Reproductive parameters of Gray Triggerfish (Balistes capriscus) from the Gulf of Mexico: sex ratio, maturity and spawning fraction

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Reproductive parameters of Gray Triggerfish (*Balistes capriscus*) from the Gulf of Mexico: sex ratio, maturity and spawning fraction

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Introduction

Our objective is to provide an update of reproductive parameters for Gray Triggerfish (*Balistes capriscus*) from the Gulf of Mexico to be used for the SEDAR 43 stock assessment. The pattern of oogenesis, estimates of interspawning interval, fecundity type and estimation of batch fecundity of Gray Triggerfish is presented in Lang and Fitzhugh (in Press). Lang and Fitzhugh also review previous reproductive studies of Gray Triggerfish and comment on its energy pattern and parental care which affects interpretation of reproductive dynamics. Herein we present new information from the Gulf of Mexico on sex ratio, maturity and the potential influence of size on spawning fraction.

Methods

Sampling and initial processing

Efforts were made to obtain lengths (FL mm), weights (kg), gonads and spines from commercial and recreational fisheries, and fisheries-independent (scientific) surveys from the Gulf of Mexico. Recreational sector samples were obtained from charterboats, headboats and private boats. Scientific surveys collected Gray Triggerfish using hook and line, traps, trawls and spear. Fish collected were weighed and measured, and the gonads were either stored on ice for later processing and fixation in the laboratory or were weighed at sea and subsamples fixed in 10% buffered formalin for histology (standard

H&E preparations). Often gonads were macroscopically sexed at the point of sampling (during trawl and reef fish surveys, and during port sampling).

Prior to 2002, a randomly selected region (anterior, medial, or posterior) on one or both lobes of the gonad was cross sectioned for collections. Starting in 2002, the posterior region of the gonad was consistently selected for sectioning (following Harris et al. 2002). Spines were extracted and ages were determined according to Allman et al. (2015).

Maturity

Based upon histological preparations of ovary sections, females displaying vitellogenic or more advanced oocytes (yolked oocytes) were defined as "mature" (consistent with prior SEDARs). Females with cortical alveoli (CA) or primary growth oocytes (PG) as the leading stage, but displaying atretic-yolked oocytes, were classified as "uncertain maturity". Females with primary growth oocytes and with no indications of prior spawning were classified as "immature". Female records used to determine maturity were taken only from the reproductive period (June, July and August). This was done to minimize uncertainty between resting or regenerating females and immature females.

In order to expand the number of maturity observations, especially among the smallest and youngest fish likely to be sampled during scientific surveys, macroscopic maturity records were added for consideration. Similar to the criteria above, only records from June, July and August from scientific surveys were retained. Macroscopic classes are described in Lang et al. 2013 and include immature, maturing, running ripe, spent and inactive (regressed). Gray Triggerfish records listed as maturing, running ripe and spent were aggregated and considered "mature", while females scored as inactive were considered to have "uncertain maturity".

Specimens were assigned 50 mm fork length classes and the proportion mature was related to length classes (mid-point) using logistic regression weighted by the numbers in each length class. Females considered to be "uncertain" in histological or macroscopic staging were censored while immature and mature totals were retained. The logistic model, based upon the Gompertz function, where P_x = proportion mature in each length or age class, was fitted to the data using maximum likelihood (logistic regression, XLSTAT version 7.5 analytical software). Model fits were compared using McFadden's r^2, a modified determination coefficient used in Logistic regression (XLSTAT version 7.5 manual and software).

Spawning fraction

As noted in Lang and Fitzhugh (in press), female Gray Triggerfish undergoing final oocyte maturation (including hydration) were very rare and could not be used to assess spawning fraction. Thus females were classified as "spawning" depending upon the presence of postovulatory follicles (POF) indicative of recent spawning activity. A comparison was made between females with and without POFs by 50 mm fork length class to assess any relationship between size and proportion of females bearing spawning markers.

Results and Discussion

Sample characteristics

From 1999-2014, n = 2370 Gray Triggerfish were sampled with sex (male or female), length and age recorded. Of those sexed histologically, n = 566, 74% were from scientific surveys based primarily upon trap (52%) and hook and line (45%) gears. Additional Gray Triggerfish were sampled and sexed macroscopically, n= 1804; primarily from scientific surveys (39% trap and trawl) and the recreational sector (59% headboat and charterboat). Very few Gray Triggerfish (n = 12 with length, age and sex) were sampled from the commercial sector for reproductive parameters.

