Update of Red Snapper, *Lutjanus campechanus*, Reproductive Life History from the MARMAP/SERFS program

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Introduction

Red Snapper, *Lutjanus campechanus*, is a large, long-lived, member of the family Lutjanidae, with a maximum reported age of 51 yr (SEDAR41, 2017). Red Snappers are distributed in marine waters throughout the Gulf of Mexico south to the Yucatan Peninsula and in United States (U.S.) Atlantic waters north to North Carolina (Nelson and Manooch, 1982; Manooch and Potts, 1997). Along the southeastern U.S., adult Red Snapper are associated with structured habitats such as coral reefs, wrecks, rocky outcroppings, and live-bottom (Moseley, 1966; Nelson and Manooch, 1982; Barans and Henry, 1984; Sedberry and Van Dolah, 1984). Red Snapper are gonochorists with indeterminate fecundity (Woods, 2003; Brulé et al., 2010) that spawn during April through November in the Atlantic waters of the southeastern U.S. with peak spawn occurring June through August (White and Palmer, 2004; Lowerre-Barbieri et al. 2015; Wyanski et al. 2015).

In preparation for SEDAR 90, fishery-independent and fishery-dependent samples collected by MARMAP, the SouthEast Area Monitoring and Assessment Program, South Atlantic (SEAMAP-SA), and the Southeast Fishery-Independent Survey (SEFIS), collectively referred to as the SouthEast Reef Fish Survey (SERFS) were added to the dataset from SEDAR 73 for a total of 16,953 specimens with known sex information and 10,161 specimens with known reproductive phase information.

Objective

1. Provide current estimates of reproductive parameters (i.e., age and size at maturity, sex ratios, and spawning fraction) for female Red Snapper in the Atlantic waters of the southeastern U.S. for an on-going assessment. The analyses were conducted on data from the period 1978-2024.
2. Estimate batch fecundity of female Red Snapper in the Atlantic waters of the southeastern U.S., taking into account size/age differences.

Data presented in this report are based on a query of the combined MARMAP/SERFS database on April 1, 2025.

Methods

Survey Design and Gear

Sampling area

- Cape Hatteras, NC, to St. Lucie Inlet, FL with limited sampling in the Florida Keys
    - General increase in sampling intensity (# of annual chevron trap deployments) through time
        - The largest increase occurred beginning in 2010, during the formation of SERFS
    - Gradual shift regarding the spatial coverage of samples through time
        - More geographic coverage in southern and northern latitudes in later years
        - The largest shift occurred beginning in 2010, during the formation of SERFS
- Sampling depths range from 13 to 212 m
    - Generally, less than 100 m

Sampling season

- May through September
    - Limited earlier and later sampling in some years

Survey Design

- Simple random sample survey design

- o Annually, randomly selected stations from a chevron video trap universe of confirmed live-bottom and/or hard-bottom habitat stations
- o No two stations are randomly selected that are closer than 200 m from each other
  - ▪ Minimum distance is typically closer to 400 m

• Video traps deployed on suspected live-bottom and/or hard-bottom in a given year (reconnaissance) are evaluated based on catch and/or video or photographic evidence of bottom type for inclusion in the universe in subsequent years

- If added to the known habitat universe, data from the reconnaissance deployment is included in index development

Primary Sampling Gear – Chevron Video Traps (video camera(s) added in 2010)
(see Collins 1990 and Smart et al. 2015 for more detailed descriptions)

• Arrowhead shaped, with a total interior volume of 0.91 m3

• Constructed of 35 x 35 mm square mesh plastic-coated wire with a single entrance funnel (“horse neck”)

• Baited with a combination of whole or cut clupeids (Brevoortia or Alosa spp., family Clupeidae), most often Brevoortia spp.

- o Four whole clupeids on each of four stringers suspended within the video trap
- o Approximately 8 clupeids placed loose in the video trap

• Soak time of approximately 90 minutes

• Daylight hours

Other Sampling Gears

- Prior to 1988 (pre chevron trap) primary gear was hook and line and snapper/bandit reel
- Other gear types below have limited temporal use with variable intensities

Data Filtering/Inclusion

- Projects coordinated by MARMAP/SERFS (Project Codes)
  - P05/Q26/Q56/T59/T60/T61/T62/T70 – MARMAP/SEAMAP-SA/SEFIS (Fishery-Independent)
  - P50/T12 – Port Sampling (Fishery-Dependent)
- Gear (Codes and Descriptions)
  - 014 - Hook and Line
  - 041 - Mini-Antillean “S” Trap
  - 043 - Snapper Reel
  - 053 - Blackfish trap
  - 061 - Short-bottom Longline
  - 065 - Speargun
  - 074 - Florida Antillean trap
  - 073 - Experimental Trap
  - 226 - Commercial High-Rise Roller Trawl
  - 324 - Chevron trap
  - 335 - Longline
  - 603 - Repetitive Timed-Drop Hook and Line
  - 604 - Standardized Sabiki Rig

See Smart et al. 2015 for full description of MARMAP/SERFS survey design and gear.

Life History Processing

All fishery-independent caught fish were weighed to the nearest gram (g) and measured in millimeters (mm) for a pinched tail maximum total length (MaxTL), in addition to fork length (FL), and standard length (SL). Fishery-dependent samples had whole weights (g) and length measurements taken (MaxTL and sometimes FL, mm). In the field, otoliths and gonad samples were removed and stored for processing following MARMAP/SERFS protocols (Smart et al. 2015). Fecundity samples were taken from individuals with ovaries that had oocytes undergoing maturation (stage-2 and stage-3 yolked oocytes) but prior to ovulation (Hunter et al. 1992). A regression equation was developed to convert fresh weight to preserved weight of gonads. When the gonad was not appropriate for fecundity, it was only prepared for histological processing and sex/phase assignment; either the whole or posterior portion, depending on the size, was fixed in an 11% seawater-buffered formalin solution.

