Age and Growth of Red Snapper, *Lutjanus campechanus*, in the Northwestern Gulf of Mexico: Implications to the Unit Stock Hypothesis

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ABSTRACT

Red snapper, *Lutjanus campechanus,* in the northwestern Gulf of Mexico are being examined for differences in age and growth parameters among populations east and west of the Mississippi River. In the first year of this three-year study, nearly 2,100 specimens from the recreational fisheries of Alabama, Louisiana, and Texas were sampled for morphometric data and otoliths. Red snapper ranged in age from 1 to 34 years (199 - 916 mm FL), from 1 to 37 years (345 - 913 mm FL), and from 2 to 45 years (315 - 846 mm FL) for Alabama, Louisiana, and Texas, respectively. Regression analyses of fork length (FL in mm) – total weight (TW in kg) relationships did not differ significantly between sexes but did differ between states (TW unavailable from Texas): $TW = 2.57 X 10^{-8} FL^{2.94}$ ($r^2 = 0.96$) for Alabama and $TW = 1.54 X 10^{-8} FL^{3.03}$ ($r^2 = 0.96$) for Louisiana. Von Bertalanffy growth models derived from FL at age were $L_\infty = 884 (1 - e^{(-0.21(t-0.12))})$ for Alabama, $L_\infty = 873 (1 - e^{(-0.24(t-0.26))})$ for Louisiana, and $L_\infty = 1{,}017(1 - e^{(-0.07(t+3.39))})$ for Texas. Elevated L_∞ and t_0 values for Texas are due to a lack of larger individuals in the sample population. Regression analysis on the first ten years of life indicated that red snapper in Texas waters grow at a slower rate then those from Alabama and Louisiana.

KEY WORDS: Growth model, otolith, red snapper

INTRODUCTION

The red snapper, *Lutjanus campechanus* (Family Lutjanidae), inhabits the continental shelves of the Atlantic coast of the United States as far north as Massachusetts and the Gulf of Mexico from Florida to the Yucatan Peninsula. It is also found in the waters off Bermuda, the Bahamas, and off Northern Cuba but is absent in the Caribbean Sea (Rivas 1966, Robins and Ray 1986, Hoese and Moore 1998).

Red snapper support an important recreational fishery in the Gulf of Mexico and the most important commercial fishery in the snapper/grouper complex from Florida to southern Texas (Goodyear 1995a). Both the commercial and recreational red snapper fisheries went essentially unregulated prior to 1990 resulting in a decrease in landings from historic highs of about 6,389 metric tons (mt) in 1965 to 1,015 mt in 1991 and from 4,734 mt in 1979 to 581 mt in 1990 for the commercial and recreational fisheries, respectively (Schirripa and Legault 1999). These declines prompted the Gulf of Mexico Fishery Management Council (GMFMC) to institute harvest quotas, minimum size limits, trip quotas for commercial fishers, creel limits for recreational fishers, and moratoria on issuing commercial reef fish permits in 1991. However, pressure on the fishery persists (Goodyear 1995a, Schirripa and Legault 1999).

An underlying critical assumption to any fisheries management strategy is that the fish being managed belong to a single unit stock. Currently red snapper in the Gulf of Mexico are managed under that assumption (Camper et al. 1993, Gold and Richardson 1994, Goodyear 1995a, Gold et al. 1997). Herein, we present our preliminary interpretations of data from the first year of a three-year, multi-institutional study investigating the stock structure of red snapper in the northern Gulf of Mexico and examining whether their management as a single unit stock is justified. We determine the ages of fish sampled from recreational sources in the northwestern Gulf of Mexico and examine these data for differences in age distributions east and west of the Mississippi River. We also use size at age information to determine and compare growth rates of red snapper from across the Gulf of Mexico.

METHODS AND MATERIALS

Red snapper from recreational catches were sampled in Alabama, Louisiana, and Texas from April through September 1999. Morphometric measurements (fork length (FL) in mm, total weight (TW) in kg, and eviscerated body weight (BW) in kg), both sagittal otoliths, and gonads were removed (and sex determined).