Sex ratio

The sex ratio for Gray Triggerfish in the GOM was slightly female dominated; 56% based upon histology (Figure 1) and 64% female based upon macroscopic observation (Figure 2). The tendency for female dominance in sex ratio is a similar finding in a few studies from the U.S. south Atlantic particularly among smaller size classes (Moore 2001, David Wyanski, personal communication). However, studies that sampled Gray Triggerfish from commercial sources in the Gulf tended to report higher ratios of males overall and at larger sizes. Hood and Johnson (1997) report a ratio of 2.1:1 males to females (n = 486) and Wilson et al. (1995) report 2:1 males to females for 154 specimens.

Maturity

Very few immature females were observed (n= 8, via histology records only, Tables 1 & 3). This is similar to the finding of no or few immature Gray Triggerfish in previous studies (Wilson et al. 1995, Hood and Johnson 1997, Moore 2001). The rarity of immature females may reflect the early life cycle of Gray Triggerfish wherein young fish are pelagic during the first year of life and quickly obtain sexual maturity after they become more reef associated and begin to be subject to selection by fishing and most survey gears (Ingram 2001). By incorporating macroscopic maturity records from the scientific trawl survey, more immature Gray Triggerfish were observed (n=18 via combination of maturity records; Tables 2 & 4). This result is likely due to the susceptibility of newly settled young Gray Triggerfish to trawling gear.

Female A_{50} was 1.5 years, and L_{50} was estimated at 169 mm FL (Figures 3 & 4, respectively). In general, these estimates of length at maturity agree with previous studies (listed below) but the increased data suggest maturity occurs at slightly older ages:

1) Wilson et al. (1995): Gulf. Low sample sizes hampered estimation of maturity but most females considered sexually mature by age 2.

2) Hood and Johnson (1997): Gulf. Females were 87.5% mature by age 1 and by 250 mm FL, females were 91% mature.

3) Ingram (2001): Gulf. Females estimated to be 100% mature by age 2.

4) Moore (2001): S. Atlantic. 0% mature at age 0, 98% at age 1, 100% at age 2.

5) MARMAP results: S. Atlantic. Length at 50% maturity estimated at 177 mm FL. Females were 80% mature by age 1 and 96% mature by age 2 (David Wyanski, personal communication).

Spawning fraction

Comparing lengths of females bearing POFs with all females suggests there is no apparent relationship between size and likelihood of detecting females in spawning condition (Figure 5). Based upon observations in the northern Gulf made by SCUBA, females on nests are not significantly different in length than females observed away from nests (Simmons and Szedlmayer 2012). These results suggest that spawning fraction and hence spawning frequency does not increase with size for GOM Gray Triggerfish and therefore the number of spawning batches does not increase with size or age. However, in the U.S. south Atlantic, larger sample sizes obtained during the reproductive season have revealed that spawning frequency does increase with age (David Wyanski, personal communication).

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Table 1. Gray Triggerfish maturity by age. Includes females sampled during June, July and August with available ages. Maturity based on histology only.

Age	Immature	Mature	Total	Proportion M
2	4	14	18	0.78
3	3	53	56	0.95
4	1	46	47	0.98
5		27	27	1.00
6		6	6	1.00
7		4	4	1.00
Total	8	150	158	

Table 2. Gray Triggerfish maturity by age. Includes females sampled during June, July and August with available ages. Maturity based upon histology and adds scientific survey records where macroscopic maturity was recorded.

Age	Immature	Mature	Total	Proportion M
0	1		1	0.00
1	4		4	0.00
2	5	19	24	0.79
3	6	64	70	0.91
4	1	72	73	0.99
5	1	42	43	0.98
6		18	18	1.00
7		7	7	1.00
Total	18	222	240	

Table 3. Gray Triggerfish maturity by fork length (mm). Includes females sampled during June, July and August. Maturity based on histology only.

Size class	Mid-bin	Immature	Mature	Total	Proportion M
150-199	175	1		1	0.00
200-249	225	2	15	17	0.88
250-299	275	3	120	123	0.98
300-349	325	2	57	59	0.97
350-399	375		12	12	1.00
450-499	475		1	1	1.00
500-549	525		1	1	1.00
Total		8	206	214	

Table 4. Gray Triggerfish maturity by fork length (mm). Includes females sampled during June, July and August. Maturity based upon histology and adds scientific survey records where macroscopic maturity was recorded.

