Reproductive Parameters for South Atlantic Scamp and Yellowmouth Grouper in Support of the SEDAR 68 Research Track Assessment

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** Methods and results for maturity, sex transition, and spawning frequency updated as per decisions made at Plenary #2 and #3. **

Summary

Fishery-independent and fishery-dependent data for Scamp (*Mycteroperca phenax*) and Yellowmouth Grouper (*Mycteroperca interstitialis*) were collected by the Marine Resources Monitoring Assessment and Prediction (MARMAP) program and the Southeast Area Monitoring and Assessment Program, South Atlantic (SEAMAP-SA) at the South Carolina Department of Natural Resources (SCDNR) and the Southeast Fisheries Independent Survey (SEFIS) at the Southeast Fisheries Science Center (SEFSC), Beaufort. Fishery-independent samples for life history were collected via MARMAP's reef fish survey efforts during 1980 to 2009, and then by the collaborative Southeast Reef Fish Survey (consisting of MARMAP, SEAMAP-SA, and SEFIS) from 2010 to 2017, mostly with chevron traps. Fishery-dependent samples for life history were collected via MARMAP's short-term port sampling efforts or special projects, mostly via snapper reel. Life history data from MARMAP and SERFS were provided to the SEFSC ageing lab in Beaufort, NC, for growth rates and meristics. Here, we provide reproductive analyses from all data sources outlined above. See Table 1 for a breakdown of available samples. Given that the two species are similar in morphology and coloration at smaller sizes, the decision to combine Scamp and Yellowmouth Grouper data was made during the October 2019 data scoping webinar.

Methods

<u>Collection</u>: Nearly all Scamp and Yellowmouth Grouper were collected with three gear types (snapper reel, chevron trap, and short bottom longline). Standardized chevron traps have been used by MARMAP since 1990 and SERFS since 2010. For details on fishery-independent sampling, see MARMAP (2009) and Smart et al. (2015) for a full description of MARMAP/SERFS survey design and gear. All specimens of these two species captured during fishery-independent sampling by MARMAP and SERFS have been processed for life history. This includes individual measurements (e.g. whole weight and fork length), removal of otoliths, removal of a gonad tissue sample for histological analysis, and removal of an ovarian tissue sample from selected specimens during 1996 and 1998 to assess fecundity.

<u>Ageing</u>: Otoliths were embedded and sectioned following standard protocols and assigned increment counts and edge codes by two readers independently (Smart et al., 2015). Calendar ages were determined from consensus ages via the rule that if the edge code was 3 or 4 and month of capture was January through July, then calendar age was increment count + 1. For all other edge codes and months, the calendar age was increment count. If there is a need to compute fractional age during the assessment, the peak spawning month is May, with May 1 as the peak for computing fractional age on a daily scale.

<u>Maturity, sex ratio, and spawning frequency</u>: Gonad tissue samples from Scamp and Yellowmouth Grouper collected by MARMAP or SERFS were processed histologically and examined under a microscope by two readers independently via standard procedures (Smart et al., 2015) to determine sex and reproductive phase. Specimens with developing, spawning, regressing, or regenerating gonads were considered sexually mature (Brown-Peterson et al. 2011); however, functional maturity for females at calendar age and fork length was estimated by filtering data to include only developing, spawning capable and immature phases from spawning months (Feb-July), with developing and spawning capable phases representing mature females. This definition of maturity included specimens with oocyte development at or beyond the vitellogenic stage. All male specimens were considered

sexually mature. Data from all months were used to estimate calendar age and fork length at sex transition. Juvenile females were included in these analyses, whereas transitional specimens were omitted. Fork length data in millimeters were rounded to the nearest cm to create 10 mm bins.

Spawning frequency (SF, number of batches per individual fish) was determined from histological examination of gonad tissue. Females were categorized as actively spawning if there were indicators of imminent (oocyte maturation, including germinal vesicle migration and hydration) or recent (postovulatory follicle complexes, POC) spawning. The total duration of spawning indicators was assumed to be 48 h. Data were restricted to include all females (juvenile and adult) from the spawning season months (February – July; Harris *et al*., 2002). No females aged 1 yr were observed to be mature and to maintain comparable sample sizes, ages 14-23 were grouped in the 14+ age. For each calendar age, the SF was obtained by multiplying the proportion of spawning females by the spawning season duration as described in Gamboa-Salazar *et al*. (2019).

