ABSTRACT

Kenneth J. Brennan. AGE, GROWTH AND MORTALITY OF LANE SNAPPER, *LUTJANUS SYNAGRIS,* FROM THE EAST COAST OF FLORIDA. (Under the direction of Roger A. Rulifson) Department of Biology, December, 2004.

Lane snapper, *Lutjanus synagris,* otoliths were collected from headboat and commercial fisheries landings and from fishery independent sampling along the east coast of Florida from 1997 to 2003 (n = 1414). Specimens ranging in size from 25 mm to 547 millimeters total length (mm TL) were measured and assigned ages. Ninety - eight percent of sectioned otoliths could be aged. Fishery-independent samples were used to clarify formation of the first annulus and to complement the fishery dependent data set for other analyses. Marginal increment analysis established that rings formed annually, primarily in June. The oldest fish encountered was 12 years and 406 mm TL. The east coast of Florida was separated into north and south regions with the dividing line at Ft. Pierce. The range in age and size for back-calculated total lengths were by regions, ages 2-10 years for north Florida were 153-437 mm TL, while south Florida fish for ages 1-12 years were back-calculated to131-397 mm TL. The von Bertalanffy growth equation for north Florida was $L_t = 443.9\,(1\text{-}e^{-0.30\,(t + 0.82)})$, and $L_t = 311.4\,(1\text{-}e^{-0.63\,(t + 0.61)})$ for south Florida. The length and weight relationship was determined using additional headboat data from 1998-2003 (n = 5837). The relationship was significantly different between regions: $W = 9.50 \times 10^{-5}\,TL^{2.670}$ ($R^2 = 0.93$, n = 2939) for north Florida, and $W = 6.94 \times 10^{-5}\,TL^{2.714}$ ($R^2 = 0.81$, n = 2898) for south Florida, where W = total weight (grams). Also, lane snapper from north Florida were typically larger at age and reached asymptotic length slower than fish from south Florida.

AGE, GROWTH AND MORTALITY OF LANE SNAPPER, *LUTJANUS SYNAGRIS,* FROM THE EAST COAST OF FLORIDA

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By

Kenneth J. Brennan

APPROVED BY:

DIRECTOR OF THESIS Roger A. Rulifson
Roger A. Rulifson, Ph.D.

COMMITTEE MEMBER
Gerhard W. Kalmus, Ph.D.

COMMITTEE MEMBER
Charles S. Manooch, III, Ph.D.

COMMITTEE MEMBER Douglas S. Vaughan
Douglas S. Vaughan, Ph.D.

CHAIR OF THE DEPARTMENT OF BIOLOGY RJ Newton
Ronald J. Newton, Ph.D.

INTERIM DEAN OF THE GRADUATE SCHOOL Paul Tschetter
Paul Tschetter, Ph.D.

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Also, I thank Jennifer Potts for her patience, help, and advice. She was a guiding light and instrumental in analyzing the data and organizing the results.

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INTRODUCTION

The complex of snapper and grouper species from the offshore waters of the South Atlantic and northern Gulf of Mexico supports numerous commercial and recreational fisheries. One important member of this complex is the lane snapper, *Lutjanus synagris.* The South Atlantic Fishery Management Council, one of eight regional fishery management councils in the United States, is charged with developing a fishery management plan for the lane snapper and other reef fish species from North Carolina to Key West, Florida. In the case of lane snapper, the last thorough and published examination of the age and growth was completed 20 years ago (Manooch and Mason, 1984). In this study I attempted to produce a current validated age and growth analysis of the lane snapper from the east coast of Florida to be used to update stock assessments.

The lane snapper, *Lutjanus synagris*, is a tropical marine fish found in the western Atlantic from northern Florida through southeastern Brazil (Manooch and Mason, 1984), and including the Gulf of Mexico. A member of the family Lutjanidae, the species is important recreationally and commercially throughout its range. Adults are common in Florida waters but rare farther north. However, juveniles and larvae occur at least as far north as North Carolina (Adams, 1976; Ahrenholz, 2000; Tzeng, 2003) but do not contribute to fisheries. Lane snapper occur in a variety of habitats including coral reefs, hard bottom limestone outcroppings, shallow water seagrass beds, and turbid mangrove-bordered estuaries. Moderate sized (to 3 kg), these fish are distinguished from other snappers by seven to eight yellow lines diagonal to the lateral line and a diffused black spot located below the soft portion of the dorsal fin. Diet consists of a variety of small fishes and crustaceans along with worms, gastropods and cephalopods (Claro and Reshetnikov, 1981; Franks and Vanderkooy, 2000).

Spawning patterns of lane snapper vary by geographical location. Erdman (1976) reported that lane snapper have a protracted spawning period with seasonal peaks. In the western Atlantic spawning is primarily in the summer months (Luiz Barbieri, personal communication, Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida). In Bermuda the spawning season is late May to early September, with a peak between June and August (Luckhurst and Dean, 2000). In the Caribbean, spawning may be more protracted. For example, in Cuba (Claro, 1994) and in Trinidad (Manickchand-Dass, 1987) lane snapper spawn from about March through September. Spawning variability may coincide with warmer water in the southern parts of its range allowing mature fish to spawn earlier, more often, and possibly even year round.

Age to maturity is early in life but may vary with location. Male lane snapper may become sexually mature at age 1, but females may not mature until age 2 (Claro and Reshetnikov, 1981; Manickchand-Dass, 1987; Luckhurst and Dean, 2000). Nevertheless, Munro and Thompson (1983) reported that both sexes matured during their first year of life in Jamaica.

Since juvenile lane snapper are uncommon in North Carolina waters and adults are rare, the source of lane snapper larvae known to ingress through North Carolina inlets is uncertain (Adams, 1976; Tzeng, 2003). Perhaps the progeny of spawning aggregations off the east coast of Florida are transported north by the Gulf Stream currents. Other dispersal mechanisms such as the North Brazil Current may contribute significantly to the dispersal of larvae throughout the eastern Caribbean (Fratantoni and Glickson, 2003) while the Florida Current and associated gyres may supply southwest Florida, the Straits of Florida, and possibly southeast Florida (Lee, 1994).

Numerous age and growth studies on lane snapper conducted throughout the South Atlantic, Gulf of Mexico, and Caribbean Sea indicate they are relatively short lived, rarely reaching the age of 19 years, compared to most reef fish species, and reach a maximum length of 50 cm TL. Most specimens landed in fisheries are <10 years old and <25 centimeters total length (cm TL) (Alegria and Menezes, 1970; Cruz, 1978; Claro and Reshetnikov, 1981; Manooch and Mason, 1984; Manickchand-Dass, 1987; Torres and Chavez, 1987; Acosta and Appeldoorn, 1992; Johnson and Collins, 1995; and Luckhurst and Dean, 2000). Growth is rapid and by age-1 lane snapper reach about 19 cm TL in south Florida (Manooch and Mason, 1984), 19-23 cm TL in Trinidad (Manickchand-Dass, 1987), and 23 cm FL in Bermuda (Luckhurst and Dean, 2000). Growth during subsequent years is slower. Generally males grow slightly faster than females and are larger at age than females (Luckhurst and Dean, 2000; Manickchand-Dass, 1987).

Lane snapper have been aged using whole otoliths (Manickchand-Dass, 1987) and sectioned otoliths (Manooch and Mason, 1984). Annulus formation is similar to other lujanids with an opaque ring forming annually on the otoliths of lane snapper (Manooch and Mason, 1984). Marginal increment analyses suggest that annulus formation in lane snapper occurs April to June in Bermuda, (Luckhurst and Dean, 2000), April to

September in the northern Gulf of Mexico (Johnson and Collins, 1995), May to August in Trinidad (Manickchand-Dass, 1987), and May and June in Cuba (Claro and Reshetnikov, 1981). The maximum age of lane snapper varies geographically, with younger and smaller fish typically found in the southern distribution. Maximum estimated age ranges from 7 years in Trinidad (Manickchand-Dass, 1987), age 10 in south Florida (Manooch and Mason, 1984) and Cuba (Claro and Reshetnikov, 1981) age 17 in the northern Gulf of Mexico (Johnson and Collins 1995), and to age 19 in Bermuda (Luckhurst and Dean, 2000).

The older fish recorded in Bermuda and northern Gulf of Mexico exceed values from the Caribbean and south Florida by a considerable margin, and may be related to colder water in the winter months that may produce slower growth and longer- lived fishes (Pauly, 1980). It is hypothesized that exploitation of older fish may not be as great in these areas because older age classes are still represented. However, the northern long-lived, slow growing populations may be as susceptible to overfishing as the faster growing southern populations.

Almost all U.S. landings of lane snapper come from Florida, where lane snapper is of minor importance commercially but moderately important to recreational anglers. Commercial and recreational fishermen in Florida catch lane snapper using a variety of gear including fish traps, beach seines, trawls, and hook-and-line. Commercially, adult lane snapper (>30 cm TL and weighing 2 kg) are caught in deep offshore waters (>30 m) with other lutjanids such as mutton snapper *(Lutjanus analis)*, gray snapper (*L. griseus)*, and red snapper *(L. campechanus)* (Manooch and Mason, 1984). Recreational fishermen catch lane snapper from headboats and private boats using hook-and-line (Huntsman, 1976). Smaller lane snapper typically are caught inshore by anglers fishing from piers, jetties, bridges, and shore (Manooch and Mason, 1984).

In 1983 the South Atlantic Fishery Management Council (SAFMC) developed a fishery management plan (FMP) for the snapper-grouper complex of the U.S. South Atlantic. Twelve amendments to the Snapper-Grouper FMP have restricted commercial gear and created recreational bag limits. The FMP implemented an 8-inch minimum (203 mm TL) size limit and a daily bag limit of 10 fish per person for lane snapper. Similar to other members of the family Lutjanidae, lane snapper landings have experienced significant decline in the southeastern United States over the past 20 years (Figure 1).

The primary objective of my study was to produce a validated age and growth analysis of the lane snapper from the east coast of Florida to be used to update stock assessments. A secondary objective was to determine if there is a difference in growth rates and estimates of mortality of lane snapper between regions of Florida's east coast. In this study I will test the following hypotheses:

1) H_O: The opaque zone on the otolith is annular.

2) H_O: There is no change in age and growth for the same geographic area due to fishery management regulations imposed in 1983.

3) H_O: There is no difference in age frequency, or size at age, or growth parameters, between regions for Florida's east coast.

4) H_O: There is no difference in the instantaneous rate of total mortality (Z) and the instantaneous rate of natural mortality (M) between regions for Florida's east coast.

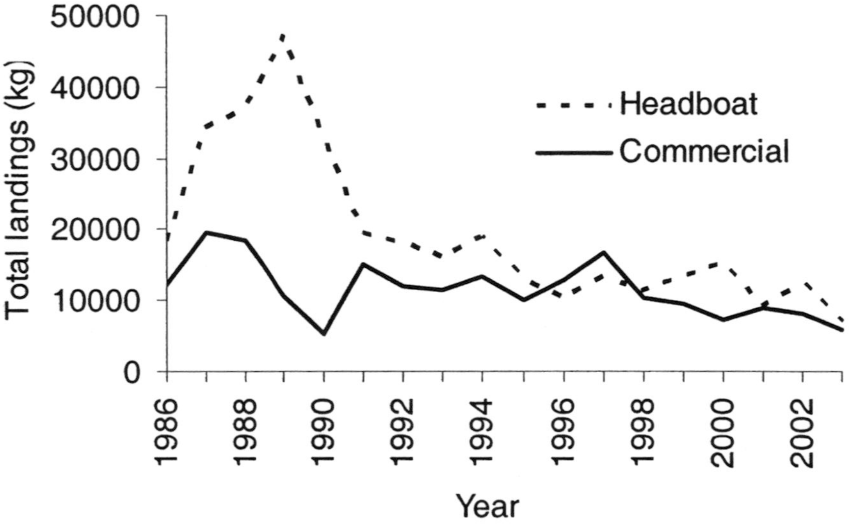


Figure 1. Commercial and headboat landings for lane snapper from Florida's east coast 1986 – 2003. (Commercial = Florida landings data, Headboat = South Atlantic Headboat Survey).

MATERIALS AND METHODS

Otolith samples (n = 1303) were collected at dockside from Jacksonville, Florida, to the Florida Keys from 1998 to 2003 by port agents of the National Marine Fisheries Service (NMFS) South Atlantic Headboat Survey (recreational fishery) and the NMFS Trip Interview Program (commercial fishery) (Table 1). Additionally, 111 juvenile fish (25 – 196 mm TL) samples were collected using a fishery independent survey in Florida Bay during 1997 and 1998. All fish were measured to the nearest mm for total length (TL) or fork length (FL), weighed to the nearest 0.01 kg, and sexed when possible.

Sagittal otoliths were removed by lifting the operculum, exposing the otic bulla, and using a wood chisel to shave away bone from the fluid-filled cavity to expose the otolith inside. This method was used to minimize disfigurement of fish destined for market or angler photographs (Matheson, 1981). Forceps were used to extract the otolith from the cavity with care not to break the sagitta or push it deeper into the cranium. Otoliths were stored dry in a coin envelope labeled with site of capture and pertinent morphological measurements.