Size class	Mid-bin	Immature	Mature	Total	Proportion M
100-149	125	1	1	2	0.50
150-199	175	3		3	0.00
200-249	225	6	16	22	0.73
250-299	275	4	156	160	0.98
300-349	325	4	87	91	0.96
350-399	375		19	19	1.00
450-499	475		2	2	1.00
500-549	525		1	1	1.00
Total		18	282	300	

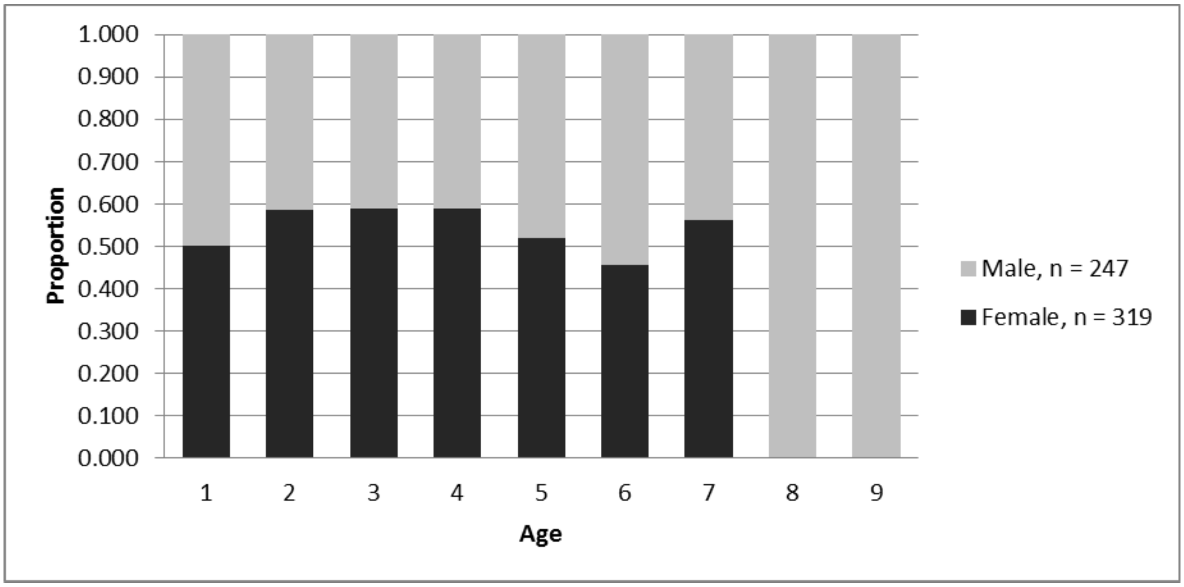

Figure 1. Sex ratio for Gray Triggerfish by age where sex was determined via histology. Overall female proportion = 0.56. Sample sources include 74% scientific survey and 26% recreational sector; 59% hook and line and 39% trap gear type.