In the laboratory, otolith processing followed MARMAP/SERFS protocols (Smart et al. 2015). In summary, left otoliths, when available, were embedded in West System 105 epoxy resin, sectioned dorsoventrally through the core to a thickness of 0.7 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.

All age data provided to SEADAR90 included increment count and calendar 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 or narrow translucent edge (MRRI code: 1 or 2), regardless of date captured, the calendar age equals the number of increments (annuli) counted on the section. If the otolith section came from a fish that was captured during or after July, regardless of edge type, the 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.

In the laboratory, histological processing followed MARMAP/SERFS protocols (Smart et al. 2015). Briefly, tissue was dehydrated, infiltrated with paraffin, embedded in paraffin, and transverse sectioned (6-8 µm thick) prior to mounting on slides and staining with double strength Gill hematoxylin and eosin-y. Sex and reproductive phase was then assigned by two readers independently without knowledge of capture date, specimen length, or specimen age using histological criteria from Brown-Peterson et al. (2011). When assignments differed, the readers re-examined the sections simultaneously to reach consensus. If consensus could not be reached, then unknown sex and/or phase was assigned.

Fecundity samples were combined between MARMAP/SERFS samples and FWRI samples, similar to Wyanski et al. (2020). Histological samples were processed and examined to assess reproductive phase and search for evidence that ovulation had begun (i.e., postovulatory complexes (POC)). All specimens with new POCs (<12-24 hrs old) were not used for the estimation of batch fecundity. Batch fecundity was estimated gravimetrically by MARMAP/SERFS and Lowerre-Barbieri et al. (2015) using the hydrated oocyte method (see Hunter and Macewics, 1985; Murua et al., 2003). The protocols for processing Red Snapper ovarian tissue were similar, except for the methods of fixing tissue and separating oocytes. Lowerre-Barbieri et al. (2015) hydraulically separated the oocytes prior to fixation in 2% neutrally-buffered formalin and then weighed subsamples, whereas MARMAP/SERFS fixed the tissue in 10% seawater-buffered formalin, weighed subsamples, transferred subsamples to 5% seawater-buffered formalin, and then separated oocytes. MARMAP/SERFS investigators obtained 2 or 3 subsamples per specimen that weighed 75-175 mg, versus 2 subsamples weighing 100 mg in Lowerre-Barbieri et al. (2015).

Life History Analysis

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., were developing, spawning capable, or regressing) was compared with the histograms for females assessed as immature and regenerating/early developing.

Maturity analysis was performed for only female Red Snapper. Females of uncertain maturity were excluded from all reproductive analyses. All specimens with known stages for maturity were included in the maturity analyses, regardless of project, gear, or source (fishery-independent and dependent; n=7,192). Fish were considered mature using the traditional definition which included all months and individuals with oocyte development at or beyond the cortical alveolar stage or specimens with beta, gamma, or delta stages of atresia (Hunter and Macewicz 1985; n=6,345). Age and length-based maturity analyses were done using calendar age and maximum (pinched tail) total length. To estimate age/length maturity ogives, age at 50% maturity (A50) and length at 50% maturity, five functions were tested and compared: logit link, probit link, cloglog link, Cauchy link and Gompertz. The best fit model was selected by Akaike information criterion (AIC; Akaike, 1973) and used to predict the maturity at age and length for Red Snapper. Age at maturity was estimated for 4 periods that were defined by timing of previous stock assessments.

- 1978-2024
- 1978-2000
- 2001-2013
- 2014-2024

To test whether the sex ratio differed significantly from parity (i.e., 1:1), we conducted three separate regression analyses to evaluate the relationship between sex ratio and year, total length (MaxTL, mm), and calendar age (with age group 20+). A regression excluding the plus group for calendar age (n=27) was also included to provide comparison. When comparing sex ratio by year, data was limited by gear to chevron trap only. When comparing with calendar age and length, all specimens with a known sex assignment, regardless gear type were assessed to maximize the age and size range. Linear and nonlinear (logarithmic and power) relationships between sex ratio and the three parameters were explored and the model with the lowest AIC was selected as model of best fit. A one-sample t-test on the intercept term was used to assess whether the ratio significantly differed from 0, indicating deviation from a 1:1 sex ratio. Estimates of spawning fraction were based on histological criteria (presence of migratory nucleus oocytes (MNOs), hydrated oocytes (HOs) oocytes or POCs 12-36 hrs old) that indicate imminent or recent spawning (Hunter and Goldberg 1980; Hunter et al. 1986). Estimates of spawning fraction represented the proportion of specimens with one or more of the above criteria among all adult females (active + inactive) by month and by calendar age. Females with uncertain and immature maturity phases were excluded. All other specimens with known stages for maturity were included in this analyses, regardless of project, gear, source (fishery-independent and dependent) or collection date.

For batch fecundity analysis, counts were converted from the preserved subsample weight to preserved whole gonad weight for estimates of batch fecundity. Any individual in which we did not have a preserved whole gonad weight, we applied a conversion developed for this study:

$$\text{preserved wt (g)} = \text{fresh wt (g)} * 0.8833 - 1.6071$$

There was a range of fresh gonad wt = 7 to 51 g, an adj. r^2 value = 0.91 and a sample size =29. Batch fecundity to MaxTL (mm) was explored with regression analysis using a linear approach, power functions, and log transformations. Two power function models (with and without intercept; $BF = bX^z$ and $BF = a + (b*X^z)$) were tested, the latter to relax forcing the intercept through the origin. The approach with the lowest AIC value was selected.

Data analyses were performed using R software (R Core Team 2023) in the RStudio environment (RStudio Team, 2023).

Results

There was minimal overlap in the peak length distributions of immature or regenerating/early developing Red Snapper and substantial overlap of regenerating/early developing and definitely mature individuals indicating that maturity stages were assigned correctly (Figure 1).