Otoliths were processed at the National Oceanic and Atmospheric Administration (NOAA) Center for Coastal Fisheries and Habitat Research located in Beaufort, North Carolina, according to standard methodologies outlined by Matheson (1981). Otoliths collected from fishery dependent sampling were mounted using methods applicable for age determination of adult fish. Whole otoliths were mounted transversely dorsoventral) using Crystalbond$^{\mathrm{tm}}$, a thermo plastic cement, to adhere each earbone to

Table 1. Number of lane snapper otolith samples by fishery and region. (north Florida = Georgia/Florida border to Fort Pierce, south Florida = Fort Pierce to Key West, Florida Bay = 1 mile north of Islamorada).

	Fishery			
Region	Independent	Commercial	Headboat	Total
North Florida	—	135	144	279
South Florida	—	934	90	1024
Florida Bay	111	—	—	111
Totals	111	1069	234	1414

a tab (1 x 1 inch) of thin cardboard. The tab was then aligned and mounted on a Buehler Isomet, model 11 – 1180, low speed saw equipped with a diamond gritted wafering saw blade. Three serial sections approximately 0.25 mm wide were cut from the otolith: one section containing the core of the otolith and the others immediately adjacent to the core (Figure 2). Sections were permanently mounted to glass microscope slides using Crystalbond^{tm}, and labeled for examination.

Prepared slides were placed on a black background and viewed under a dissecting microscope at 18.8x magnification using reflected light. A video camera and monitor were connected to the microscope to facilitate viewing and analysis. Immersion oil was applied to each slide to increase clarity of otolith sections. Under reflected light, otolith sections have alternating opaque white rings and dark translucent rings. Opaque rings are hypothesized to be annuli (Manooch and Mason, 1984) and each was counted as one year's growth. Using Image Pro software, measurements (mm) were recorded in along a lateral plane on the dorsal lobe of the otolith section from the focus to each ring (annulus) and from the focus to the otolith edge (radius). The distance between the last annulus and the otolith edge (marginal increment) also was recorded to validate the annual periodicity of opaque ring deposition. Data were entered into Excel computer software for analysis (Figure 3).

Sagittal otoliths of juvenile lane snapper (< 203 mm TL) from Florida Bay were analyzed to determine time of first annulus formation and to complement fishery dependent samples for the basic relationships of fish length (TL) and otolith radius (OR), and fish length and fish weight (W). Otoliths were mounted for micro-structural analysis

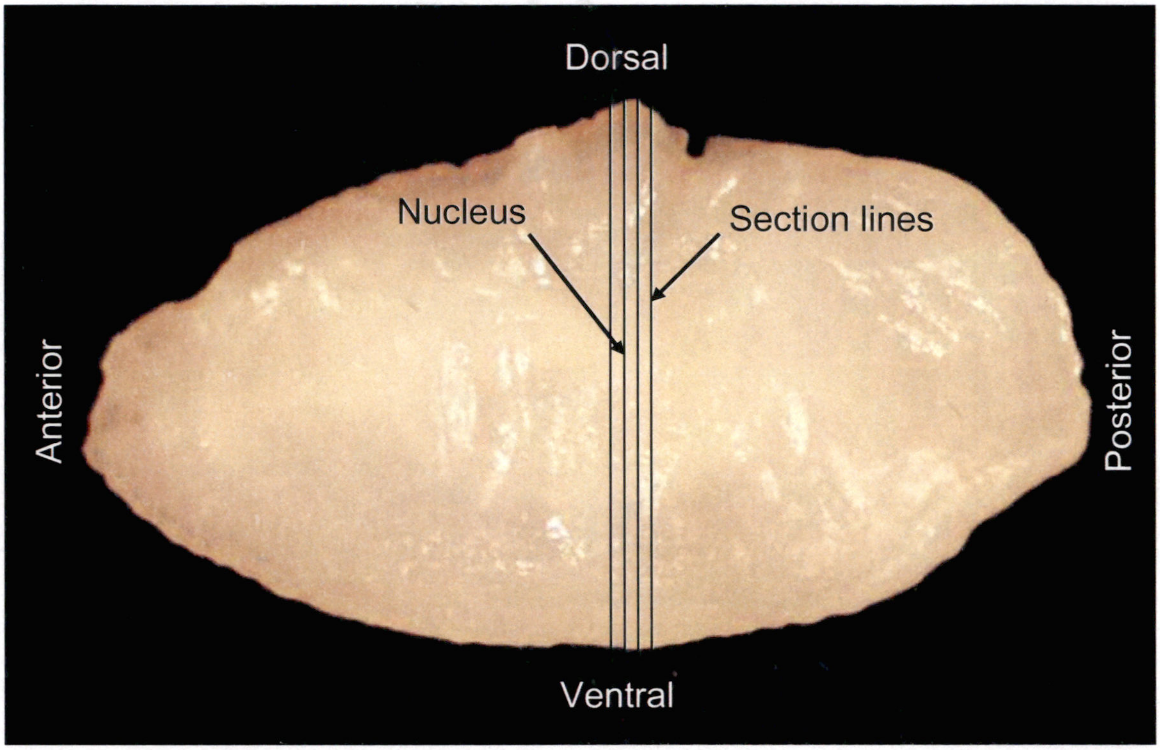


Figure 2. Sagittal otolith and transverse plane for sectioning.

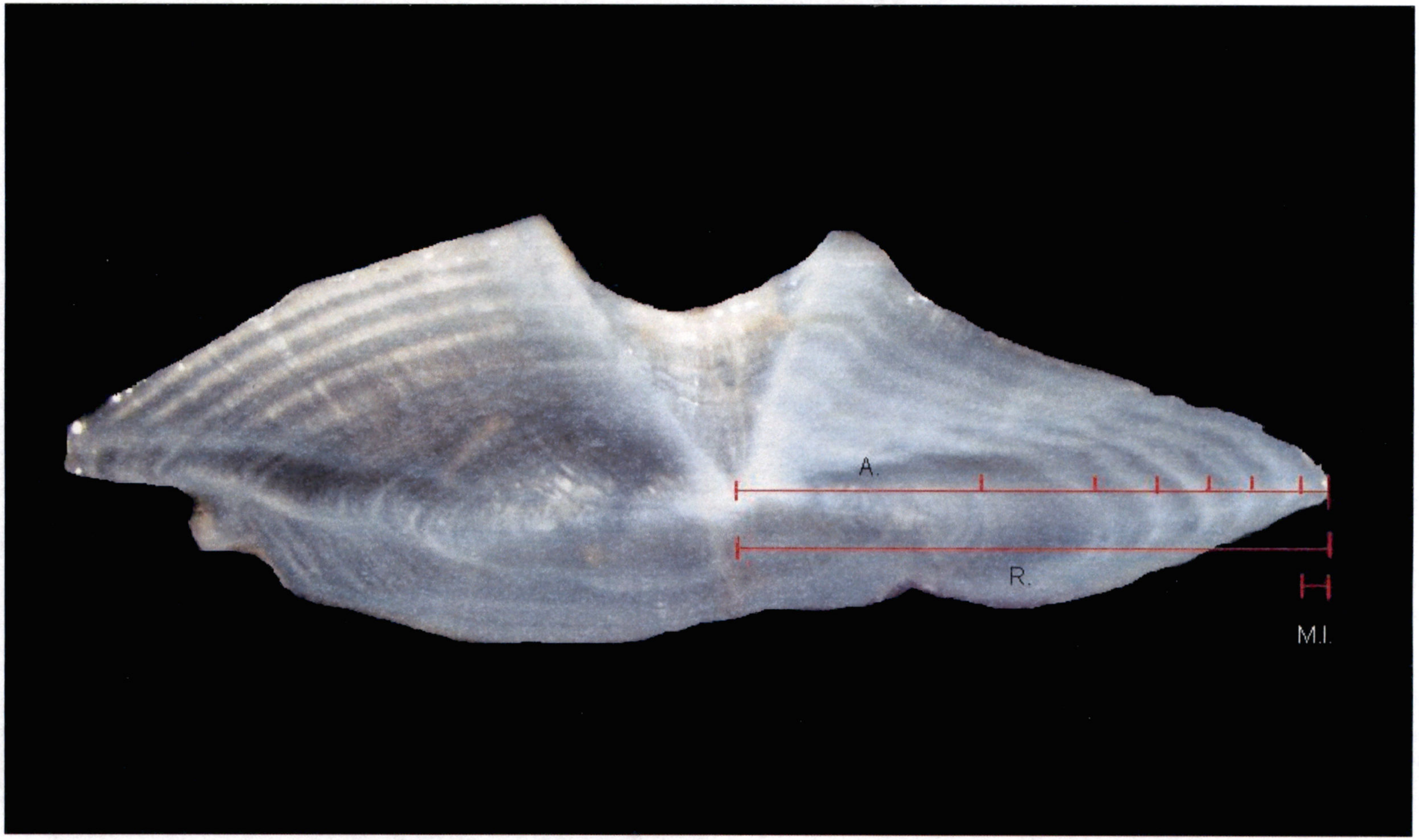


Figure 3. Image Pro photo of sectioned lane snapper otolith and measurements:
A. = Annular measurements; R. = Otolith radius; M.I. = Marginal increment.

using methods described by Secor et al., (1992). Each otolith was embedded in resin, sectioned, and mounted to a glass slide. Each section was then polished until the otolith core was visible and a thin section (10 microns) was achieved. The otoliths were examined at 18.8x magnification using the same microscope and software as used for ototliths removed from larger fish. Measurements were recorded from the focus to the radius and, if present, to the first annulus.

Using fish ages 2, 3, and 4 the month of annulus formation was determined by calculating the mean monthly marginal increment values by age and for all ages combined. These means were plotted against the month of capture, with the minimum values indicating the month and season of annulus formation.

An otolith radius-fish length relationship is used to generate back-calculated size at age for separate and pooled regions. First, I examined the relationship using linear regression:

$$TL = a + b\,(OR),$$

where TL = fish total length (mm),

OR = otolith radius (μ), and

a and b are the intercept and slope of the regression, respectively.

Next, the linearized ln-ln regression:

$$TL = aOR^b,$$

corrected for transformation bias with ½ MSE (Mean Square Error), was analyzed to determine the best fit (Beauchamp and Olson, 1973).

Back-calculated total lengths were derived using the log transformed regression model of the observed total length (TL) on otolith radius (OR) with the body proportionality hypothesis (BPH) method to account for individual fish growth (Francis, 1990). The following equation represents this method:

$$TL_i = ((a + b * S_i)/(a + b * OR))*TL,$$

where TL_i = fish total length at annulus i,

a = intercept from the TL – OR regression,

b = slope from the TL – OR regression,

S_i = measurement to the ith annuli, and

OR = otolith radius.

Back-calculated size at age data were used to test for size selective mortality, otherwise known as Lee's phenomenon. This phenomenon exists when back-calculated lengths at age are smaller for younger ages when using ageing structures from older fish in the sample (Ricker, 1975). This would imply that faster growing individuals are recruiting to a fishery sooner, or that sampling gear is preferentially selecting faster growing fish at a young age. To determine if this trend was present, the distance from the focus to the first and second annuli on age were regressed on observed fish age. If the slope is significantly different from zero, size selective mortality exists. And if the slope is negative, then older fish have smaller distance measurements when young. (e.g., 1-2 years old). The size selective nature of fishing, especially when managing with minimum size limits, causes bias in apparent mean size at younger ages. This larger fraction of young fish, when used in fitting a growth model (e.g., von Bertalanffy), can biased model parameters (Goodyear, 1996). Young-of-year fish from Florida Bay were included in analyses estimating von Bertalanffy (1938) growth equations for north and south Florida to partially overcome this problem.

Mean back-calculated sizes at age were fit to the von Bertalanffy (1938) growth model and theoretical growth parameters and sizes at age were estimated. Size at age was estimated using the following equation:

$$L_t = L_\infty \, (1 - \exp(-K(t - t_0)),$$

where L_t = mm TL at age t,

L_∞ = the theoretical asymptotic length,

K = the growth coefficient, and

t_0 = theoretical age when fish length is equal to 0.

Theoretical lengths at age were derived for back-calculated lengths at age calculated from all annuli measurements as well as from the those using only the last annulus. Vaughan and Burton (1994) recommend using only length at last annulus in von Bertalanffy (1938) fit to avoid violating the assumption of independence among measured lengths. The back-calculated lengths from this study were compared to Manooch and Mason's (1984) study to determine if any significant change has occurred in growth due to fishery management regulations imposed in 1983.

Age–length keys (Ricker, 1975) were developed for north and south Florida by grouping aged fish in 25- mm length intervals for all ages. Additionally, the percentage of fish, by age group, were calculated to compare age frequency distributions by region.