Fecundity: Samples of ovarian tissue from only Scamp were examined by Harris *et al.* (2002) to determine batch fecundity. Data from that study were re-analyzed due to the updated methodology used to calculated calendar age for the SEDAR68 assessment. The power function was recommended based on discussions from previous assessments (Bubley and Wyanski, 2017). This was due to the assumption that fecundity is a function of volume instead of a function of length.

Data analysis:
Analyses were completed with statistical software R, vers. 3.0.2 (R Core Team, 2013). To estimate age and length at maturity and at sex transition, a generalized linear model with a Logit, Probit, c-log, or Cauchy link was fit to maturity data in RStudio, vers. 3.5.2 (RStudio, 2018), and the best fit model was determined by comparing AIC values (Akaike, 1973). Spawning frequency was related to calendar age via polynomial regression, adding orders in a step-wise process and choosing the best fitting model via Akaike's Information Criterion (Akaike, 1978). To determine the relationship between batch fecundity and fish size (mm FL), the nls function in the stats package was used for power equation fitting (vers. 3.6.0 (R Core Team, 2019).

Results

Collection: Most specimens were collected by MARMAP and SERFS during fishery-independent sampling (52.4%) and through sampling of commercial catches by MARMAP (40.7%; Table 1). Overall, the primary gear types were snapper reels (50.0%), chevron traps (40.4%), and short bottom longline (5.3%). Only 0.6% (29 of 5,014) of the specimens examined were Yellowmouth Grouper. Of the 5,014 specimens examined, age and reproductive phase data were available for 4,546 specimens.

Maturity: The Logit model provided the best fit for estimating female calendar age at functional maturity (Table 2) and fork length at functional maturity (Table 3).
Estimated Female Age and Length at 50% Maturity: 2.9 years and 375.2 mm, respectively (Fig. 1).

Sex Ratio: The Probit model provided the best fit for estimating calendar age at sex transition (Table 4) and fork length at sex transition (Table 5).
Estimated Age and Length at 50% Sex Transition (to Male): 10.6 years and 646.9 mm, respectively

(Fig. 2).

Spawning frequency: Spawning frequency had a significant dome-shaped relationship with calendar age, with the best-fit model being a second order polynomial ($y = -4.710 + 6.148x - 0.425x^2$ with R^2 = 0.608, p = 0.002; Figure 3). Predicted values of SF were highest for ages 6-8 yr and lowest for the oldest females (Table 6). Note that no females aged 1 yr were observed to be mature.

Batch Fecundity: Batch fecundity was estimated by applying the power function to the data from Harris *et al.* (2002). The specimens were collected in 1996 (n=72) and 1998 (n=4) and ranged in fork length (FL) from 406 to 657 mm. Batch Fecundity = b * FL^z, with b= 0.0000316 and z= 3.53.

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Table 1. Sample availability for reproductive analyses by species and source, COM= commercial, FD= fishery-dependent, FI= fishery-independent, REC= recreational, UNK= unknown origin, and YM= Yellowmouth Grouper.

	FI		FI	COM		COM	REC		REC	UNK		UNK	Grand
Year	**Scamp**	**YM**	**Total**	**Scamp**	**YM**	**Total**	**YM**	**Scamp**	**Total**	**Scamp**	**YM**	**Total**	**Total**
1979	0	0	0	0	0	0	0	0	0	69	0	69	69
1980	17	0	17	0	0	0	0	0	0	45	0	45	62
1981	2	0	2	0	0	0	0	0	0	80	1	81	83
1982	3	0	3	0	0	0	0	0	0	0	0	0	3
1983	11	0	11	0	0	0	0	0	0	0	0	0	11
1984	16	0	16	0	0	0	0	0	0	0	0	0	16
1985	11	0	11	0	0	0	0	0	0	0	0	0	11
1986	7	0	7	0	0	0	0	0	0	0	0	0	7
1987	7	0	7	0	0	0	0	0	0	0	0	0	7
1988	30	0	30	0	0	0	0	0	0	0	0	0	30
1989	15	0	15	0	0	0	0	0	0	0	0	0	15
1990	74	1	75	0	0	0	0	0	0	0	0	0	75
1991	54	0	54	0	0	0	0	0	0	0	0	0	54
1992	57	0	57	0	0	0	0	0	0	0	0	0	57
1993	83	0	83	2	0	2	0	0	0	0	0	0	85
1994	127	0	127	0	0	0	0	0	0	0	0	0	127
1995	181	10	191	0	0	0	0	10	10	0	0	0	201
1996	153	0	153	856	4	860	0	358	358	4	0	4	1375
1997	192	0	192	0	0	0	0	0	0	0	0	0	192
1998	121	0	121	0	0	0	0	0	0	0	0	0	121
1999	88	0	88	0	0	0	0	0	0	0	0	0	88
2000	64	0	64	0	0	0	0	0	0	1	0	1	65
2001	95	0	95	0	0	0	0	0	0	0	0	0	95
2002	58	0	58	0	0	0	0	0	0	0	0	0	58
2003	47	0	47	0	0	0	0	0	0	0	0	0	47
2004	86	0	86	0	0	0	0	0	0	0	0	0	86
2005	85	2	87	426	0	426	0	0	0	0	0	0	513
2006	48	2	50	341	0	341	0	0	0	0	0	0	391
2007	84	2	86	179	2	181	0	0	0	0	0	0	267
2008	20	0	20	0	0	0	0	0	0	0	0	0	20
2009	43	0	43	4	0	4	0	0	0	0	0	0	47
2010	76	0	76	0	0	0	0	0	0	0	0	0	76
2011	89	0	89	0	0	0	0	0	0	0	0	0	89
2012	83	0	83	7	0	7	0	0	0	0	0	0	90
2013	94	0	94	0	0	0	0	0	0	0	0	0	94
2014	116	0	116	0	0	0	0	0	0	0	0	0	116
2015	99	0	99	0	0	0	0	0	0	0	0	0	99
2016	71	4	75	0	0	0	0	0	0	0	0	0	75
2017	96	1	97	0	0	0	0	0	0	0	0	0	97
Grand Total	2603	22	2625	1815	6	1821	0	368	368	199	1	200	5014

Table 2. Best fit for female age at functional maturity (Logit) in Scamp/Yellowmouth Grouper during the period 1979-2017.

Distribution	N	A_{50} (yr)			Estimate	Std. Error	z value	Pr(>|z|)
Logit	**1011**	**2.9**		**(Intercept)**	**-6.1129**	**0.7237**	**-8.447**	**<2e-16**
				CalAge	**2.0936**	**0.1998**	**10.477**	**<2e-16**

Calendar Age (yr)	**N**	**Prop. mature (observed)**	**Prop. mature (predicted)**
1	2	0.000	0.018
2	27	0.148	0.127
3	64	0.516	0.542
4	172	0.913	0.906
5	277	0.989	0.987
6	244	0.996	0.998
7	97	1.000	1.000
8	41	1.000	1.000
9	34	1.000	1.000
10	18	1.000	1.000
11	11	1.000	1.000
12	18	1.000	1.000
13	4	1.000	1.000
14	1	1.000	1.000
15	0	NA	1.000
16	0	NA	1.000
17	0	NA	1.000
18	0	NA	1.000
19	0	NA	1.000
20	1	1.000	1.000

Table 3. Best fit for female fork length at functional maturity (Probit) in Scamp/Yellowmouth Grouper during the period 1979-2017.

Distribution	**N**	**L_{50} (mm)**			**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
Logit	1085	375.2		**(Intercept)**	-16.7155	1.6901	-9.89	<2e-16
				Fork Length	0.0446	0.0042	10.74	<2e-16

Table 4. Best fit for female age at sex transition (Probit) in Scamp/Yellowmouth Grouper during the period 1979-2017.

Distribution	N	A_{50} (yr)			Estimate	Std. Error	z value	Pr(>|z|)
Probit	**4357**	**10.6**		**(Intercept)**	**-3.07207**	**0.07969**	**-38.55**	**<2e-16**
				CalAge	**0.28968**	**0.01014**	**28.56**	**<2e-16**