All undamaged sagittal otoliths were weighed to the nearest 0.1mg. The left otolith from each individual was thin sectioned with the Hillquist model 800 thin-sectioning machine equipped with a diamond embedded wafering blade and precision grinder (Cowan et al. 1995). In those instances where the left otolith was damaged or unavailable, the right otolith was used. Examinations of otolith sections were made with a dissecting microscope with transmitted light and polarized light filter.

Counts of annuli (opaque zones) were made on the medial surface of the transverse section along the ventral side of the sulcus groove (Figure 1). Annulus counts were done by two independent readers without knowledge of date of capture or morphometric data of the fish. The appearance of the otolith margin, or edge condition, was coded as opaque or translucent (Beckman etal. 1989). Sections were recounted by both readers when initial counts disagreed. When a consensus could not be reached on the second reading, annulus counts of the more experienced reader were used. Ages of red snapper were estimated from opaque annulus count and adjusted for edge condition when necessary. A uniform hatching date of 1 July was assigned based on previous studies of red snapper reproduction (Render 1995; Collins et al 1996).

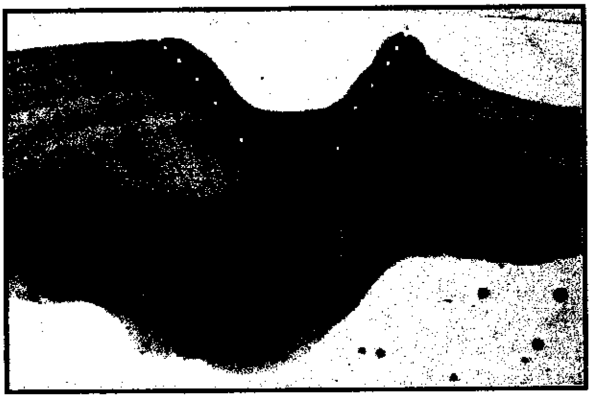

Figure 1. Photomicrograph of a transverse section at the core of a red snapper sagittal otolith. White squares indicate annuli counted for age estimation.

Length – weight regressions were fit with linear regression (SAS,1985) to the model $TL = a\ TW^{b}$ with $\log_{10}$ transformed data for Alabama and Louisiana specimens (weight data not available for Texas specimens). Analysis of covariance was used to compare sexes and sample sources (states). Von Bertalanffy growth models were fit for FL with nonlinear regression (SAS 1985) in the form: $L_t = L_\infty(1 - e^{[-k(t-t_0)]})$ where L_t is estimated fork length at age t, L_∞ is the theoretical maximum fork length, k is the growth coefficient, and t_0 is a hypothetical age when length is zero. Growth of red snapper in the first ten years of life appears to be linear (Szedlmayer and Shipp 1994, Patterson 1999), therefore, growth was also evaluated by performing a linear regression of FL at age with a general linear model (GLM) (SAS 1985). Significance level for statistical analyses was 0.05.

RESULTS

During the first year of this three-year project, 2,098 red snapper were sampled from recreational sources including charter boats and dive and fishing tournaments (AL = 786, LA = 737, TX = 575). Among the 1,037 males and 1,014 females sampled from the three states, males ranged from 240 - 868mm, 345 - 913mm, and 315 - 844mm FL for Alabama, Louisiana, and Texas, respectively (Figure 2). Females ranged from 254 - 916mm, 365 - 910mm, and 315 - 795mm FL for Alabama, Louisiana, and Texas, respectively. Komolgorov-Smirnov two sample tests (Tate and Clelland 1957) indicated no significant differences in length distributions between sexes or among sample sources.