Initially, only samples collected for this study with whole weights reported were analyzed to determine the length–weight relationship (n = 185). Due to this relatively small sample size in this study, an additional analysis was completed to strengthen this relationship by using additional lengths and weights for lane snapper obtained from the headboat survey from 1998 to 2003 for the east coast of Florida (n = 5839). The weight – length relationship was determined by using a linearized (ln–ln) regression. The equation:

$$ln(W) = a + b * \ln(TL)),$$

was transformed to $W = aL^b$, adjusting for the transformation bias with ½ MSE from linearized regression (Beauchamp and Olson, 1973), where W = whole weight in (g) and L = total length (mm).

Various life history approaches for estimating natural mortality (M) were explored. Two methods, Pauly (1980) and Hoenig (1983) are commonly used in stock assessments (Vaughan et.al., 1992; Manooch et. al., 1998; Potts, 2000). Ralston's (1987) equation was developed with data obtained from 19 populations of snapper and grouper stocks. A method by Alverson and Carney (1975) also has been used in stock assessments to estimate M.

I calculated M using the following equation from Pauly (1980):

$$\log_{10}M = 0.0066 - 0.279 \log_{10}L_\infty + 0.6543 \log_{10}K + 0.4634 \log_{10}T,$$

where L_∞ = the asymptotic length,

K = the Brody growth coefficient, and

T = the mean annual seawater temperature (^oC).

Sea surface temperature readings were derived from buoys operated by the NOAA's National Oceanographic Data Center during 2003 (Figure 4). Monthly averages provided mean annual temperatures for north Florida and south Florida.

Hoenig's (1983) method derives M using the following equation:

$$\ln M = 1.46 - 1.01 \ln t_{max},$$

where t_{max} = the maximum age in an unexploited population.

In actual practice this equation is usually *ln* Z, but if the data is from an unexploited population the Z = M. If the population is exploited than Z > M and this estimate would be the upper limit on M.

Ralston's (1987) method derives estimates of M from the equation:

$$M = 0.0189 + 2.06 * K,$$

where K = the Brody growth coefficient.

Alverson and Carney (1975) equation for M is,

$$0.38 * t_{max} = 1/K * \ln(M + 3*K)/M,$$

where t_{max} = maximum age of the fish, and

K = the Brody growth coefficient.

Natural mortality estimates for the present study were compared to Manooch and Mason (1984) using the same method, Pauly (1980), as well as the estimates derived from all the equations.

The estimates for instantaneous rate of total mortality were preliminary values based on the age frequency data from this study and did not include more detailed catch data from all fisheries that land lane snapper. Total mortality (Z) was estimated by regressing the log of the age frequency on age for fully recruited ages. Modal age or age + 1 is used to determine fully recruited ages. The absolute value of the slope of the

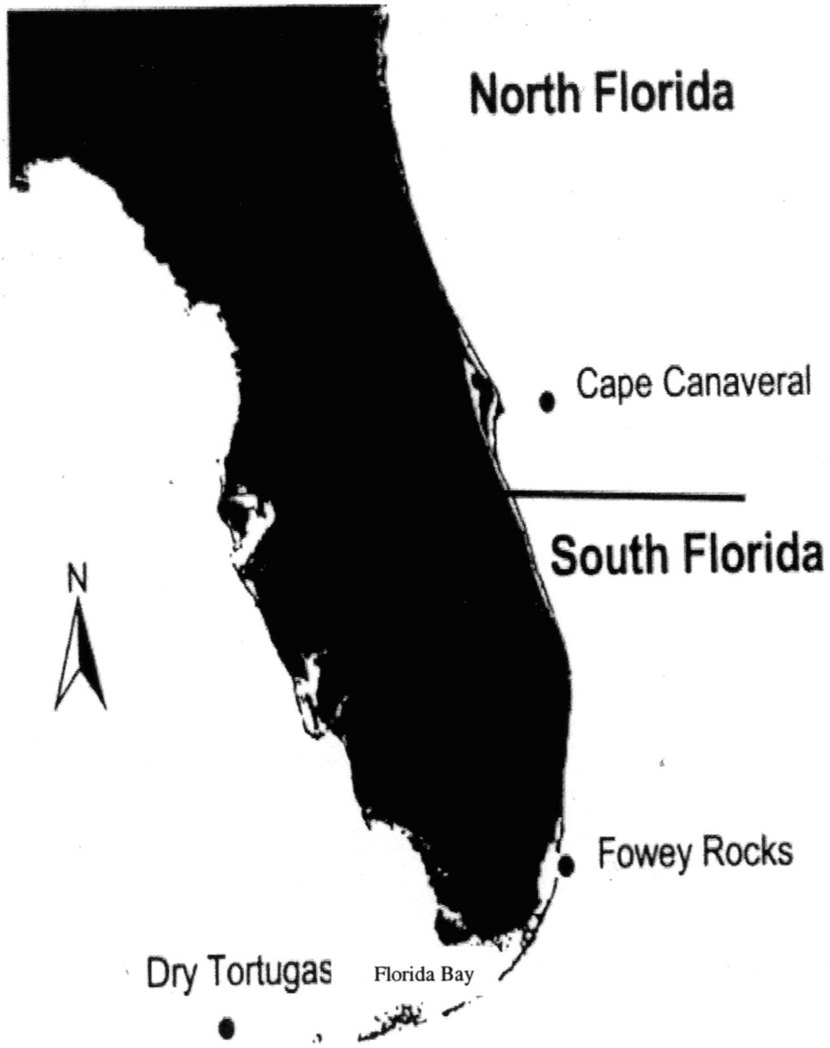


Figure 4. Geographic scope of study by region, with buoy locations(●) for sea surface temperatures for 2003 (Source: Burton, 2001).

descending right limb is Z (Beverton and Holt, 1957). These estimates were compared by region and for all data combined.

RESULTS

General Considerations

Otolith samples collected from the headboat and commercial fisheries from 1990 to 2003 (n = 1604) were processed for age determination and analysis. Earlier years, 1990 to 1997, were inconsistent in sampling effort by area and fishery, so consequently the sample set was reduced to those collected from 1998 to 2003 (n = 1414) (Table 1). Fishery-independent samples collected from Florida Bay were included for age validation of 0-1 year old fish, which otherwise would not have been available with a size limit (8-in TL; 203 mm) imposed on the recreational and commercial fisheries.

Most fish lengths were recorded in total length (TL); fork lengths (FL) were converted to total length using the equation $TL = -2.6252 + 1.0891 FL$, $R = 0.999$ (Manooch and Mason, 1984).

Age Analysis

Lane snapper otolith sections showed a clear concentric pattern of alternating translucent bands and opaque rings, which could be examined and used to age the fish. Young-of-year fish from Florida Bay improved overall understanding of first annulus formation. When present, false annuli occurred primarily between the first and second annuli. Ninety-eight percent (1396 of 1414) of the sectioned otoliths were assigned ages. Fractures and lack of clarity were the reasons for otoltihs not being aged.

Age Validation

Marginal increment analysis of all ages and ages 2 - 4 years old were calculated and plotted for all fisheries and regions combined to determine month of annulus formation (Figure 5). Opaque zones were revealed as annular and formed in late spring, primarily in June. Validation using frequency distribution of measurements from the focus to each annulus showed consistency in the range of modes for ages 1-6 (Figure 6). The overlap of measurements between annuli in this distribution increased with age, while the distance between the rings decreased with the slowing of somatic growth in older fish. This was also reported by Manooch and Mason (1984) and subsequently influenced their decision to exclude 9 and 10 year old fish from further aging procedures because the distances were not discernible. In this study the use of Image Pro software facilitated measuring these distances with confidence, allowing older fish to be included in back calculations.

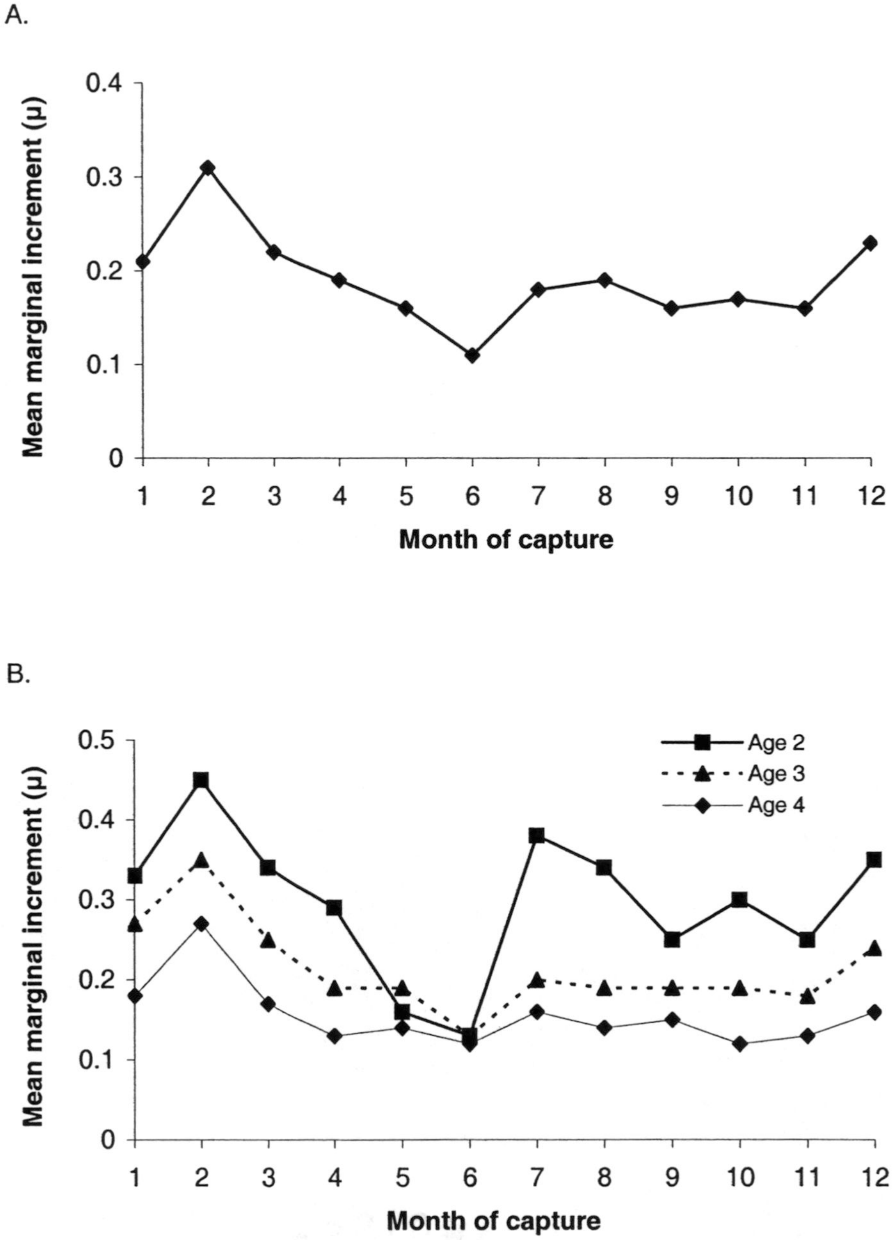
Fish Length – Otolith Radius Relationship

The total length and otolith radius relationship was analyzed using ln-ln transformed linear regression. The data fit this regression better than the linear regression (Figure 7). The resulting equation for all data combined was

$$TL = 71.99 \times OR^{1.12} \ (n = 1396, R^2 = 0.87).$$

Fish length-otolith radius relationships were calculated for each region. Fishery-independent samples (small fish ages 0 -1 year old) were included because regulations excluded lane snapper smaller than eight inches (203 mm TL). Incorporation of these

A.



B.

Figure 5. Marginal increment analysis for lane snapper from the east of Florida. A. All data combined (n = 1353); B. Ages 2-4 (n = 937).

