypothesized that fish brought up from depths greater than 21 m may experience considerably greater mortality. Jeff has provided us with a model for how to evaluate hook-and-line mortality for a number of different species. He developed a unique holding system that will allow us to test the effect of capture on other species such as grouper, mangrove snapper, vermilion snapper, and amberjack, as the need arises.

Jeff's investigation into the life history of red snapper has demonstrated to us that juvenile red snapper prefer to live around oil and gas platforms and other types

of structural habitat; and that red snapper appear to move away from the structures as they get older, presumably because they are less subject to predation.

Jeff's research has left us with several questions that will provide the framework for future research projects by graduate students and scientists. We need to understand how red snapper movement will be affected by the removal of oil and gas platforms. Are these platforms critical to the early life history stages of red snapper? Will the future removal of oil and gas platforms affect our coastal populations? He has also provided us with a framework for conducting further age and growth studies on red snapper. As harvest continues on this species, we will need to have an understanding of how the age structure of the population changes over time. We now know that otoliths are an acceptable tool for aging red snapper, and that their routine collection will continue to provide insight into the age structure of the population.

Had Dr. Render continued on his career path, he would have lead the reef fish program for the National Marine Fisheries Service, whose current objective is to determine how to improve management of red snapper and other reef fish populations in the Gulf of Mexico. He would have continued his research on the life history and behavior of red snapper and likely added other species to his charge over time. He would have become an important leader in the field of fisheries research.

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VITA

Jeffrey Howard Render was born January 6, 1958 in Pontiac, Michigan. His interest in wildlife and the environment was initially cultivated during time spent hunting with his family and friends in the northern woods, and later his interest moved into marine fisheries while working at the Louisiana State University Coastal Fisheries Institute.

In 1980 he received a B.Sc. degree from Mississippi State University, and in 1981 he moved to Louisiana to attend graduate school at LSU. Jeff received a M.Sc. degree in Wildlife Management in May of 1984, comparing the forage preferences of eastern cottontail rabbits. He accepted a position with the Coastal Fisheries Institute, working on a variety of projects dealing with the life history of fishes such as king mackerel, butterfish, black drum, mullet, sheepshead and, most recently, red snapper. His interest in red snapper behavior and life history led him to enroll in the Ph.D. program at LSU in 1988.

Jeff died at sea in August of 1995 while conducting research on the life history of red snapper. He will be awarded a posthumous doctoral degree from the Department of Oceanography and Coastal Sciences in December of 1995.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Jeffrey Howard Render

Major Field: Oceanography and Coastal Sciences

Title of Dissertation: The Life History (Age, Growth and Reproduction) of Red Snapper (Lutjanus campechanus) and Its Affinity for Oil and Gas Platforms

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination: