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AGE, GROWTH, AND MORTALITY OF LANE SNAPPER FROM SOUTHERN FLORIDA

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Abstract: Rings on sectioned otoliths were used to determine ages of lane snapper, *Lutjanus synagris,* sampled from the south Florida headboat and commericial handline and trap fisheries. Rings were identified and counted on 76% of the otoliths examined, and measurements were made on 61%. The oldest fish encountered was 10 years and 512 mm TL. Back-calculated mean lengths at annulus formation were 135, 196, 233, 261, 285, 310, 338, 367, 411 and 426 mm TL for age groups 1 to 10, respectively. The von Bertalanffy equation describing theoretical growth was $\ell_t = 501(1 - e^{-0.1337(t+1.49)})$. The length-weight relationship was $W = 0.000102TL^{2.6524}$. The relationship of fork length to total length was $TL = -2.6252 + 1.0891FL$. Lane snapper were fully recruited to the hook-and-line fishery as 5 year old fish. A Beverton and Holt yield-per-recruit model suggests a maximum yield-per-recruit of 500 g when instantaneous fishing mortality was 0.5 and recruitment ages were 1.5 to 3.0 years.

The lane snapper, *Lutjanus synagris,* known in Latin America as Pargo biajaiba and Dibujo de una biajaiba, is a tropical and warm temperate marine fish, which commonly occurs in the western Atlantic from the northern coasts of Florida to southeastern Brazil and is often reef associated. Occasionally, juveniles are found as far north as North Carolina as a result of Gulf Stream transport of eggs and larvae and are probably not indicative of local, established populations. The habitat of adults is highly variable. It includes irregular substrates such as coral reefs, rock outcroppings, and shipwrecks offshore, and smooth bottom usually associated with seagrass beds and mangrove thickets inshore. Larger individuals generally occur offshore, smaller fish are found in estuaries and coastal waters (Starck and Schroeder 1971).

Like other lutjanids, the lane snapper is important to both recreational and commercial fisheries. The species is common throughout its range and is caught by hook-and-line, beach seines, fish traps, and trawls. Recreational anglers fish for reef fish from headboats or smaller private boats, using manual or electric reels, sturdy boat rods, heavy monofilament line, and two-hook bottom rigs baited with squid or cut fish (Huntsman 1976). This form of deep water fishing is very popular off Florida where the lane snapper is caught along with mutton snapper, *Lutjanus analis,* gray snapper, *L. griseus,* red snapper, *L. campechanus,* and yellowtail snapper, *Ocyurus chrysurus,* as well as grunts (Haemulidae), groupers (Serranidae), and porgies (Sparidae). Smaller reef fish, including young lane snappers, are caught by anglers fishing from piers, jetties, bridges, and the shore.

Three previous studies have been published on the age and growth of lane snapper (Rodríguez Pino 1962; Alegría and Menezes 1970; and Claro and Reshetnikov 1981). However, all three were primarily directed at small (young) fish, hence the data are only marginally useful in calculating growth parameters needed to derive harvest strategy models for the fishable stock(s) off Florida.

Our research was part of the National Marine Fisheries Service, Southeast Fisheries Center's continuing major research program on reef fisheries. Special appreciation is extended to Robert L. Dixon, Beaufort Laboratory, and Harold Brusher, Panama City Laboratory, who directed field sampling activities along the east coast of Florida and in the Florida Keys, respectively.

The objectives of this study were to: 1) determine the age structure and growth rates of lane snapper in south Florida, 2) estimate total instantaneous mortality rates from catch curves derived from recreational headboat catches, and 3) construct a yield-per-recruit model to demonstrate the effects of different levels of fishing and recruitment age on potential yields. Such information is needed by various regional Fishery Management Councils for preparing reef fishery management plans as provided for under the Fishery Conservation and Management Act of 1976.

METHODS

Lane snapper were sampled from recreational and commercial boats operating out of ports along the east coast of Florida from Jacksonville southward to Key West, 1977 to 1982. A total of 931 fish were weighed to the nearest tenth of a kilogram and measured (total length or fork length to the nearest millimeter), and scales and otoliths were removed from 423 lane snapper. Fork lengths were later converted to total lengths.

Scales were removed from under the tip of the posteriorly extended pectoral fin and were placed in labeled coin envelopes. Four to six scales per sample were mounted dry between two glass slides and were examined at 40X on an Everbach[1] scale projector.