Red Snapper included in the reproductive analyses for SEDAR 90 were captured between latitude 24.34° and 35.36° N and at a depth range of 14 to 212 meters, from fishery-independent and fishery-dependent sources, between 1978 – 2024 (n=16953). Specimens ranged in size from 159 to 997 mm MaxTL. All specimens smaller than 159 mm had unknown sex assignments (n=18). Increment counts in sagittal otoliths ranged from 0-45. Raw data were provided to the SEDAR 90 Data Workshop in 2025.

Overall, calendar age for females at 50% maturity (A50) was 1.17 yr (Gompertz, proportion mature = exp((-lamda/k)*exp(-k*age)); 95% confidence intervals (CI) = 1.07-1.27 yr; 1) and length at 50% maturity (L50) was 301 mm MaxTL (Logit, 95% CI = 262-345 mm; Table 2). Mature gonads were present in 44% of females at age 1, 77% of age 2, 95% of age 3, 98% of age 4, and 100% of females age 5 or older (Table 3). Mature gonads were present in 12% of females at MaxTL of 251-275 mm, 40% of females at MaxTL of 276-300, 69% of females at MaxTL of 301-325 mm, 87% of females at MaxTL of 326-350 mm, 96% of females at MaxTL of 376-400 mm, and 100% of females at MaxTL of 451 mm or larger (Table 4). The analysis of calendar age at maturity for the various time periods revealed the Gompertz model produced the lowest AIC value for all time periods. Age at maturity for female Red Snapper in 1978-2000, 2001-2013, & 2014-2024 was 1.99 yr (Gompertz, 95% CI = 0.30-3.68 yr), 1.45 yr (Gompertz, 95% CI = 1.06-1.87 yr) and 1.12 yr (Gompertz, 95% CI = 1.02-1.23 yr), respectively (Table 1). The analysis of length at maturity for the various time periods revealed the Logit link model produced the lowest AIC value for 2 of the 3 periods, with cLogLog model fitting best for the earliest time period. Length at maturity for female Red Snapper from 1978-2000, 2001-2013, & 2014-2024 was 395mm MaxTL (cLogLog, 95% CI = 208-748), 321mm MaxTL (Logistic, 95% CI = 199-514) and 298mm MaxTL (Logistic, 95% CI = 255-348), respectively (Table 2).

The overall female to male sex ratio for Red Snapper for all samples was 0.96 (Table 5). When comparing sex ratio across years of chevron trap catches, there was no significant difference in the regression relationship (Logarithmic: $t(34) = –0.917$, $p = 0.366$; Adj $R^2 = -0.005$). Differences in sex ratio for Red Snapper was apparent at certain age and size classes (Figure 2 & 3; Table 6 & 7). The regression analysis indicated a statistically significant positive relationship was also observed between MaxTL and sex ratio (Logarithmic: $t(31) = 4.09$, $p < 0.001$; Adj $R^2 =0.33$), showing a slight increase in female bias with fish size. A statistically significant positive relationship between calendar age and sex ratio was found using a power function ($t(19) = 2.98$, $p = 0.008$; Adj $R^2 =0.47$), suggesting that sex ratios were increasingly female biased in older age groups. This relationship increased almost two-fold when the plus 20-year-old group was excluded from analysis ($t(18) = 6.99$, $p = 0.017$; Adj $R^2 =0.83$).

Spawning season for Female Red Snapper is April-November, with peak being June through September (Figure 4; Table 8). Proportion of spawners to all adult females not limited by spawning season by calendar age was 0.22 in age 1 fish and 0.55 for ages 2+, but ranged from 0.49-0.69 in the other age groups (Table 9).

A total of 129 Red Snapper were collected from 1999-2023 to assess batch fecundity, including an additional 32 specimens collected and processed by MARMAP/SERFS since 2019 that were added to the dataset (n=97) analyzed for SEDAR73. The 129 specimens ranged in length from 314 to 958 mm MaxTL, in whole weight from 470 g to 11,830 g and in calendar age from 2 to 18 yr. Although the fits of the linear regression equations were good, the logarithmic function model was applied to the data because batch fecundity exhibited a non-linear relationship with total length (MaxTL) and whole weight (W), and to a lesser degree with calendar age (Figure 5 & Table 10; Adj. $R^2 = 0.57-0.76$). Having few samples over the length of 900 mm, weight of 9000 g and the age of 10 led to higher uncertainty in batch fecundity at larger sizes and ages. Future sampling efforts should target filling this data gap.

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Tables

Table 1. Results of various regression model analyses for age 50% at maturity for female Red Snapper, by period. Data for all projects and gears were combined. Age is expressed in calendar age. n=number of fish used in analyses, A_{50}= age at which 50% of population has reached sexual maturity. Proportion mature = exp((-lamda/k)*exp(-k*age).

					Parameter Estimates	
Period	Model	n	A_{50}	95% CI	lambda (Std Err)	k (Std Err)
1978-2024	Gompertz	7076	1.17	1.07-1.27	3.844 (0.357)	1.267 (0.038)
1978-2000	Gompertz	489	1.99	0.30-3.68	26.997 (15.302)	1.602 (0.189)
2001-2013	Gompertz	738	1.47	1.06-1.87	6.567 (1.795)	1.33 (0.108)
2014-2024	Gompertz	5849	1.12	1.02-1.23	3.885 (0.396)	1.300 (0.043)

Table 2. Results of various regression model analyses for length 50% at maturity for female Red Snapper, by period. Data for all projects and gears were combined. Length is maximum (pinched tail) total length (MaxTL) in mm. n=number of fish used in analyses, L_{50}=length at which 50% of the population has reached sexual maturity. Logit: Proportion mature = 1/1+ exp-((a+(b*MaxTL)); cLogLog: Proportion mature =1−exp(−exp(a +(b*MaxTL))).