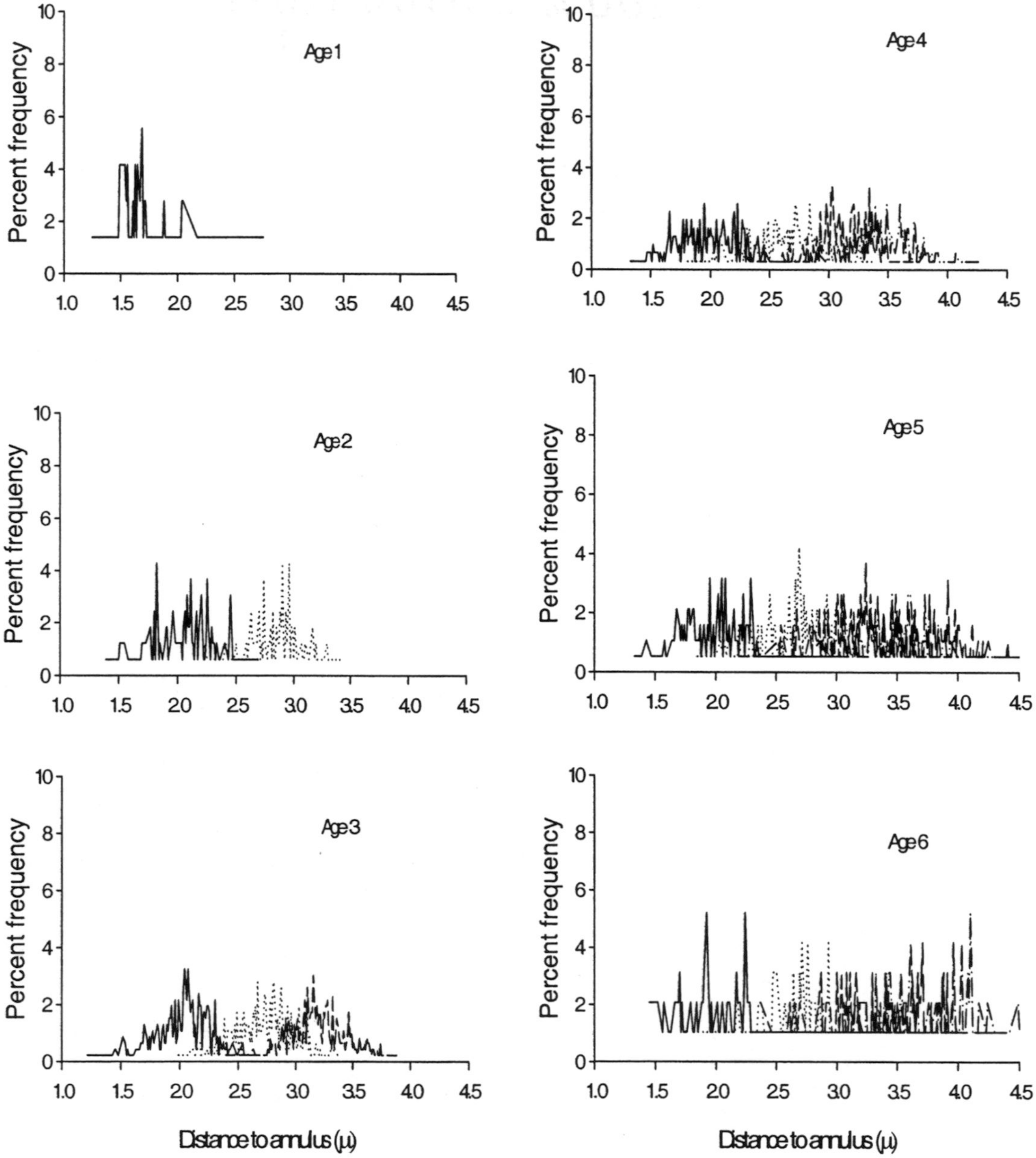


Figure 6. Frequency distribution of measurements from focus to each annulus, ages 1-6, for lane snapper from the east coast of Florida.

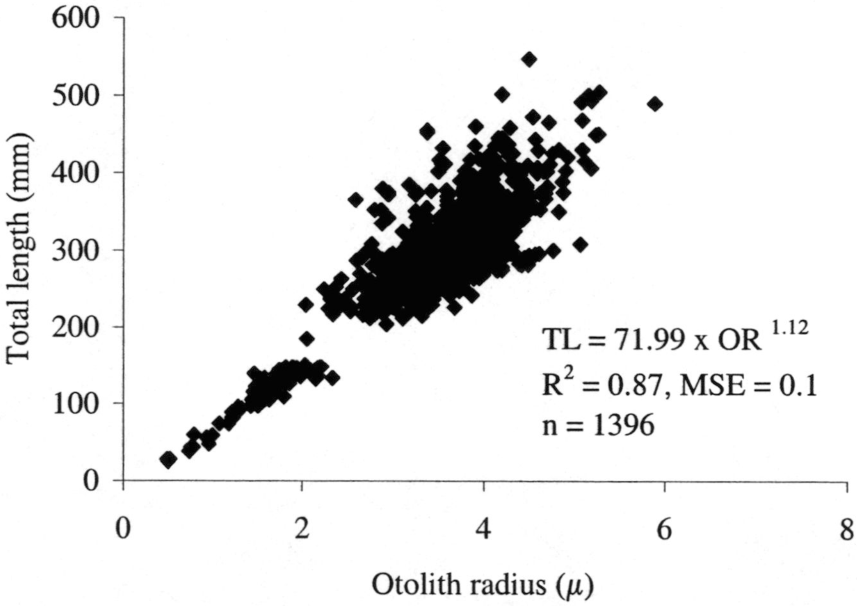


Figure 7. Total length - otolith radius relationship for lane snapper from the east coast of Florida.

small fish improved the fit of the regression:

$$TL = 65.37 \times OR^{1.25} \quad (n = 379,\ R^2 = 0.95) \text{ for north Florida, and}$$

$$TL = 71.81 \times OR^{1.10} \quad (n = 1119,\ R^2 = 0.91) \text{ for south Florida.}$$

Weight – Length Relationship

The relationship between weight and length increased exponentially (Figure 8). The low sample size (n = 185) resulted from most fish being eviscerated at sea. Only 185 of the 1303 fish sampled were landed whole. The equation that best fit these data was

$$W = 3.27 \times 10^{-5}\ TL^{2.847},\ R^2 = 0.98,\ n = 185.$$

This ln – ln transformed regression was corrected for transformation bias with ½ MSE. The relationship is similar to that reported by Manooch and Mason (1984), and was expressed

$$W = 1.02 \times 10^{-5}\ TL^{2.652},\ R^2 = 0.96,\ n = 101.$$

To strengthen the length – weight relationship when comparing regions, an increased sample size was used by pooling all lane snapper samples with recorded weights and corresponding lengths from the headboat survey on the east coast of Florida from 1998-2003 (n = 5837). The length – weight regression was tested statistically using ANCOVA and showed a significant difference in the intercept (t = 2.09, p = 0.0365), whereas the slope (t = -1.63, p = 0.1031) was not significantly different between north Florida and south Florida. Both regions increased exponentially with the north being slightly heavier at length then the south region (Figure 9). These relationships were described by the following equations:

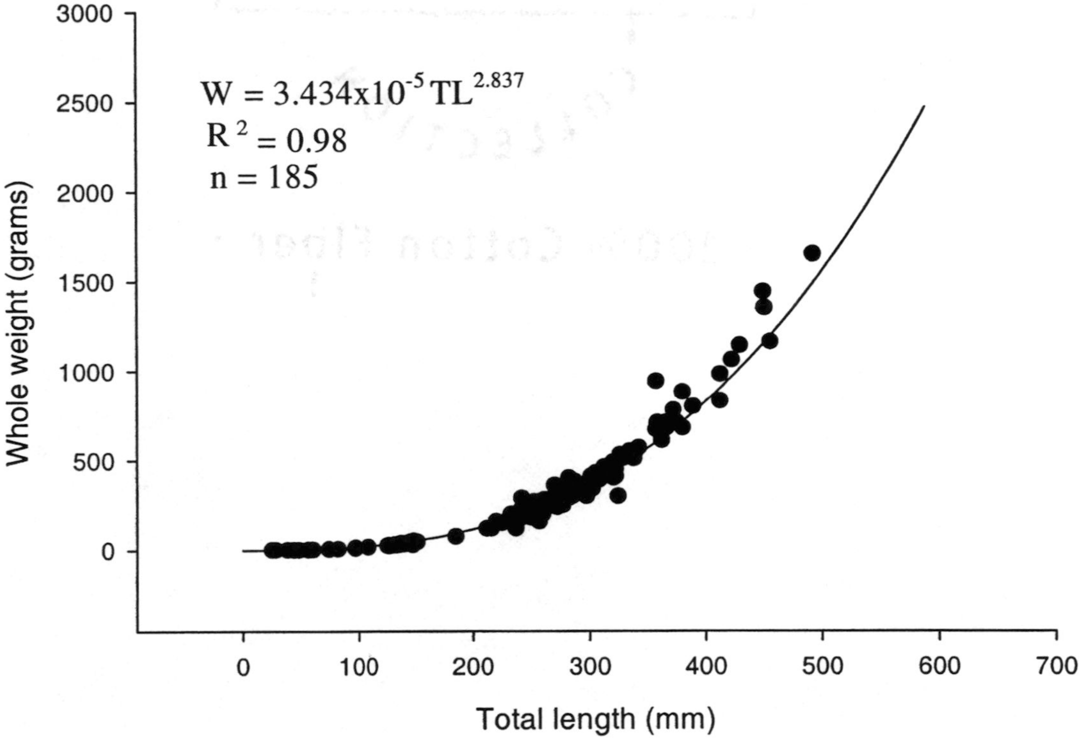


Figure 8. Weight – length relationship for lane snapper from the east coast of Florida (present study).

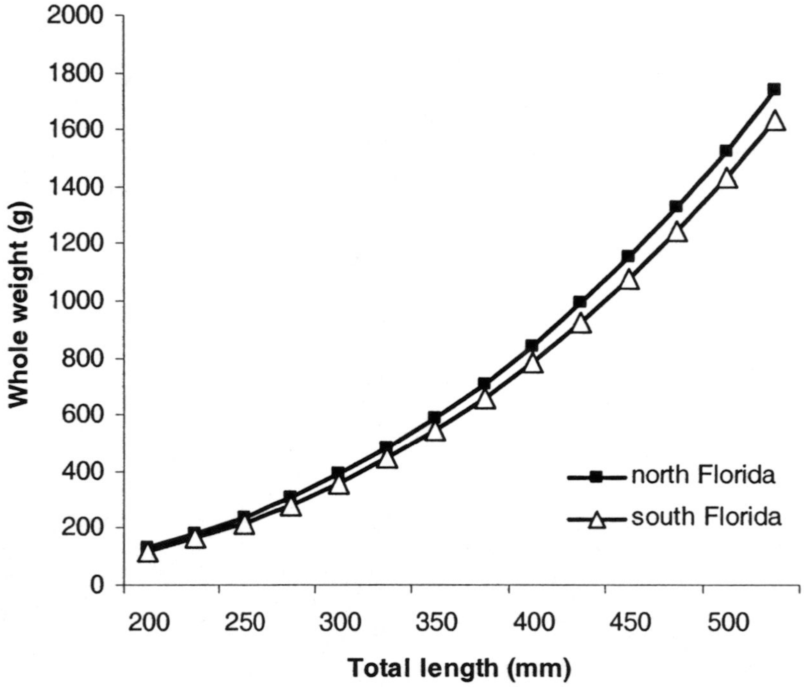


Figure 9. Total length – weight relationship for lane snapper, east coast of Florida (1998 – 2003), by region.

$W = 9.50 \times 10^{-5}\ TL^{2.670}$ ($R^2 = 0.93$, n = 2939) for north Florida,

$W = 6.94 \times 10^{-5}\ TL^{2.714}$ ($R^2 = 0.81$, n = 2898) for south Florida, and

$W = 6.79 \times 10^{-5}\ TL^{2.724}$ ($R^2 = 0.89$, n = 5837) for data combined.

Growth

Both oldest and largest fish were caught by the commercial fishery. The oldest fish, a 12 year old female (406 mm TL), was caught in south Florida; while 10 years was the oldest age recorded from north Florida. The largest fish captured was a 8 year old female measuring 547 mm TL landed in north Florida. Observed mean total lengths showed wide ranges in lengths at age for all ages (Table 2), a phenomenon also reported by Manooch and Mason (1984) (Table 3). The protracted spawning season for lane snapper, March to September (Luiz Barbieri, personal communication, Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida) may contribute to the range in lengths related to each year class. When comparing size at age of my study to the Manooch and Mason (1984) study from 20 years ago, the present study showed larger mean lengths at age for 2-7 year old fish and similar lengths in both studies for ages 8-10 (Figure 10). Ages 0 and 1 were constrained by sample size in the earlier study due to the absence of young-of-year fish (fishery-independent samples).

Comparing regions revealed overall total length (TL) at age was greater for north Florida than for south Florida (Figure 11). This difference was tested statistically using ANOVA ($F = 399.37$; $P < .0001$) resulting in a highly significant difference between regions. Ages 2-3 showed only a slight difference in mean length 255 and 292 mm for

Table 2. Mean observed total length (mm) of lane snapper at age from the east coast of Florida by regions.

	north Florida				south Florida				All Areas Combined			
Age	n	Mean TL (mm)	S.E.	Range	n	Mean TL (mm)	S.E.	Range	n	Mean TL (mm)	S.E.	Range
0					42	89	35	25-135	42	89	35	25-135
1					9	237	14	217-263	73	151	41	97-263
2	9	255	20	216-295	154	253	20	204-329	163	253	20	204-329
3	51	292	37	233-394	412	281	27	212-372	463	282	28	212-394
4	82	335	33	261-417	229	290	30	226-422	311	302	37	226-422
5	80	355	40	266-472	109	312	37	248-425	189	330	44	248-472
6	31	381	45	295-460	65	322	47	242-429	96	341	53	242-460
7	11	420	59	333-501	21	314	55	242-492	32	350	75	242-501
8	8	422	70	338-547	7	321	31	282-363	15	375	75	282-547
9	3	479	42	430-505	4	315	31	280-350	7	385	94	280-505
10	2	459	13	450-468	2	386	41	357-415	4	423	49	357-468
11												
12					1	406		406-406	1	406		406-406
Total	277				1055				1396			

Table 3. Observed total length (mm) of lane snapper aged by sectioned otolihs for Manooch and Mason (1984) from southeast Florida (regions and fisheries combined).

	Age	Number	Total length (mm) Mean length	Standard deviation	Range
	0	1	168.0	—	—
	1	2	193.5	6.4	189-198
	2	29	219.4	12.0	195-250
	3	33	243.2	21.3	208-309
	4	69	273.7	32.7	205-357
	5	69	296.1	40.9	237-397
	6	57	305.1	50.7	242-416
	7	35	345.7	57.2	286-457
	8	18	375.8	63.7	283-495
	9	5	428.0	55.7	335-474
	10	2	461.0	72.1	410-512
Total		320			

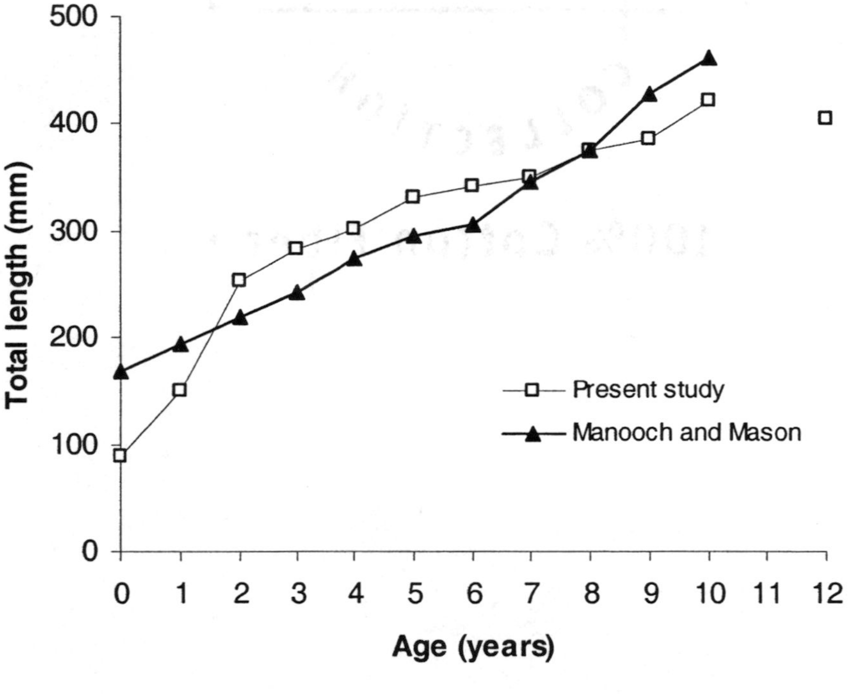


Figure 10. Mean observed total length (mm) at age, present study vs. Manooch and Mason (1984).

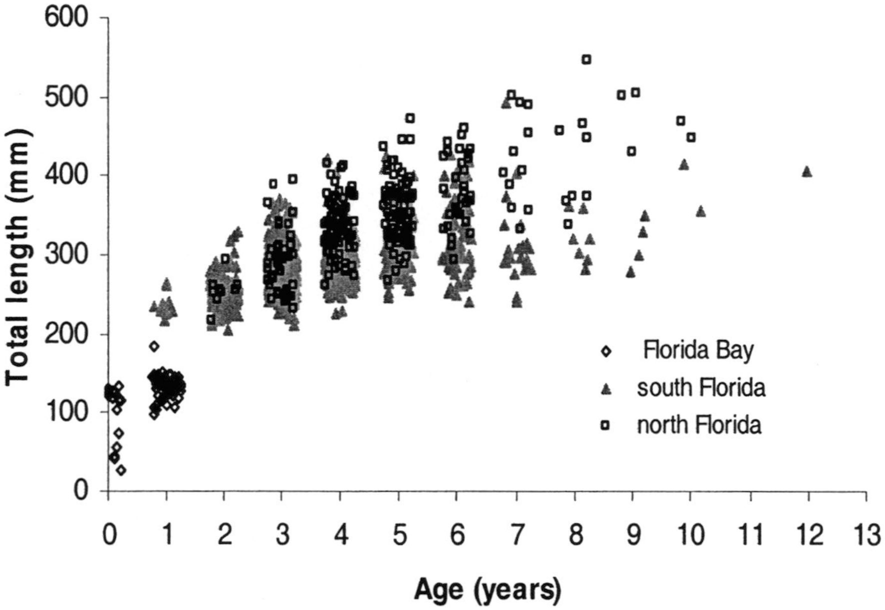


Figure 11. Total length at age for lane snapper, by region, north and south Florida (present study).

the north, 253 and 281 mm for the south, respectively. Ages 3-10 diverged, with north Florida showing a significantly larger size at age for this range (Figure 12).

Observed size at age for lane snapper was also compared by fisheries to determine if differences were present between fishery-independent, headboat and commercial growth characteristics (Figure 13). The overlap for all ages suggests very little difference occurs, and for this reason subsequent analyses combined data across fisheries.

Mean back-calculated sizes at age for the present study and for Manooch and Mason (1984) are shown in Table 4. Because Manooch and Mason's (1984) results were uncorrected for BPH (body proportional hypothesis), the method described by Francis (1990), back-calculated means from the present study were also calculated without BPH adjustment for this comparison only (Figure 14). Overall, the data and plots are similar with only a slight difference in size at age.

The preferred back-calculated lengths at age were derived from the method described by Francis (1990) for the body proportional hypothesis (BPH). This method uses the regression of the length on age, and accounts for variation among individual fish from the value predicted by the regression, by assuming constant proportionality between observed and predicted back-calculated length. Florida Bay data were combined with north Florida and south Florida separately as was the case with the regression model for TL on OR. Mean back-calculated sizes at age for both regions were consistent with other Growth characteristics examined in this study. The mean back-calculated lengths at age for north Florida was greater for ages 3-10 (Table 5), while ages 1-2 were slightly higher for south Florida (Table 6). This noticeable separation can be clearly seen in Figure 15.

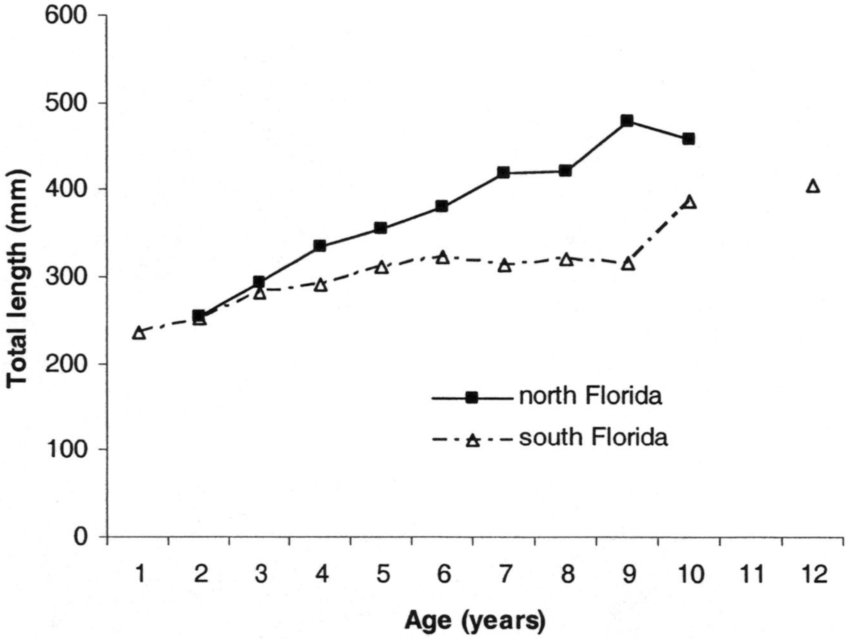


Figure 12. Mean observed total length (mm) at age by region, east coast of Florida (present study).

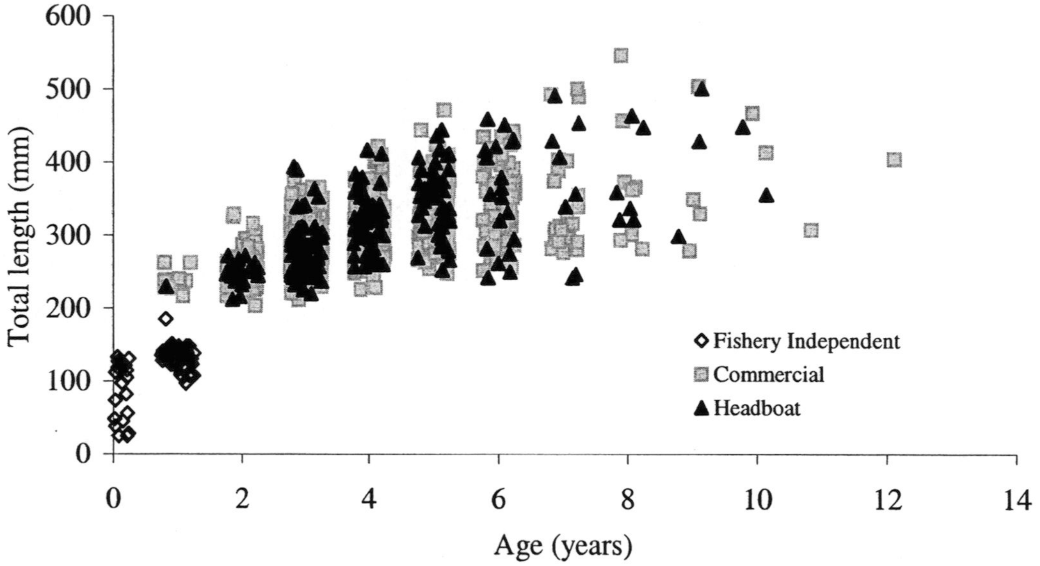


Figure 13. Total length (mm) at age of lane snapper by fishery from the east coast of of Florida, all data combined (present study).

Table 4. Back-calculated total lengths (mm) of lane snapper aged by sectioned otoliths.

A. Back-calculated total lengths (mm) of lane snapper aged by sectioned otoliths, no BPH used - Florida all data combined (present study).

		Mean back-calculated total length at time of annulus formation											
Observed age	N	1	2	3	4	5	6	7	8	9	10	11	12
1	72	135											
2	163	162	229										
3	462	159	221	264									
4	310	155	214	257	288								
5	189	155	211	254	288	315							
6	96	156	209	250	283	310	333						
7	32	170	224	261	289	314	337	357					
8	15	156	212	251	280	303	326	350	371				
9	7	149	208	243	271	295	317	338	359	382			
10	4	146	202	245	276	302	326	350	371	392	412		
11	—												
12	1	150	227	252	282	303	322	347	365	392	410	424	444
Number of calculations		1352	1280	1117	655	345	156	60	28	13	6	2	1
Weighted means		157	218	259	287	313	332	352	368	387	411	426	444
Increment		157	61	41	28	26	19	20	16	19	24	15	18

B. Back-calculated total lengths (mm) of lane snapper aged by sectioned otoliths, no BPH used - Manooch and Mason (1984).

		Mean back-calculated total length at time of annulus formation									
Observed age	N	1	2	3	4	5	6	7	8	9	10
1	2	160									
2	27	148	205								
3	26	139	201	235							
4	54	133	196	237	264						
5	57	132	192	231	259	283					
6	43	132	193	228	257	282	302				
7	26	131	192	230	261	289	312	331			
8	16	134	197	235	266	286	318	340	359		
9	4	129	196	233	264	294	325	356	385	412	
10	3	127	189	232	267	302	335	363	389	409	426
Number of calculations		258	256	229	203	149	92	49	23	7	3
Weighted means		135	196	233	261	285	310	338	367	411	426
Increment		135	61	37	28	24	25	28	30	43	15

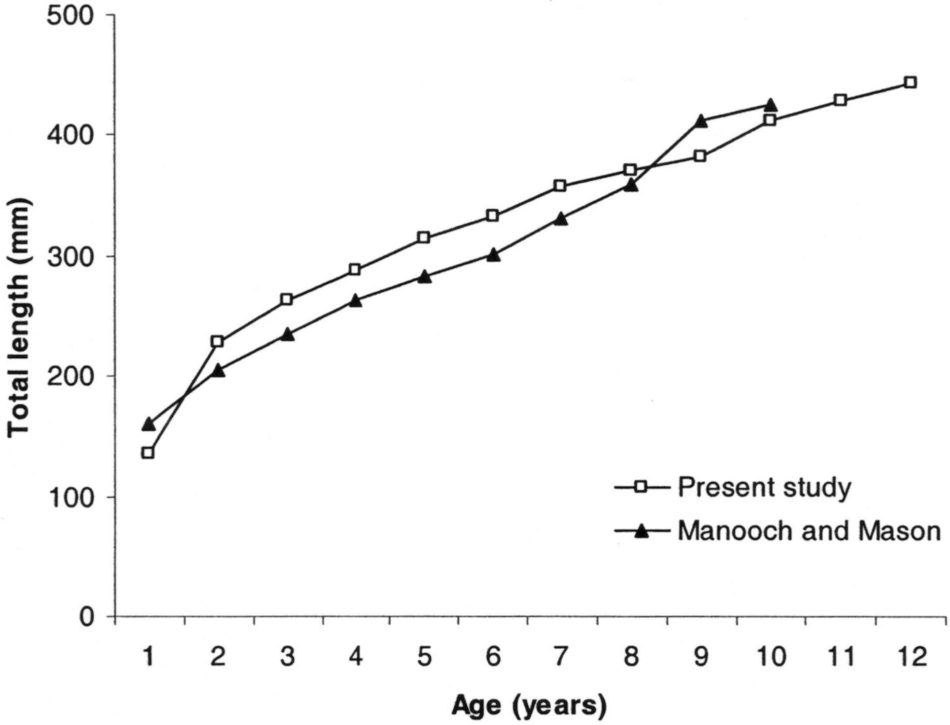


Figure 14. Back-calculated (to last annulus) total lengths (mm) of lane snapper, this study vs. Manooch and Mason (1984), not adjusted for BPH.

Table 5. Back-calculated total lengths (mm) of lane snapper aged by sectioned otoliths adjusted for BPH - north Florida.

		Mean back - calculated total length at time of annulus formation									
Observed Age	N	1	2	3	4	5	6	7	8	9	10
1	—	—									
2	9	153	225								
3	51	157	222	270							
4	82	155	220	274	316						
5	80	148	204	256	302	338					
6	31	149	205	253	297	336	365				
7	11	159	216	265	301	339	373	402			
8	8	149	202	245	281	312	344	379	408		
9	3	146	205	248	285	318	355	389	426	461	
10	2	127	190	234	272	301	325	353	379	409	437
Number of calculations		277	277	268	217	135	55	24	13	5	2
Weighted means		152	213	264	305	335	361	389	408	440	437
Increment		152	61	51	41	30	26	28	19	32	-3

Table 6. Back-calculated total lengths (mm) of lane snapper aged by sectioned otoliths adjusted for BPH - south Florida.

		Mean back - calculated total length at time of annulus formation											
Observed Age	N	1	2	3	4	5	6	7	8	9	10	11	12
1	72	131											
2	154	161	227										
3	411	159	220	262									
4	228	152	209	250	277								
5	109	153	209	248	277	300							
6	65	150	201	239	268	292	313						
7	21	154	202	233	255	274	292	307					
8	7	141	197	232	254	270	285	300	315				
9	4	128	181	210	233	251	264	278	291	306			
10	2	146	194	238	263	286	310	331	349	364	378		
11													
12	1	137	205	228	254	272	289	312	328	351	367	379	397
Number of calculations		1074	1002	848	437	209	100	35	14	7	3	1	1
Weighted means		154	216	254	274	293	304	304	314	329	374	379	397
Increment		154	62	38	20	19	11	0	10	15	45	5	18

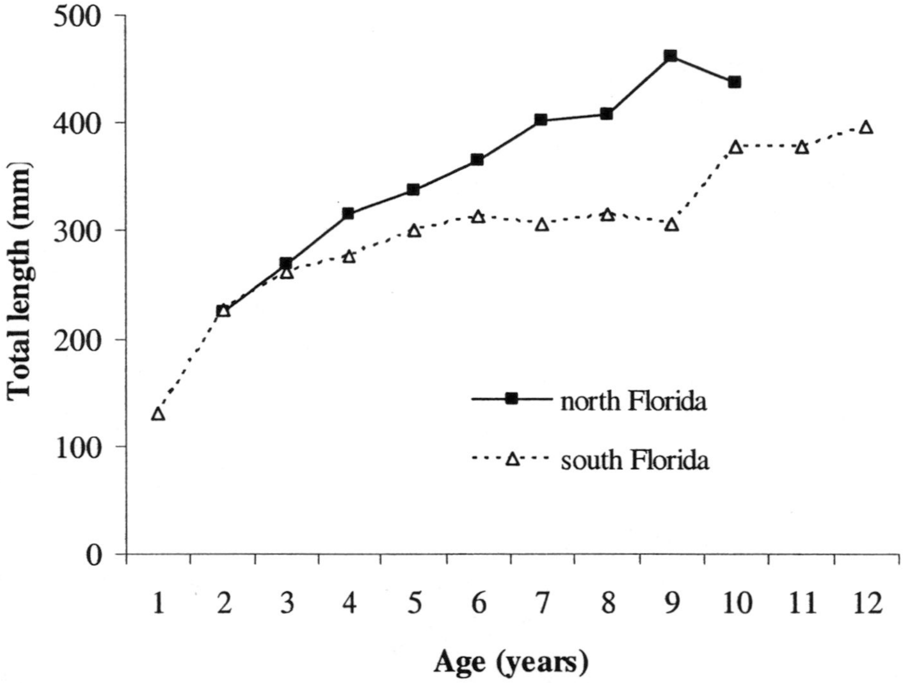


Figure 15. Mean back-calculated size at age for lane snapper, by region present study corrected for body proportional hypothesis (BPH).

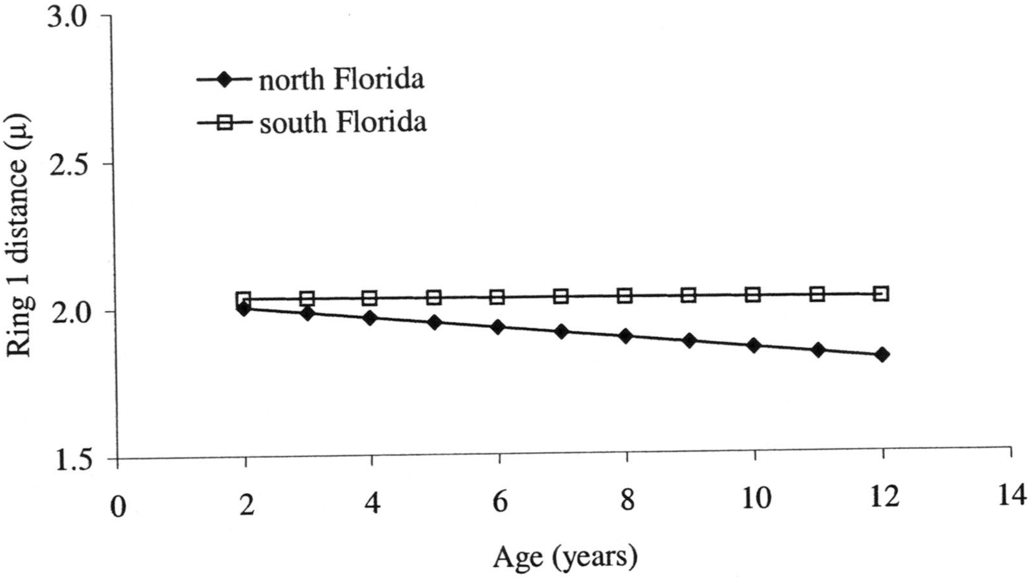
Lee's Phenomenon

Smaller size at a given age for fish captured at an older age was found, suggesting size-selective mortality was present in both north Florida and south Florida. Linear regression of the measurements from the focus to the first annulus (A1), and to the second annulus (A2) was used to test if the slope was significantly different from zero (Figure 16). In north Florida for A1, the difference was only slightly significant ($n = 276$, $p = 0.0977$) and insignificant for south Florida ($n = 1014$, $p = 0.8663$). Comparing regions by the same method for A2 resulted in a highly significant difference in the slope of the regression for both regions. North Florida at the $p<0.1$ level was $p = 0.0010$, while for south Florida at the same level of significance it was $p = 0.0015$. The slope of the regression where it was significantly different was negative; i.e., decreasing size at ages 1or 2 with increasing age of fish.

Von Bertalanffy Growth Parameters

Theoretical growth parameters were compared for the present study to Manooch and Mason (1984) and by regions in Florida. Both comparisons used the von Bertalanffy (1938) growth equation, however when comparing studies, the back-calculated lengths at age of Manooch and Mason (1984) did not adjust for BPH (Francis, 1990). Therefore, data from the present study used back-calculated lengths without the BPH correction and all measurements to annuli strictly or the purpose of comparison with Manooch and Mason (1984) and should not be used in future analyses. The results showed theoretical growth is greater from years 1-9 for the present study and similar in older fish (Figure17).

A.



B.

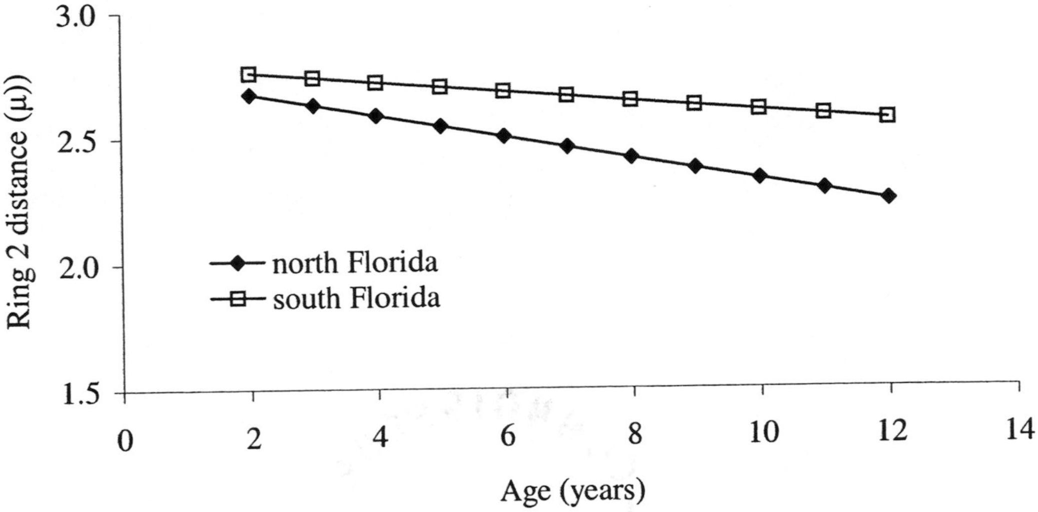


Figure 16. Lee's phenomenon comparison between regions, north Florida and south Florida. A. Age 1 ring mesurements. B. Age 2 ring measurements.

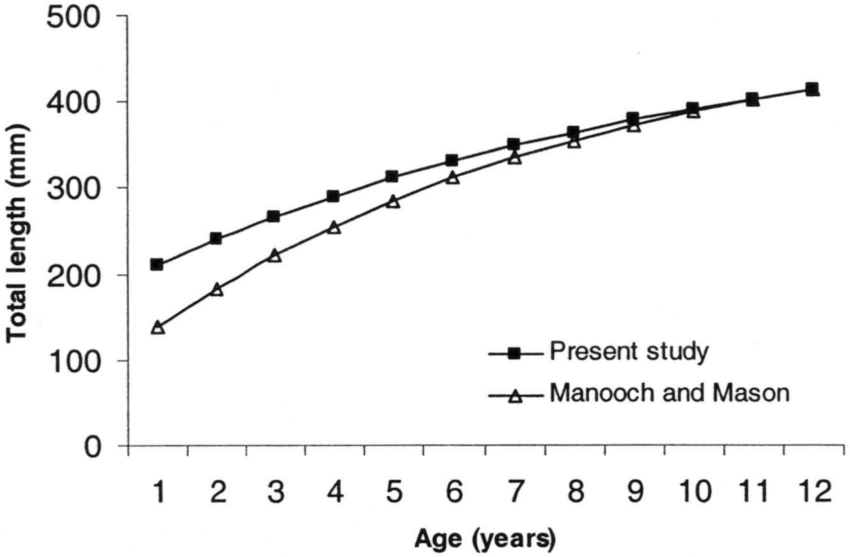


Figure 17. Theoretical growth of lane snapper, this study vs. Manooch and Mason (1984).

The following von Bertalanffy (1938) growth equations were obtained:

$L_t = 501\ (1\text{-}e^{-0.13\ (t + 1.49)})$ Manooch and Mason (1984), and

$L_t = 516\ (1\text{-}e^{-0.10\ (t + 4.25)})$ Present study (without BPH correction).

Because evidence of size-selective mortality for both regions was observed, only back-calculations to the most recent annuli (Vaughan and Burton, 1994) were used for estimating growth parameters of the von Bertalanffy (1938) growth equation. Results from the analysis between regions showed a significant difference (Figure 18). The von Bertalanffy (1938) growth equations using the corrected back-calculated lengths at age to the last annulus were

$L_t = 381.4\ (1\text{-}e^{-0.34\ (t + 0.36)})$ for all data combined;

$L_t = 443.9\ (1\text{-}e^{-0.30\ (t + 0.82)})$ for north Florida, and

$L_t = 311.4\ (1\text{-}e^{-0.63\ (t + 0.61)})$ for south Florida.

