Marine Resources Monitoring, Assessment and Prediction Program: Report on Atlantic Red Snapper, *Lutjanus campechanus*, Life History for the SEDAR 41 Data Workshop

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Introduction

Red Snapper, *Lutjanus campechanus*, is a large, long-lived, member of the family Lutjanidae. Red Snappers are distributed in marine waters throughout the Gulf of Mexico south to the Yucatan Peninsula and in United States Atlantic waters north to North Carolina (Nelson and Manooch, 1982; Manooch and Potts, 1997). Adult Red Snapper are associated with structured habitats such as coral reefs, wrecks, gas and oil platforms, rocky outcroppings, and live-bottom habitats (Powles and Barans, 1980; Moseley, 1966; Nelson and Manooch, 1982). The mean maximum depth in the commercial Red Snapper fishery, in the Gulf of Mexico, was 71 m (range 19 to 823 m; SEDAR 15).

The periodicity of increment formation for Red Snapper otoliths in the Atlantic was found to be June through August by White and Palmer (2004). In contrast, McInerny (2007) reports that increment formation occurs in April. The difference is probably related to sampling location, as 88% of McInerny's Red Snapper samples came from Florida.

The maximum recorded age for Red Snapper, using otolith opaque zone counts is 57 years for the Gulf of Mexico (Allman et al. 2002), and 54 years for the Atlantic (McInerny, 2007). Using measurements of nuclear-bomb carbon 14 in otoliths, Baker and Wilson (2001) confirmed that the longevity of Red Snapper in the Gulf of Mexico is at least 55 years.

White and Palmer (2004) is the only published reference on the reproductive biology of Red Snapper along the Atlantic coast of the southeastern U.S. Fishery-independent and fishery-dependent samples collected by the South Carolina Department of Natural Resources' (SCDNR) Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program during 2000-2013 were added to the White and Palmer (2004) data set (for a total of 3019 specimens) in preparation for SEDAR 41. The sexual pattern in Red Snapper is gonochorism. Red Snapper from the Atlantic waters of the southeastern U.S. spawn during May through October with peak spawning occurring July through September (White and Palmer, 2004).

There is a dearth of information regarding young (age 1 or less) Red Snapper, from the Atlantic waters of the southeastern U.S. Unlike the Gulf of Mexico, where young Red Snapper have been extensively studied (Workman & Foster, 1994; Szedlmayer & Howe, 1997; Workman et al., 2002; Bentley et al., 2005; Patterson & Wilson, 2005; Gallaway et al., 1999; Gazey et al., 2008), there are no published reports of young-of-year (YOY) Red Snapper in the Atlantic (Rindone, et al, In press). Although White and Palmer (2004) comment on examining five YOY (59-133 mm Total Length) specimens to aid in the first annulus determination, they did not include those specimens in their data set for analysis. Those five specimens, plus an additional one YOY captured in 1980 by MARMAP, and 13 YOY captured in 2013 by Southeast Area Monitoring, Assessment, and Prediction-South Atlantic (SEAMAP-SA; n=7) and Southeast Fishery-Independent Survey (SEFIS; n=6), have been added to the White and Palmer (2004) Red Snapper data set in preparation for SEDAR 41 (Total YOY N=19) .

This report describes analyses of data collected by MARMAP, SEAMAP-SA, and SEFIS whose combined efforts comprise the Southeast Reef Fish Survey (SERFS, for details of these programs see Ballenger et al. 2012b).

Materials and methods

The Southeast Reef Fish Survey's (SERFS) primary sampling area is between Cape Hatteras, NC and Cape Canaveral, FL, however, for SEDAR 41, the data includes samples of Red Snapper specimens collected from coastal and offshore waters between Cape Lookout, North Carolina, and Key West, Florida, between 1977-2013 (n=3019). Specimens were collected during standard sampling by the MARMAP program (fishery-independent, SCDNR-Marine Resources Research Institute (MRRI) Project IDs: P05, Q26, T59, & T60) using blackfish traps (gear code 053), chevron traps (MRRI gear code 324), commercial high rise roller trawl (gear code 226), flatline otter trawl, Florida traps (gear code 074), hook and line gear (gear code 014), mini-Antillean "S" traps (gear code 041), mongoose type Falcon trawl (233), short-bottom longline (gear code 061), snapper/bandit reel (gear code 043), and 3/4 scale Yankee trawl (gear code 022); Collins, 1990; Harris and McGovern, 1997; Harris et al, 2004; MARMAP, 2009). Red Snapper specimens were obtained from commercial catches (fishery-dependent, Project IDs: P50, T12) using snapper/bandit reel (gear code 043) and speargun (gear code 065). Summary tables were generated for gear deployment, fish collected, and fish aged per gear type and year (Tables 1, 2, & 3; Appendices A & B).

Whole Red Snapper were weighed to the nearest gram (g) and maximum (pinched tail) total length (TL), fork length (FL), and standard length (SL) were measured to the nearest mm. The left sagittal otolith and, when possible, the right sagittal otolith were removed from all fish and stored dry prior to processing.

In the laboratory, the left otolith was embedded in West System 105 epoxy resin, sectioned dorsoventrally to a thickness of 0.4 mm, and mounted on glass microscope slides using Accu-mount 60 mounting medium (Baxter Scientific Products). One to three otolith sections were examined with transmitted light under a dissecting microscope. Counts were made from the core of each otolith to the outer edge of each opaque zone and to the edge of the otolith. Sections were examined independently by two readers and re-examined jointly when differences in age estimation occurred. If disagreement persisted, the specimen was eliminated from age analyses. In addition, quality and edge type was recorded (Table 4).

Age Data

All age data provided to SEADAR41 included increment count, calendar age, and fractional age. The adjusted calendar age is based on timing of annulus formation (July) and width of translucent edge present. If the otolith section had an opaque edge, regardless of date captured, the calendar age equals the number of increments (annuli) counted on the section. If the otolith section had a translucent edge and was captured during or after July, the calendar age equals the number of increments counted on the section. If the otolith section had a narrow translucent edge (MRRI code: 1 or 2) and was captured before July, then calendar age equals the number of increments counted on the section. If the otolith section had a wide translucent edge (MRRI code: 3 or 4) and was captured before July, then calendar age equals the number of increments counted on the section plus one. The fractional age was calculated by adding or subtracting fractions of a year, corresponding to the month of capture from the calendar age, using a July 1 birth date. The analyses of age, growth, and reproduction in this report were based on adjusted calendar age.

Reproductive data

A sample from the posterior portion of the gonad were fixed in 10% seawater formalin solution for 7-14 days and transferred to 50% isopropanol for 7-14 days. Tissue samples were processed in an Auto-Technicon 2A Tissue Processor or automated (self-enclosed) tissue processor and blocked in paraffin. Three transverse sections (6-8 m) were cut from each sample with a rotary microtome, mounted on glass slides, stained with double-strength Gill hematoxylin, and counterstained with eosin-y.

Two readers independently determined sex and reproductive state using standard histological criteria (Table 5). When assignments differed, the readers re-examined the section simultaneously to determine reproductive state. To ensure that females were correctly assigned to the immature and regenerating categories, the length frequency histogram of females that were definitely mature (i.e., those that were developing, spawning or regressing) was compared with histograms of immature and regenerating females.

Specimens with developing, spawning, regressing, or regenerating gonads were considered sexually mature. For females, this definition of maturity included specimens with oocyte development at or beyond the cortical alveolar stage and specimens with beta, gamma, or delta stages of atresia (Hunter and Macewicz 1985). To estimate length at 50% maturity (L50) and age at 50% maturity (A50) the PROBIT procedure (SAS Institute, Inc., 1990) was used. The LOGISTIC procedure was used to determine which model (Gompertz, Logistic, or Normal) provided the best fit to maturity data.

Females were considered to be in spawning condition if they possessed one or more of the following criteria: migratory nucleus oocytes, hydrated oocytes, and postovulatory complexes (POCs). We obtained two estimates of spawning frequency based on histological criteria (presence of migratory nucleus (MN) or hydrated (HO) oocytes; presence of POCs 12-36 hr old) that indicate imminent or recent spawning (Goldberg 1980; Hunter et al. 1986). Estimates of spawning frequency represented the proportion of specimens with each criterion among reproductively active females (i.e., vitellogenic oocytes present, developing and spawning reproductive states) collected during the spawning season. To evaluate the level of reproductive activity in the population over the spawning season (i.e., spawning fraction), an analysis was run to calculate the proportion of spawners among all adult females (active+inactive) by month. To calculate spawning fraction, a spawner is considered any female with at least one indicator of imminent spawning (MN or HO oocytes) or recent spawning (POCs).

Sex ratio data were analyzed using a Chi-square goodness of fit test to determine if these ratios differed among size classes from an expected 1:1 (Zar, 1984). The information presented in this report on spawning seasonality, sexual maturity, and sex ratio is based on the most accurate technique (histology) utilized to assess reproductive condition in fishes.

Results

Red Snapper included in the analyses for SEDAR 41 were captured between latitude 24.34° and 35.02° N and at a depth range of 7 to 97 meters, from fishery-independent and fishery-dependent sources, between 1978 – 2013 (n=3019). Specimens ranged in size from 59 to 997 mm TL. Increment counts in sagittal otoliths ranged from 0-45. All Red Snapper < 150 mm TL (n=32) were captured at depth of 7-18 meters ($\overline{x}$=15 m). Raw data were provided to the SEDAR 41 Data Workshop in 2014.

Length-length and length-weight conversions

Total length was strongly correlated to FL, SL, and total body weight in pounds (lbs) among fishery-independent samples regardless of sex or gear (Table 6).

Length-at-Age

The age range for Red Snapper in the samples was 0-45 (fishery-dependent and independent combined). The age range for fishery-independent Red Snapper was 0-26 (1981 to 2013). The von Bertalanffy growth curve demonstrated visually that Red Snapper, sexes combined, from fishery-independent data do not approach asymptotic size until nearly age 20 (Figure 1). In addition, von Bertalanffy growth curves based on fishery-independent data demonstrated that growth in Red Snapper did not differ between sexes (Figure 2), whereas, there was a temporal difference in growth rate (k) (1978-2000 vs 2001-2013)(Table 7; Figure 3). Due to the higher growth rate in 2001-2013, further analyses were performed, between time periods, on separate data sets in many cases outlined below. Each time period (1978-2000 and 2001-2013) had similar numbers of specimens (1978-2000, n=1387; 2001-2013, n=1632). Strict Red Snapper management restrictions, i.e. prohibition of Red Snapper, were implemented since 2001 (SAFMC/SERO, 2014). Sampling effort for Red Snapper increased after 2009 with the start of SEFIS.

Reproduction

There was little overlap in the length distributions of immature or regenerating/CAO Red Snapper and substantial overlap of regenerating/CAO and definitely mature individuals, indicating that maturity stages were assigned correctly for both sexes (Figures 4a and 4b). All fishes staged for maturity were included in the analyses below, regardless of project, gear, or source (fishery-independent and dependent). Age and length-based maturity analyses were done using calendar age and maximum (pinched tail) total length. Age for females at 50% maturity (A50) was 1.6 yr (Logistic, proportion mature = 1 - 1/(1 + exp(a+b*age)); 95% confidence intervals (CI) = 1.4-1.8 yr) and length at 50% maturity (L50) was 340 mm TL (Logistic, 95% CI = 331-349 mm; Table 8). Mature gonads were present in 29% of females at age 1, 62% of age 2, 91% of age 3, 96% of age 4, and 100% of females age 5 or older (Table 9

& 10). Mature males were present in 93% of age 1, 96% of age 2, 98% of age 3, and 100% of age 4 or older (Table 9). The Model could not be fit to the data to produce a reliable estimate of age for males at 50% maturity (A50). Length at 50% maturity (L50) for males was 160 mm TL (Logistic, 95% CI = 68-205 mm).

Age and length at maturity for male and female Red Snapper were significantly different between time periods (1978-2000 & 2000-2013; Table 10). Age at maturity for female Red Snapper in 1978-2000 and 2001-2013 was 2.0 yr (Logistic, 95% CI = 1.6-2.2 yr) and 1.5 yr (Logistic, 95% CI = 1.3-1.7 yr), respectively.

Length at maturity for female Red Snapper from 1978-2000 and 2001-2013 was 381 mm TL (Logistic, 95% CI = 366-392) and 321 mm TL (Logistic, 95% CI = 311-330; Table 8) respectively. Length at maturity for male Red Snapper from 1978-2000 and 2001-2013 was 169 mm TL (Logistic, 95% CI = -20-236) and 102 mm TL (Logistic, 95% CI = -301-192) respectively.

Analyses indicated that there are differences in sex ratio for Red Snapper, among certain age and size classes (Table 11 & 12). Males were predominant at sizes less than 400 mm TL and ages less than 3. Females were predominant at sizes greater than 600 mm TL and ages greater than 10. The overall sex ratio for Red Snapper was not significantly different from the expected 1:1.

Spawning season for Female Red Snapper is April-November, with peak being June-August (Figure 5). The capture of spawning females in November had not been previously reported. To evaluate the level of reproductive activity in the population over the spawning season, an analysis was run to calculate the proportion of spawners among all adult females (active+inactive) by month. The results showed that the proportion of female Red Snapper with at least one indicator of imminent spawning (MN or hydrated oocytes) or recent spawning (postovulatory complexes) is consistently around 0.5, as the proportion ranged from 0.45 to 0.54 during June through September, which includes the peak of spawning (Table 13). To determine if age (size) has an effect on spawning proportion, the data were also examined by age class within month. The results showed that the overall proportion of spawners was relatively consistent at Ages 2-14, ranging from 0.29 to 0.48. At Age 1, the overall proportion of spawners was somewhat lower (0.14) and there was evidence of a higher proportion (0.55) of spawners in a combined age category representing the oldest age classes (Ages 15-38); however, sample sizes were small ($\leq$ 14).

The proportion of female Red Snapper from chevron trap catches with indicators of imminent or recent spawning among specimens with oocytes undergoing vitellogenesis was consistently around 0.25 to 0.35 for most months of the spawning season (Table 14); monthly sample sizes ranged from 30 in October to 127 in June. The overall proportion of females with MN or hydrated oocytes (0.23) was similar to the proportion with POCs 12-36 h old (0.22). The inverse of the average of the two proportions (0.225) corresponded to the occurrence of a spawning event approximately every 4-5 d. Data from hook-and-line catches revealed much greater variability in the estimates of overall proportion of spawning females, 0.08 for females with MN or hydrated oocytes vs. 0.32 for females with POCs 12-36 hr old; however, monthly sample sizes were smaller, ranging from 12 to 67.

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Appendix A: SCDNR-MRRI Project Codes and descriptions

The following projects represent the source of Red Snapper for SCDNR/MRRI/MARMAP program:

Fishery Independent Projects

Project **P05**: MARMAP, 1973-2014. Long-term (41 years) reef fish monitoring project.

Project **P94**: SEAMAP, 1986-2014. Long-term (28 years) coastal water (trawl) survey project.

Project **Q26**: MARFIN /MARMAP (Gag spawning project), 1995. MARFIN grant funded project to verify gag spawning areas/aggregations.

Project **T59**: SEAMAP Complement, 2009-2014. Short-term (4 years) reef fish monitoring project.

Project **T60**: SEFIS, 2010-2014. Short-term (4 years) reef fish monitoring project.

Fishery Dependent Projects

Project **P50**: Commercial Fishery, 1980-2009, Red Snapper otoliths and gonads collected by SCDNR personnel from the commercial fishery. There were no regulations for Red Snapper 1980-1983. Commercial regulations for Red Snapper from 1984-1992 include a size limit of 12" TL (305 mm). Commercial regulations for Red Snapper during 1993-2009 include a size limit of 20" TL (508 mm). Samples collected in 2012-2013 are from the 'Red Snapper Emergency Rule' (mini-seasons) established to allow limited harvest for the recreational and commercial fishery. In 2012 the number of days the Red Snapper season was open for recreational and commercial fishery was six and 14 days respectively. In 2013 the number of days the Red Snapper season was open for recreational and commercial fishery was three and 43 days respectively.

Project **T12**: Commercial Fishery/MARFIN (Red grouper project- east coast of Florida & Georgia), 1999-2001, Red Snapper otoliths and gonads collected by commercial fishermen from the commercial fishery, provided to SCDNR personnel. Commercial regulations for Red Snapper during 2000-2001 include a size limit of 20" TL (508 mm). However, fishermen possessed a LOA (Letter of Amendment) or "permit" to collect undersize specimens.

Appendix B: SCDNR-MRRI Gear Codes and descriptions

The following gear types represent the gear types utilized to collect Red Snapper for SCDNR/MRRI/MARMAP program, including fishery independent and fishery dependent sources.

Fishery Independent Sources (SCDNR/MRRI/MARMAP-SEAMAP-SEFIS)

Gears	MRRI Gear Code
Blackfish Traps	053
Chevron Trap	324
Commercial High Rise Roller Trawl	226
Experimental Trap	073
Flatline Otter Trawl	071
Florida Antillean Trap	074
Hook and Line	014
Mini-Antillean “S” Trap	041
Mongoose type Falcon trawl	233
Short-bottom Longline	061
Snapper Reel	043
¾ Scale Yankee Trawl	022

Fishery Independent Sources (Commercial Fishery)

Gears	
Snapper Reel	043
Speargun	065

Table 1. Number of positive gear deployments with Red Snapper, by gear type. 014= hook and line; 019=dip net; 022=Yankee trawl; 041=mini Antillean s-trap- baited; 043=snapper/bandit reel, electric or manual; 053=blackfish trap; 065=spear gun; 073=experimental trap; 074=Florida Antillean trap; 233=75’ Falcon Trawl without TED; 324=chevron trap. MRRI Gear codes. . 000=unknown.

Number of Gear Deployments (Trips) Used for Life History															
Year	**000**	**014**	**022**	**041**	**043**	**053**	**061**	**065**	**071**	**073**	**074**	**226**	**233**	**324**	**Totals**
1977	0	0	1	0	2	0	0	0	0	0	0	0	0	0	3
1978	0	0	1	1	1	0	0	0	0	0	0	0	0	0	3
1979	2	0	0	0	6	0	0	0	2	0	0	0	0	0	10
1980	0	0	0	0	5	0	0	0	0	0	0	1	0	0	6
1981	0	0	0	0	2	0	0	0	0	0	2	0	0	0	4
1982	0	0	0	0	3	0	0	0	0	0	1	0	0	0	4
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	6	0	0	0	0	0	0	0	0	0	6
1985	0	0	0	0	0	2	0	0	0	0	1	0	0	0	3
1986	1	0	0	0	1	1	0	0	0	0	1	0	1	0	5
1987	0	1	0	0	2	1	0	0	0	0	0	0	0	0	4
1988	0	1	0	0	4	1	0	0	0	0	1	0	0	7	14
1989	0	3	0	0	1	0	0	0	0	0	0	0	0	4	8
1990	0	2	0	0	1	0	0	0	0	0	0	0	0	8	11
1991	0	2	0	0	0	0	0	0	0	0	0	0	0	9	11
1992	0	1	0	0	0	0	0	0	0	0	0	0	0	9	10
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12
1994	0	2	0	0	2	0	0	0	0	0	0	0	0	19	23
1995	0	4	0	0	0	0	0	1	0	0	0	0	0	14	19
1996	0	1	0	0	17	0	0	0	0	0	0	0	0	9	27
1997	0	0	0	0	41	0	0	0	0	0	0	0	0	7	48
1998	0	1	0	0	2	0	0	0	0	0	0	0	0	8	11
1999	0	0	0	0	15	0	0	0	0	0	0	0	2	4	21
2000	0	0	0	0	25	0	0	7	0	0	0	0	2	8	42
2001	0	0	0	0	7	0	0	3	0	0	0	0	0	7	17
2002	0	0	0	0	2	0	0	0	0	0	0	0	0	15	17
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
2005	0	0	0	0	1	0	0	0	0	0	0	0	0	7	8
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5
2007	0	2	0	0	0	0	1	0	0	0	0	0	0	8	11
2008	0	2	0	0	2	0	0	0	0	0	0	0	0	11	15
2009	0	3	0	0	7	0	0	1	0	1	0	0	0	9	21
2010	0	3	0	0	1	0	0	0	0	0	0	0	1	73	78
2011	0	6	0	0	0	0	1	0	0	0	0	0	0	70	77
2012	0	29	0	0	10	0	1	3	0	0	0	0	0	155	198
2013	0	47	0	0	12	0	0	0	0	0	0	0	4	142	205
Total	3	110	2	1	178	5	3	15	2	1	6	1	10	625	

Table 2. Number of Red Snapper collected, per gear type. 014= hook and line; 019=dip net; 022=Yankee trawl; 041=mini Antillean s-trap- baited; 043=snapper/bandit reel, electric or manual; 053=blackfish trap; 065=spear gun; 073=experimental trap; 074=Florida Antillean trap; 233=75' Falcon Trawl without TED; 324=chevron trap. MRRI Gear codes. 000=unknown.

Number of Red Snapper Available for Life History															
Year	**000**	**014**	**022**	**041**	**043**	**053**	**061**	**065**	**071**	**073**	**074**	**226**	**233**	**324**	**Total**
1977	0	0	1	0	2	0	0	0	0	0	0	0	0	0	3
1978	0	0	1	2	1	0	0	0	0	0	0	0	0	0	4
1979	6	0	0	0	42	0	0	0	19	0	0	0	0	0	67
1980	0	0	0	0	11	0	0	0	0	0	0	5	0	0	16
1981	0	0	0	0	3	0	0	0	0	0	8	0	0	0	11
1982	0	0	0	0	39	0	0	0	0	0	1	0	0	0	40
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	37	0	0	0	0	0	0	0	0	0	37
1985	0	0	0	0	0	2	0	0	0	0	1	0	0	0	3
1986	7	0	0	0	1	1	0	0	0	0	1	0	1	0	11
1987	0	2	0	0	2	1	0	0	0	0	0	0	0	0	5
1988	0	5	0	0	14	1	0	0	0	0	1	0	0	29	50
1989	0	4	0	0	2	0	0	0	0	0	0	0	0	5	11
1990	0	3	0	0	1	0	0	0	0	0	0	0	0	24	28
1991	0	10	0	0	0	0	0	0	0	0	0	0	0	22	32
1992	0	11	0	0	0	0	0	0	0	0	0	0	0	21	32
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	31	31
1994	0	6	0	0	7	0	0	0	0	0	0	0	0	44	57
1995	0	7	0	0	0	0	0	4	0	0	0	0	0	29	40
1996	0	3	0	0	44	0	0	0	0	0	0	0	0	11	58
1997	0	0	0	0	145	0	0	0	0	0	0	0	0	26	171
1998	0	2	0	0	23	0	0	0	0	0	0	0	0	25	50
1999	0	0	0	0	187	0	0	0	0	0	0	0	3	22	212
2000	0	0	0	0	261	0	0	138	0	0	0	0	2	17	418
2001	0	0	0	0	11	0	0	51	0	0	0	0	0	9	71
2002	0	0	0	0	3	0	0	0	0	0	0	0	0	39	42
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5
2005	0	0	0	0	1	0	0	0	0	0	0	0	0	12	13
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
2007	0	5	0	0	0	0	1	0	0	0	0	0	0	29	35
2008	0	3	0	0	10	0	0	0	0	0	0	0	0	29	42
2009	0	3	0	0	27	0	0	2	0	7	0	0	0	11	50
2010	0	3	0	0	1	0	0	0	0	0	0	0	1	168	173
2011	0	8	0	0	0	0	1	0	0	0	0	0	0	121	130
2012	0	70	0	0	23	0	1	5	0	0	0	0	0	430	529
2013	0	132	0	0	15	0	0	0	0	0	0	0	7	375	529
Total	13	277	2	2	913	5	3	200	19	7	12	5	14	1547	

Table 3. Number of Red Snapper aged, per gear type. 014= hook and line; 019=dip net; 022=Yankee trawl; 041=mini Antillean s-trap- baited; 043=snapper/bandit reel, electric or manual; 053=blackfish trap; 065=spear gun; 073=experimental trap; 074=Florida Antillean trap; 233=75’ Falcon Trawl without TED; 324=chevron trap. MRRI Gear codes. 0=no Red Snapper captured. 000=unknown.

Number of Aged Red Snapper Available for Life History															
Year	**000**	**014**	**022**	**041**	**043**	**053**	**061**	**065**	**071**	**073**	**074**	**226**	**233**	**324**	**Totals**
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	10	0	0	0	0	0	0	4	0	0	14
1981	0	0	0	0	3	0	0	0	0	0	8	0	0	0	11
1982	0	0	0	0	36	0	0	0	0	0	0	0	0	0	36
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
1985	0	0	0	0	0	2	0	0	0	0	1	0	0	0	3
1986	0	0	0	0	1	1	0	0	0	0	1	0	0	0	3
1987	0	1	0	0	1	1	0	0	0	0	0	0	0	0	3
1988	0	4	0	0	14	1	0	0	0	0	1	0	0	28	48
1989	0	2	0	0	2	0	0	0	0	0	0	0	0	4	8
1990	0	3	0	0	1	0	0	0	0	0	0	0	0	24	28
1991	0	7	0	0	0	0	0	0	0	0	0	0	0	19	26
1992	0	11	0	0	0	0	0	0	0	0	0	0	0	20	31
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	29	29
1994	0	6	0	0	7	0	0	0	0	0	0	0	0	42	55
1995	0	7	0	0	0	0	0	4	0	0	0	0	0	28	39
1996	0	2	0	0	37	0	0	0	0	0	0	0	0	10	49
1997	0	0	0	0	138	0	0	0	0	0	0	0	0	24	162
1998	0	2	0	0	21	0	0	0	0	0	0	0	0	25	48
1999	0	0	0	0	180	0	0	0	0	0	0	0	3	19	202
2000	0	0	0	0	251	0	0	124	0	0	0	0	2	15	392
2001	0	0	0	0	9	0	0	30	0	0	0	0	0	7	46
2002	0	0	0	0	3	0	0	0	0	0	0	0	0	38	41
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5
2005	0	0	0	0	1	0	0	0	0	0	0	0	0	12	13
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6
2007	0	5	0	0	0	0	1	0	0	0	0	0	0	29	35
2008	0	3	0	0	10	0	0	0	0	0	0	0	0	29	42
2009	0	3	0	0	26	0	0	2	0	7	0	0	0	11	49
2010	0	3	0	0	0	0	0	0	0	0	0	0	0	167	170
2011	0	8	0	0	0	0	1	0	0	0	0	0	0	120	129
2012	0	62	0	0	18	0	1	5	0	0	0	0	0	416	502
2013	0	129	0	0	13	0	0	0	0	0	0	0	7	368	517
Totals	0	258	0	0	784	5	3	165	0	7	11	4	12	1502	

Table 4. Otolith Edge type and Quality criteria.

Otolith Edge Type

Code	Description
1	Opaque zone on the edge.
2	Narrow translucent zone on edge Width less than about 30% of previous increment
3	Medium translucent zone on edge Width about 30-60% of previous increment
4	Wide translucent zone on edge Width more than about 60% of previous increment

Otolith Quality

Code	Description	Analysis consequence
A	Unreadable	Omit otolith from analysis
B	Very difficult to read	Age estimate between readers are expected to be >2 year for young, and > 4 yrs for old fish (>10 yrs) Agreement on age may be difficult to reach, in which case otoliths should be classified as A and omitted from the analysis.
C	Fair readability	Age estimates between readers should be within 2 year in young, and within 4 years in old fish (>10 yrs). Agreement after second reading is expected after some discussion.
D	Good readability	Age estimates between readers should be within 1 year for young, to 2 years in Old fish (> 10 years). Agreement after second reading is expected without much discussion.
E	Excellent readability	Age estimates between readers should be the same.

Table 5. Histological criteria used to determine reproductive state in Red Snapper (modified from Wallace and Selman (1981); Hunter and Macewicz (1985); Hunter et al. (1986); Wenner et al. (1986); West (1990); Davis and West (1993)).

Reproductive Stage	**Male**	**Female**
1-Immature	Small transverse section compared to resting male; spermatogonia & little or no spermatocyte development	Oogonia & primary growth oocytes only (< 60 m), no evidence of atresia. Relative to resting female, area of transverse section of ovary is smaller, lamellae lack muscle and connective tissue bundles are not as elongate, oogonia are abundant along margin of lamellae, ovarian wall is thinner. See below
2-Developing	Development of cysts containing primary and secondary spermatocytes through some accumulation of spermatozoa in lobular lumina and ducts.	See below (2B, 2C, 2D, 2E, 2F, & 2G)
3-Migratory Nucleus oocytes & Hydrated oocytes (Spawning)	Predominance of spermatozoa in lobules and ducts; little or no occurrence of spermatogenesis.	Completion of yolk coalescence and hydration in most advanced
4-Regressing	No spermatogenesis; some residual spermatozoa in shrunken lobules or ducts.	More than 50% of vitellogenic oocytes undergoing alpha or beta atresia.
5-Regenerating	Large transverse section compared to immature male; little or no spermatocyte development; empty lobules and ducts; some recrudescence (spermatagonia through primary spermatocytes) possible at end of stage.	Oogonia & primary growth oocytes only (> 60 m), traces of all stages of atresia. Relative to immature female, area of transverse section of ovary is larger, lamellae more elongate, oogonia are less abundant along margin of lamellae, bundles of connective and muscle tissue present, ovarian wall is thicker.
2B-Developing, recent spawn (POC)		Vitellogenic oocytes predominant and POCs (postovulatory complex) <12 h old (sensu Hunter et al.1986).
2C-Developing, recent spawn (POC)		Vitellogenic oocytes predominant and POCs 12-24 h old (sensu Hunter et al.1986).
2D-Developing, recent spawn (POC)		Vitellogenic oocytes predominant and POCs >24 h old (sensu Hunter et al. 1986)
2E-Early developing, cortical alveolar (CAO)		Most advanced oocytes in cortical-alveolar stage. Cortical form in peripheral cytoplasm. Oil droplets form around germinal vesicle.
2F-Developing, vitellogenesis		Most advanced oocytes in yolk-granule or yolk-globule stage.
2G-Oocyte maturation		Most advanced oocytes in migratory-nucleus stage. Partial coalescence of yolk globules. Nucleus has moved away from center of cell, being replaced by coalescing oil droplets. By the time of ovulation, one large oil droplet is present.

Table 6a. Red Snapper length versus length relationships, all data combined. TL=pinched maximum total length, FL=fork length, SL=standard length. All lengths are in mm. n=number of fish used for each analyses. R2 is the correlation coefficient adjusted for degrees of freedom.

	Equation	n	a	b	R2
All Fish	TL=a+b*FL	1824	1.326	1.068	0.999
	TL=a+b*SL	1894	19.579	1.213	0.994
	FL=a+b*SL	1828	17.104	1.136	0.995
Males	TL=a+b*FL	798	1.537	1.068	0.999
	TL=a+b*SL	822	20.851	1.209	0.993
	FL=a+b*SL	798	18.610	1.131	0.994
Females	TL=a+b*FL	908	1.290	1.069	0.999
	TL=a+b*SL	923	19.275	1.214	0.994
	FL=a+b*SL	912	16.715	1.137	0.995

Table 6b. Red Snapper length (mm) versus weight (lbs) relationships, all data combined. Note: weights measured in grams and converted to pounds (lb). WT=fish wet weight in pounds, TL= pinched maximum total length, FL=fork length, SL=standard length. All lengths are in mm. n=number of fish used for each analyses. R2 is the correlation coefficient adjusted for degrees of freedom.

	Equation	n	a	b	R2
All Fish	Log (WT) = a + b*log(TL)	1867	-17.196	2.996	0.989
	Log (WT) = a + b*log(TL)	1790	-17.051	3.006	0.995
	Log (WT) = a + b*log(TL)	1859	-15.883	2.894	0.991
Males	Log (WT) = a + b*log(TL)	813	-17.281	3.009	0.993
	Log (WT) = a + b*log(TL)	788	-17.091	3.012	0.994
	Log (WT) = a + b*log(TL)	811	-15.853	2.888	0.989
Females	Log (WT) = a + b*log(TL)	909	-17.261	3.007	0.994
	Log (WT) = a + b*log(TL)	897	-17.071	3.009	0.994
	Log (WT) = a + b*log(TL)	912	-15.918	2.900	0.990

Table 7a. Estimates of Von Bertalanffy growth parameters based on non-linear regression analysis using available maximum (pinched tail) total length (mm) and calendar age data. n=number of aged fish used in analysis of fishery-independent samples. Linf= predicted asymptotic TL, SE= standard error, k=predicted growth rate, t0= predicted age at theoretical length=0.

	n	Linf	SE	k	SE	t0	SE
All Fish	1803	1007	19.68	0.168	0.01	-0.623	0.07
Males	792	983	30.62	0.167	0.01	-0.753	0.12
Females	896	1013	27.05	0.173	0.01	-0.521	0.10

Table 7b. Estimates of Von Bertalanffy growth parameters in two time periods (Early: 1977-2000 and Late: 2001-2013) based on non-linear regression analysis using pinched maximum total length (TL mm) and calendar age data of fishery-independent samples. n=number of aged fish used in analysis. Linf= predicted asymptotic TL, SE=standard error, k=predicted growth rate, t0=predicted age at theoretical length=0.

	n	Linf	SE	k	SE	t0	SE
All Fish	1803	1007	19.68	0.168	0.01	-0.623	0.07
Early	425	989	103.61	0.117	0.02	-1.550	0.31
Late	1378	976	15.55	0.193	0.01	-0.458	0.06

Table 8. Results of various regression model analyses for age and length at maturity for male & female Red Snapper, by period. Data for all projects and gears were combined. Age is expressed in calendar age and length is maximum (pinched tail) total length in mm. n=number of fish used in analyses, A_{50}= age at which 50% of population has reached sexual maturity, L_{50}=length at which 50% of the population has reached sexual maturity.

				Parameter	Estimate
Analysis	n	Model	Period	Intercept (Std Err)	Calendar Age (Std Err)
Female Age at Maturity	480	Logistic	1978-2000	-3.210 (0.653)	1.616 (0.224)
Female Age at Maturity	732	Logistic	2001-2013	-2.877 (0.449)	1.868 (0.204)
Female Age at Maturity	1212	Logistic	1978-2013	2.507 (0.328)	1.537 (0.128)
Female Size at Maturity	517	Gompertz	1978-2000	-9.538 (1.481)	0.024 (0.004)
Female Size at Maturity	749	Logistic	2001-2013	-14.828 (1.826)	0.046 (0.006)
Female Size at Maturity	1266	Probit	1978-2013	-6.44 (0.545)	0.019 (0.002)
Male Age at Maturity	430	Logistic	1978-2000	-0.311 (0.854)	1.376 (0.341)
Male Age at Maturity	625	Logistic	2001-2013	1.639 (0.876)	1.088 (0.422)
Male Age at Maturity	1055	Logistic	1978-2013	1.151 (0.572)	1.063 (0.250)
Male Size at Maturity	464	Gompertz	1978-2000	-1.551 (0.640	0.007 (0.002)
Male Size at Maturity	648	Logistic	2001-2013	-1.614 (1.690)	0.016 (0.005)
Male Size at Maturity	1112	Logistic	1978-2013	-2.816 (1.038)	0.018 (0.003)

Table 9. Percentage of mature specimens by maximum (pinched tail) total length interval (TL, mm) for female & male Red Snapper, by period. Specimens in the developing, spawning, regressing, or regenerating states were considered mature. *n*=number of specimens available from all projects and gears.

	Females				Males			
	1978-2000		2001-2013		1978-2000		2001-2013	
	n=517		*n*=749		*n*=464		*n*=648	
mm TL	%	*n*	%	*n*	%	*n*	%	*n*
201-225	25	4	100	3	25	4	100	3
226-250	67	3	78	9	67	3	78	9
251-275	72	7	96	26	72	7	96	26
276-300	100	14	88	26	100	14	88	26
301-325	94	16	100	20	94	16	100	20
326-350	77	13	100	32	77	13	100	32
351-375	90	20	100	48	90	20	100	48
376-400	96	25	98	53	96	25	98	53
401-425	96	27	100	44	96	27	100	44
426-450	100	12	100	41	100	12	100	41
451-475	100	14	100	30	100	14	100	30
476-500	100	19	100	29	100	19	100	29
501-525	100	48	100	29	100	48	100	29
526-550	100	64	100	35	100	64	100	35
551-575	100	54	100	32	100	54	100	32
576-600	100	42	100	22	100	42	100	22
601-625	100	22	100	20	100	22	100	20
626-650	100	14	100	24	100	14	100	24
651-675	100	7	100	8	100	7	100	8
676-700	100	7	100	24	100	7	100	24
701-725	100	6	100	22	100	6	100	22
726-750	100	8	100	20	100	8	100	20
751-775	100	5	100	16	100	5	100	16
776-800	100	6	100	10	100	6	100	10
801-825	100	3	100	9	100	3	100	9
826-850	100	1	100	7	100	1	100	7
851-875			100	8			100	8
876-900	100	3	100	1	100	3	100	1
901-925								
926-950								
951-975								
976-1000								

Table 10. Percentage of mature specimens by calendar age for female and male Red snapper, by period. Specimens in the developing, spawning, regressing, or regenerating states were considered mature.

	Females			Males		
	1980-2013 *n*=1212	1980-2000 *n*=480	2001-2013 *n*=732	1980-2013 *n*=1055	1978-2000 *n*=430	2001-2013 *n*=625
Age	% mat	% mat	% mat	% mat	% mat	% mat
0	--	--	--	0	0	--
1	29	0	32	93	88	94
2	62	50	66	96	90	98
3	91	86	96	98	98	99
4	96	94	98	100	99	100
5	100	100	100	100	100	100
6	100	100	100	100	100	100
7	100	100	100	100	100	100
8	100	100	100	100	100	100
9	100	100	100	100	100	100
10	100	100	100	100		100
11	100	100	100	100		100
12	100	100	100	100		100

Table 11. Red Snapper sex ratio by maximum (pinched tail) total length (mm) 1978-2013, including all projects and gears.

Total Length	Female: Male	Male *n*	Female *n*	Proportion female	Total *n*
201-225		4	0	0.00	4
226-250		9	0	0.00	9
251-275	0.03	30	1	0.03	31
276-300	0.11	37	4	0.10	41
301-325	0.34	35	12	0.26	47
326-350	0.60	42	25	0.37	67
351-375	0.55	66	36	0.35	102
376-400	0.57	76	43	0.36	119
401-425	0.99	70	69	0.50	139
426-450	0.98	53	52	0.50	105
451-475	1.00	43	43	0.50	86
476-500	1.21	48	58	0.55	106
501-525	1.09	77	84	0.52	161
526-550	1.07	99	106	0.52	205
551-575	0.95	86	82	0.49	168
576-600	1.05	64	67	0.51	131
601-625	1.45	42	61	0.59	103
626-650	1.18	38	45	0.54	83
651-675	1.73	15	26	0.63	41
676-700	1.39	31	43	0.58	74
701-725	1.93	28	54	0.66	82
726-750	1.57	28	44	0.61	72
751-775	2.14	21	45	0.68	66
776-800	2.81	16	45	0.74	61
801-825	1.58	12	19	0.61	31
826-850	1.38	8	11	0.58	19
851-875	1.38	8	11	0.58	19
876-900	3.00	4	12	0.75	16
901-925		0	4	1.00	4
926-950		0	2	1.00	2
951-975					0
976-1000		0	2	1.00	2
		1090	1106		2196

Table 12. Red Snapper sex ratio by Calendar Age, 1980-2013, including all projects and gears.

Age	Male	Female	Proportion Female	Total
1	52	14	0.21	66
2	206	112	0.35	318
3	320	329	0.51	649
4	246	222	0.47	468
5	102	164	0.62	266
6	47	89	0.66	136
7	27	65	0.71	92
8	11	26	0.70	37
9	4	10	0.72	14
10	7	7	0.50	14
11	1	3	0.75	4
12	1	5	0.83	6
13	1	4	0.80	5
14	1	3	0.75	4
15	1	1	0.50	2
16	0	3	1	3
17	0	1	1	1
18				
19	1	2	0.67	3
20				
21	3	0		3
22	0	1	1	1
23	0	1	1	1
24	1	0		11
25	1	1	0.50	2
26	1	0		1
27				
28	0	1	1	1
29-45	2	2	0.50	4
Total	1037	1065		2102

Table 13. The proportion of Red Snapper spawners (# female spawners / # adult females) by month, by increment group, 1978-2013, including all projects and gears.

Calendar Age and Sample Size

Month	**Monthly prop. spawners**	**1**	**# spawners**	n	**2**		n	**3**		n	**4**		n	**5**		n
May	0.21				0.27	4	15	0.16	12	76	0.10	3	31	0.19	8	43
Jun	0.50				0.36	5	14	0.49	34	69	0.45	25	55	0.59	10	17
Jul	0.54				0.54	13	24	0.63	22	35	0.53	8	15	0.45	9	20
Aug	0.45	0.33	2	6	0.43	12	28	0.33	7	21	0.40	6	15	0.52	16	31
Sep	0.53	1.00	8	8	0.16	3	19	0.16	2	13	0.25	3	12	0.83	15	18
Oct	0.35				1.00	3	3	0.25	8	32	0.38	5	13	0.50	3	6
Total				14			103			246			141			135
Prop. spawners, May-Oct		**0.14**			**0.36**			**0.35**			**0.35**			**0.45**		

Table 13 continued. The proportion of Red Snapper spawners (# female spawners / # adult females) by month, by increment group, 1978-2013, including all projects and gears.

Calendar Age and Sample Size

Month	**Monthly prop. spawners**	**6**		n	**7**		n	**8**		n	**9-11**		n	**12-14**		n	**15-38**		n	**Total**	**# spawners**	**Monthly prop.**
May	0.21	0.22	5	23	0.46	6	13	0.31	4	13	0.00	0	3	0.67	2	3	0.50	2	4	224	47	0.21
Jun	0.50	0.57	8	14	0.83	5	6	1.00	1	1	1.00	2	2	0.00	0	1	0.67	2	3	182	92	0.50
Jul	0.54	0.43	3	7	0.44	7	16	1.00	3	3				0.50	2	4	1.00	1	1	125	68	0.54
Aug	0.45	0.36	4	11	0.50	4	8	0.33	1	3	1.00	1	1	0.33	1	3	1.00	1	1	122	55	0.45
Sep	0.53	0.60	12	20	0.33	3	9	0.50	2	4	1.00	1	1	1.00	1	1	1.00	2	2	99	52	0.53
Oct	0.35																			54	19	0.35
Total				75			52			24			7			12			11	806	332	
Prop. spawners, May-Oct		**0.43**			**0.48**			**0.33**			**0.29**			**0.42**			**0.55**					

Table 14. Female Red Snapper spawning frequency by month, 1978-2013, including all projects and two gear types (chevron trap and hook-and-line.   Proportion of spawning females among reproductively active females (i.e., those with oocytes undergoing vitellogenesis) was estimated using two methods: 1) presence of migratory nucleus (MN) or hydrated (HO) oocytes, and 2) presence of postovulatory complexes (POCs) 12-36 hr old.

	Chevron trap Prop. spawners			Hook-and-line Prop. spawners		
Month	MN or HO	POC	n=	MN or HO	POC	n=
May	0.09	0.16	115	0.06	0.21	67
Jun	0.26	0.34	127	0.14	0.34	29
Jul	0.28	0.23	96	0.04	0.58	24
Aug	0.30	0.12	103	0.08	0.42	12
Sep	0.16	0.35	57	0.03	0.42	29
Oct	0.33	0.07	30	0.17	0.08	12
Total #	120	117	528	13	56	173
Prop. spawners, May-Oct	**0.23**	**0.22**		**0.08**	**0.32**	

Spawning Frequency (# female spawners / # active females) by gear for Red Snapper. Active females have oocytes undergoing vitellogenesis and/or maturation.

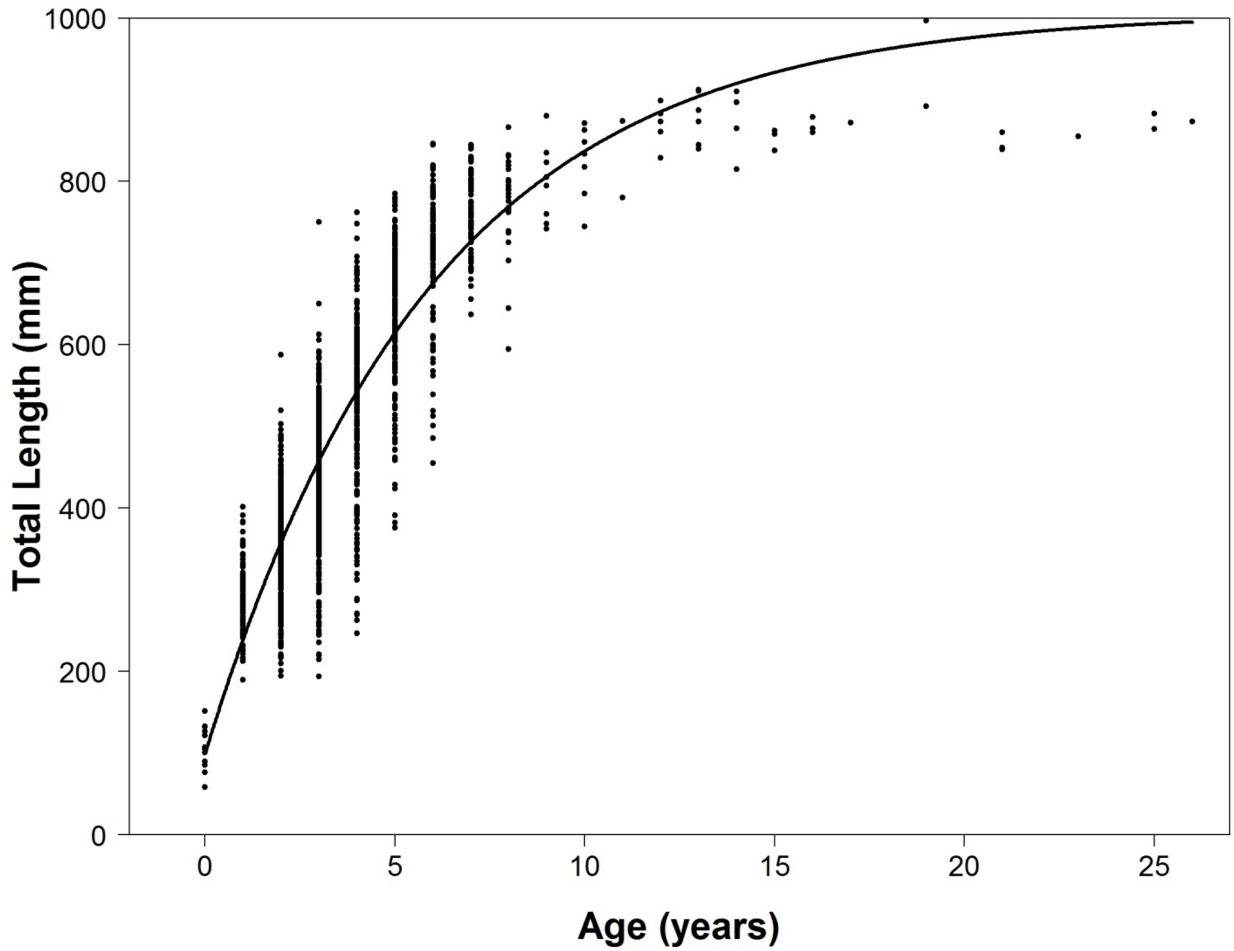


Figure 1. Von Bertalanffy growth curve derived for fishery-independent Red Snapper data, sexes combined, 1978-2013. Total length represents maximum (pinched tail) length.

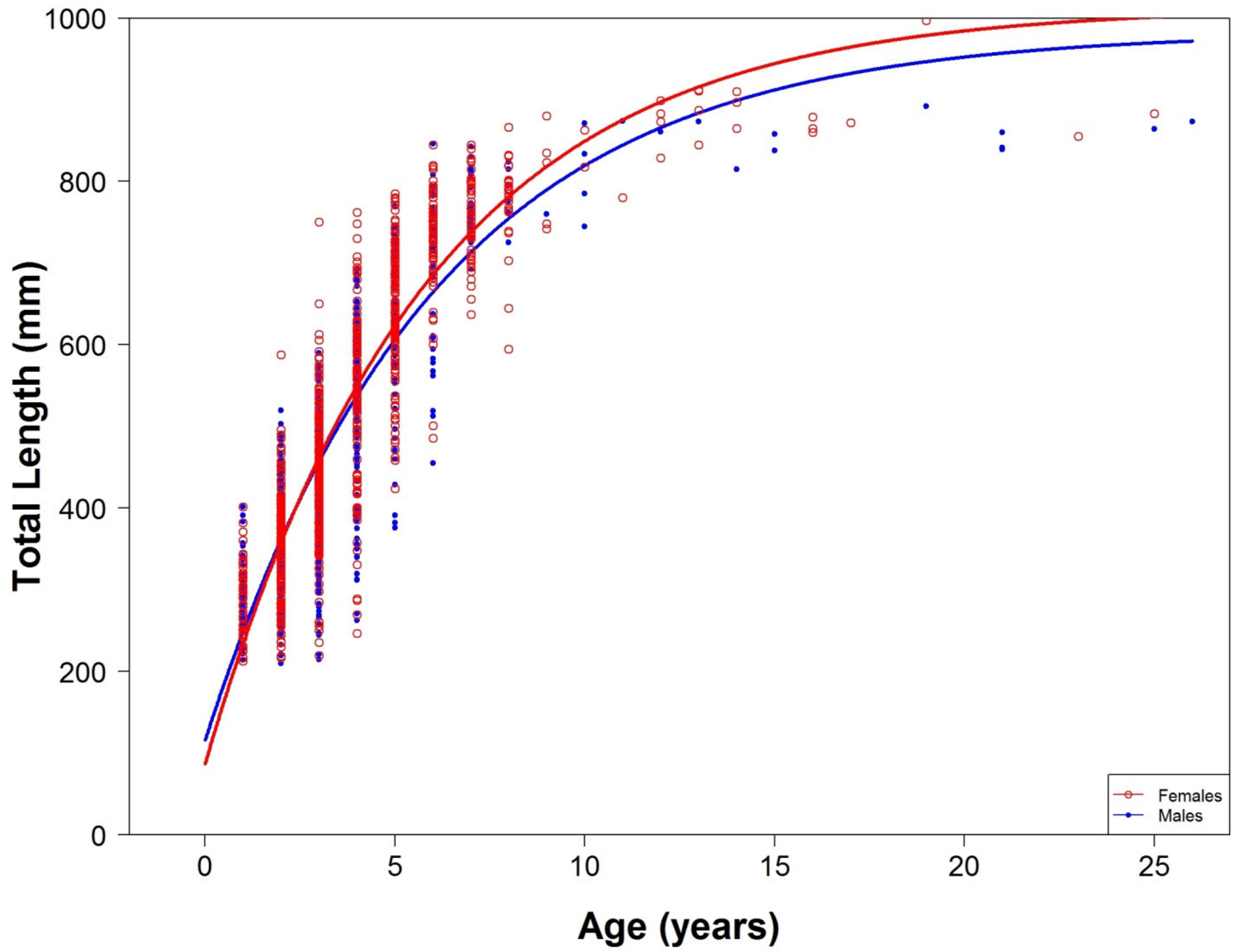


Figure 2. Von Bertalanffy growth curves derived for fishery-independent Red Snapper data, male & female, 1978-2013. Total length represents maximum (pinched tail) length.

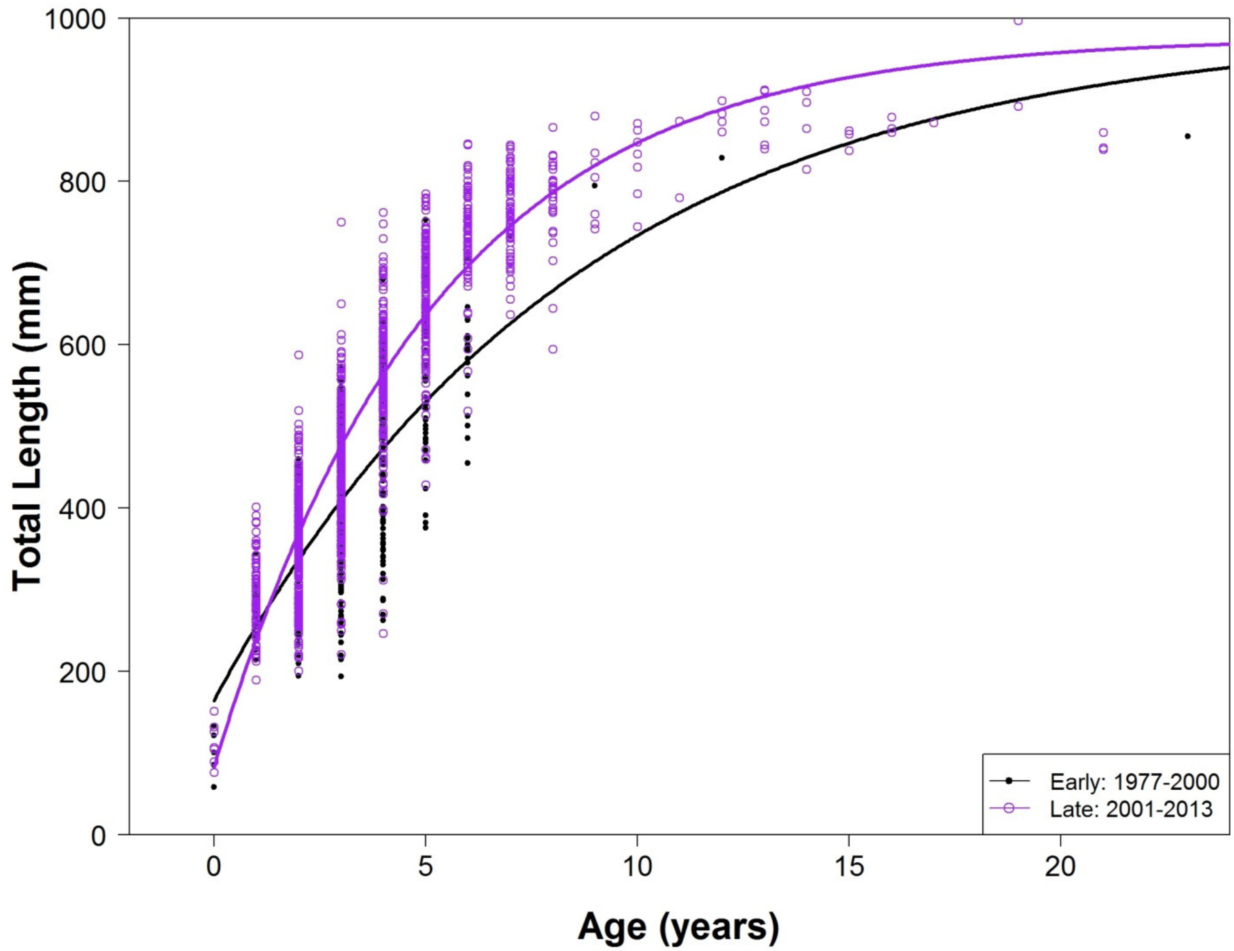
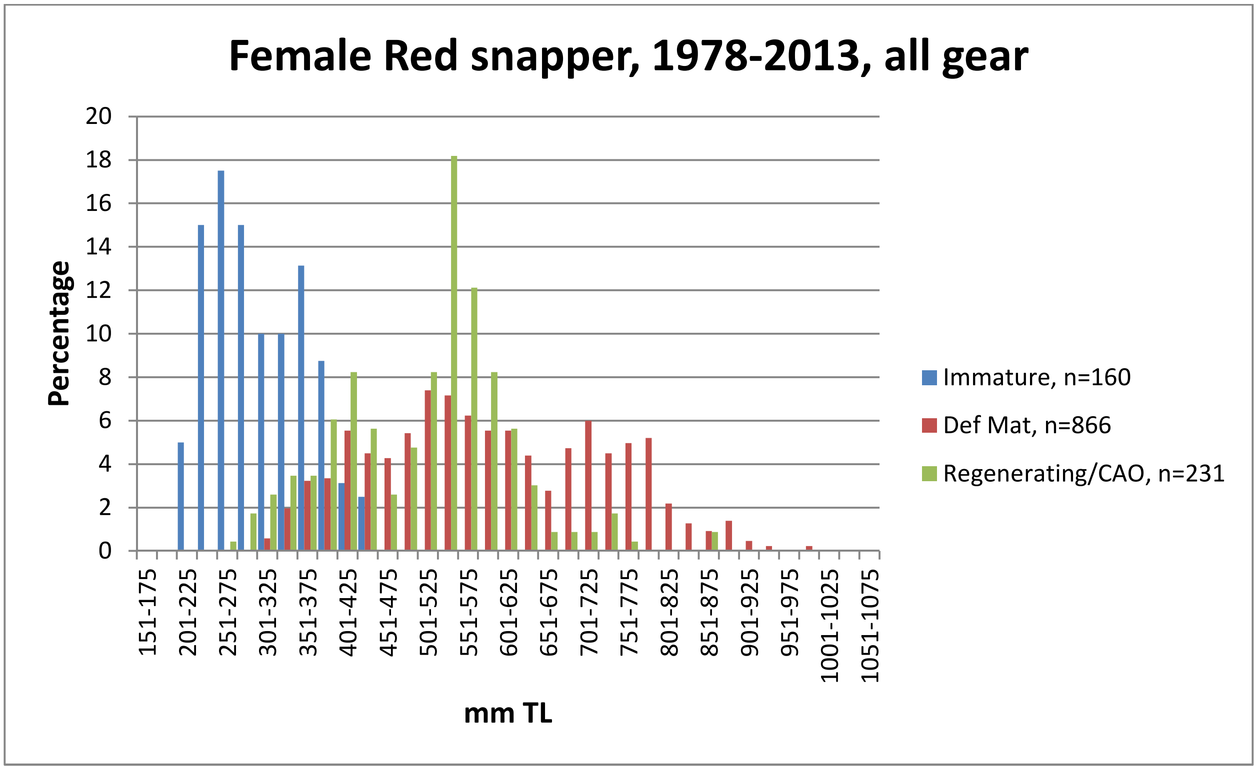


Figure 3. Von Bertalanffy growth curves derived for fishery-independent Red Snapper data, sexes combined, for two periods, 1978-2000 and 2001-2013. Total length represents maximum (pinched tail) length.



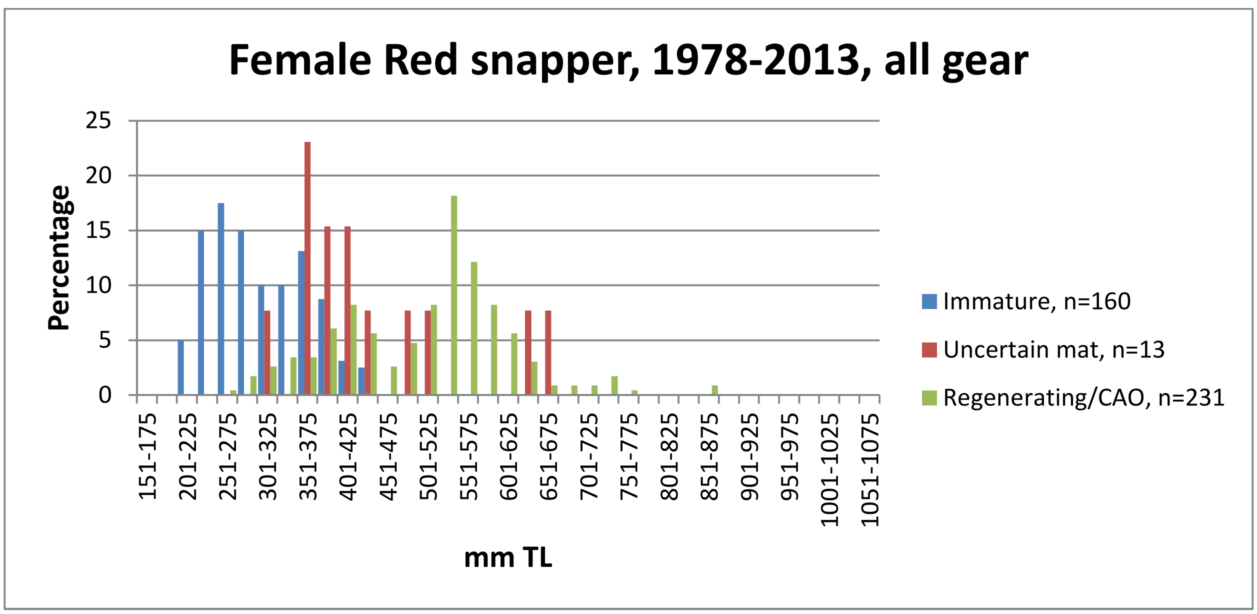


Figure 4a & 4b. A comparison of female Red Snapper length-frequency histograms specimens that were categorized as 1) immature, 2) definitely mature, or 3) regenerating or presence of cortical alveolar oocytes (CAO). Definitely mature specimens were developing, spawning capable, or regressing. **B**. Female Red Snapper histological staging of immature, regenerating/CAO and uncertain maturity. Both graphs provide data from all years and all gears. n= numbers of fish.

