2. Life history of *Lutjanus analis* inhabiting Florida waters

Craig Faunce[1], Janet Tunnell[2], Mike Burton[3], Karole Ferguson[4], Joe O'Hop[2], Robert Muller[2], Mike Feeley[4], Laura Crabtree[2]

[1]*Florida Fish and Wildlife Research Institute, 19100 Southeast Federal Highway, Tequesta, Florida 33469*

[2]*Florida Fish and Wildlife Research Institute, 100 Eighth Avenue SE, St. Petersburg, Florida 33701*

[3]*National Marine Fisheries Service, 101 Pivers Island Road, Beaufort, North Carolina 28516*

[4]*Florida Florida Fish and Wildlife Research Institute, 2796 Overseas Highway, Suite 119 Marathon, FL 33050*

2.1 Overview (Group membership, Leader, Issues)

The life history group membership was comprised by Craig Faunce (leader), Janet Tunnell, Laura Crabtree, Karole Ferguson, Michael Feeley, Michael Burton. Robert Muller and Joe O'Hop provided some additional information during the working group's discussions and report writing.

Three species constitute the majority of snapper (Family Lutjanidae) targeted by fishermen in nearshore waters of Florida; the lane snapper (*Lutjanus griseus*), gray snapper (*Lutjanus griseus*) and the mutton snapper (*Lutjanus analis*). Mutton snapper achieve the largest body size of these snappers, and represent a valuable fishery resource. Users have conveyed concern that the abundance of this species has been in decline. These concerns prompted the Florida Fish and Wildlife Conservation Commission to initiate the Southeast Data Assessment and Review (SEDAR) process whereby available information on the biology and fishery of this species are assembled and reviewed. As part of this process, scientists and stakeholders were selected to participate in one of several working groups. This life history section report summarizes information from available sources that incorporate both fishery-dependent and -independent data (Table 2.1). Sections 2.3. and 2.4 draw upon (SEDAR 15A-DW-15, Faunce et al. 2007).

2.2 Stock Definition and Description

Online summaries of the taxonomy and biology of this species are available from Murray and Bester (2007) and Froese and Pauly (2007). *Lutjanus analis* were first described by Georges Cuvier in 1828 from a Hispanolan specimen, and is synonymous with *Mesoprion sobra* (Cuvier 1828), *Mesoprion isodon* (Valenciennes 1829) and *Mesoprion rosaceus* (Poey 1870). Common names in English include mutton snapper, mutton fish, king snapper, virgin snapper, snapper, and in Spanish include pargo, pargo cebado, pargo cebal, pargo colorado, pargo criollo (Cuba), pargo mulato, and sama.

Although mutton snapper are reportedly distributed within the Western Atlantic from Brazil north to Massachusetts, the majority of information on the biology of this species comes from a more limited geographic range. For example, spawning locations of mutton snapper are reported from the Turks and Caicos, Florida, the Bahamas, and Cuba (SCRFA 2007), and detailed information on the biology of this and other snappers is available from Cuba and Florida (Burton 2002; Barbieri and Colvocoresses 2003; Claro and Lindeman 2003; Burton et al. 2005). The strong Caribbean, loop, and Gulf stream currents of the region are sufficient to maintain a homogenous population at the genetic level (Shulzitski, et al. 2005). However, at ecologically meaningful scales (10-100 km), models that couple larval behaviors and hydrodynamics reveal that propagule emigration from Cuba (particularly from northeast and north central regions), to southeastern Florida occurs, but that their contribution is low in terms of the total number of advected larvae over the planktonic larval duration of ca. 30 days (Lindeman et al. 2001; Paris et al. 2005). For these reasons, the unit stock of mutton snapper for this SEDAR is considered at the functional population level, and is defined as the total number of individuals that use waters within the jurisdiction of the South Atlantic Fishery Management Council (SAFMC) and the Gulf of Mexico Fishery Management Council (GMFMC). Occurrence of this species in the nearshore bays of Florida confirm that juveniles of this species is limited to points south of Jupiter Inlet on the Atlantic coast, and Charlotte Harbor on the Gulf Coast (A. Acosta FIM data).

2.3 Natural Mortality

Prior to this assessment, the only published natural mortality estimate of *L. analis* was provided by Burton (2002) but the SAFMC Snapper Grouper Plan Development Team used a natural mortality rate of 0.2 per year based on only having otoliths from fish of ages 1-14 and they applied this rate to all ages (SAFMC 1990) . Although fish up to 29 years were observed by Burton (2002), an examination of the age-frequency distributions revealed that no fish were observed between 18 and 29 years of age. For this reason Burton (2002) calculated two natural mortality estimates; one for fishes up to 17 years, and one for fishes up to the maximum age of 29. This is significant, because age-frequencies from this SEDAR also show fewer fishes over 18 years; however, fish were observed in all age classes including 40 years (Table 2.2). From these data, it was concluded that the *L. analis* population consists of two portions; one of individuals up to 18 years that reside where fishermen regularly harvest (hypothesized to be the Florida shelf less than 30 meters), and older fishes that are found in comparatively lightly fished locations, such as deep (e.g., greater than 50 meters) or spatially remote locations (e.g., areas west of the Dry Tortugas and Pulley Ridge). This second portion of the population is believed to represent a relatively ligthly exploited portion of the population. The older fishes (Table 2.2; fish that were 25 years or older) were largely from areas west of the Dry Tortugas, and were caught at depths between 20 and 140 fathoms (36 to 256 meters) by commercial long line fishermen. As a result, because total mortality, Z, is equal to natural mortality (M) and fishing mortality (F) then an analysis of the proportion of fishes in age classes older than 18 years would provide an approximate estimate of natural mortality (M) and not F. As evidence, consider that the recreational fishery for mutton snapper operates nearshore and 95% of their landings are fish aged 7 years or less while the commercial fishery operates in deeper water and 95% of their landings are fish aged 21 years old or less (Figures 2.1 and 2.2).

Burton (2002) estimated natural mortality from equations derived from meta-analyses. For example, Hoenig (1983) who related total longevity (t_{max}) to natural mortality (M) according to an empirical relationship derived from an examination of fish with different life histories and longevities: $\ln(\hat{M}) = 1.44 - 0.982 * \ln(t_{\max})$. According to this relationship, estimates of natural mortality from Burton (2002) became 0.26 per year for ages 1-17 and 0.14 per year for ages 1-29, and 0.11 per year for the t_{max}=40 yr in this assessment because fishes up to 40 years were observed (Table 2.2). By the nature of the equation, estimates of M will dramatically change with different t_{max} values. It is perhaps better then to estimate M based on multiple ages. For this reason we used a catch curve (Chapman and Robson 1960). To ensure that the data were as comparable as possible, we only included fish aged 18 years and older caught from the Dry Tortugas and southeast Florida shelf long line fishery. There were 162 mutton snapper that met these criteria. The Chapman-Robson catch curve estimated total mortality at 0.13 per year- similar to the estimate from Hoenig (1983). Instead of assuming that a single natural mortality rate applies to all ages, we derived age-specific M values using Lorenzen's (2005) method. His approach uses the relationship between age and length and is scaled to a "target" mortality rate.

Based on the above, and the age-and-growth information from Faunce et al. (2007), we scaled the calculated age-specific rates (Table 2.3) for ages 3-40 to 0.11 per year, the estimate that we obtained from Hoenig's (1983) regression (Figure 2.3).

2.4 Discard Mortality

Discard mortality for mutton snapper has not been examined prior to this SEDAR, necessitating the inclusion and examination of alternative data. Data were obtained from two sources. First, the online search engine Cambridge Scientific Abstracts were culled for relevant articles from earliest to present within the default "Natural Resources" database using the following keywords: fishing mortality, grouper, snapper, mutton snapper, catch, release and mortality. Articles were deemed relevant if they focused on a species with similar body size to mutton snapper (< 1 m total length), with similar life history strategies (adults reside on marine reefs), collected with similar gear types (hook and line). Discard mortality from SEDAR 7 (Gulf of Mexico red snapper, *Lutjanus campechanus*, section 6.0) was selected as a second source (Table 2.4).

Discard mortality is influenced by the factors of hook type, hook placement, time of handling, and depth of capture (the latter being the result of barotrauma caused by the super-inflation of the swim bladder upon ascent). Of these factors, depth of capture is best represented in the available data. In order to identify general trends in the data, it was assumed that the average depth and mortality of fish captured could be adequately represented by the midpoint between the minimum and maximum reported values in each study (e.g., the data were normally distributed and that the mode=mean)- an assumption supported by Wilson et al. (2005). Two groups of data could be easily discerned from the data; those collected in less than 30 m depth, and those collected at greater depths. This division point of 30 m also has significance since a large proportion of the Florida shelf is near or below this depth (Figure 2.4). Therefore the shallow depth group can be considered a proxy for fishes collected nearshore and available to recreational anglers. This approximation is supported by a study using fish traps for snappers that was designed to collect specimens from recreational fishery locations, including *L. analis* made during 2000-2003 by the Florida Fish and Wildlife Conservation Commission (Barbieri & Colvocoresses 2003) on the Atlantic Florida shelf. The depths at which the traps were deployed averaged 22.6 meters, and 95% confidence intervals (1.96 * standard deviation) place approximate boundaries on the "typical" recreational fishing for reef species in that area between 14.5 and 30.7 m deep (n=485).

Mortality rates for red snapper (*L. campechanus*) and other reef species were drastically different between depth groups, and averaged 15% (range 1-58 %) for the shallow group and 66% (range 44 – 86%) for the second group (Table 2.3). These values were statistically different based on t-test comparison of means ($p<0.001$), and provide the first method to assign discard mortality rates to *L. analis*.

Limited data were available on *Lutjanus analis* release condition from head boat observations made in eastern and western Florida during 2005-06 (Beverly Sauls, FWC unpublished; Table 2.5). Comparing these limited data with *Lutjanus campechanus* data reveals that discard mortality rates were neither consistently greater or lower than red snapper mortality rates for the two depth classes (Figure 2.5). However, discard mortality for *L. analis* was lower than for *L. campechanus* in three of four instances, suggesting that discard mortality rates for *L. analis* may be lower than for *L. campechanus* at all depths. The high mortality of *L. analis* in shallow (< 60' or ca. 20 m) depths on the east coast of Florida could be an artifact of the low sample size (four fish).

Because of these differences, a more attractive method to assigning release mortality would be to examine how rates change with depth as a continuous variable rather than within discrete depth bins. This type of data is only available for *L. campechanus*, and when available information was combined, it was revealed that discard rates could be effectively modeled using a logistic regression (Figure 2.6). The final form of this model was:

$$y = \frac{79.12}{1 + \left(\frac{x}{34.10}\right)^{-5.55}}$$

where *x* is discard depth and *y* is the discard mortality rate (%). Examination of residuals and test results revealed that the model was adequate and statistically significant ($p<0.001$). Because this model can be used to estimate discard mortality for a variety of depths, it is the recommended as the preferable option to assign discard mortality rates for *L. analis*. An important assumption is that the relationship between mortality and depth for *Lutjanus campechanus* can be applied to *L. analis*. Examination of limited data from head boat at-sea surveys indicate that this assumption may not be correct, and that its acceptance adopts a more conservative approach to discard mortality rates for *L. analis*.

2.5 Age

Biological samples were examined from four sources (Table 2.1). Details pertaining to otolith processing, ageing and precision are found in (SEDAR 15a, DW-17, Tunnell et al. 2007). Ring deposition occurred once a year between the months of February and June. The observation of the last ring on the margin was minimal during these months, but the common occurrence of a small margin (less than 2/3 translucence) and the decrease in the frequency of a large margin (more than 2/3 translucence) in June and July confirms that rings are annuli and are formed by June (Figure 2.7). These data agree with similar findings presented by Burton (2002).

Substantial differences in the maximum age for mutton snapper were revealed. While the maximum age from Florida was previously estimated at 29 years by Burton (2002), the maximum age has been extended to 40 years in the current analysis (Table 2.2). Fishes aged from 0-10 were collected from Tequesta, ages 1-17 collected from the Keys, and ages 1-29 collected in the Burton (2002) data set. It should be noted however that the proportion of fish above age 17 in the data set of Burton (2002) is quite small, and a maximum age of 17 years was also observed among the two fishery independent data sets of FWRI. Despite differences in sampling gear and location, the age-structure of mutton snapper in Florida are remarkably similar among data sets (Figure 2.8). In total, 90% of the fish examined were less than eight years of age, or 20% of their maximum life span (Figure 2.9). Differences in size at age by sex were negligible (Table 2.5).

2.6 Growth

Age-length (total length with the tail compressed, TL_{max}) information was fitted to the von Bertalanffy (1938) growth function using a size-truncated model (PROC MODEL, SAS ver. 9.1.3)

$$L_t = L_{\inf}\left(1 - e^{-K(t - t_0)}\right)$$

where L_t is the size at age t (years), L_{inf} is the theoretical maximum size, K is the growth function or slope, and t_0 is the theoretical age when fish length is zero, or x-axis "fitting parameter". Truncation of length data was based on the time of otolith collection and if it was collected from a fishery dependent or independent source. Fishery independent data had no length truncation, whereas dependent data collected from 1992 through 1994 was truncated due to a minimum size limit of 12 inches, and data collected from 1995 through the present was truncated due to a minimum size limit of 16 inches.

The Gaussian nonlinear maximum-likelihood estimator reached minimum tolerance of 0.001 after 146 runs with 7172 data points (Table 2.2; 1 missing length), and explained the majority of the variance in the data (adjusted r^2=0.84). Examination of residuals indicated no systematic trends with body size, and all parameters were statistically significant (Table 2.6). These data compare well to observed size at age estimates (Figure 2.10) and those from other studies (Table 2.7).

2.7 Reproduction

2.7.1 Timing

More is known about the age and growth of mutton snapper than its reproduction. This SEDAR contains new reproductive data for Florida. Fish were collected with Chevron traps, hook and line, and spearfishing gear during 1998-2002 from the mainland (Tequesta) and the Florida Keys (Marathon). This data set was first described by Barbieri and Colvocoresses (2003) and is hereafter termed the FWC dataset. The spawning season can be inferred from indices relating gonad weight to body weight (gonadosomatic index, or GSI) and directly assessed from examination of the gonads. Plots of GSI during each month showed elevated values during April-June (Figure 2.11). This trend closely matches newly available data from the "South Florida" (Fort Pierce South) dataset of Burton (2002) that show elevated values during March-July. These data also agree with trends in GSI from Cuba and Puerto Rico that demonstrate peak values during May-June (Claro 1981; Figuerola and Torres 2001).

Direct examination of the gonads revealed differences in gonad maturity stages (GMS) between FWC laboratories. The occurrence of stage 3 (presence of vitellogenic oocytes), and stage 4 (hydrated oocytes) spanned April-September in Tequesta and January-October in the Keys (Figure 2.12). Based on GSI and the presence of GMS 3 and 4 females, the reproductive season for this species spans March-July with a peak in activity during April-June (Figure 2.13).

2.7.2. Size at maturation

Following the recommendations of Hunter and Macewicz (1985, 2003) the reproductive stage of gonads for the peak spawning period (April-June) was evaluated using histological methods for the purposes of generating a size- and age- based maturation schedule for female *Lutjanus analis*. Gonad maturity stages (Table 2.9) were assigned a maturity value of 1 if greater than stage 1 (immature, primary oocytes only present or sex undetermined due to lack of development) and a value of zero if GMS=1. These data were fit to a logistic regression

$$y = \frac{1}{\left(1 + \left(e^{-R*(x - L_{50})}\right)\right)}$$

where *y* is the proportion mature, L_{50} is the point at which 50% of individuals are mature, and *x* is equal to either size or age (PROC NLIN, SAS ver 9.1.3). To ensure accuracy of the data, analyses were restricted to fishes that were collected during the spawning season (i.e., if maturity were to occur, it would be observed). Both models were significant and explained the majority of variance in the data (Tables 2.10a,b).

Fifty percent of females achieved sexual maturity at 353 mm TL_{max} and 2.07 years of age (Figures 2.14 and 2.15 respectively). These values are very different from data (macroscopic determinations only, not histological) from Cuba, as Claro (1981) reported a L_{50} for this species to be 520 mm fork length (FL; ca. 574 mm TL_{max}) and 5-6 years of age. Similarly, Figuerola and Torres (2001), using histological criteria, reported a L_{50} of 414 mm FL (ca. 459 mm TL_{max}) for *L. analis* in Puerto Rico. A shift in cohort-specific maturity schedules over time is consistent with a genetic change at the population level, and a change towards smaller size at maturity is consistent with the expected life-history response to high rates of selective exploitation (Marshall and Browman 2007). If the data of prior estimates from Caribbean populations is indicative of fishes inhabiting Florida waters in the past, then current estimates of size-at-maturity are comparatively small and may indicate growth overfishing in the Florida population. However, we recommend further analyses of the maturity data from Tequesta and the Florida Keys, and if possible, maturity data from Puerto Rico before accepting the size- and age- at-maturity values from the regressions. There were some differences in the staging criteria and in the months included in the size-at-maturity curve in the Puerto Rico study (Figuerola and Torres 2001).

2.7.3. Timing and trends in reproduction

Available information on the timing of spawning comes from Garcia-Cagide et al. (2001) and Claro and Lindeman (2003), who place peak spawning 6-7 days after the full moon during May and June. Our best information on the spawning behavior of mutton snapper come from the area of the Dry Tortugas, Florida. M. Domeier observed an aggregation of mutton snapper during 1991 that had been heavily exploited and described these fishes as milling a few meters off the bottom yet exhibiting no clear behaviors related to spawning- suggesting these behaviors occur at night (Domeier and Colin 1997). Johannes et al. (1999) explain that fishes in spawning condition exhibit “spawning stupor” or a general ignorance to observation by divers. The longest data set relating to *L. analis* spawning comes from Burton et al. (2005), who conducted yearly observations of *Lutjanus analis* group size during the full and new moons of May-July during 1999-2004. Their observations revealed increases in the number of *Lutjanus analis* present over time. During 1999-2000 only solitary individuals were observed, during 2001 this number increased to 10, during 2002-2003 this number increased to 100 and during 2003-2004 over 200 individuals were observed (Burton et al. 2005). Because this normally solitary fish was observed in groups during suspected spawning periods and exhibited the stupor disposition, these authors concluded that they were witnessing fishes within a spawning aggregation.

Despite numerous attempts, spawning behaviors and courtship have yet to be documented for *Lutjanus analis*, however results offer indirect evidence that area closures where *L. analis* occurs during spawning months are correlated with an increase in numbers of this species during summer spawning months of subsequent years.

2.8 Movements and Migrations

Mutton snapper exhibit spatial separation of adult and juvenile members of the local population, and thus constitute a nursery species as defined by Beck et al. (2001). After a pelagic larval period of ca. 31 days, mutton snapper settle onto a suite of available habitats including, nearshore vegetated habitats such as seagrass beds < 10 m deep (Lindeman et al. 2000). Although data are limited, it is reasonable that mutton snapper undergo ontogenetic habitat shifts from shallow vegetated habitats to alternative structure including the reef tract in response to changing exposure to predation caused by increasing body size (e.g., Dahlgren and Eggleston 2000). Given that the number of individuals is expected to decline with size and age (i.e., the instantaneous mortality assumption of Ricker (1975)) supporting evidence comes from decreasing density of this species from seagrass beds, to mangroves, to coral reefs in the Netherland Antilles (Nagelkerken et al. 2000). However, *Lutjanus analis* is rarely observed within mangrove shorelines that are commonly used as secondary habitats for reef fishes such as members of the families Lutjanidae, suggesting perhaps hardbottom is used by this species as a secondary habitat (Serafy et al. 2003, Eggleston et al. 2004). The 1996 amendment to the Sustainable Fisheries Act requires fishery management plans to be amended to identify and describe essential fish habitat (EFH) for more than 700 federally managed fishery stocks (Schmitten 1999). The fishery management plan for the U.S. Caribbean summarized occurrence information for mutton snapper within various habitats during its ontogeny (Table 2.11). From this summary, two potential distribution bottlenecks can be identified; the distribution of larvae within the planktonic environment, and the distribution of spawning adults on coral reef and hardbottom habitats.

Little is documented regarding the seasonal migrations of mutton snapper along coastlines. Fishermen in Martin County (Atlantic Coast of Florida) note a spike in catch rates during the Fall (November) and Winter (February) that may be related to the latitudinal movement of fishes into the region (B. Hartig, B. Taylor pers. com). Perhaps the most significant movement patterns of mutton snapper occurs during the summer, when normally solitary individuals aggregate during days and weeks of travel time to specific locations that persist from days to two weeks throughout the Caribbean (Domeier and Colin 1997). In Florida, Lindeman et al. (2000) reported 22 locations identified by fishermen in the lower Keys that may serve as spawning aggregations for snapper; only three of which were particular to mutton snapper. Claro and Lindeman (2003) report nine snapper spawning locations in Cuba; four of which were used by mutton snapper. Although data on movement are limited, inference as to these migrations have been made from observations taken over almost 100 years. Fishermen in Key West noted that fish close to shore were caught year round with the exception of the summer months when this species undergoes migrations towards spawning sites (Schroeder 1924). More recently, Claro (1981) summarized the movement patterns of mutton snapper during the summer months in northwest Cuba. Fishes are depicted migrating from patch and reef crest habitats towards a specific point, the Corona de San Carlos for spawning, larvae are advected along shore, and then move shoreward for settlement in the surrounding embayment.

2.9 Meristics and Conversion Factors

A suite of length-length and length-weight conversions were calculated that facilitated comparisons between the data from other studies in the Caribbean and those reported here. Conversions incorporated a large range of possible values and were statistically significant (Table 2.12). Here we have added one length-length relationship; total length (relaxed) to/from total length (maximum). This relationship is provided to meet needs that may arise from new measurement rules set forth by the State of Florida whereby fishes are measured to maximum total length by extending the dorsal edge of the caudal fin to its horizontal (maximum) extension. Also, the total length (relaxed) from total length (max) relationship may be helpful in converting total lengths observed in visual (dive) surveys to their corresponding equivalents in total length (max).

2.10 Comments on the Adequacy of Data for Assessment Analyses

Ample data were gathered and analyzed for this portion of SEDAR 15a to support decisions regarding the status of the stock. We feel confident that the assessments of age and growth presented here represent the best data available. Ample data are available to confidently place boundaries on the spawning season and timing of spawning during the lunar period. Data on size and age at maturity was examined for the Florida population for the first time, and substantial differences were revealed between these estimates and the Caribbean. These differences could be due to differences in biology between populations or time periods rather than in the quality of data sources, but additional analyses are needed to adjust for methodological differences . However, histological samples of reproductively active (gonad maturity stage 4 and 5) fish remain rare, representing grounds for data improvement including fecundity. Estimates of mortality are based on the best methods and data available, however release mortality data on *L. analis* are relatively rare compared to other members of the family Lutjanidae.

2.11 Research Recommendations

The biology of *Lutjanus analis* during reproduction remains perhaps the greatest unknown in the life-history of this species. Despite its relatively large body size, exploited status, and gregarious nature during reproduction, the behaviors, location, and sources of individuals of spawning aggregations in Florida and the greater Caribbean remains elusive. Seasonal migration patterns are completely unknown and based on speculation. Primary habitats used by this species during various stages of its ontogeny are undefined. This information would reveal the dependence of the Florida population on various habitats and locations, e.g., a given spawning location; critical information since models have revealed that contributions to the Florida population of *L. analis* in the form of larvae from outside southern sources is minimal (Paris et al. 2005), and that the Florida population is biologically “on its own”. Because of the aforementioned difficulties and differences in staging criteria, we recommend further review of the maturity data from Tequesta and the Florida Keys, and Puerto Rico before accepting the size- and age- at-maturity values from the regressions reported here.

2.12 Itemized list of tasks for completion following workshop

Growth:
Models to describe length at age have been run and an error corrected by Craig Faunce, Joe O’Hop and Walter Ingram on April 24th. The number of otoliths used in the most recent growth model is 4056, however over 7000 otoliths have been aged (J. Tunnell). This gross discrepancy between the number of aged otoliths and those used in the model resulted from a mismatch in size and age data with collection information from samples obtained from NOAA Panama City. Correction of this data, in particular those fish older than 32 years is needed.

- **Janet Tunnell and Joe O’Hop have been tasked with correcting the data.**

Mortality:
Discussions with Bob Muller indicate that the choice of either a static or dynamic discard mortality rate will depend upon having adequate catch vs. depth information for mutton snapper.

- **These data are needed from Beverly Sauls**.

Age structure:

Age-structure of the mutton snapper population is completed and there are no immediate data needs.

- **Joe O'Hop is to provide data to Bob Muller for final estimation of natural mortality.**

Reporting:
Efforts are underway on two white papers; mortality of mutton snapper (Craig Faunce) and ageing methods and precision (Janet Tunnell). These papers are being written to streamline the final life-history section for the final SEDAR 15 report.

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2.14 Tables

Table 2.1. Summary of data sets used in SEDAR 15a.

Parameter	Dependent Sampling*	M. Burton (2002)	FWRI Tequesta**	FWRI Keys**
Data type relative to fishery	dependent	dependent and independent	independent	independent
Duration	1979-2006	1992-2000	1998-2002	1998-2002
Chevron traps			**x**	
Hook and Line	**x**	**x**	**x**	**x**
Spearfishing	**x**	**x**	**x**	**x**
Port sampling	**x**	**x**	**x**	**x**
Otoliths	**x**	**x**	**x**	**x**
GSI		**x**	**x**	**x**
GMS			**x**	**x**
Fecundity			**x**	**x**

*NMFS Trip Interview Program, NMFS Southeast Head Boat Survey, and Fisheries Information Network (FIN) Biological Sampling
**Independent Study

Table 2.2. Observed age-frequency data for *Lutjanus analis*.

			N		
Age	FWRI St. Petersburg*	M. Burton	FWRI Tequesta Independent Study	FWRI Keys Independent Study	TOTAL
0	4		107		111
1	11	7	49	5	72
2	315	143	67	81	606
3	1346	326	245	98	2015
4	1147	295	91	54	1587
5	587	247	34	34	902
6	352	145	12	22	531
7	272	105	7	10	394
8	162	67	7	7	243
9	90	32	1	2	125
10	55	13	2	2	72
11	65	9		2	76
12	42	7			49
13	32	2			34
14	34	3		1	38
15	30	1		1	32
16	31	1			32
17	26	4		1	31
18	24				24
19	24				24
20	24				24
21	18	1			19
22	16				16
23	7	1			8
24	10	1			11
25	11	1			12
26	11				11
27	12				12
28	9				9
29	6	1			7
30	3				3
31	9	1			10
32	4				4
33	7				7
34	8				8
35	3				3
36	3				3
37	2				2
38	1				1
39	2				2
40	3				3
TOTAL	4818	1413	622	320	7173

* includes otoliths aged at FWRI and contributed from multiple sources, including NMFS Panama City Laboratory, FWRI, NMFS Beaufort Laboratory, NMFS Cooperative Research studies, and others.

Table 2.3. Age-specific natural mortality rates for *Lutjanus analis* following Lorenzen (2005) using the age and growth parameters in Table 4 and the mortality at t_{max} of 0.11 (Faunce et al. 2007). Total length (TL_{max}, tail compressed) is equivalent to the expected size at age from growth estimates.

Age	Length ($TL_{max,}$ mm)	M
0	166	0.399
1	271	0.273
2	360	0.216
3	436	0.184
4	501	0.163
5	556	0.148
6	603	0.138
7	643	0.130
8	677	0.124
9	706	0.120
10	731	0.116
11	752	0.113
12	770	0.111
13	786	0.109
14	799	0.107
15	810	0.106
16	819	0.105
17	827	0.104
18	834	0.103
19	840	0.102
20	845	0.102
21	849	0.101
22	853	0.101
23	856	0.100
24	859	0.100
25	861	0.100
26	863	0.100
27	865	0.099
28	866	0.099
29	867	0.099
30	868	0.099
31	869	0.099
32	870	0.099
33	870	0.099
34	871	0.099
35	871	0.099
36	872	0.099
37	872	0.099
38	872	0.099
39	873	0.099
40	873	0.099

Table 2.4. Discard mortality information from literature and SEDAR 7 sources. Depth bin 1 = < 30 m, depth bin 2 = > 30 m depth.

Source	Species	Mean depth(m)	30m depth bins	Average M*
CSA				
Wilson and Burns, 1996[1]	*E. morio* and *M. phenax*	22.0	1	7.0
Wilson and Burns, 1996[2]	*E. morio* and *M. phenax*	59.5	2	67.0
St. John and Syers, 2005[3]	*Glaucosoma hebraicum*	7.0	1	21.0
St. John and Syers, 2005[4]	*Glaucosoma hebraicum*	52.0	2	86.0
Broadhurst et al., 2005[5]	*Pagrus auratus*	.	1	18.0
Wilson et al., 2005[6]	*Lutjanus campechanus*	46.0	2	69.0
SEDAR 7				
Parker, 1985	*Lutjanus campechanus*	22.0	1	21.0
Parker, 1985	*Lutjanus campechanus*	30.0	1	11.0
Gitschlag and Renaud, 1994[7]	*Lutjanus campechanus*	22.5	1	1.0
Gitschlag and Renaud, 1994[8]	*Lutjanus campechanus*	28.5	1	10.0
Gitschlag and Renaud, 1994[9]	*Lutjanus campechanus*	38.5	2	44.0
Render and Wilson, 1994	*Lutjanus campechanus*	21.0	1	20.0
Patterson et al., 2002	*Lutjanus campechanus*	21.0	1	9.0
Patterson et al., 2002	*Lutjanus campechanus*	27.0	1	14.0
Patterson et al., 2002	*Lutjanus campechanus*	32.0	1	18.0
Diamond et at., 2004[10]	*Lutjanus campechanus*	30.0	2	53.0
Diamond et at., 2004[11]	*Lutjanus campechanus*	40.0	2	71.0
Diamond et at., 2004[12]	*Lutjanus campechanus*	50.0	2	69.0
Wilson and Nieland, 2004[13]	*Lutjanus campechanus*	60.0	2	69.5

* estimated from mid-point in range of mortality estimates

(1) In-situ study 0-14% < 44 m
(2) In-situ study on depth and mortality 67% >44m
(3) Demersal reef fish hook catch and release condition 0-14 m
(4) Demersal reef fish hook catch and release condition 45-59 m
(5) Estuarine hook and line tournament
(6) Commercial Multi-hook gear -9 -85m (ave. = 46m)
(7) 21-24m -for fish <32 cm
(8) 27-30m – for fish <32 cm
(9) 37-40m – for fish <32 cm
(10) 30m - oil platform study (Texas)
(11) 40m - oil platform study (Texas)
(12) 50m - oil platform study (Texas)
(13) Commercial 30-90m

Table 2.5. 2005-06 At-sea head boat observer data for mutton snapper, *Lutjanus analis*; release conditions from east (EFL) and west (WFL) Florida.

		Release Condition					
Region	Median Depth	Good	Fair	Poor	Dead	Total	Proportion*
EFL	<60'	2	1	1		4	0.50
	>60'	50	10	13	3	76	0.38
WFL	<60'	37	1			38	0.03
	>60'	14	2	2		18	0.22

*assumes all fishes not in good condition suffer complete mortality following a precautionary approach.

Table 2.6. Observed age at length data for *Lutjanus analis* a) Females b) Males c) All data combined

a)

Females n = 1615				
Age	n	Mean TL_{max} (mm)	S.D.	Range (mm)
0	20	205	77.5	116-478
1	12	289	50.3	223-390
2	175	397	40.1	227-509
3	591	438	38.0	318-580
4	424	493	49.4	396-655
5	193	563	61.9	382-727
6	86	634	63.3	424-770
7	38	674	52.6	569-802
8	27	696	64.1	572-815
9	11	724	68.0	554-806
10	8	723	72.7	600-838
11	4	757	47.0	700-801
12	6	724	70.5	613-808
13	2	683	38.5	656-711
14	4	779	104.4	639-877
15	4	822	37.0	770-851
16	1	806		806
17	3	801	77.9	721-877
18	0			
19	1	690		690
20	2	729	86.9	667-790
21	0			
22	0			
23	2	738	3.1	736-740
24	0			
25	1	750		750

b)

Males n = 2006				
Age	n	Mean TL_{max} (mm)	S.D.	Range (mm)
0	10	232	31	195-281
1	22	299	58.5	210-409
2	211	400	41.5	279-562
3	755	439	44.0	231-672
4	517	496	48.3	360-654
5	280	565	62.0	405-730
6	105	628	63.9	420-754
7	47	661	72.5	463-774
8	18	677	92.9	399-810
9	9	699	51.4	609-782
10	3	729	72.2	646-779
11	6	736	78.6	629-860
12	3	757	59.4	689-798
13	0			
14	1	835		835
15	4	695	88.5	569-776
16	1	714		714
17	1	827		827
18	3	756	51.7	705-808
19	2	785	103.5	712-858
20	3	753	80.9	663-819
21	1	754		754
22	0			
23	0			
24	0			
25	1	667		667
26	1	835		835
27	1	800		800
28	0			
29	0			
30	0			
31	1	848		848

Table 2.6. Continued.

c)

All		n = 7173							
Age	n	Mean TL_{max} (mm)	S.D.	Range (mm)	Age	n	Mean TL_{max} (mm)	S.D.	Range (mm)
0	111	161	53.2	105-478	21	19	870	45.4	754-964
1	72	259	83.9	99-409	22	16	863	55.4	716-939
2	606	399	39.3	191-562	23	8	787	74.8	645-868
3	2015	438	40.9	231-672	24	11	845	40.1	795-915
4	1587	495	52.7	310-705	25	12	838	84.0	667-944
5	902	565	64.0	281-808	26	11	865	37.6	810-912
6	531	629	68.0	400-947	27	12	850	47.0	749-901
7	394	671	67.3	463-857	28	9	873	49.0	790-950
8	243	695	72.3	399-852	29	7	865	33.3	832-950
9	125	727	77.3	513-923	30	3	897	60.6	828-936
10	72	751	75.7	593-901	31	10	873	37.7	812-923
11	76	773	71.6	540-904	32	4	843	54.3	770-901
12	49	788	73.5	613-904	33	7	851	41.1	792-896
13	34	813	59.5	646-890	34	8	863	18.2	836-882
14	38	820	59.7	639-939	35	3	841	16.5	822-852
15	32	810	76.1	569-942	36	3	861	57.6	799-912
16	32	824	84.5	601-958	37	2	867	13.5	857-876
17	31	824	71.7	596-917	38	1	876		876
18	24	831	57.0	705-905	39	2	840	1.9	838-841
19	24	850	67.5	690-953	40	3	832	26.8	804-857
20	24	829	77.3	663-947					

Table 2.7. Nonlinear likelihood summary of von Bertalanffy (1938) growth parameter estimates.

Parameter	Estimate	Standard Error	P value
L_{∞} (TLmax, mm)	874.44	5.26	<0.0001
K	0.16	0.002	<0.0001
t_0	-1.32	0.024	<0.0001
CV	0.112	0.0009	<0.0001

Table 2.8. Compilation of von Bertalanffy (1938) growth equation estimates for *Lutjanus analis*.

	-t_0	**K**	**L_∞ (mm)**	**Obs. max. TL**	**Ages**	**Location**	**Method**	**n**	**MMMI***	**Source**
1a ♀♂	0.94	0.16	869	880	1-17,21, 23,29	FL Atlantic Coast	Otoliths – MIA**, TL	1395	May	Burton, 2002
1b ♂	0.94	0.17	860	834		FL Atlantic Coast	Otoliths – MIA, TL	339		Burton, 2002
1c ♀	1.41	0.14	929	902		FL Atlantic Coast	Otoliths – MIA, TL	272		Burton, 2002
2	0.58	0.153	862	860	1-14	FL Atlantic Coast	Otoliths – MIA, TL	1005	Mar-May	Mason & Manooch, 1985
3	0.62	0.17	1,028		1-8	Margarita Island, Venezuela	urohyral bones- MIA, FL	266	Nov	Palazon & Gonzalez, 1986
4	1.42	0.116	807.5		1-9	NE Cuban shelf	urohyral bones- MIA, FL	2587	Jan	Pozo, 1979
5a	0.35	0.15	880		1-9	SW Cuba	FL		May	Claro, 1981
5b	0.43	0.1	1,170		1-8	NW Cuba	FL		May	Claro, 1981
6				642		Jamaica	FL			Thompson & Munro, 1974
7	1.32	0.16	874	964	0-40	FL Atlantic Coast	Otoliths – MIA, TLmax	7172	June	SEDAR 15A (This study)

* MMMI=Month of Minimum Marginal Increment.
** MIA=Marginal Increment Analysis; TL=Total Length; TLmax=TL (tail compressed to maximum length); FL=Fork Length

Table 2.9. Histological staging criteria used in this study for determining the maturity stage of female specimens of *Lutjanus analis*.

Stage	Maturity description	Description
1 - Immature	Immature	Only primary growth oocytes present; no atresia; ovarian membrane thin; ovarian membrane should be free of any large folds (indicative of stretching due to previous spawning.
2 - Developing	Mature	Only primary growth, cortical alveoli and a few partially yolked oocytes may be present; there may be minor atresia
3- Fully developed / Partially spent / Redeveloping	Mature	Primary growth to advanced yolked oocytes present; may have some left over hydrated oocytes and POFs from previous spawning; might have atresia of advanced yolked oocytes, but no major atresia (only minor/moderate) of other oocytes
4 – Final oocyte maturation (FOM) / Hydrated	Mature	Primary growth to FOM/hydrated oocytes present; may have minor/moderate atresia of advanced yolked oocytes; germinal vessel migration (beginning of FOM); hydrated oocytes unovulated.
5 – Running ripe	Mature	Primary growth to ovulated, hydrated oocytes present; often minor/moderate atresia of advanced yolked oocytes; occasionally only hydrated and primary growth oocytes present; most of the hydrated oocytes will be concentrated in the lumen, giving the ovary cross-section the appearance of a jelly donut.
6 - Regressing	Mature	Primary growth and cortical alveoli oocytes present; yolked oocytes being resorbed; major atresia; may be remnant hydrated oocytes or degenerating POFs.
7 – Resting or Regenerating	Mature	Most oocytes (>90%) are primary growth; may have other oocytes in late stages of atresia; more follicular tissues than immature fish; presence of large folds on the ovarian membrane (indicative of stretching due to previous spawning).

Table 2.10. Logistic model fits for maturity related to (a) size and (b) age for *Lutjanus analis* during the peak spawning months of April-June residing in Florida. SE=standard error, SS=sum of squares for model F-tests.

A) Size

Parameter	Estimate	SE	
R	0.056	0.010	
L_{50} (TLmax, mm)	353.5	3.43	
Variance Source	DF	SS	P
Model	2	136.8	<0.001
Error	180	6.23	

B) Age

Parameter	Estimate	SE	
R	3.682	0.831	
A_{50} (Years)	2.072	0.054	
Variance Source	DF	SS	P
Model	2	126.1	<0.001
Error	168	6.87	

Table 2.11. Summary of occurrence and abundance patterns within various marine habitats for life-history stages of *Lutjanus analis* within the Caribbean (Table adapted from Essential Fish Habitat Generic Amendment to the Fishery Management Plans of the U.S. Caribbean Including a Draft Environmental Assessment. October 1998 accessed via the worldwide web). Table demonstrates population distribution bottlenecks during spawning until settlement.

	Life History Phase				
Habitat	Eggs	Larvae	Juvenile	Adult	Spawners
Planktonic	Present	Present			
Mangroves			Present	Present	
Seagrass			Present	Present	
Algae			Present	Present	Occasional
Plain			Present	Present	Present
Reef			Present	Present	Present
Reef/SAV interface			Present	Present	Occasional
Sand			Present	Present	Occasional
Hardbottom			Present	Present	Present
Mud			Occasional		Occasional

Table 2.12. Length-length (mm) and Length-weight relationships developed for Florida *Lutjanus analis*. Regressions are in the form Y = *a* + *b*X. SL: standard length (mm); FL: fork length (mm); TL: total length (mm); TW: total weight (kg), GW: gutted weight (kg).

LENGTH-LENGTH

Source	Y (mm)	*a*	*b*	X (mm)	*n*	Min X (mm)	Max X (mm)	Avg. X* (mm)	MSE*	Adj. r^2	Σx^2*	Σxy*	Σy^2*
SEDAR 15a	SL	-13.531	0.882	FL	1031	195	784	428.20	30.263	0.99	8578038.63	7567047.22	6706349.82
	$TL_{relaxed}$**	10.015	1.065	FL	1511	195	784	428.23	99.463	0.99	11062316.23	11777983.29	12690039.76
	TL_{max}***	28.956	1.222	SL	969	163	680	365.68	65.511	0.99	6600011.90	8068471.07	9927001.96
	TL_{max}	8.804	1.087	FL	951	195	768	428.40	16.165	0.99	7958892.75	8655554.36	9428537.15
	TL_{max}	6.179	1.015	$TL_{relaxed}$	957	208	831	462.02	37.030	0.99	9244272.70	9387564.91	9568442.07
Burton 2002	TL	8.91	1.08	FL	249					0.99			
	TL	20.53	1.21	SL	285					0.99			
Thompson and Munro (1983)	SL	-2.0	0.85	FL			220	450					
	TL	7.0	1.09	FL			220	450					

LENGTH-WEIGHT

Source	Ln (Y [kg])	Ln(a)	b	Ln (X[mm])	*n*	Min [mm]	Max [mm]	Avg. Ln(X [mm])	MSE	Adj. r^2	Σx^2	Σxy	Σy^2
SEDAR 15a	TW	-16.5739	2.8670	SL	492	209	680	5.9037	0.01094	0.97	18.1573	52.0576	154.6092
	TW	-18.0306	3.0275	FL	3232	215	829	6.0832	0.01642	0.96	132.2398	400.3635	1265.1756
	TW	-18.3791	3.0402	$TL_{relaxed}$	945	261	851	6.1438	0.02287	0.92	26.7678	81.3787	268.9721
	TW	-18.6469	3.0789	TL_{max}	459	270	858	6.1749	0.00645	0.98	15.3513	47.2642	148.4668
	GW	-18.1915	3.0487	FL	1101	270	877.5	6.4105	0.00597	0.99	56.3955	171.9311	530.7154
Burton 2002	TW	-18.42	3.05	TL	413	~300	~875			0.96			
	TW	-17.93	3.08	SL	282	~160	~710			0.98			
Bohnsack and Harper (1988)	TW	-4.8030	3.0112	FL	365	116	722			0.97			
Watanabe (2001)	TW	-18.4207	3.0499	TL									

*Avg. X, MSE, Σx^2, Σxy, Σy^2 - Mean of independent variable (X), mean square error and corrected sums of squares (CSS) for the independent variable (X), corrected sum of cross-products for XY, and CSS for the dependent variable (Y); used for generating prediction intervals and for analysis of covariance (Zar 1996), and MSE also used for bias corrections for the means of log-transformed data [e.g., Haddon (2001)]. Usually, lengths were measured to the nearest centimeter, and weight to the nearest 0.02 kg. However, some data may have been taken using length measurements to the nearest 0.5 cm or in fractions of inches and weight measurements to the nearest 0.1 or 0.01 pound. Estimates derived from the above equations should be rounded to the nearest centimeter and nearest 0.02 kg. The number of decimal places shown in the table were meant solely to reduce rounding errors for calculations of the prediction intervals and for generating sums of squares and cross-products needed for analysis of covariance.

$TL_{relaxed}$** - Tail flat, in its natural state

TL_{max}*** - Tail compressed to its maximum length

2.15 Figures

Figure 2.1. Proportion of *Lutjanus analis* captured by the recreational (pink line, squares) and commercial (blue line, diamonds) sectors.

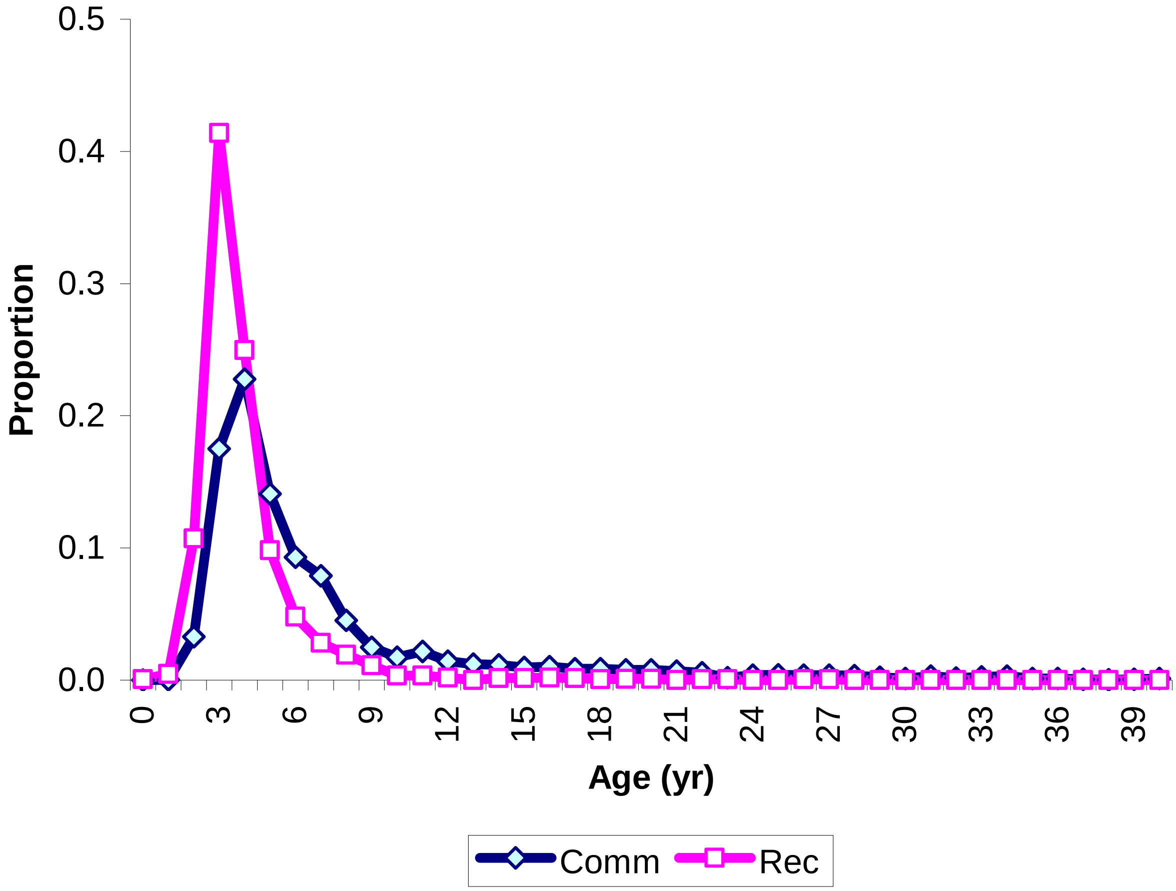


Figure 2.2. Cumulative distribution of *Lutjanus analis* catch by the recreational and commercial fishery sectors.

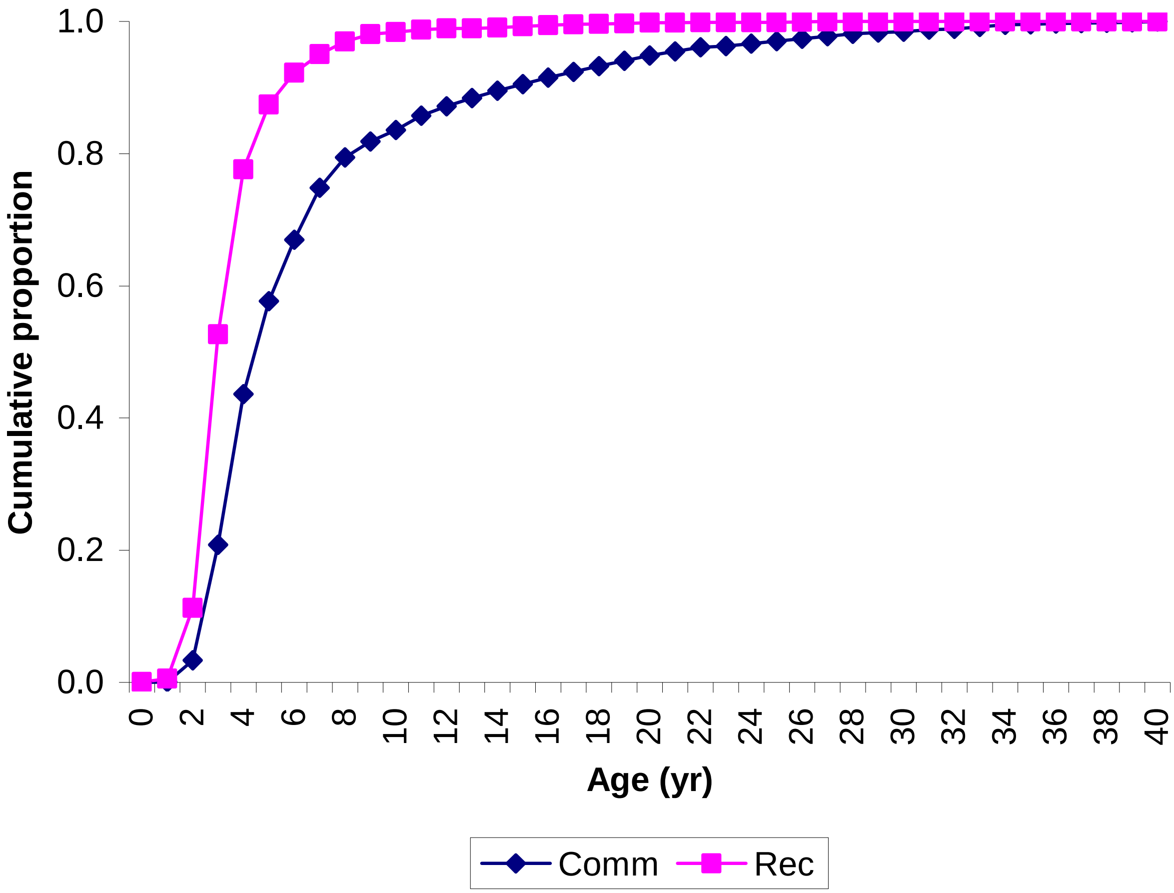


Figure 2.3. Age-specific natural mortality rates for *Lutjanus analis*.

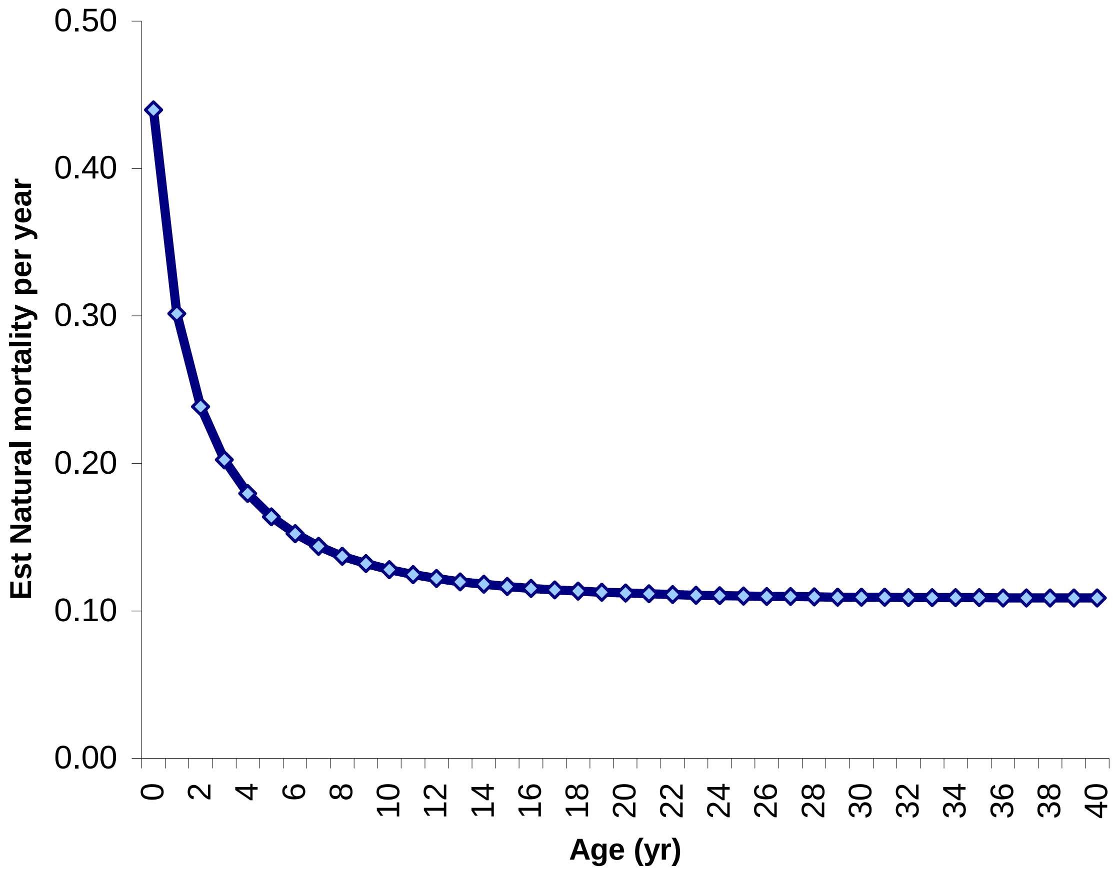


Figure 2.4. Satellite image and color enhancement of Florida bathymetry illustrating the preponderance of red and orange (depths less than 30 m) on the majority of the Florida shelf. Image courtesy of Google earth, while layer produced by USGS.

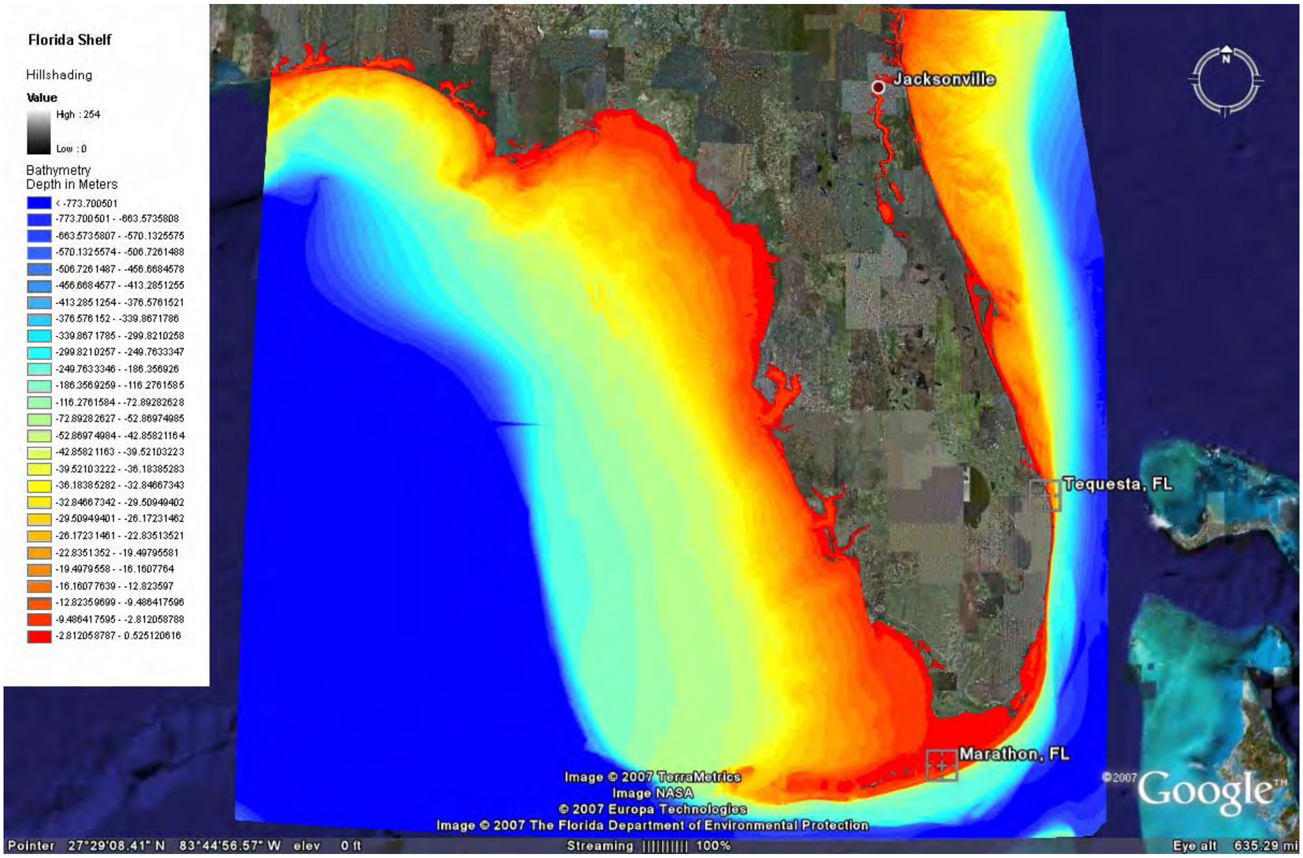


Figure 2.5. Discard mortality rates for two depth classes; <30m = depth class 1, and > 30 m = depth class 2.

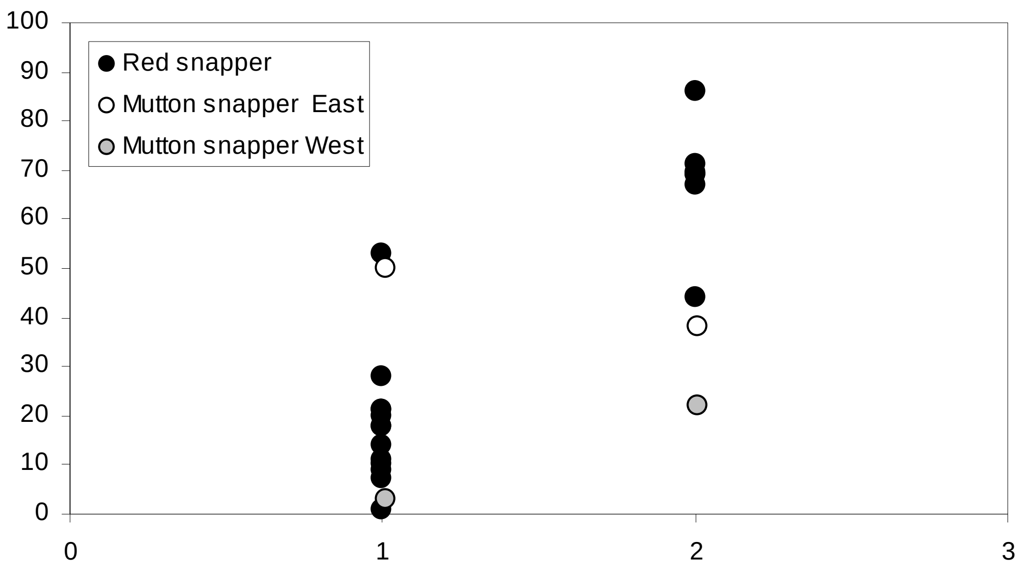
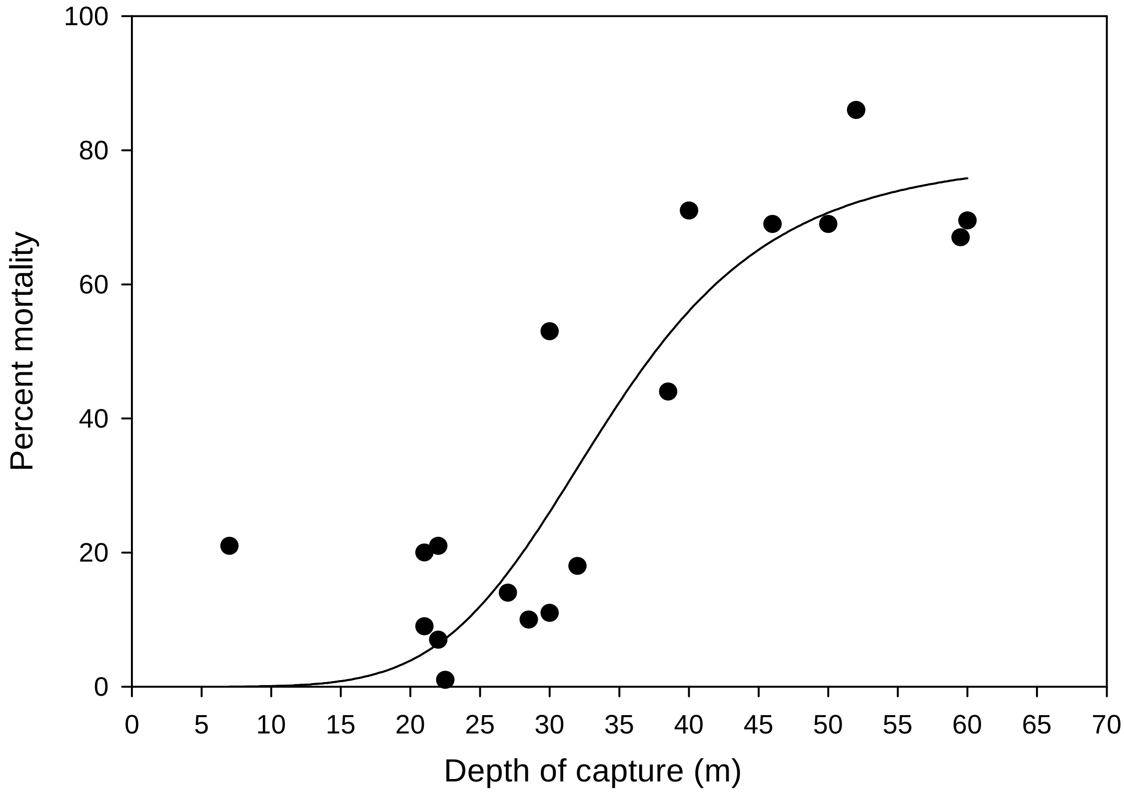


Figure 2.6. Discard mortality as a function of depth of capture (top figure) and associated residuals with fitted logistic curve (bottom).



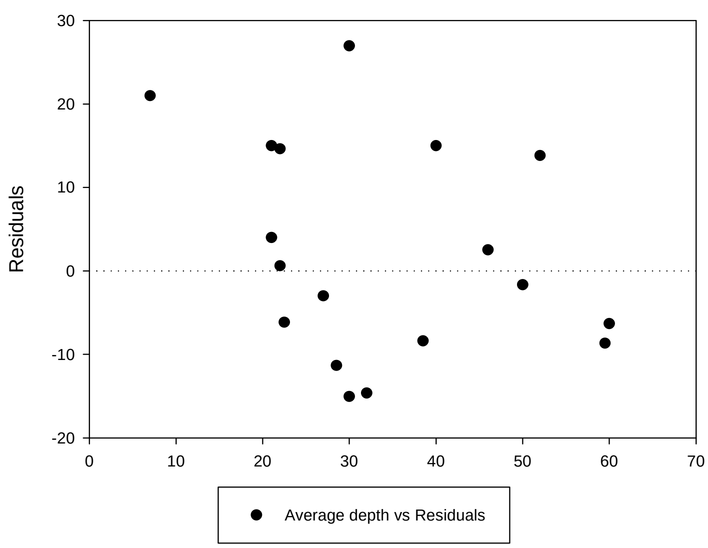


Figure 2.7. Percent frequency of edge type by month for the calibration set of *Lutjanus analis* otoliths.

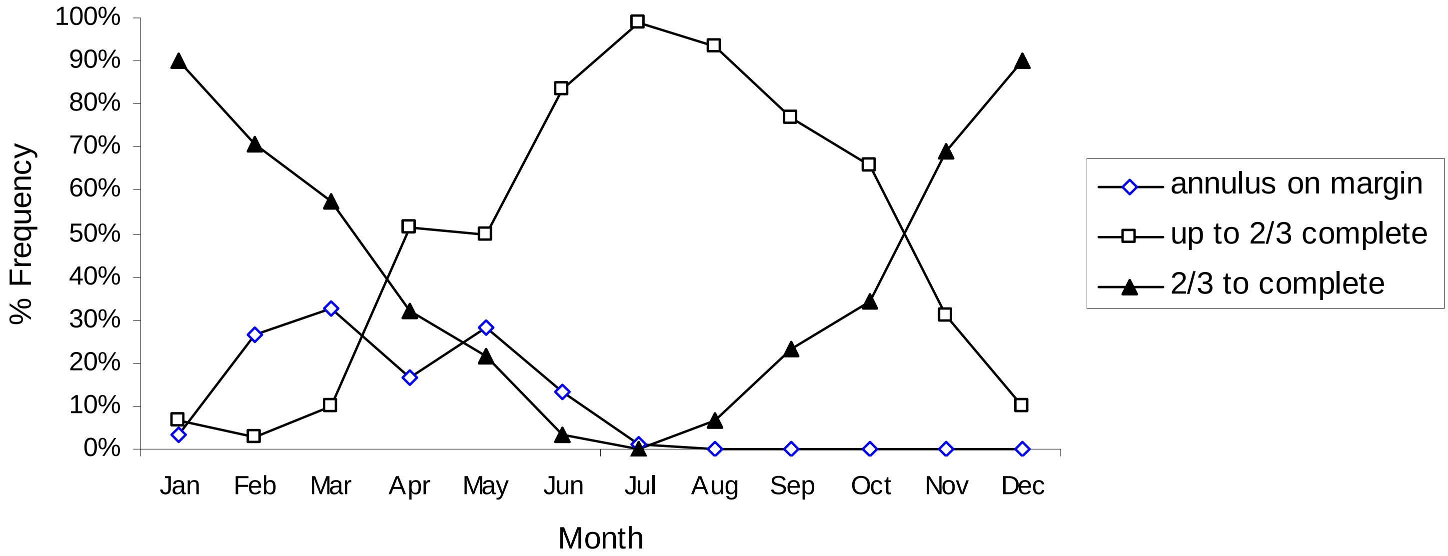


Figure 2.8. Age frequency (proportion) for *Lutjanus analis* by project.

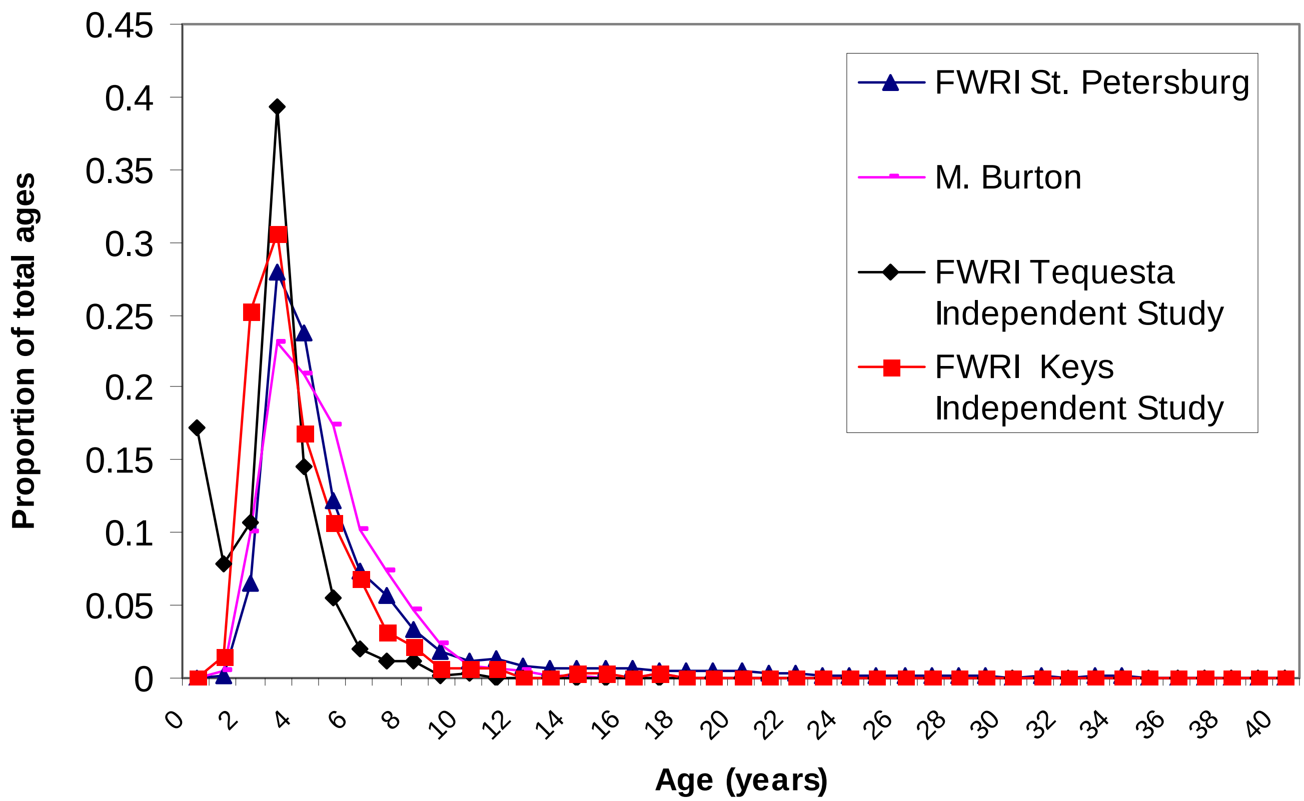


Figure 2.9. Cumulative percent age frequency of *Lutjanus analis*.

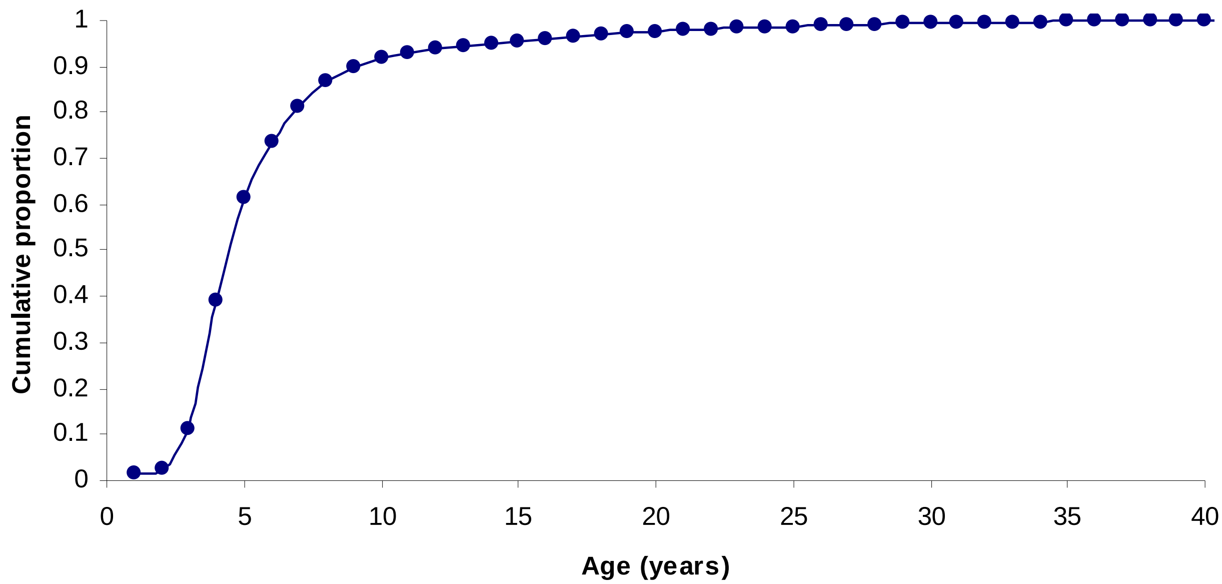


Figure 2.10. Total length ($TL_{max,}$ mm) at age and estimated size at age from von Bertalanffy (1938) growth function of the current study.

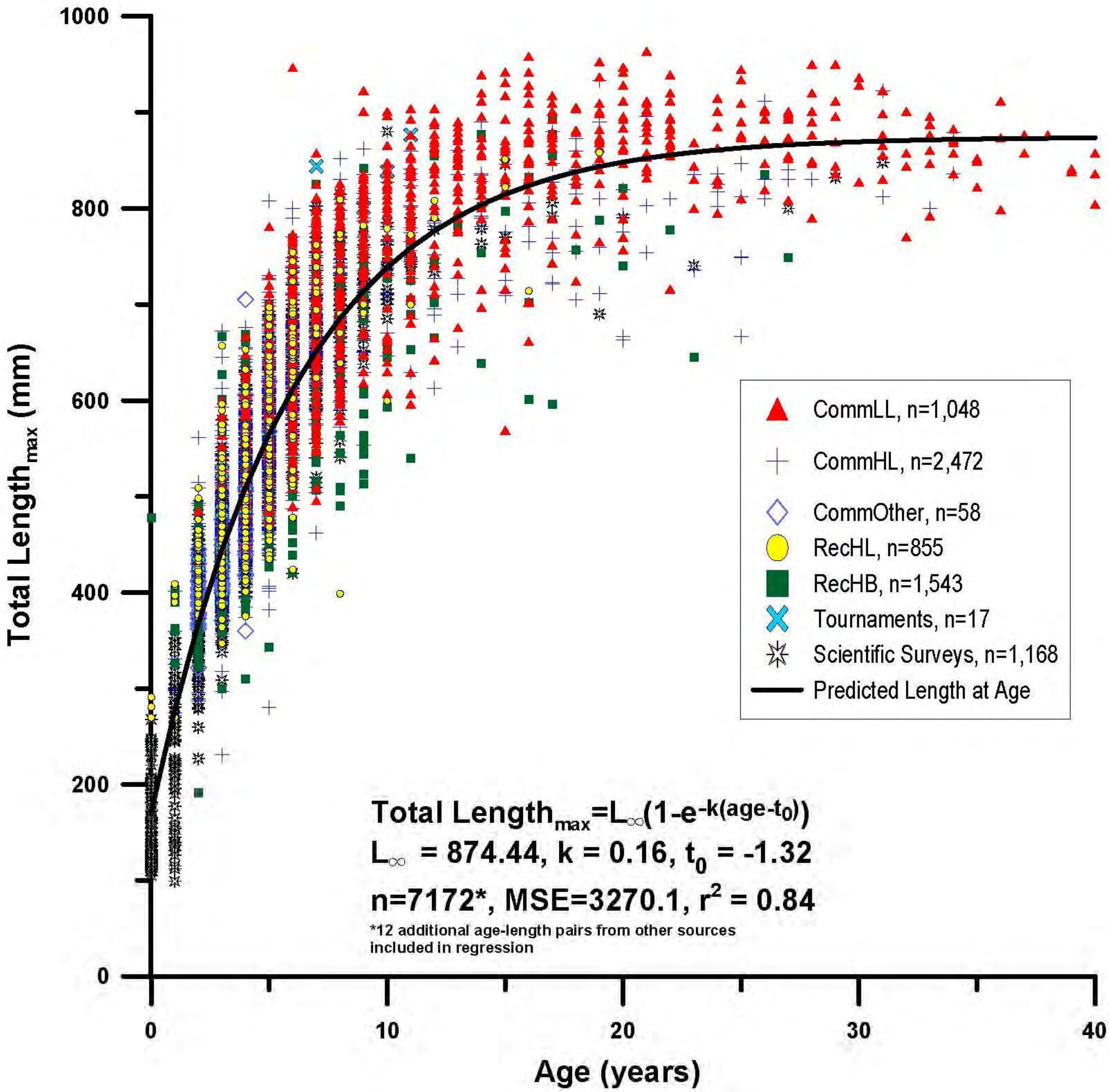


Figure 2.11. Female gonadosomatic index of *Lutjanus analis* (average ± 1 standard error) from two data sources. Horizontal lines indicate yearly averages. Reproductive seasonality is inferred during months of elevated GSI values.

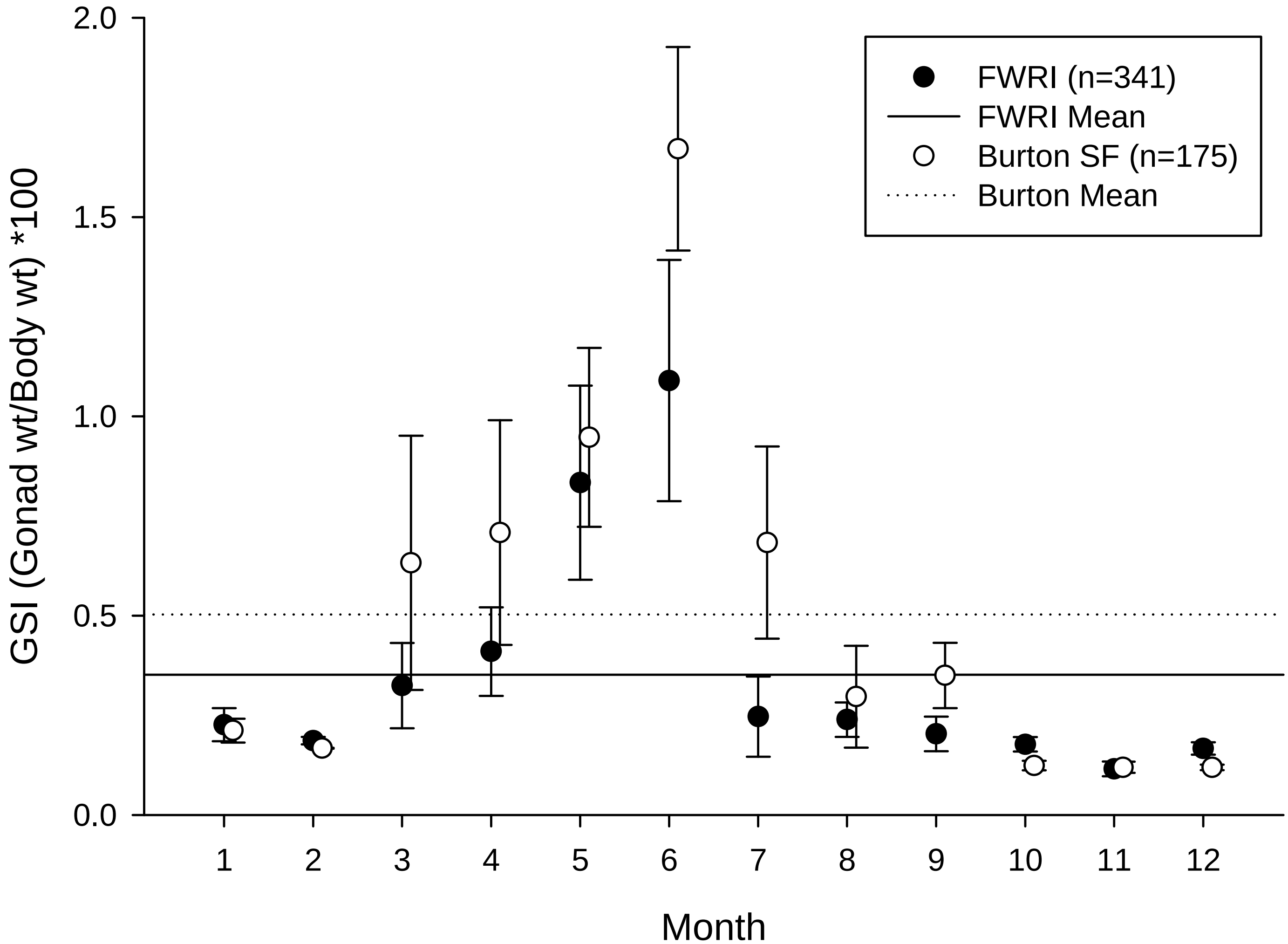


Figure 2.12. Gonad maturity stages for female *Lutjanus analis* observed as a proportion of all females from the two FWC laboratories during each month of the year. Stages: 2=developing, 3=vitellogenic oocytes dominate; 4=gravid (hydrated oocytes present); 6=regressing, 7=resting.