These equations represent my best estimates of the theoretical growth curves for east coast lane snapper. Significant difference was determined comparing the 95% confidence intervals for north vs. south. North Florida had a range of 415 - 472 for $L_{\square}$ for the 95% confidence interval, while south Florida had a range of 306 – 317 for $L_{\square}$. Since the confidence intervals are disjoint (do not overlap), these theoretical growth curves can be considered significantly different.

Age – Length Key

Age – length keys were developed by grouping aged fish by total length in 25-mm length intervals by age class, for north and south Florida. The percentage of fish by age group was calculated for each length interval (Table 7). Age- length keys can be

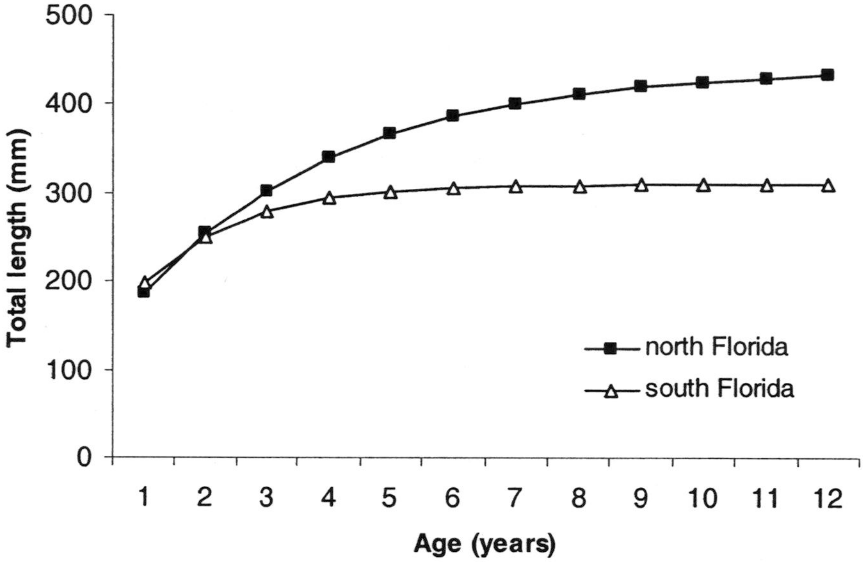


Figure 18. Theoretical growth of lane snapper for the east coast of Florida, by region (present study).

Table 7. Age - length key for lane snapper from south Florida (A.) and north Florida (B.). Total fish by age class (percent).

	Age Yyears)											
	1	2	3	4	5	6	7	8	9	10	11	12
TL (mm)												
A.												
200	1 (6.7)	11 (73.3)	3 (20.0)									
225	9 (8.9)	54 (53.5)	30 (29.7)	4 (4.0)	1 (1.0)	1 (1.0)	2 (2.0)					
250	2 (0.6)	78 (24.4)	148 (46.3)	75 (23.4)	11 (3.4)	6 (1.9)						
275		8 (2.5)	148 (47.1)	88 (28.0)	40 (12.7)	18 (5.7)	9 (2.9)	2 (0.6)	1 (0.3)			
300		2 (1.4)	55 (39.6)	35 (25.2)	23 (16.5)	14 (10.1)	5 (3.6)	3 (2.2)	1 (0.7)		1 (0.7)	
325		2 (3.2)	18 (29.0)	16 (25.8)	16 (25.8)	7 (11.3)	2 (3.2)		1 (1.6)			
350			10 (24.4)	7 17.1)	10 (24.4)	10 (24.4)		2 (4.9)	1 (2.4)	1 (2.4)		
375				2 (20.0)	5 (50.0)	2 (20.0)	1 (10.0)					
400				2 (15.4)	2 (15.4)	6 (46.2)	1 (7.7)			1 (7.7)		1 (7.7)
425					1 (50.0)	1 (50.0)						
450												
475							1 (100)					
500												
B.												
200		1 (100)										
225		1 (10.0)	9 (90.0)									
250		6 (31.6)	9 (47.4)	3 (15.8)	1 (5.3)							
275		1 (3.1)	17 (53.1)	9 (28.1)	4 (12.5)	1 (3.1)						
300			8 (17.4)	22 (47.8)	14 (30.4)	2 (4.3)						
325			4 (7.0)	26 (45.6)	21 (36.8)	4 (7.0)	1 (1.8)	1 (1.8)				
350			2 (4.9)	10 (24.4)	15 (36.6)	9 (22.0)	2 (4.9)	3 (7.3)				
375			2 (6.9)	8 (27.6)	14 (48.3)	4 (13.8)	1 (3.4)					
400				4 (25.0)	7 (43.8)	3 (18.8)	2 (12.5)					
425					3 (25.0)	6 (50.0)	1 (8.3)	1 (8.3)	1 (8.3)			
450					1 12.5)	2 (25.0)	1 (12.5)	2 (25.0)		2 (25.0)		
475							2 (100)					
500							1 (33.3)		2 (66.7)			
525												
550								1 (100)				

used to develop catch at age matrices derived from length frequency data, assuming age samples were randomly sampled from fisheries. Age frequencies distributions from north and south Florida were compared to determine when lane snapper recruit to the fishery (Figure 19). Fish in south Florida were caught primarily at age 3 years old, while in north Florida the trend shows the majority of fish are 4-5 years old.

Mortality

Natural mortality (M) was estimated and compared by region using various equations (Table 8). The method used by Pauly (1980), which includes L_∞ and K, along with mean annual seawater temperature, estimated M at 0.71 for north Florida and 0.69 for south Florida. Hoenig's (1983) equation, which derives M using maximum age (t_{max}), yielded estimates of 0.42 and 0.35 for north and south Florida respectively. Ralston's (1987) method used K (Brody growth coefficient), and estimated M at 0.62 for north Florida and 1.32 for south Florida. Finally, M was estimated using the method of Alverson and Carney (1975), which uses K and the maximum age of the fish. The estimates of M for this equation were 0.42 and 0.11 for north and south Florida, respectively.

My estimate of M = 0.63, based on all data combined, was higher then Manooch and Mason's (1984) estimate of M = 0.40, using the same method by Pauly (1980). Estimates calculated from the equation by Hoenig (1983) compared more closely to the previous study.

Estimates of total mortality (Z) were obtained by regressing the natural log of the

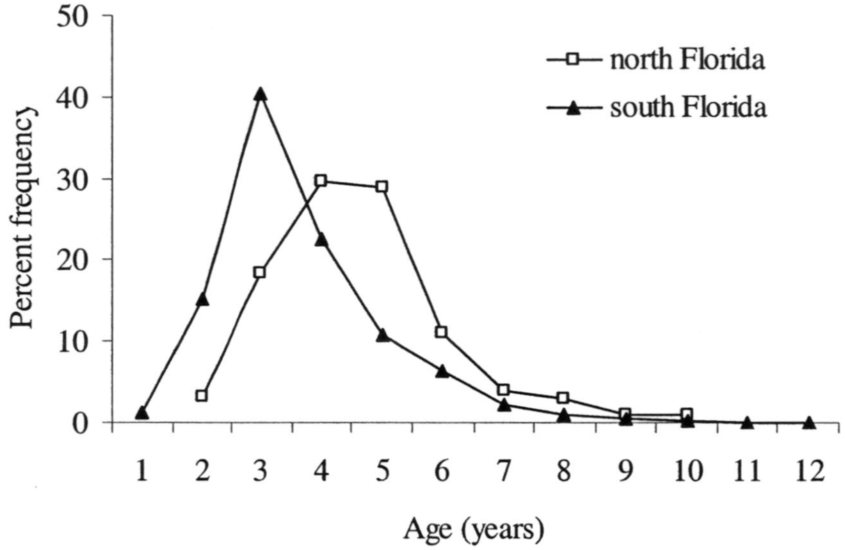


Figure 19. Age frequency distribution of lane snapper for the east coast of Florida, by region (present study).

Table 8. Estimates of natural mortality (M) for lane snapper from the east coast of Florida, by region.

Method	North Florida	South Florida	Variables
Pauly (1980)	0.71	0.69	$L\infty$, K, Mean seawater temperature
Hoenig (1983)	0.42	0.35	Max age
Ralston (1987)	0.62	1.32	K
Alverson and Carney (1975)	0.42	0.11	K and Max age

age frequency on age for fully-recruited fish from north and south Florida separately, and all data combined. Lane snapper are fully recruited to the fishery at age 5 for north Florida and age 4 for south Florida based on the age-length keys for each region. Estimates for north Florida were lower (Z = 4.42) than south Florida (Z = 5.47); and the estimate for all data combined was slightly higher than south Florida (Z = 5.65). These estimates are preliminary results using the data in this study and do not include the various components of a more comprehensive estimate for total mortality.

DISCUSSION

Lane snapper otoliths exhibit opaque zones which I have validated as annuli on sagittal otolith sections. Annuli are deposited in late spring, primarily in June, when otolith growth is slowest and the mean marginal increment distance is minimal. This is in agreement with recent findings for lane snapper from southeast Florida (Acosta, personal communication, Florida Fish and Wildlife Conservation Commission, Marathon, Florida). For comparison, Gray snapper, *Lutjanus griseus,* from the same geographic range, lay down an annular mark during the same time of year (Burton, 2001). Biological and environmental factors such as temperature, food availability, maturity and other causes may affect time of annulus formation. These factors may also create checks or false annuli, adding uncertainty in age determination. Nevertheless, sectioned otoliths remain the preferred structure for assigning ages to many species of fish.

Beamish and McFarlane (1983) strongly recommend validation for all ages in any age determination study. Young-of-year (0-1) are not readily available for most age and growth studies where samples are obtained from fisheries, making validation of the first annuli very difficult. However, my study validated first annulus formation using fishery-independent samples from Florida Bay (n = 111). Marked-recapture and rearing juveniles are methods that can also accomplish validation of the first annuli. Mark-recapture methods have associated problems from handling that may affect growth and survival. Validation using controlled rearing has been attempted most recently on red porgy *Pagrus pagrus*, and black sea bass *Centropristis striata* (James Morris, personal communication, National Marine Fisheries Service, Beaufort, North Carolina). Although this method has merit, the growth rate of most fish under confined conditions is difficult to relate to the natural population (Manooch, 1987).

The relationship between weight and length was consistent with other studies that showed weight increased exponentially with increased length (Grimes 1978; and Garcia et al., 2003). Comparing the weight –length relationship by regions showed a similar increase based on a large sample size for Florida's east coast. Lane snapper from north Florida were found to be slightly heavier, which may be related to genetics, metabolic rate, primary food production, water temperature, or other environmental differences.

Mean observed and back-calculated sizes at age for 2-7 year old lane snapper were somewhat larger for my study compared to findings from 20 years ago (Manooch and Mason 1984). Mean back-calculated lengths from Manooch and Mason (1984) for ages 1-5 were 135, 196, 233, 261, and 285 mm TL, respectively, were smaller than my study for the same ages 157, 218, 259, 287, and 313 mm TL. Parameter estimates of K and L_∞ from the two studies using the same method were similar. My study had a slightly greater theoretical asymptotic length ($L_\infty = 516$) than Manooch and Mason (1984), $L_\infty = 501$, and the Brody growth coefficient (K) was somewhat lower for my study, $K = 0.10$, in relation to Manooch and Mason (1984) who reported $K = 0.13$. Collectively the results of this comparison based on the same geographic area and ageing method would suggest that size and bag limits implemented in 1983 may have had the desired effect for the east coast of Florida. These regulations are intended to increase yields and allow smaller fish the opportunity to attain larger size at age over their life span. Bag limits may have had a positive effect as well with under size fish being released, and thus theoretically able to contribute to the stock over time.

Conversely, separating Florida into two regions led to the observation that management success was not as apparent as when the entire east coast of Florida was examined. Differences by region were significant for size at age, and other growth characteristics, such as L_∞ and K. Noteworthy is that this study is the first to report these latitudinal differences for lane snapper. It is similar to other studies, however, in that fish from north Florida are typically larger than are those from south Florida (Manooch and Matheson, 1981; Burton, 2001; Potts and Manooch, 2001).

Back-calculated lengths at age were greater for north Florida using constant proportionality of observed fish length to predicted fish length (BPH). I choose to use the body proportional hypothesis (BPH) method which is more widely used rather then the scale (otolith) proportional hypothesis (SPH), also described by Francis (1990). The SPH method assumes constant proportionality of otolith radius (OR) to predicted OR (Francis, 1990) for back-calculations.