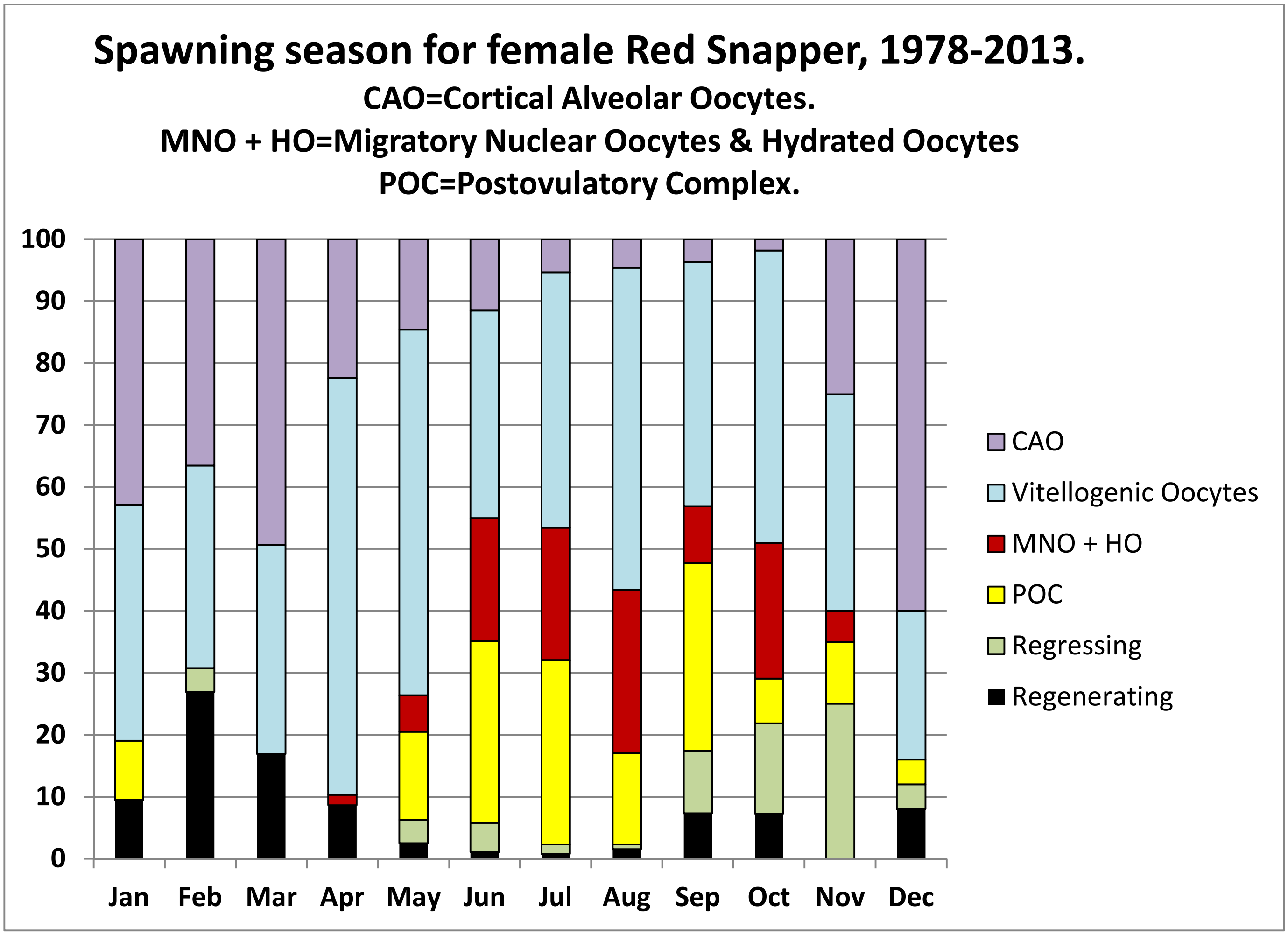


Figure 5. Female Red snapper spawning seasonality, 1978-2013. CAO= cortical alveolar oocytes, MNO + HO= Migratory Nucleus Oocytes and Hydrated Oocytes, POC=Postovulatory Complex.

ADDENDUM

Update: Marine Resources Monitoring, Assessment and Prediction Program:

Report on Atlantic Red Snapper, *Lutjanus campechanus*,

Life History for the SEDAR 41 Data Workshop.

SEDAR41-DW35-B
MARMAP Technical Report 2015-00X
July 2015

Marine Resources Research Institute

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Introduction

This internal report is an update to SEDAR41-DW35 in preparation for the upcoming resumption of the SEDAR41 assessment on Red Snapper. One additional year of data (2014) was added to the life history file, including reproductive data based on histology and age data. The following is a bulleted summary of the results; methods of data analyses were the same as those in the original report. These data will be combined with those from Florida Wildlife Research Institute to estimate reproductive parameters for SEDAR41.

Results:

- There was little overlap in the length distributions of immature and regenerating/CAO female (A) and male (B) Red Snapper, and substantial overlap of regenerating/CAO and definitely mature individuals, indicating that maturity stages were assigned correctly (Figure 1).
- 704 specimens of Red Snapper were collected during fishery-independent sampling by the South East Reef Fish Survey (SERFS) in 2014; sex and reproductive phase assigned to all specimens; 690 of 704 specimens were aged.
- 55 specimens of Red Snapper from fishery-dependent samples (recreational fisheries) were collected and processed by SERFS in 2014; sex and reproductive phase assigned to 50 of 55 specimens; 49 specimens were aged.
- Female maturity: 38% at Age 1, 91% at Age 3, and 100% at Age 5 and older (Table 1). Age at 50% maturity (A50) for females was 1.2 yr (Logistic model, proportion mature = 1 - 1/(1 + exp(a+b*age)); 95% confidence intervals = 1.0-1.4 yr).
- Male maturity: 94% at Age 1, 98% at Age 2, and 100% at Age 4 and older (Table 1). A model could not be fit to the data to produce a reliable estimate of age at 50% maturity.
- Overall sex ratio was 1.04 females to 1 male (Table 2); not significantly different from 1:1 (chi-squared=0.84; P=0.36).
- Spawning fraction analysis revealed that the number of egg batches per female per spawning season was 0.1 at Age 1 and an average of 40.7 at Ages 2+ (Table 3).
- The natural log (Ln) of batch fecundity was significantly related to Ln total fish weight (R^2=0.87), Ln maximum TL (R^2=0.84), and calendar age (R^2=0.43); see Table 4.

Literature cited

Harris, P.J., D.M. Wyanski, D.B. White, P.P. Mikell, and P.B. Eyo. 2007. Age, growth, and reproduction of Greater Amberjack off the southeastern U.S. Atlantic coast. Trans. Amer. Fish. Soc. 136:1534-1545.

Table 1. Percentage of mature specimens by calendar age for female and male Red Snapper collected by the South East Reef Fish Survey during 1980-2014; data from all gear types were included. Specimens in the developing, spawning, regressing, or regenerating states were considered mature. Logistic model was used to generate predicted values (=1 - 1/(1+EXP(-1.556+1.283*age).

Calendar Age (yr)	N	Females Prop. Mat (observed)	Females Prop. Mat (predicted)		N	Males Prop. Mat (observed)
0			0.17		1	0.00
1	91	0.38	0.43		97	0.94
2	317	0.76	0.73		367	0.98
3	446	0.91	0.91		402	0.99
4	262	0.96	0.97		281	1.00
5	184	1.00	0.99		112	1.00
6	108	1.00	1.00		60	1.00
7	94	1.00	1.00		36	1.00
8	53	1.00	1.00		23	1.00
9	26	1.00	1.00		13	1.00
10	8	1.00	1.00		7	1.00
11	4	1.00	1.00		1	1.00
12	6	1.00	1.00		3	1.00
13+	34	1.00	1.00		16	1.00
Total	1633				1419	

Table 2. Sex ratio by calendar age for female and male Red Snapper collected by the South East Reef Fish Survey during 1980-2014; data from all gear types were included. Sex ratio does not differ from 1:1 (chi-squared=0.84; DF=1, P=0.36).

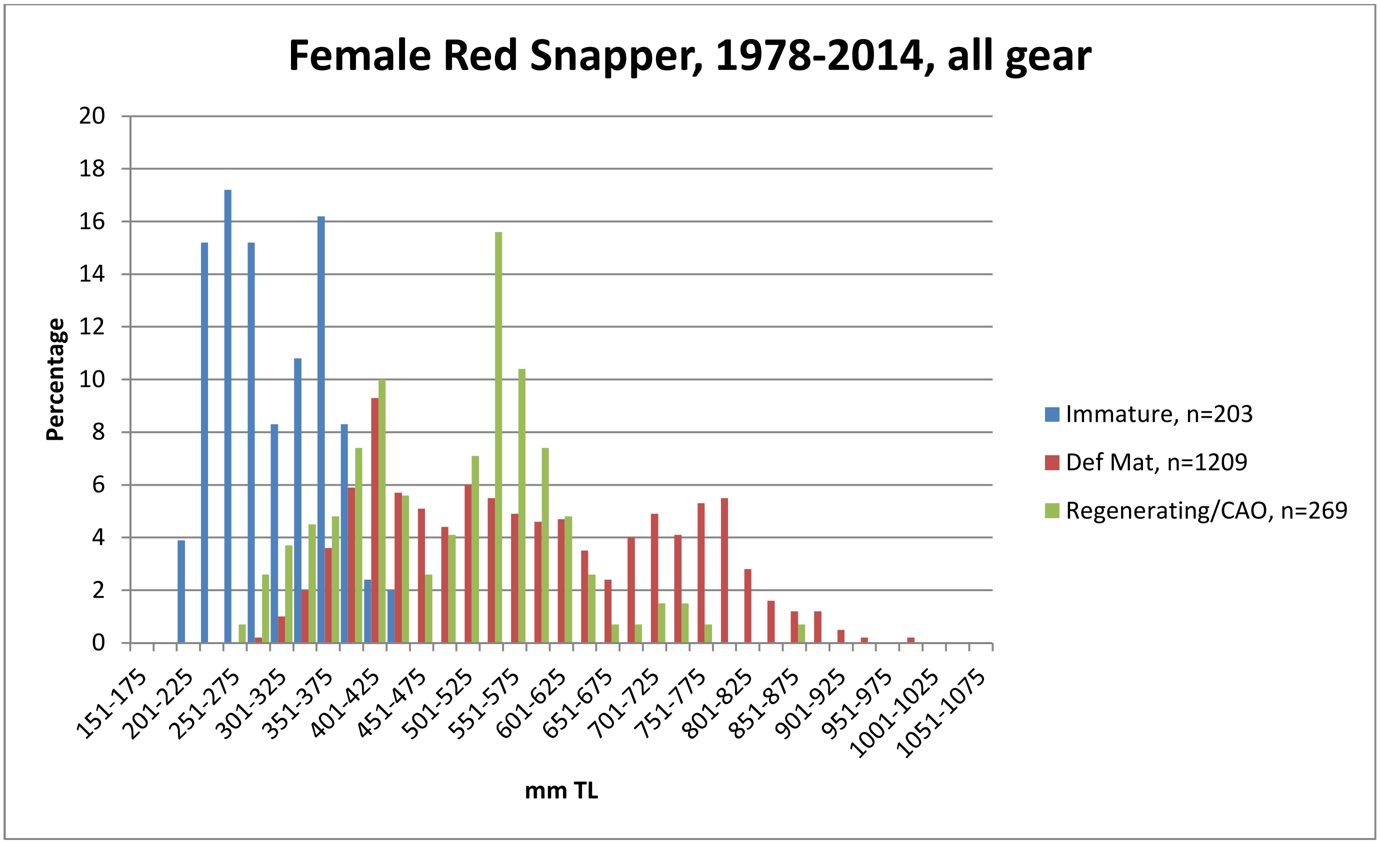
Calendar Age (yr)	**# Male**	**# Female**	Obs. Prop. Female
1	91	35	0.28
2	359	241	0.40
3	397	403	0.51
4	280	251	0.47
5	112	184	0.62
6	60	108	0.64
7	36	94	0.72
8	23	53	0.70
9	13	26	0.67
10	7	8	0.53
11	1	4	0.80
12	3	6	0.67
13	1	7	0.88
14	2	7	0.78
15	2	4	0.67
16	0	5	1.00
17	2	1	0.33
18	1	0	0.00
19	1	3	0.75
20			
21	3	0	0.00
22	0	1	1.00
23	0	1	1.00
24			
25	1	1	0.50
26	1	0	0.00
27			
28	0	2	1.00
29			
30-46	2	2	0.50
Total	1398	1447	0.51