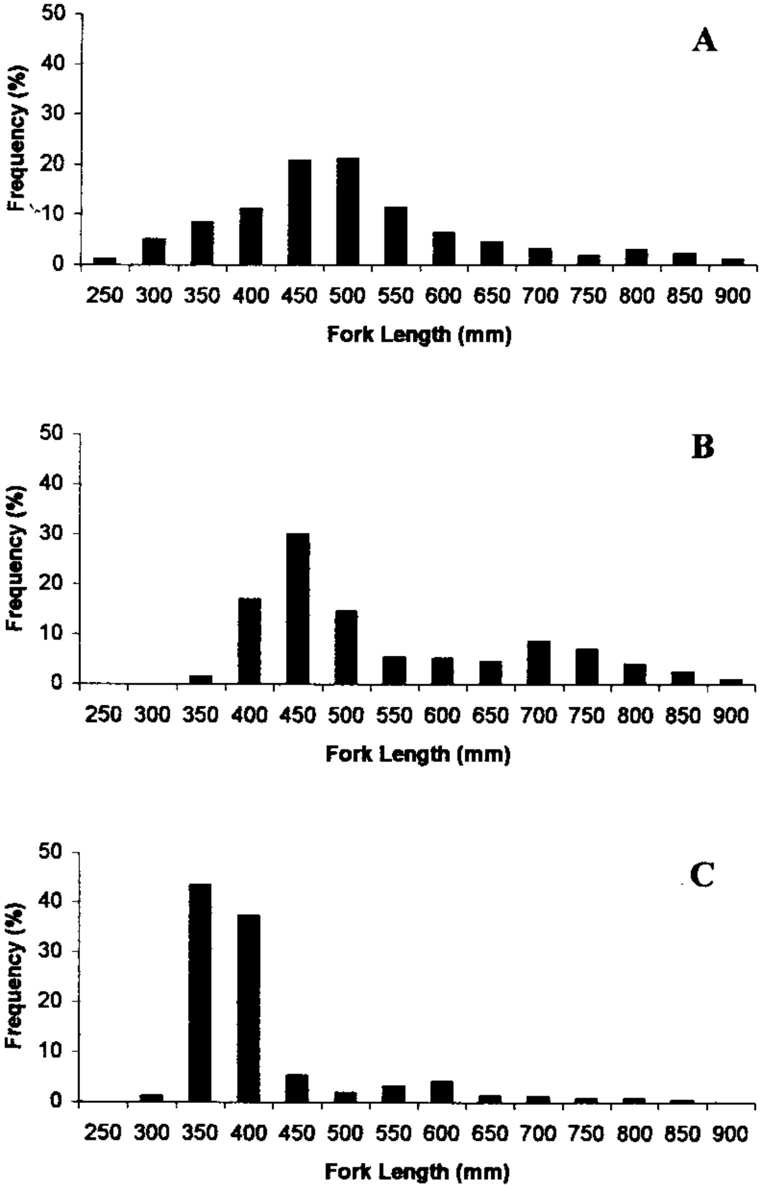

Figure 2. Length frequency distribution of red snapper sampled from recreational catches in A) Alabama (199 - 916mm FL), B) Louisiana (345 - 913mm FL) , and C)Texas (315 - 846mm FL).

Regression analyses of FL–TW relationships did not differ significantly between sexes. Neither the slopes (df = 1, 1524; F = 2.76; $P < 0.096$) nor the intercepts (df = 1,1524; F = 2.18; $P < 0.1397$) were found to be significantly different; thus data for the two sexes were combined. Regression analysis between states did differ, however, for slopes (df = 1,1524; F = 77725.47; $P < 0.001$) and for intercepts (df = 1,1524; F = 153.11; $P < 0.001$), so predictive models were generated for each state:

$TW = 2.57 \text{ X } 10^{-8}\, FL^{2.94}$ ($r^2 = 0.96$) for Alabama
$TW = 1.54 \text{ X } 10^{-8}\, FL^{3.03}$ ($r^2 = 0.96$) for Louisiana
(TW unavailable from Texas).

Two thousand and fifty-nine otoliths were available and sectioned for age determination. Of those, nine were deemed unreadable by both readers 1 and 2 and were excluded from further analysis. Of the remaining 2050 sections, consensus was reached in the initial count on 1,841 (89.8%) individuals. A second reading produced consensus on 2,045 (99.8%) individuals. Red snapper in this study ranged in age from 1 to 45 years (Figure 3). Alabama fish ranged in age from 1 to 34 years; only 18 of the 772 fish (2.3%) aged from Alabama were over 15 years old. Louisiana red snapper ranged from 2 to 37 years with only 27 out of 712 fish (3.8%) over 15 years. Texas fish ranged from 2 to 45 years with only 4 out of 567 (0.7%) aged individuals over 15 years. Komolgorov-Smirnov two sample tests indicated no significant differences in age distributions between sexes or among sources.