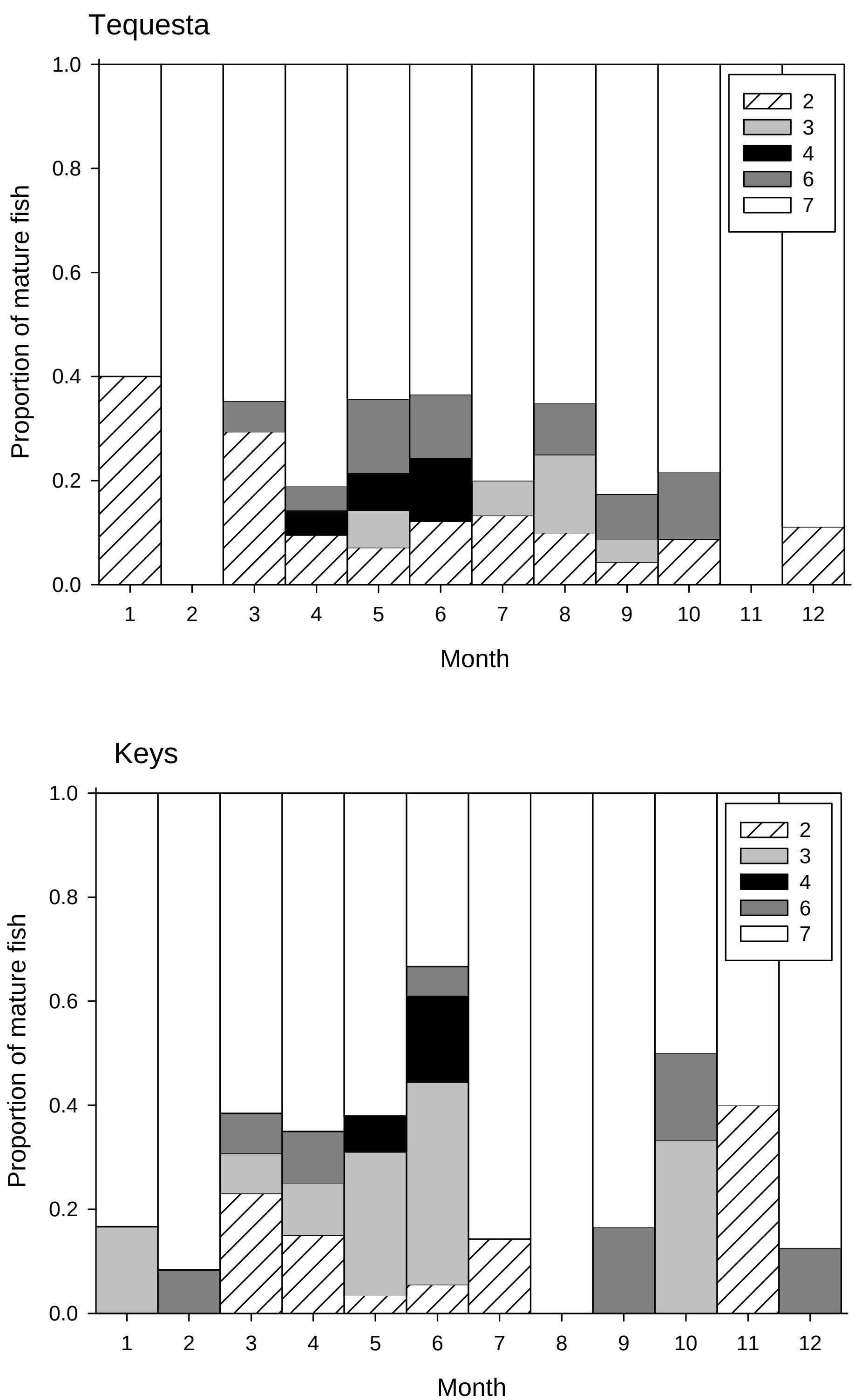
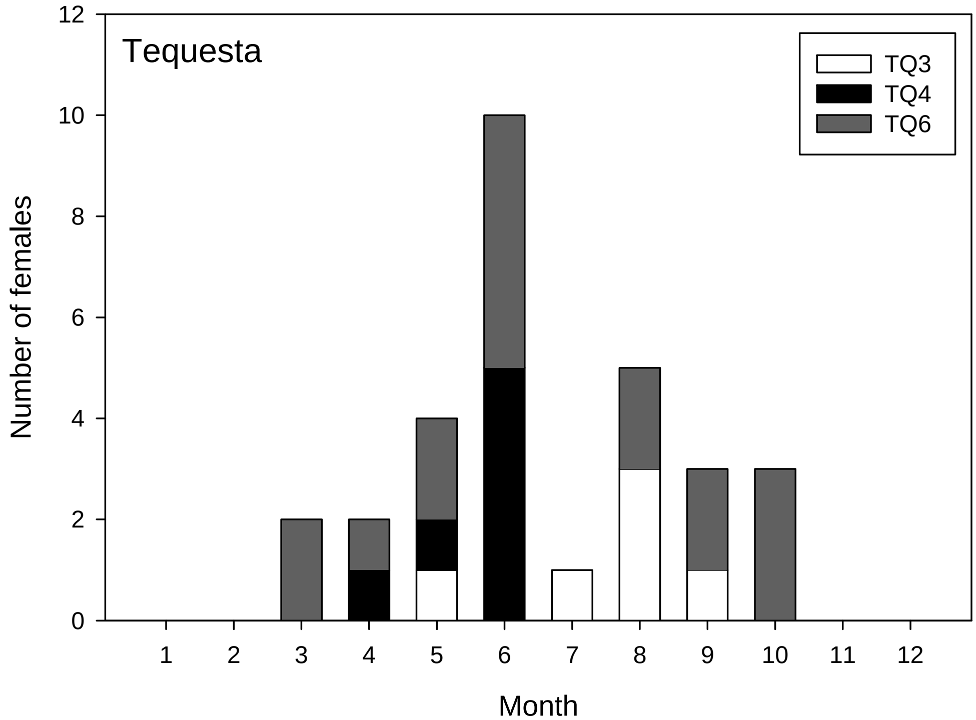


Figure 2.13. Gonad maturity stages 3-6 of female *Lutjanus analis* collected in Florida waters. Gonad maturity stages follow Figure 6.



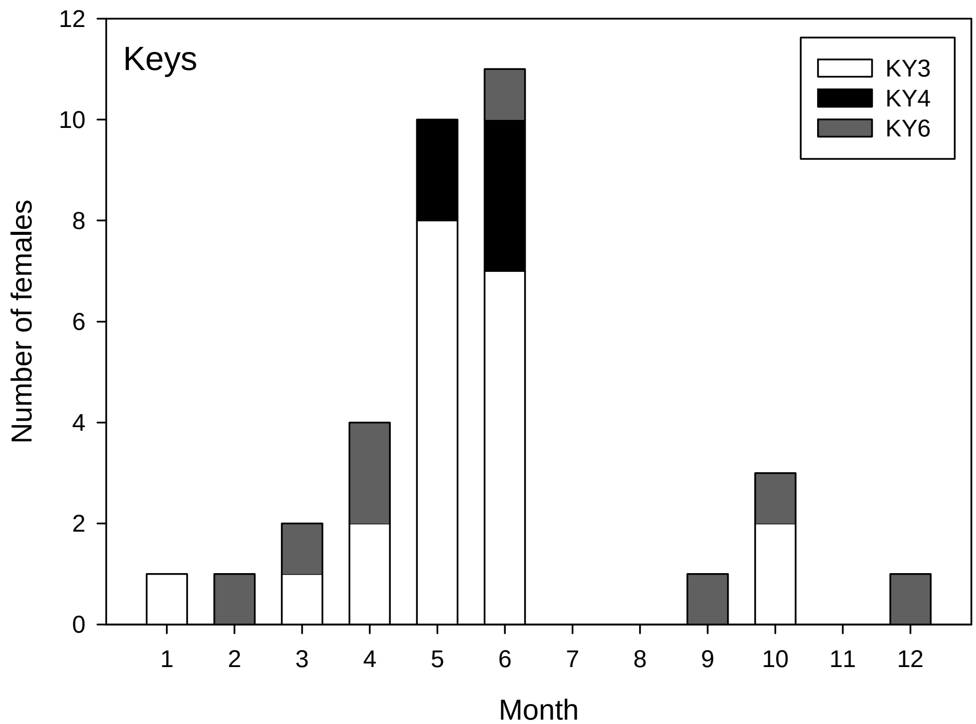


Figure 2.14. Maturity schedule for female *Lutjanus analis* residing in Florida waters in terms of size (TL_{max}, mm) compared to two Caribbean data sources. Black long dashed line indicates recreational 16" size limit.

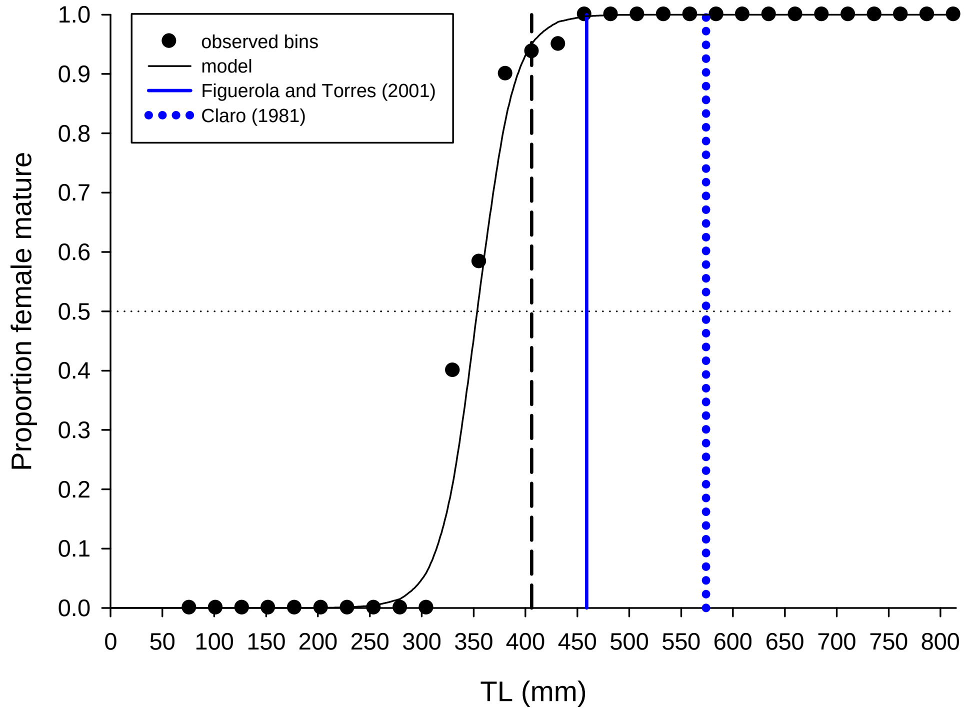


Figure 2.15. Maturity schedule for female *Lutjanus analis* residing in Florida waters in terms of age (years) compared to prior published results from Cuba.