Period	Model	n	L_{50}	95% CI	Parameter Estimate a (Std Err)	 b (Std Err)
1978-2024	Logit Logistic	7106	300.65	262-345	-6.979 (0.237)	0.023 (0.001)
1978-2000	cLogLog Logistic	460	395.16	208-748	-8.946 (1.489)	0.023 (0.004)
2001-2013	Logit Logistic	755	320.66	199-514	-14.906 (1.833)	0.047 (0.006)
2014-2024	Logit Logistic	5882	297.89	255-348	-15.122 (0.613)	0.051 (0.002)

Table 3. Percentage of mature specimens by calendar age for female Red snapper, by period. Specimens in the developing, spawning, regressing, or regenerating states were considered mature.

	1978-2024		1978-2000		2001-2013		2014-2024	
	n=7076		n=489		n=738		n=5849	
Calendar Age	Observed %	n	Observed %	n	Observed %	n	Observed %	n
0	0	1					0	1
1	43.8	528	0	5	31.8	44	45.3	479
2	77.1	1715	50	46	66.9	136	78.9	1533
3	95.1	2273	88	175	96.0	177	95.6	1921
4	98.0	985	94.6	148	97.8	91	98.7	746
5	99.8	513	100	55	100	118	99.7	340
6	100	315	100	26	100	68	100	221
7	100	198	100	14	100	53	100	131
8	100	125	100	2	100	23	100	100
9	100	101	100	5	100	5	100	91
10	100	88	100	5	100	2	100	81
11	100	40	100	2	100	1	100	37
12+	100	194	100	6	100	20	100	168

Table 4. Percentage of mature specimens by maximum (pinched tail) total length interval (MaxTL, mm) for female 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.

	1978-2024		1978-2000		2001-2013		2014-2024	
	n=7097		n=460		n=755		n=5882	
MaxTL (mm)	Observed %	n	Observed %	n	Observed %	n	Observed %	n
151-175	0	4					0	4
176-200	0	10					0	10
201-225	0	58	0	2	0	6	0	50
226-250	0.8	118	0	7	0	17	1.1	94
251-275	12.0	242	0	7	4.5	22	13.1	213
276-300	39.7	305	33.3	6	10.0	20	41.9	279
301-325	68.9	376	40.0	5	47.6	21	70.6	350
326-350	86.5	481	21.4	14	84.6	26	88.7	441
351-375	92.4	578	16.7	18	85.4	41	95.6	519
376-400	96.2	631	58.1	31	93.1	29	98.4	571
401-425	98.9	539	90.0	30	97.7	44	99.6	465
426-450	99.1	433	78.6	14	97.2	36	100	383
451-475	100	381	100	8	100	34	100	339
476-500	100	364	100	25	100	31	100	308
501-525	100	318	100	47	100	30	100	241
526-550	100	294	100	69	100	30	100	195
551-575	100	228	100	38	100	30	100	160
576-600	100	196	100	33	100	26	100	137
601-625	100	166	100	23	100	34	100	109
626-650	100	139	100	17	100	27	100	95
651-675	100	137	100	7	100	19	100	111
676-700	100	141	100	8	100	36	100	97
701-725	100	157	100	15	100	41	100	101
726-750	100	132	100	9	100	33	100	90
751-775	100	170	100	9	100	38	100	123
776-800	100	198	100	5	100	37	100	156
801-825	100	114	100	1	100	17	100	96
826-850	100	88	100	3	100	9	100	76
851-875	100	42	100	3	100	8	100	31
876-900	100	34	100	3	100	8	100	23
901-925	100	15			100	4	100	11
926-950	100	4	100	2			100	2
951-975	100	1					100	1
976-1000	100	3	100	1	100	1	100	1

Table 5. Red Snapper sex ratio and proportion female by year for chevron trap gear only, including all projects.

Year	Male n	Female n	Total n	Female:Male	Proportion Female
All Samples	8642	8295	16937	0.96	0.49
1988	12	17	29	1.42	0.59
1989	1	3	4	3	0.75
1990	14	10	24	0.71	0.42
1991	9	10	19	1.11	0.53
1992	7	13	20	1.86	0.65
1993	13	18	31	1.38	0.58
1994	22	21	43	0.95	0.49
1995	11	14	25	1.27	0.56
1996	5	4	9	0.80	0.44
1997	13	13	26	1	0.50
1998	16	9	25	0.56	0.36
1999	13	8	21	0.62	0.38
2000	8	9	17	1.13	0.53
2001	5	4	9	0.80	0.44
2002	21	15	36	0.71	0.42
2003	1	3	4	3	0.75
2004	4	1	5	0.25	0.20
2005	6	6	12	1.00	0.50
2006	4	2	6	0.50	0.33
2007	13	15	28	1.15	0.54
2008	12	17	29	1.42	0.59
2009	4	7	11	1.75	0.64
2010	85	79	164	0.93	0.48
2011	50	70	120	1.40	0.58
2012	204	221	425	1.08	0.52
2013	151	219	370	1.45	0.59
2014	289	330	619	1.14	0.53
2015	454	478	932	1.05	0.51
2016	567	524	1091	0.92	0.48
2017	769	723	1492	0.94	0.48
2018	1039	906	1945	0.87	0.47
2019	955	868	1823	0.91	0.48
2021	233	214	447	0.92	0.48
2022	926	883	1809	0.95	0.49
2023	959	796	1755	0.83	0.45
2024	788	743	1531	0.94	0.49

Table 6. Red Snapper sex ratio by maximum (pinched tail) total length (MaxTL, mm) 1978-2024, including all projects and gears.