Von Bertalanffy growth models to describe red snapper size at age were fitted for each state (Figure 4). The resultant models for FLat age are:

AL: $FL(mm) = 884[1 - e^{-0.21(t-0.63)}]$ ($r^2 = 0.99$)
LA: $FL(mm) = 873[1 - e^{-0.24(t-0.73)}]$ ($r^2 = 0.99$)
TX: $FL(mm) = 1023[1 - e^{-0.07(t+2.92)}]$ ($r^2 = 0.98$)

Predicted FL at age for red snapper from the three states generated with each of the models above illustrate rapid growth to an age of approximately 10 years after which an asymptote is approached and growth is in length is negligible.

Regression analysis of FL at age to evaluate growth of red snapper in the first ten years of life indicated significant differences among states (Figure 5). Alabama and Louisiana differed significantly for slopes (df = 1,1378; F = 2898.54; $P < 0.0001$) and intercepts (df = 1,1378; F = 30.29; $P < 0.0001$). Alabama and Texas also exhibited significant differences in both slopes (df = 1,1282; F = 1993.79; $P < 0.0001$) and intercepts (df = 1,1282; F = 72.01; $P < 0.0001$). Not surprisingly, Louisiana and Texas showed significant differences in slopes (df = 1,1188; F = 1711.34; $P < 0.0001$) and intercepts as well (df = 1,1188; F = 164.4; $P < 0.0001$).