Otoliths (sagittae) were removed either by making a cross cut in the cranium with a hacksaw, thus exposing the earbones, or by opening the otic bulba with a wood chisel and entering the cranium from under the operculum. The latter technique was used to avoid disfiguring fish, which were to be sold. Otoliths were stored dry in labeled vials or coin envelopes and were examined first whole and then again after being sectioned. Whole otoliths were placed in a blackened-bottom watch glass containing clove oil and were viewed under a dissecting microscope at 20X using reflected light. Reflected light revealed two distinct types of rings, an opaque ring that appeared white and a transluscent or hyaline band that looked dark. Opaque rings were counted as annuli. Measurements were made from the core to each ring and to the otolith radius. Since the field of measurement may vary between species, we examined representative otoliths microscopically before sectioning to identify the area where rings were more legible and where erosion of the edge was minimal. Otoliths were then aligned and mounted in a chuck to prevent lateral movement and sectioned with a Buehler[1] Isomet 11-1180 low speed saw yielding three, 0.012-inch sections. Sections were read and measured in the same manner as described above for whole otoliths. A detailed discussion of methods for preparing and sectioning otoliths is provided by Matheson (1981).

RESULTS AND DISCUSSION

Examination of several hundred

[1]Mention of products does not mean an endorsement by the NMFS, NOAA.

scales from 150 fish of various sizes revealed that scales were not useful in aging lane snapper. The majority of the scales examined were regenerated. Those that were not regenerated were thick, often abnormally formed, and rarely possessed a consistent pattern of markings. Scales and urohyal bones removed from lane snapper in Cuban waters had numerous false rings (Claro and Reshetnikov 1981).

Whole otoliths (as used by Rodríguez Pino 1961; Alegría and Menezes 1970; and Claro and Reshetnikov 1981) were somewhat more readable than scales, but sectioned otoliths were even more legible. On sectioned otoliths, rings were clear and, since they were formed around the entire structure, were easily counted and measured. Growth marks could be identified on 76% of all those examined, and measurements could be made on 61%.

Validating that rings occurring on fish hardparts are true annuli and represent age, is important yet particularly difficult for subject species that inhabit tropical waters, where temperatures are relatively stable. We felt, however, that it was unnecessary for us to validate the rings since Alegría and Menezes (1970), Rodríguez Pino (1962), and Claro and Reshetnikov (1981) had already aged lane snapper from tropical waters, had easy access to young fish (ages 0 to 3) throughout the year, and had documented the time of annulus formation.

Length Conversions

An equation to convert fork length (FL) to total length (TL) was developed since some of the fish in this study were measured in FL and some were measured in TL, and all previously published papers referred only to FL. The following equation was based on random stratified sampling of fish lengths:

$$TL = -2.6252 + 1.0891\ FL;$$
$$r = 0.999 \text{ and } n = 100.$$

Observed Growth

Exclusion of smaller size classes by the hook-and-line fishery reduced the availability of younger fish for our study; only one young-of-year fish (168 mm) was collected (Table 1). Rodríguez Pino (1962) found young-of-year lane snapper in Cuban waters ranging from 60 to 159 mm FL (63 to 171 mm TL).

Although mean observed length increased with age, there was much variation for a specific age (Table 1), which is expected when collection date and areas were not identical, and when the spawning season is extended, as is true for lane snapper. Rodriguez Pino (1962) also found much variation in length with

Table 1. Observed age-total length data for 320 lane snapper aged by reading sectioned otoliths.

Age	Number	Mean Length	Range	Standard deviation
0	1	168.0	—	—
1	2	193.5	189-198	6.36
2	29	219.4	195-250	12.01
3	33	243.2	208-309	21.33
4	69	273.7	205-357	32.65
5	69	296.1	237-397	40.85
6	57	305.1	242-416	50.67
7	35	345.7	286-457	57.19
8	18	375.8	283-495	63.67
9	5	428.0	335-474	55.68
10	2	461.0	410-512	72.12
Total	320			

observed age. For example, his age 1 fish ranged from 139 to 225 mm; age 2 fish, 161 to 279 mm; age 3, 204 to 301 mm; and age 4, 237 to 345 mm TL (all converted from FL). The oldest fish we examined had 10 rings and was 512 mm TL. A fish 553 mm TL was reported by a sampler, but we were unable to obtain the otoliths.

Back-Calculated Growth

Lengths by age for all years and areas combined were back calculated from an otolith radius-fish length regression equation derived by regressing projected otolith radius on total fish length. Because fishing gear selectivity caused a majority of the measurements to occur within a relatively narrow size range, we subsampled fish length measurements after first grouping them into 50-mm size intervals. The equation was log TL = −0.2699 + 1.4261 log OR; or $TL = 0.7635\, OR^{1.4261}$, r = 0.9334 and n = 100, where TL = total fish length in mm, and OR = otolith radius in micrometer units. We substituted the means of the distances from the focus to each annulus for OR in the above equation, calculated the mean length of all fish in each age group at the time of each annulus formation, and then calculated mean growth increment for each year (Table 2).