Calendar Age (yr)	N	# Female	# Male	Proportion Male (Obs)	Proportion Male (Pred)
1	7	7	0	0.000	0.003
2	87	87	0	0.000	0.006
3	278	278	0	0.000	0.014
4	718	710	8	0.011	0.028
5	1008	963	45	0.045	0.052
6	792	727	65	0.082	0.091
7	403	337	66	0.164	0.148
8	291	197	94	0.323	0.225
9	248	141	107	0.431	0.321
10	162	88	74	0.457	0.430
11	90	44	46	0.511	0.546
12	86	34	52	0.605	0.657
13	57	15	42	0.737	0.756
14	53	11	42	0.792	0.837
15	28	8	20	0.714	0.899
16	10	2	8	0.800	0.941
17	11	2	9	0.818	0.968
18	6	0	6	1.000	0.984
19	2	0	2	1.000	0.992
20	6	1	5	0.833	0.997
21	4	0	4	1.000	0.999
22	5	0	5	1.000	1.000
23	3	1	2	0.667	1.000
24	0	0	0	NA	1.000
25	0	0	0	NA	1.000
26	0	0	0	NA	1.000
27	0	0	0	NA	1.000
28	0	0	0	NA	1.000
29	0	0	0	NA	1.000
30	1	0	1	1.000	1.000
31	0	0	0	NA	1.000
32	0	0	0	NA	1.000
33	0	0	0	NA	1.000
34	1	0	1	1.000	1.000

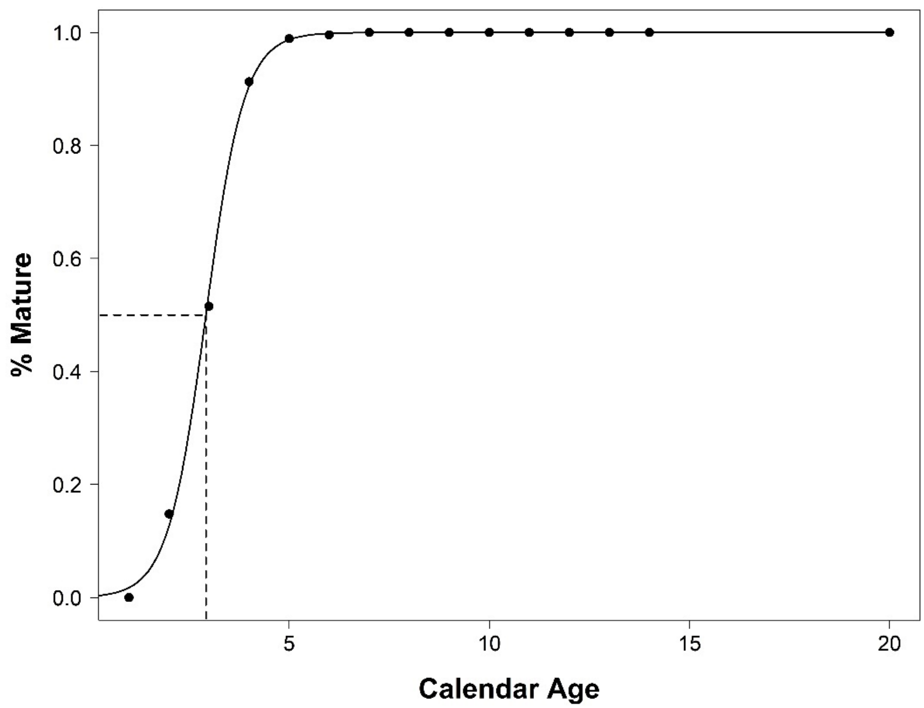
Table 5. Best fit for female fork length at sex transition (Probit) in Scamp/Yellowmouth Grouper during the period 1979-2017.

Distribution	**N**	**L_{50} (mm)**			**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
Probit	4584	646.9		**(Intercept)**	-7.7646	0.2256	-34.41	<2e-16
				Fork Length	0.0120	0.0004	31.53	<2e-16

Table 6. Predicted values of spawning frequency (SF, number of batches per individual fish) at calendar age for Scamp/Yellowmouth Grouper during the period 1979-2017 from a second-order polynomial regression model, with sample size (N) at each age. No Age 1 females were mature, and ages 14-23 were pooled. Predicted value of SF for age 14+ was negative (-1.97), therefore observed value was provided. Model equation $y = -4.710 + 6.148x - 0.425x^2$

Calendar Age (yr)	**SF**	**N**
1	1.01	2
2	5.88	46
3	9.91	145
4	13.08	411
5	15.40	603
6	16.87	507
7	17.49	226
8	17.26	115
9	16.18	94
10	14.25	41
11	11.47	25
12	7.84	25
13	3.36	11
14+	0.03	17