The lack of older fish from both regions may have influenced these findings, most notable, theoretical growth. The K (Brody growth coefficient) values for north and south Florida are 0.30 and 0.63, respectively. The south Florida K value is higher then previously reported for lane snapper, with published ranges of K from 0.126 – 0.530 (Claro and Reshetnikov, 1981; Manooch and Mason, 1984; Manickchand-Dass, 1987; Acosta and Appeldoorn, 1992; Claro et. al., 2001). The differences in values are attributed to the method used to derive the von Bertalanffy equation, this is evident when comparing values from the Manooch and Mason (1984) study to the present study. The von Bertalanffy equation resulted in K values considerably lower, 0.13 for Manooch and Mason (1984) and 0.10 for the present study. In general, growth estimates for other lutjanids show high variability throughout the south Atlantic, Gulf of Mexico, and Caribbean with published ranges for K of 0.078 – 0.70 (Pauly, 1980; Manooch, 1987; Claro et. al., 2001). Advances in methodology, i.e. BPH, and equipment for reading otoliths, which were used in this study may also account for variation between contemporary studies and earlier studies.

Another explanation for the differences in growth estimates in this study is that fishing pressure is greater in south Florida. Studies by Manooch and Matheson (1981), and Burton (2001) show higher estimates of fishing mortality (F) on gray snapper for all fisheries for south Florida compared to north Florida. This was attributed to the fact that population density is greater on the southeast coast of Florida as opposed to northeast Florida, and access to the fishing grounds is much easier (Burton, 2001). In the Caribbean, Claro (1981) reported the oldest lane snapper from the Golfo de Batabano, Cuba to be 6 years old and attributes the lack of older fish to extensive fishing pressure. Although older fish (> 6 years old) were reported in my study, the frequency of occurrence was low, making up only 11 % (n = 156) of the total fish aged (n = 1396). It is this author's opinion, that fishing pressure in Florida is the primary reason older fish are not better represented in this study and population, since fishing gear, primarily hook and line, does not exclude or reduce capture of larger (older) fish.

Compounding this issue is the possibility that younger and faster growing fish from the south appear to be recruiting to the fishery sooner than the north. This would result in size selective mortality. Furthermore, to the extent that growth is a heritable trait, harvesting the faster growers could result in a shift in the stock toward slow-growing individuals (Goodyear, 1996). Although Lee's phenomenon was present in north Florida, asymptotic size was considerably higher (443.9) compared to south Florida where L_∞ is much lower (311.4). Lane snapper from south Florida exhibited rapid growth from 0-2 years old, but reached asymptotic length earlier then fish from north Florida. Asymptotic length was still lower in the recent study by Acosta (personal communication, Florida Fish and Wildlife Conservation Commission, Marathon, Florida) which reported $L_\infty = 268.4$ for lane snapper in the Florida Keys. Pauly (1980) contends that asymptotic lengths (L_∞) of fish from cooler regions are larger and the growth coefficient (K) is lower than those of fish from warmer habitats. This supports my findings and the differences between regions using growth estimates for north and south Florida. These distinct differences between regions could be characterized as separate stocks within this population.

Mortality estimates for this study were made with aged samples under the assumption that sampling methods were unbiased. If this is not the case, this may lead to bias in my results. Another factor that must be considered is the obvious differences between regions of Florida. For this reason, it is my recommendation that mortality estimates be developed from a more complete consideration of fisheries landings, length frequency sampling, and application of my age-length keys (Table 7). Estimates of total mortality that are estimated in a stock assessment for this species, must include the landings data for all fisheries, generally by year, area and gear type. Area-specific age - length keys are combined with length frequency to calculate the percentage of fish at age for each fishery and year. This proportion at age multipled by catch in number would give catch in numbers at age for each fishery and year. Total catch added across fisheries for a given year would provide total catch in numbers at age for all fisheries, otherwise known as a catch matrix. Catch curves based on cohorts can be used to derive instantaneous total mortality (Z), or more complex virtual population analysis (VPA).

In conclusion, this is the most current and comprehensive study on lane snapper for the east coast of Florida since 1984. I have demonstrated regional differences in growth characteristics in Florida that must be considered in future stock assessments and management alternatives. Although the population of lane snapper on the east coast appears healthy, the evidence presented in this study suggests that the more heavily fished regions may require a review of management policies in those fisheries. Increased size limits may be appropriate to address size selectivity in these areas. The minimum size of 8 inches TL (203 mm TL), should be increased to 10 inches TL (254 mm TL) in south Florida to reduce the problem of smaller, faster growing fish entering the fishery. Since lane snapper are recruiting to the fishery at an older age and larger size presently in north Florida, this increase may not be necessary in that region. Tagging and genetic studies should be completed before any final decision. Finally, analyses should also include comprehensive mortality estimates and VPAs for each region, with management recommendations based on these results. In the future, managers should consider a regional approach to management issues in Florida, and other areas with increased demands on stocks.

LITERATURE CITED

Acosta, A. and R.S. Appeldoorn. 1992. Estimation of growth, mortality and yield per recruit for *Lutjanus synagris* (Linnaeus) in Puerto Rico. Bulletin of Marine Science, 50:282-291.

Adams, M.S. 1976. The ecology of eelgrass, *Zostera marina* (L.), fish communities. I. Structural analysis. Journal of Experimental Marine Biology, 22:269-291.

Ahrenholz, D.W. 2000. Periodicity of growth increment formation in otoliths of juvenile gray snapper (*Lutjanus griseus*) and lane snapper (*Lutjanus synagris*). The Journal of the Elisha Mitchell Scientific Society, 116:251-259.

Alverson, D.L. and M. Carney. 1975. A graphic review of the growth and decay of population cohorts. Journal du Consiel, Conseil International pour L'Exploration de la Mer, 36:133-145.

Alegria, C., J.R. and M..F. Menezes. 1970. Edad y crecimiento del ariaco, *Lutjanus synagris* (Linnaeus), en el nordeste del Brasil. Arquivos de Ciencias do Mar, 10:65-68.

Beamish, R.J. and G.A. McFarlane. 1983. The forgotten requirement for age validation in fisheries biology. Transactions of the American Fisheries Society, 112:735-743.

Beauchamp, J.J. and J.S. Olson. 1973. Corrections for bias in regression estimates after logarithmic transformations. Ecology, 54 (6):1403-1407.

Beverton,R.J.H. and S.J. Holt. 1957. On the dynamics of exploited fish populations. Fishery Investigations Series II, Marine Fisheries, Great Britain Ministry of Agriculture, Fisheries and Food, 19:533p.

Burton, M.L. 2001. Age, growth, and mortality of gray snapper, *Lutjanus griseus*, from the east coast of Florida. Fishery Bulletin, 99:254-265.

Claro, R. (ed). 1994. Ecologia de los peces marinos de Cuba. Centro de Investigaciones de Quintana Roo, Mexico.

Claro, R, and K.C. Lindeman, L.R. Parenti. 2001. Ecology of the marine fishes of Cuba. Smithsonian Institution.

Claro, R., and Y. S. Reshetnikov. 1981. Ecolgia y ciclo de vida de la biajaiba, *Lutjanus synagris* (Linnaeus), en la platforma Cubana. Ser. Oceanologia Academia de Ciencias de Cuba, 1974: 1-28.

Cruz, R. 1978. Algunas consideraciones sobre la pesqueria de biajaiba (*Lutjanus synagris*, Linne 1758) en la plataforma suroccidental de Cuba. Revista Cubana de Investigaciones Pesqueras, 3:51-82.

Erdman, D. 1976. Spawning patterns of fishes from the northeastern Caribbean FAO Fisheries Report, 200: 145-170.

Francis, R.I.C.C. 1990. Back-calculation of fish length: a critical review. Journal of Fisheries Biology, 36:883-902.

Franks, J.S. and K.E. Vanderkooy. 2000. Feeding habits of juvenile lane snapper *Lutjanus synagris* from Mississippi coastal waters, with comments on the diet of gray snapper *Lutjanus griseus*. Gulf and Caribbean Research, 12:11-17.

Fratantoni, D. and D.A. Glickson. 2003. North Brazil current ring generation and evolution observed with SeaWiFS. Journal of Physical Oceanography, 32:1058-1074.

Garcia, E.R., J.C. Potts, R.A. Rulifson and C.S. Manooch, III, 2003. Age and growth of yellowtail snapper, *Ocyurus chrysurus*, from southeastern United States. Bulletin of Marine Science, 72:909-921.

Goodyear, P.C. 1996. Minimum size for red grouper: consequences of considering variable size at age. North American Journal of Fisheries Management, 16:505-511.

Grimes, C.B. 1978. Age, growth, and length-weight relationship of vermilion snapper, *Rhomboplites aurorubens*, from North Carloina and South Carolina waters. Transactions of the American Fisheries Society, 107:454-456.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin, U.S., 82:898-903.

Huntsman, G.R. 1976. Offshore fishing in North Carolina and South Carolina. United States National Marine Fisheries Service, Marine Fisheries Review, 38:13-23.

Johnson, A.G. and A.L. Collins. 1995. Age, growth, and mortality of lane snapper from northern Gulf of Mexico. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies, 49:178-186.

Lee, T.N. 1994. Evolution of the Tortugas gyre and its influence on recruitment in the Florida Keys. Bulletin of Marine Science, 54:621-646.

Luckhurst, B.E. and J.M. Dean. 2000. Age, growth, and reproduction of the lane snapper *Lutjanus synagris* (Pisces: Lutjanidae) at Bermuda. Marine Ecology Progress Series, 203:255-261.

Manickchand-Dass, S. 1987. Reproduction, age and growth of lane snapper, *Lutjanus synagris* (Linnaeus) in Trinidad, West Indies. Bulletin of Marine Science, 40:22-28.

Manooch, C.S., III. 1987. Age and growth of snapper and groupers. In, Ed. J. J. Polvina and S. Ralston. Tropical snapper and groupers biology and fisheries management. Westview Press, Boulder, CO, 659 p.

Manooch, C.S., III, and R.H. Matheson, III. 1981. Age, growth and mortality of gray snapper collected from Florida waters. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies. 35:331-344.

Manooch, C.S., III, J.C. Potts, M.L. Burton, and D.S. Vaughan. 1998. Population assessment of vermilion snapper, *Rhomboplites aurorubens*, from the southeastern United States. NOAA Technical Memorandum NMFS-SEFSC-411. 59p.

Manooch, C.S. III and D.L. Mason. 1984. Age, growth, and mortality of lane snapper from southern Florida. Northeast Gulf Science, 7:109-115.

Matheson, R.H., III. 1981. Age, growth, and mortality of two groupers, *Epinephelus drummondhayi* (Goode and Bean) and *Epinephelus niveatus* (Valenciennes), from North Carolina and South Carolina. M.S. thesis, North Carolina State University, Raleigh, 73p.

Munro, J.L. and R.W. Thompson. 1983. The biology, ecology and bionomics of the snappers, Lutjanidae. *In,* Munro, J. L. (ed) Caribbean Coral Reef Fishery Resources. Studies and Reviews, 7:94-109.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Consiel, Conseil International pour L'Exploration de la Mer, 39:175-192.

Potts, J.C. 2000. Population assessment of two stoacks of white grunt, *Haemulon plumieri*, from the southeastern coast of the United States. NOAA Technical Memorandum NMFS-SEFSC-442. 67p.

Potts, J.C., C.S. Manooch, III and D.S. Vaughan. 1998. Age and growth of vermilion snapper, *Rhomboplites aurorubens*, from the southeastern United States. Transactions of the American Fisheries Society. 127:787-795.

Ralston, S. 1987. Mortality rates of snappers and groupers. In, Ed. J. J. Polvina and S. Ralston. Tropical snapper and groupers biology and fisheries management. Westview Press, Boulder, CO, 659 p.

Reshetnikov, Y.S. and R. Claro. 1975. Cycles of biological processes in tropical fishes with reference to *Lutjanus synagris*. Journal of Ichthology, 16: 711-723.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Journal of the Fisheries Research Board of Canada, 26:479-541.

Secor, D.H., J.M. Dean, and E.H. Laban. 1992. Manual for otolith removal and preparation for microstructural examination. Canadian Special Publication of Fisheries and Aquatic Sciences, 117:19-57.

Torres, R. and E. Chavez. 1987. Evaluation and diagnosis of the lane snapper (*Lutjanus synagris*) fishery in the stste of Yucatan. Ciencias Marinas (Universida Autonoma de Baja California), 13:7-29.

Tzeng, M.W. 2003. Ingress of transformation stage gray snapper, *Lutjanus griseus* (Pisces: Lutjanidae) through Beaufort Inlet, North Carolina. Bulletin of Marine Science, 72(3):891-908.

Vaughan, D.S. and M.L. Burton. 1994. Estimation of von Bertalanffy growth parameters in the presence of size-selective mortality: a simulated example with red grouper. Transactions of the American Fisheries Society, 123:1-8.

Vaughan, D.S., G.R. Huntsman, C.S. Manooch, III, F.C. Rohde, and G.F. Ulrich. 1992. Population characteristics of the red porgy, *Pagrus pagrus*, stock off the Carolinas. Bulletin of Marine Science, 50:1-20.

von Bertalanffy, L. 1938. A quantitative theory of organic growth. Human Biology, 10:181-243.