Growth in length for the first two years was very rapid (135 and 61 mm TL, respectively) and continued at a relatively fast rate for the third year. Annual growth increments for ages 4 to 8 were relatively constant at about 25 to 30 mm TL (Table 2). Mean increment values for ages 9 and 10 are of doubtful accuracy because the annuli were extremely close together and therefore difficult to measure precisely. For these older fish, tenths of micrometer units become important, but rings that close together are almost impossible to discern and measure. For these reasons (primarily small sample sizes), we eliminated ages 9 and 10 from further aging procedures. Our back-calculated values are compared in Table 3 with those reported by Alegría and Menezes (1970), Rodríguez Pino (1962), and Claro and Reshetnikov (1981).

The von Bertalanffy equation, $\ell_t = L\,(1-e^{-K(t-t_0)})$, was selected to describe the theoretical growth of lane snapper. The curve was fitted to back-calculated lengths (Everhart, Eipper and Youngs 1975; Ricker 1975). The growth parameters L_∞ and K were obtained in-

Table 2. Back-calculated length (TL) of 258 lane snapper 1 to 10 years old.

		Length at time of annulus formation									
Age	Number	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
Weighed means		134.7	195.6	232.5	260.9	284.8	309.7	337.9	367.4	410.7	426.0
Increment		134.7	60.9	36.9	28.4	23.9	24.9	28.2	29.5	43.3	15.3

itially by fitting a Walford line (Walford 1946): $\ell_{t+1} = L(1-k) + k_t$, where ℓ_t = total fish length at age t, k = slope of the Walford line, and $L\infty$ = maximum length. The equation for our data is ℓ_{t+1} = 70.4357 + 0.8517 ℓ_t, r = 0.9917. Since the slope (k) is equal to e^{-K}, K = −1n 0.8517, or 0.1605. A preliminary value of 475 for $L\infty$ was obtained by solving the equation $L\infty = \frac{\text{y intercept}}{1-k}$. These estimates of K and $L\infty$ seemed reasonable, but we also used the Marquardt method (Nelson 1980) to estimate K, and $L\infty$, and t_o, and found that $L\infty$ = 501 mm, K = 0.1337, and t_o = −1.49. We accepted these as our best estimates. Therefore, our theoretical cal growth equation is $\ell_t = 501 (1-e^{-0.1337(t+1.49)})$. From the equation we calculated lengths at age (Figure 1).

Length-Weight Relationship

To calculate the relationship of fish weight (g) to total fish length (TL in mm), we arranged lengths in order of smallest to largest and stratified them by 50-mm intervals. We used all fish <200 mm and >450 mm because there were few of them and took random subsamples from each of the other 50-mm intervals so that n would equal, or be greater than, 100. The length-weight equation for lane snapper was

$$W = 0.000102\ TL^{2.6524};$$
$$n = 101 \text{ and } r = 0.9627.$$

Mortality Estimates

Mortality estimates may be obtained from catch curves if the age distribution is known by plotting the log of the age frequency on age. The absolute value of the slope of the linear descending right limb of the curve estimates the mean instantaneous total mortality (Z) (Beverton and Holt 1957). Since lane snapper were not fully recruited to the headboat fishery until age 5, total mortality estimates were based on fish age 5 and older. To construct the catch curves, we assigned ages to unaged fish whose lengths were known. Fish of known age were grouped by 25-mm length intervals and the percent age distribution for each group was calculated. All ages were not equally represented in the sample. Unaged fish were grouped similarly; estimated on the basis of percentages in the corresponding group of known age (Ricker 1975). The instantaneous mortality rate of 0.678 for 1977 to 1982 (Figure 2) was similar to that for gray snapper (0.60) from the same area (Manooch and Matheson 1981).

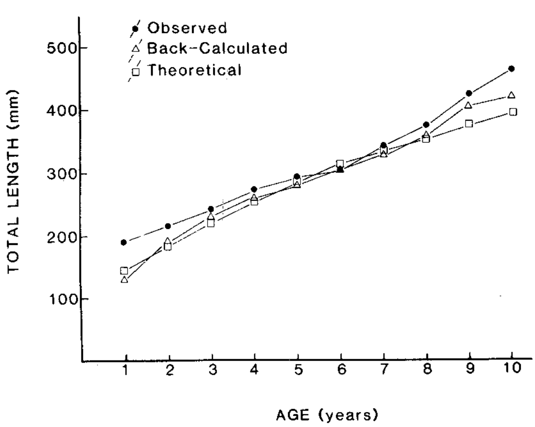

Figure 1. Observed, back-calculated, and theoretical growth curves for lane snapper aged from otoliths.