MaxTL (mm)	Male n	Female n	Total n	Female:Male	Proportion Female
151-175	1	4	5	4	0.80
176-200	19	10	29	0.5	0.34
201-225	80	62	142	0.8	0.44
226-250	172	135	307	0.8	0.44
251-275	307	269	576	0.9	0.47
276-300	440	331	771	0.8	0.43
301-325	535	417	952	0.8	0.44
326-350	672	531	1203	0.8	0.44
351-375	830	632	1462	0.8	0.43
376-400	873	711	1584	0.8	0.45
401-425	720	613	1333	0.9	0.46
426-450	601	531	1132	0.9	0.47
451-475	483	459	942	1.0	0.49
476-500	426	434	860	1.0	0.50
501-525	386	380	766	1.0	0.50
526-550	314	349	663	1.1	0.53
551-575	273	281	554	1.0	0.51
576-600	193	235	428	1.2	0.55
601-625	172	202	374	1.2	0.54
626-650	164	182	346	1.1	0.53
651-675	120	165	285	1.4	0.58
676-700	154	183	337	1.2	0.54
701-725	103	193	296	1.9	0.65
726-750	125	153	278	1.2	0.55
751-775	128	193	321	1.5	0.60
776-800	115	223	338	1.9	0.66
801-825	82	125	207	1.5	0.60
826-850	51	95	146	1.9	0.65
851-875	21	50	71	2.4	0.70
876-900	9	39	48	4.3	0.81
901-925	2	19	21	9.5	0.90
926-950	3	6	9	2	0.67
951-975	1	1	2	1	0.50
976-1000	0	3	3	Inf	1.00

Table 7. Red Snapper sex ratio by Calendar Age from 1978-2024, including all projects and gears.

Calendar Age	Male n	Female n	Total n	Female:Male	Proportion Female
0	1	4	5	0.25	0.20
1	657	851	1508	0.77	0.44
2	1937	2480	4417	0.78	0.44
3	2516	2744	5260	0.92	0.48
4	1217	1268	2485	0.96	0.49
5	594	472	1066	1.26	0.56
6	415	272	687	1.53	0.60
7	223	124	347	1.80	0.64
8	154	73	227	2.11	0.68
9	103	63	166	1.63	0.62
10	99	49	148	2.02	0.67
11	45	32	77	1.41	0.58
12	49	23	72	2.13	0.68
13	41	14	55	2.93	0.75
14	29	15	44	1.93	0.66
15	20	9	29	2.22	0.69
16	21	9	30	2.33	0.70
17	20	7	27	2.86	0.74
18	16	6	22	2.67	0.73
19	10	4	14	2.50	0.71
20+	14	13	27	0.93	0.48

Table 8. The spawning fraction of Red Snapper (# female spawners/# adult females) by month group from 1978-2024, including all projects, and gears. A spawner had one or more indicators of spawning. MNO = Migratory Nucleus Oocytes, HO = hydrated oocytes, POC = postovulatory complex. Adult females included active and inactive adults.

Month	Adult n	Spawners n	Spawning Fraction (MNO, HO, POC)
Jan	21	2	0.10
Feb	45	0	0
March	85	1	0.01
April	372	53	0.14
May	1136	408	0.36
June	1597	1107	0.69
July	1007	724	0.72
Aug	927	485	0.52
Sept	900	485	0.54
Oct	118	42	0.36
Nov	24	5	0.21
Dec	25	1	0.04

Table 9. The spawning fraction of Red Snapper (# female spawners/# adult females) by calendar age group in MARMAP/SERFS histological data from 1978-2024, including all months, projects, and gears. A spawner had one or more indicators of spawning. MNO = Migratory Nucleus Oocytes, HO = hydrated oocytes, POC = postovulatory complex. Adult females included active and inactive adults.

Calendar Age (yr)	Adult n	Spawners n	Spawning Fraction (MNO, HO, POC)
1	225	50	0.22
2	1305	703	0.54
3	2134	1200	0.56
4	954	471	0.49
5	504	282	0.56
6	313	172	0.55
7	195	103	0.53
8	123	70	0.57
9-11	224	121	0.54
12-14	109	64	0.59
15-19	72	50	0.69
20+	9	5	0.56
2+	5942	3241	0.55

Table 10. Recommended logarithmic regression equations BF= EXP a+b*Log(X) for Red Snapper batch fecundity (BF) versus maximum (pinched tail) total length (MaxTL, mm), Total weight (g), and calendar age.

X	Range of X	a	SE_a	b	SE_b	n	Adj. R^2
MaxTL (mm)	314 to 958	-1674955	159880.8	4205.278	272.6782	129	0.649163
Whole Weight (g)	470 to 11830	-139117	65099.14	242.1331	14.41984	129	0.687011
Calendar Age	2 to 18	-234475	104903.8	195154.9	18623.24	126	0.465382