Figures



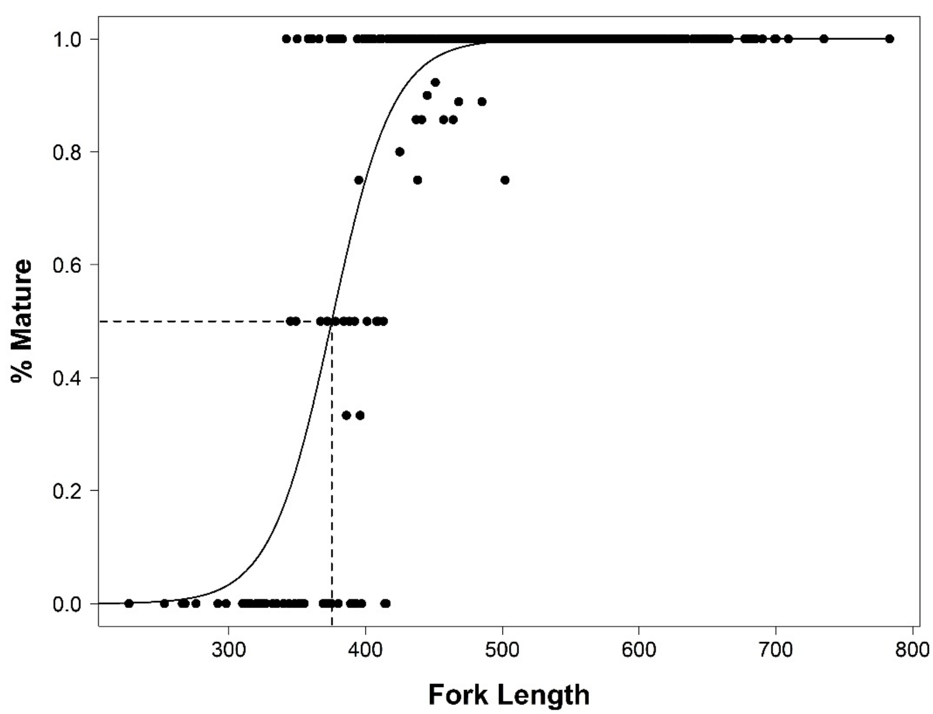


Figure 1. Calendar age (Logit) in years and length in mm (Logit) at functional maturity in female Scamp/Yellowmouth Grouper during the period 1979-2017.

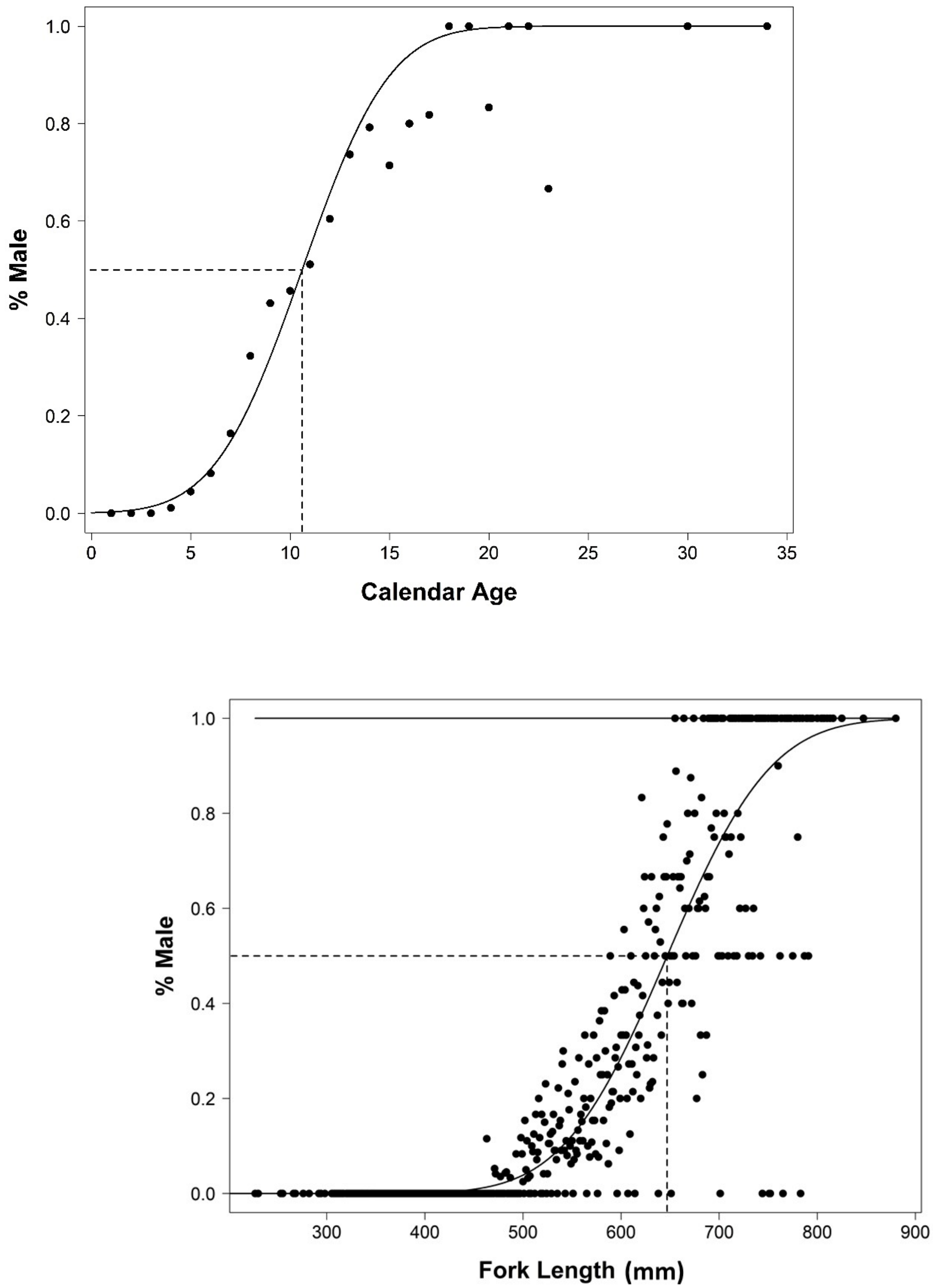


Figure 2. Calendar age in years and length (Probit) at sex transition in female Scamp/Yellowmouth Grouper during the period 1979-2017.

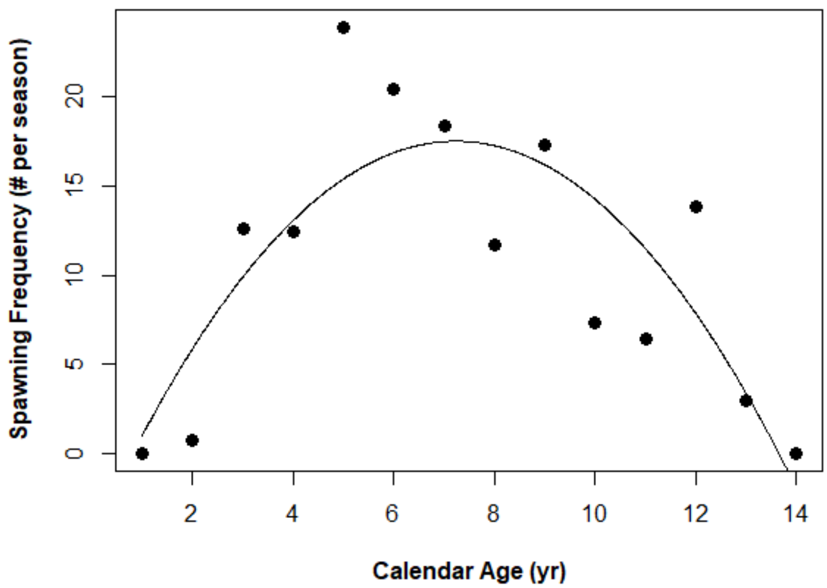


Figure 3. Observed (filled circles) spawning frequency at calendar age for Scamp/Yellowmouth Grouper during the period 1979-2017. A second-order polynomial regression model was fitted to the data (solid line). No age 1 females were mature, and ages 14-23 were pooled. Model equation $y = -4.710 + 6.148x - 0.425x^2$ with R^2 = 0.608, p = 0.002.

Figure 4. Batch fecundity at fork length (FL) for Scamp collected during 1996 (n=72) and 1998 (n=4). Batch Fecundity = b * FL^z, with b= 0.0000316 and z= 3.53.