Table 3. The proportion of spawners (# female spawners / # adult females) by calendar age for female Red Snapper collected by the South East Reef Fish Survey during 1980-2014; data from all gear types were included. Spawners had histological indicators of spawning that persist for ~34 hr (10 hr for oocyte maturation + 24 hr for postovulatory follicles), based on Fitzugh et al. 2012 (SEDAR31-DW07). Spawning season duration = first and last occurrence of spawners during Apr – Sep. # batches = (Prop. Spawners/34 hr*24 hr day^{-1}) * spawning season duration in days.

Calendar Age (yr)	# adult females	# Spawners (OM, POC; ~34 hr)*	Prop. Spawners (~34 hr)	Est. Spawning Season Duration (d)	# Batches/ind.fish by Age
1	35	4	0.114	1	0.1
2	230	127	0.552	138	53.8
3	295	124	0.420	152	45.1
4	166	58	0.349	167	41.2
5	158	68	0.430	158	48.0
6	99	41	0.414	164	47.9
7	81	37	0.457	118	38.0
8	51	21	0.412	133	38.7
9-11	30	11	0.367	83	21.5
12-14	19	9	0.474	72	24.1
15-38	17	8	0.471	121	40.2
Total	1181	508			
2+	1146	504	0.440	131	40.7

Table 4. Equations relating Ln batch fecundity and total fish weight (g), maximum TL, and calendar age for Red Snapper collected by the South East Reef Fish Survey during 1999-2014. Batch fecundity based on counts of oocytes undergoing maturation (coalescence of yolk and oil droplets through hydration) in two 100-mg subsamples of ovarian tissue per specimen. See Harris et al. (2007) for additional details of methodology.

Dependent Variable (units)	Equation	Range of TL or weight	Intercept (a)	SE	slope (b)	SE	Adjusted R^2	F	n
Max. TL (mm)	Ln(Batch fec)= a + b (Ln Max. TL)	375-862 mm	-18.01	2.70	4.838	0.426	0.84	128.9	25
Whole Wt (g)	Ln(Batch fec)= a + b (Ln Whole wt)	758-11,830 g	-0.027	1.013	1.602	0.127	0.87	157.8	25
Calendar age (yr)	Ln(Batch fec)= a + b (Age)	2-15 yr	11.140	0.41	0.299	0.069	0.43	18.94	25



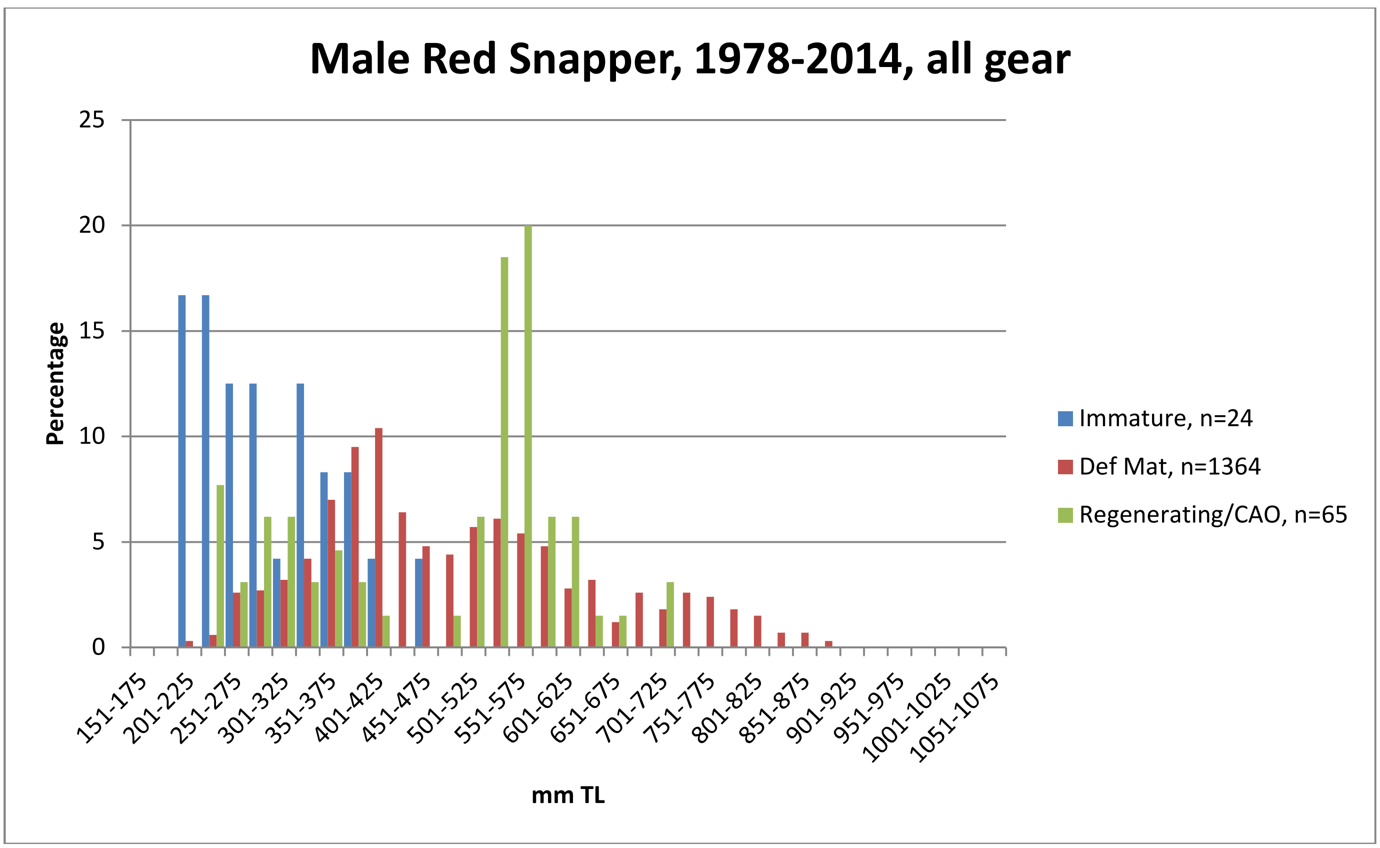


Figure 1. Comparison of length-frequency histograms for female (A) and male (B) Red Snapper collected by the South East Reef Fish Survey during 1978-2014 that were categorized as 1) immature, 2) definitely mature, or 3) regenerating or presence of cortical alveolar oocytes (CAO). Definitely mature specimens were developing, spawning capable, or regressing. n= numbers of fish

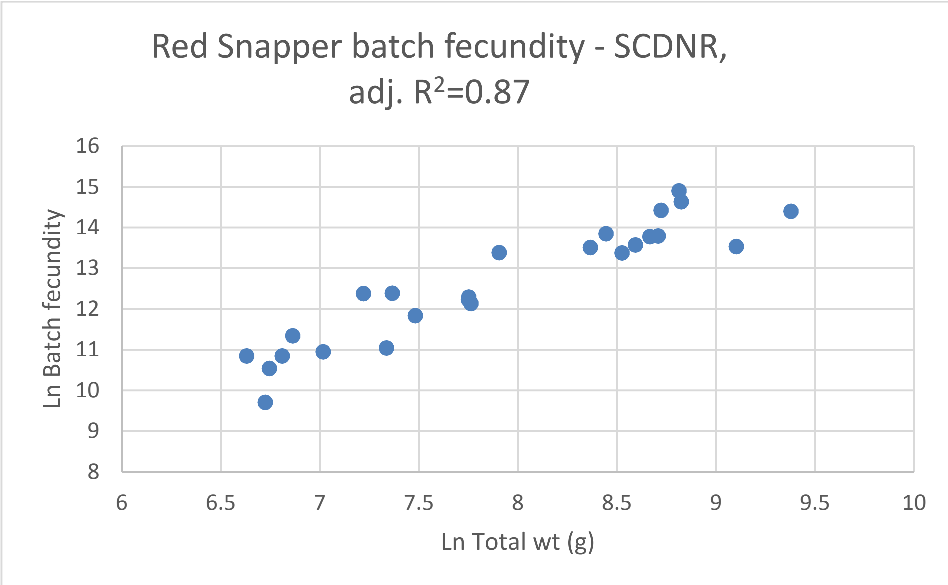


Figure 2. Ln batch fecundity (BF) vs. Ln total weight (TW; g) for Red Snapper (n=25) collected by the South East Reef Fish Survey during 1999-2014. BF = -0.027+1.602*TW