__Figures__

a

b

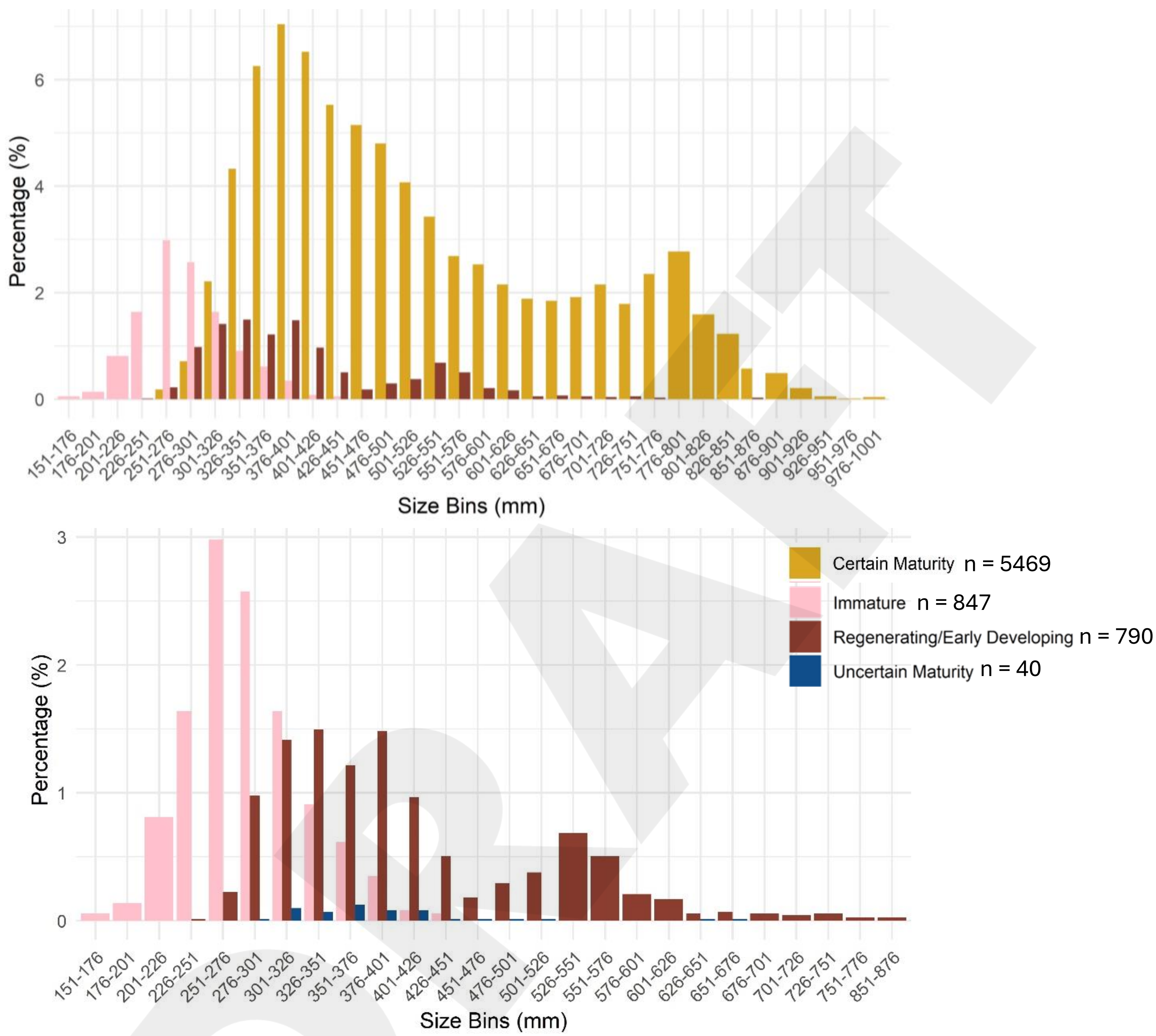

Figure 1. a. A comparison of female Red Snapper length-frequency histograms specimens that were categorized as 1) immature, 2) definitely mature, or 3) regenerating or early developing. Definitely mature specimens were developing, spawning capable, or regressing. **b**. Female Red Snapper histological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

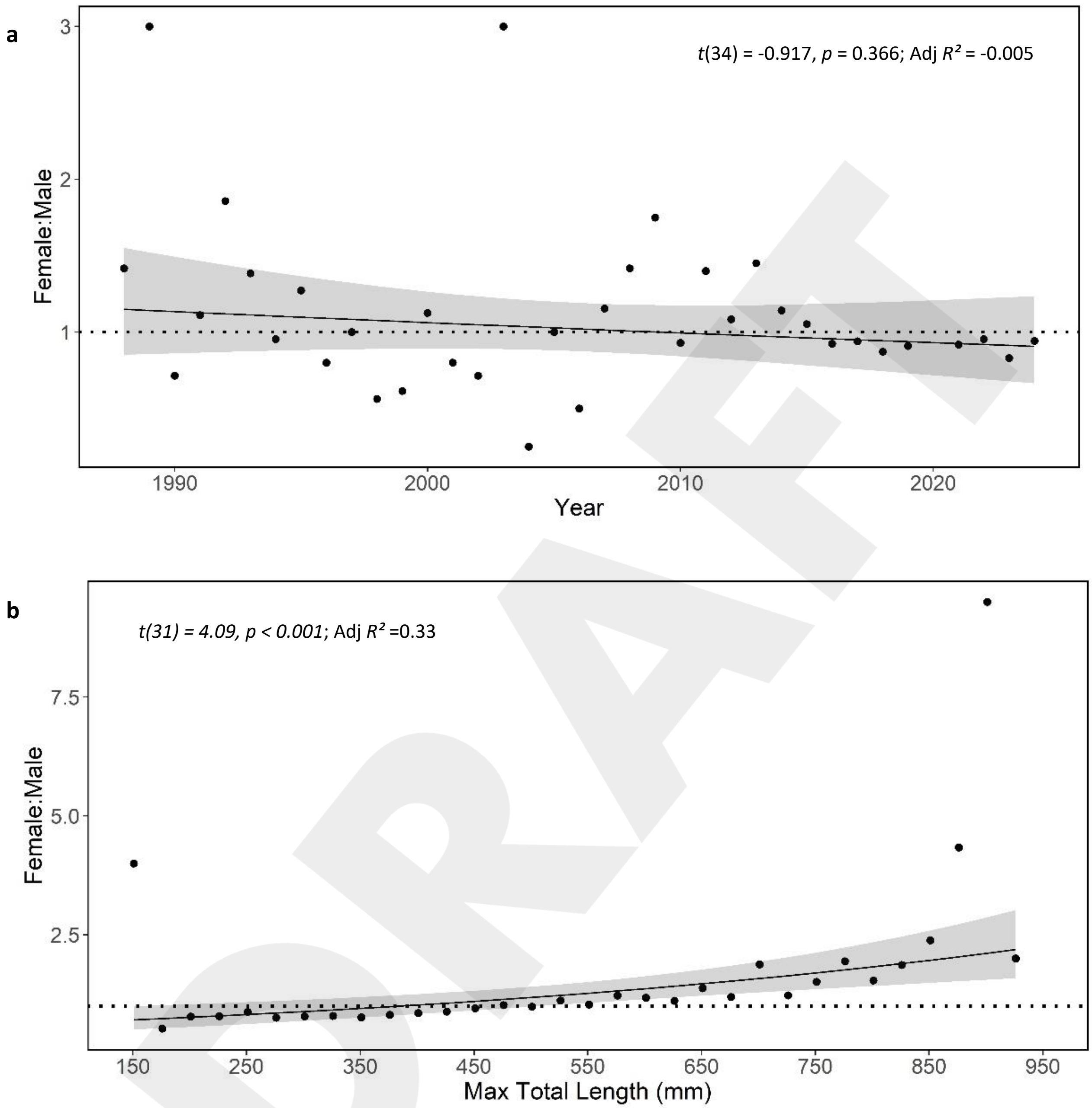

Figure 2. Female to Male Sex Ratio for Red Snapper by **a**) year (Chevron Trap Only) and **b**) Max TL in mm. Black line represents the linear regression of sex ratio by the respective variable, the gray shaded region represents standard error and the black dotted line represents the 1:1 sex ratio.

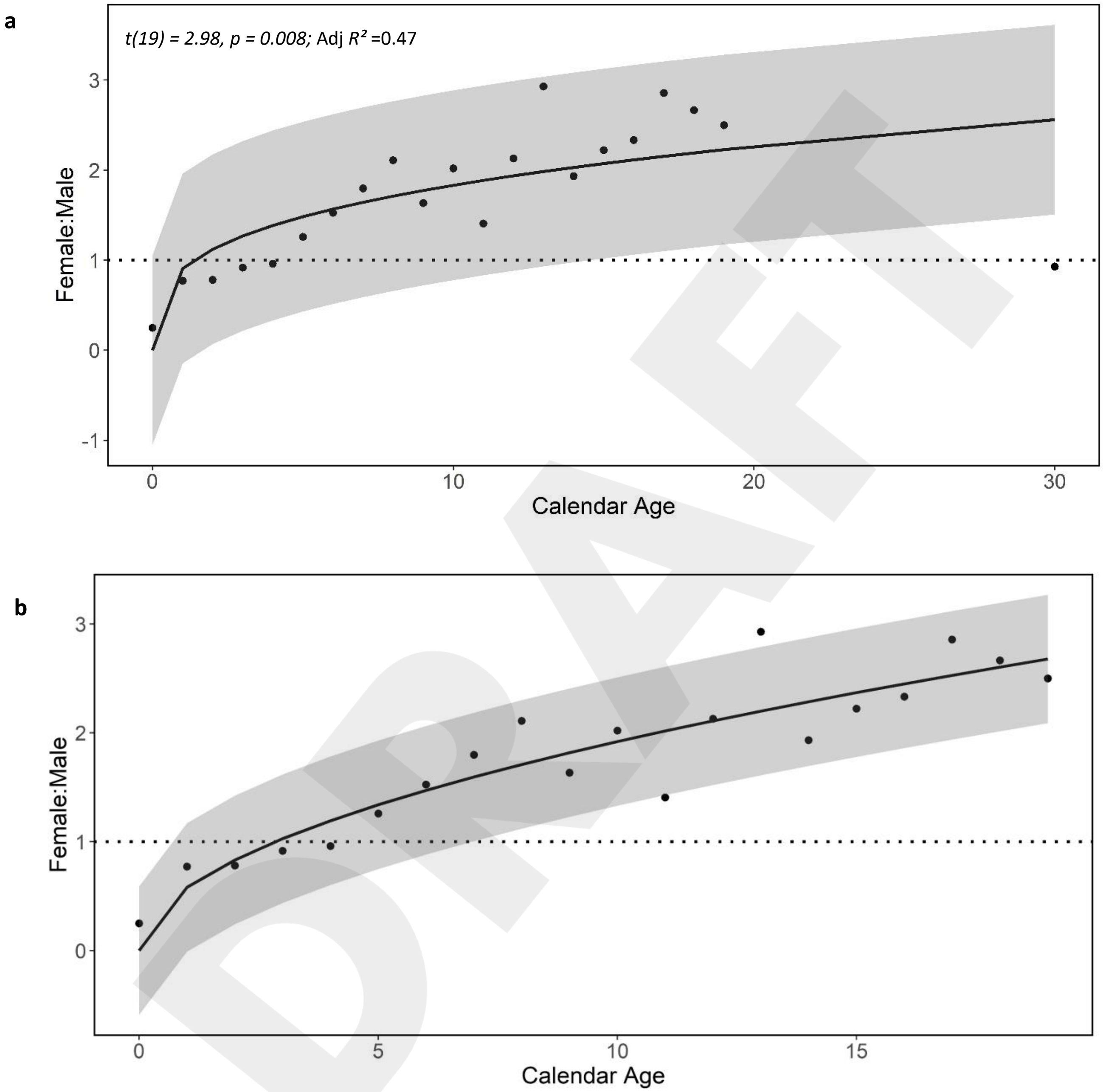

Figure 3. Female to Male Sex Ratio for Red Snapper by calendar age **a**) including and **b**) excluding the plus 20-year-old age group. Black line represents the linear regression of sex ratio by the respective variable, the gray shaded region represents standard error and the black dotted line represents the 1:1 sex ratio.