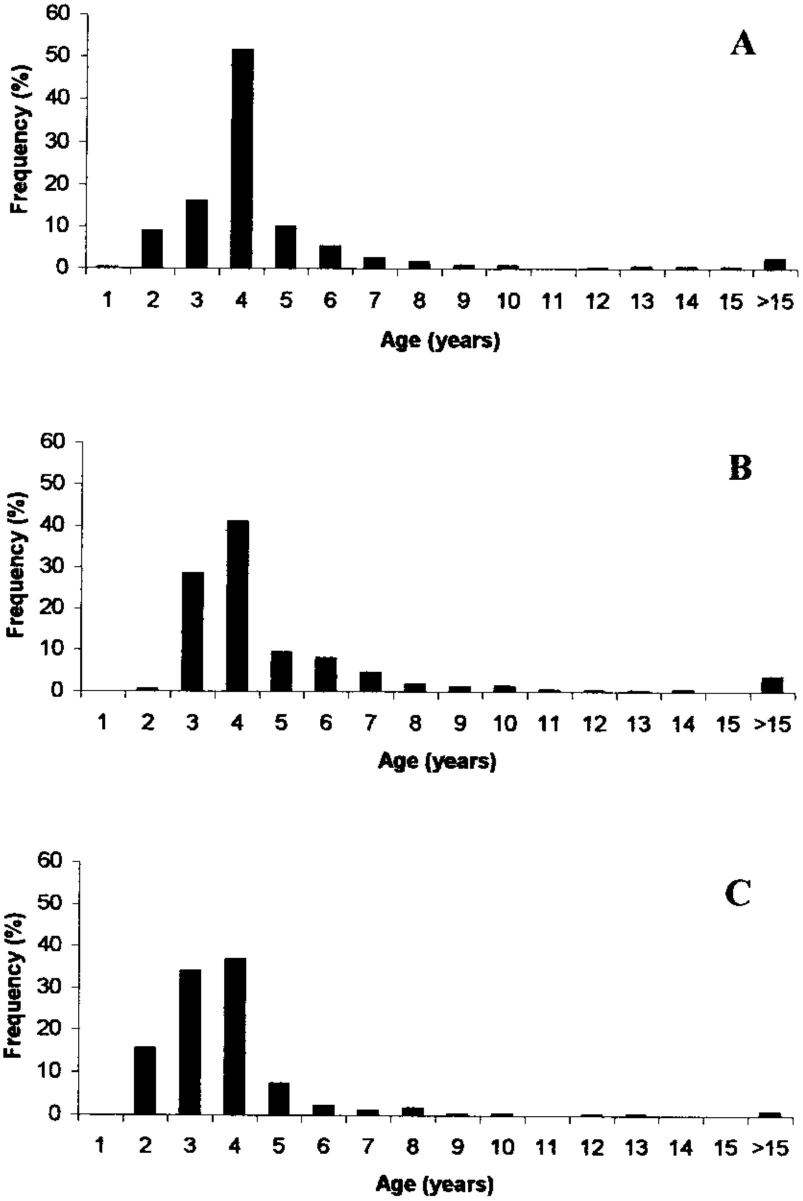

Figure 3. Age frequency distribution for red snapper sampled from recreational sources in April to September 1999 in A) Alabama, B) Louisiana, and C) Texas.

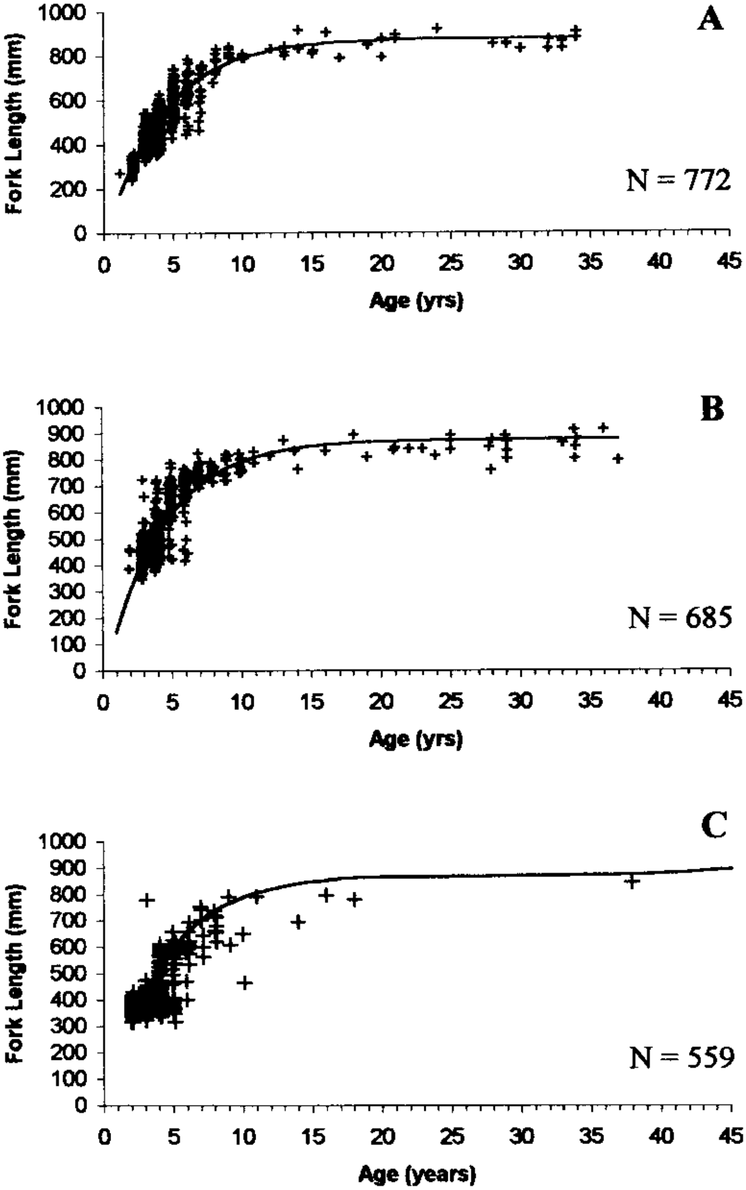

Figure 4. von Bertalanffy growth models fit for red snapper sampled from recreational catches in April – September 1999 for A) Alabama, B) Louisiana, and C) Texas.