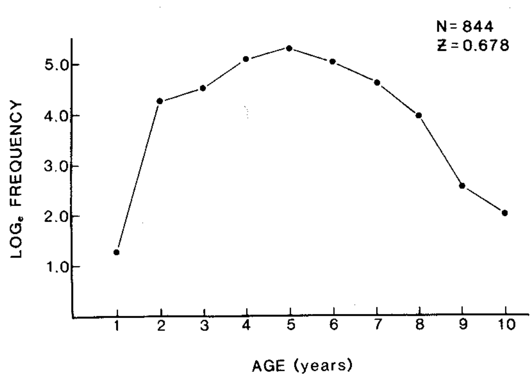

Figure 2. Age frequency distribution for lane snapper sampled from the headboat fishery operating off the east coast of Florida.

Table 3. Comparison of back-calculated lengths (TL) at age for lane snapper from South Florida, Brazil, and Cuba.

Age	South Florida (present study)	Brazil (Alegría & Menezes)	Cuba (Rodríguez Pino)	Cuba (Claro & Reshetnikov)
1	134.7	120.0	181.4	135.5
2	195.6	199.0	220.6	180.7
3	232.5	262.0	255.5	233.5
4	260.9	312.0	287.1	280.9
5	284.8	351.0	293.6	312.1
6	309.7	383.0	326.3	352.7
7	337.9	—	—	—
8	367.4	—	—	—
9	410.7	—	—	—
10	426.0	—	—	—

Yield-Per-Recruit Model

Estimates of productivity or yield are a requisite for proper management. Since stock size/recruitment relationships and extended annual catch and effort statistics are not presently available for lane snapper, we used a yield-per-recruit model in which yield-per-recruit, as a function of recruitment age and fishing mortality, is expressed as a fraction or percentage of surface area of the model (Beverton and Holt 1957). Yield-per-recruit is defined as the ratio of total weight (kg) of fish that could be taken from a cohort divided by the number of individuals of the cohort that entered the fishery. Parameter estimate requirements are minimal, yet allow an analysis of the relationships between fishing mortality, recruitment age, and equilibrium yield.

The yield model for lane snapper was constructed according to the techniques outlined by Huntsman, Manooch, and Grimes[2]. Instantaneous natural mortality (M) and growth parameters such as L_∞, W_∞, and K shaped the response surface, while instantaneous fishing mortality (F) and age at recruitment to the fishery (T_r) were independent variables that determined yield. Growth parameters K, L_∞, and t_o were derived from the van Bertalanffy equation, and W_∞ was calculated by using the L_∞ value in the length-weight relationship. Maximum age attained and maximum age in the fishery were determined from the basic aging data. Instantaneous natural mortality was calculated by using the multiple regression model described by Pauly (1980), which is based on the empirical relationship of M to annual mean water temperature (°C), K, and L_∞. M for lane snapper was calculated as 0.40. Since F + M = Z (Ricker 1975),

[2]Huntsman, G.R., C.S. Manooch, III, and C. B. Grimes. Yield-per-recruit Model of Some Reef Fishes of the U.S. South Atlantic Bight. Unpublished manuscript. National Marine Fisheries Service, Beaufort Laboratory, Beaufort, N.C. 28516-9722.

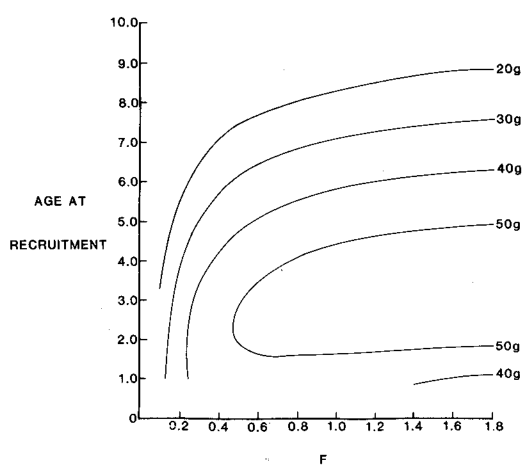

Figure 3. Yield-per-recruit model for lane snapper (F = fishing mortality).

F = 0.28 (0.68 – 0.40 = 0.28).

The yield model for lane snapper (Figure 3) suggests that South Florida headboats (partyboats) are harvesting approximately 80% of the potential yield at current levels of T_r (3.5 years) and F (0.3). According to the model, changing T_r alone will not increase Y/R substantially.

As with other relatively long-lived, slow-growing reef fish, lane snapper may be over exploited by a large, intensive fishery. A low intensity fishery on the other hand, should take most of the yield available and allow a sufficient number of fish to live to ages of maturity to allow sustained high yields.

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