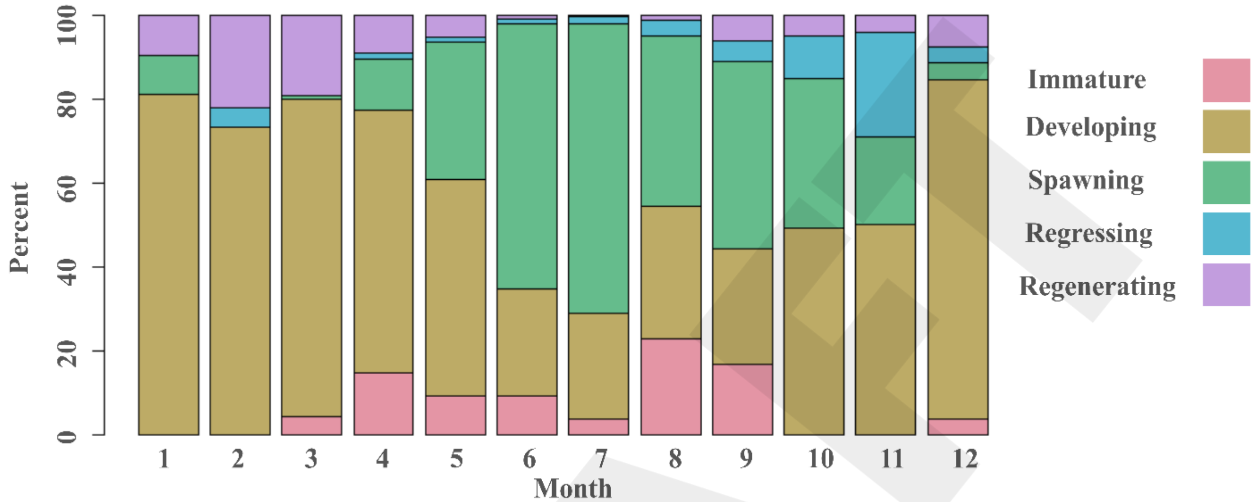

Figure 4. Female Red snapper spawning seasonality, 1978-2023. Developing includes specimen with cortical alveolar oocytes (CAO) and vitellogenesis and Spawning includes specimen with Migratory Nucleus Oocytes (MNO) and Hydrated Oocytes (HO) and Postovulatory Complexes (POC).

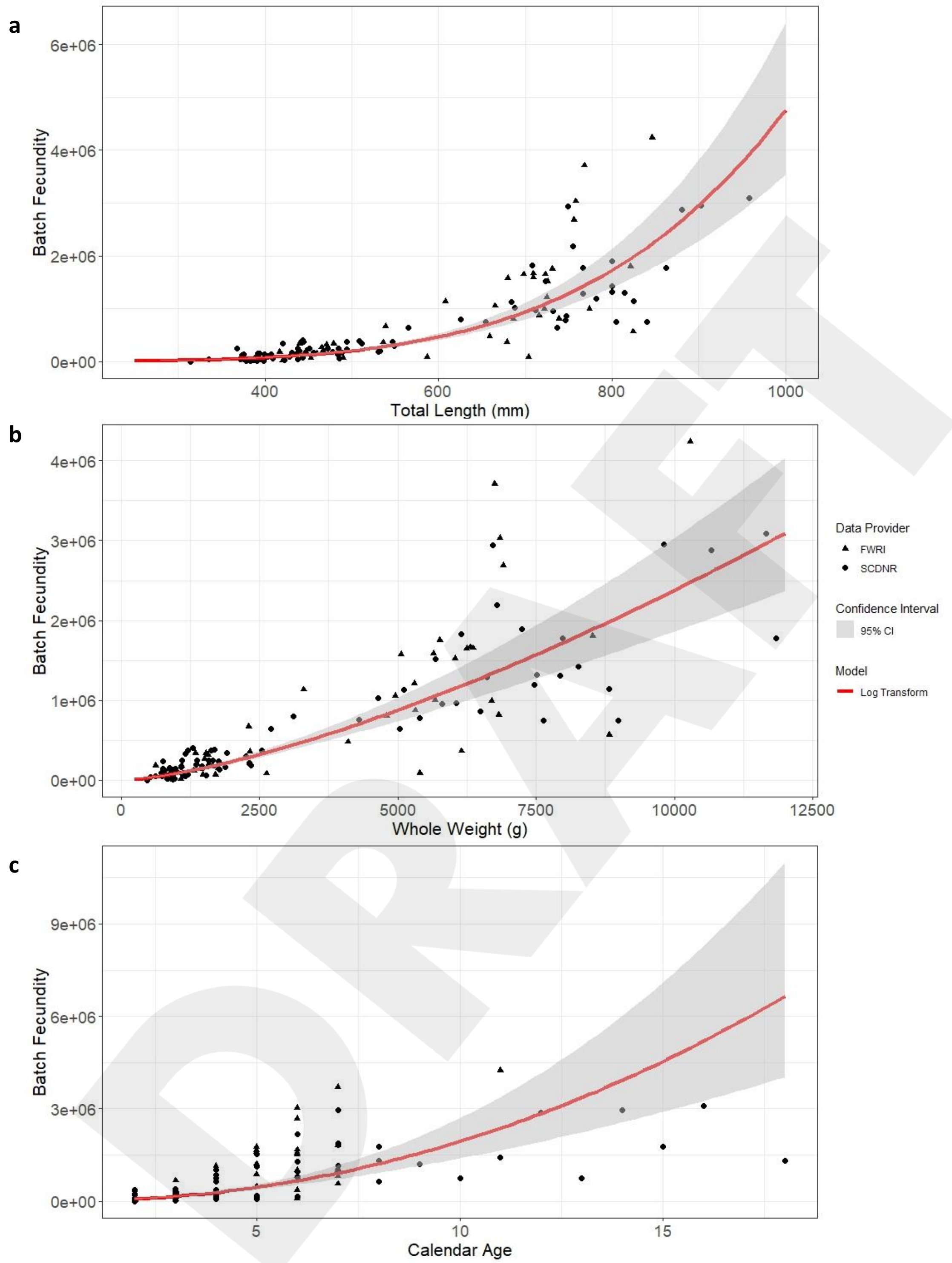

Figure 5. Non-linear regression analysis of batch fecundity (BF) versus **a**) total length and **b**) total weight **c**) Calendar Age in Red Snapper using the logarithmic function (Red Line, BF= EXP a+b*Log(X)) with 95% confidence intervals (gray shaded region). The Red Snapper were collected in 1999-2023 primarily during fishery-independent sampling off the Atlantic coast of the southeastern United States by Florida's Fish & Wildlife Research Institute (FWRI, closed triangles) and the SouthEast Reef Fish Survey at South Carolina Department of Natural Resources (SCDNR, closed circles).