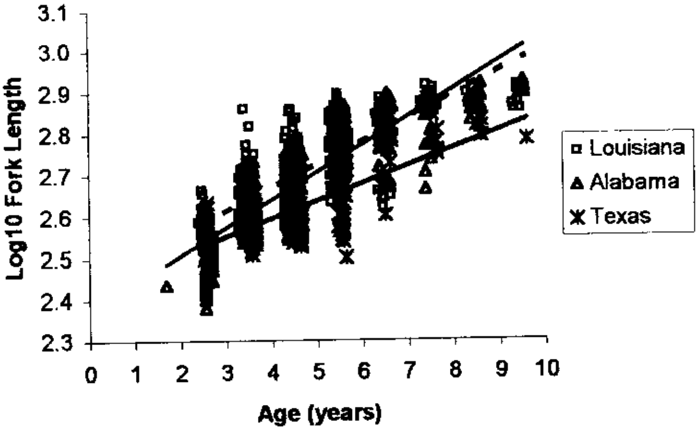

Figure 5. Linear regression of Log$_{10}$ transformed fork length on age examining growth rates in the first ten years of life of red snapper sampled from Alabama (thin, solid black line), Louisiana (dotted black line), and Texas (thick gray line) in April through September 1999.

CONCLUSIONS

Several studies of red snapper age and growth mentioned herein have validated that otoliths do accrete one annulus per year during the winter and spring and can therefore be accurately used to determine age (Wilson et al. 1994, 1997, Render 1995, Manooch and Potts 1997, Patterson 1999). The pattern of winter-spring annulus formation is consistent with that reported for other long-lived fish in the northern Gulf of Mexico (Beckman et al. 1989, Beckman et al. 1990, Beckman et al. 1991). In addition, Baker (1999) used radiometric age estimates to validate the continued use of otolith sections as the best method to estimate age for red snapper.

The age distributions from this study are not representative of the red snapper population in the Gulf of Mexico. Due to minimum size limits on the recreational fishery, age 0 and age 1 snapper are not represented adequately in our sample population. The majority of fish sampled in all three states fall between the ages of 2 – 5 years (76% of aged fish) perhaps reflecting migratory aspects of red snapper life history. After migration from shallow waters, these fish reside around structures such as oil and gas platforms to seek refuge from large predators (Render 1995). Because these platforms harbor large populations of red snapper as well as other species (Stanley and Wilson 1996 , 1998), they are preferred destinations of recreational and commercial fishermen. In addition, few old red snapper were sampled. Though large adults were targeted at fishing and dive tournaments, only

49 fish (2.9%) were found to be over 15 years old. The small numbers of older adults could be due to natural or fishing mortality, or due to emigration away from the platforms where they are less susceptible to capture.

The growth models in this study produced results similar to those in previous red snapper studies (Nelson and Manooch 1982, Szedlmayer and Shipp 1994, Patterson 1999). All show a rapid growth in the first ten years of life followed by a leveling of growth rate. The models' fit for Alabama and Louisiana differ, however, from the Texas model in that they produced lower L_{∞} and higher K values. This may be an artifact of sampling. Both Alabama and Louisiana personnel sampled fishing tournaments targeting larger, older individuals. These fish pull the vonBertalanffy curve down producing a smaller maximum theoretical size. Goodyear (1995b) warned that non-random, or selective sampling such as fishing tournaments could introduce significant bias into growth functions. The lack of larger individuals in the sample population resulted in elevated L_{∞} and t_0 values for Texas. Szedlmayer and Shipp (1994) reported an L_{∞} of 1025. This value is likely due to a small sample size (n = 409) in which only 11 fish were aged over 10 years old. The range in values of parameters derived from these various growth models are more a reflection of the size and age distribution of the sample population of each study than true growth effects of red snapper from different regions.

The regression analysis of FL at age indicated a difference in growth rates of red snapper among Alabama, Louisiana, and Texas in the first ten years of life. Although this difference was significant between all three states, red snapper from Texas clearly show a slower rate of growth than those from Alabama and Louisiana. Texas fish also display a smaller maximum size at 846 mm FL compared to 916 mm FL for Alabama and 913 mm FL for Louisiana red snapper. This slower rate of growth does not, however, have an affect on longevity as the oldest fish in this study (aged at 45 years) came from Texas waters. These differences in growth rates could be an indication of possible biologically meaningful management stocks within the fishery and could have profound affects on how the fishery is managed in the future. Should separate stocks exist, fishery units could be assessed and managed on a sub-regional basis, providing the opportunity to adjust regulations to the unique needs of sub-regional populations and resource users.

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