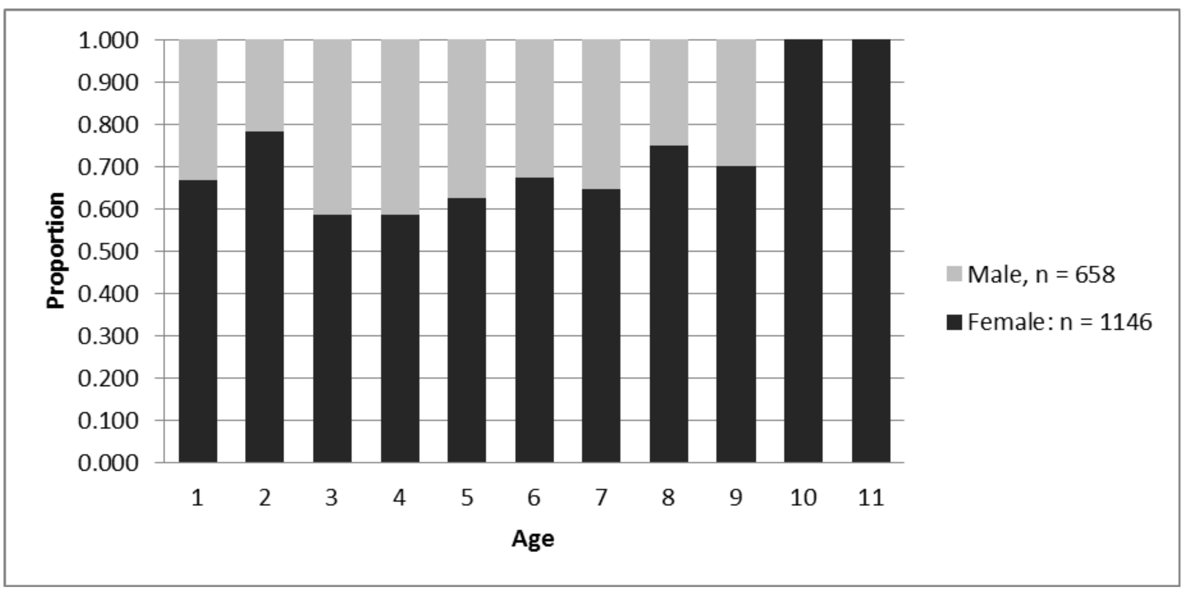

Figure 2. Sex ratio for Gray Triggerfish by age where sex was only determined by macroscopic observation (histological samples unavailable). Overall female proportion = 0.64. Sample sources include 38% scientific survey and 59% recreational sector; 65% hook and line, 26% trap and 9% trawl gear type.

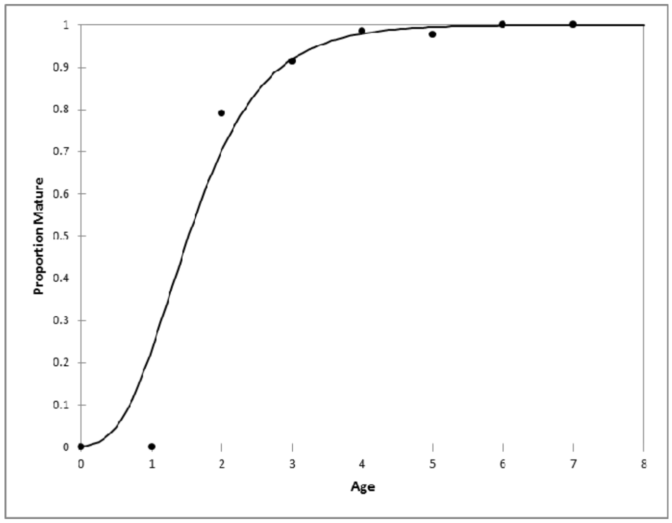

Figure 3. Logistic regression of proportion females mature by Age. A_{50} = 1.5 years. Total n = 240, data summarized in Table 2. Gompertz (EXCEL format): proportion M = exp(-exp(-(-1.81+1.43*age))). R^2(McFadden) = 0.293. Based upon records from June July and August for histological maturity (all available records) and macroscopic maturity from scientific surveys.

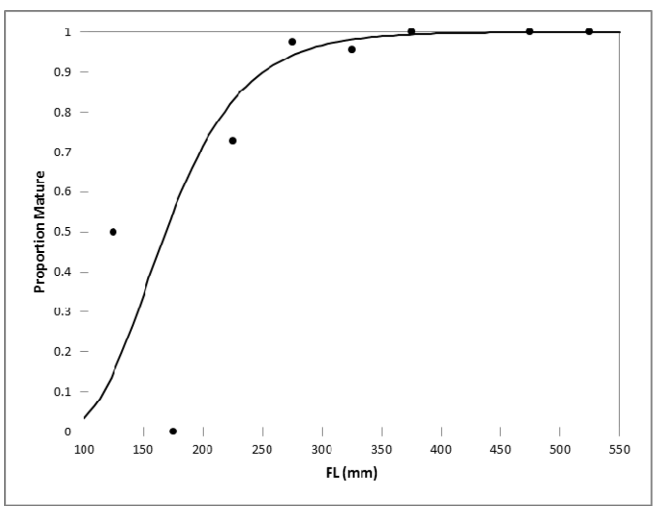

Figure 4. Logistic regression of proportion females mature by fork length. L_{50} = 169 mm FL. Total n = 300, Gompertz (EXCEL format): proportion M = exp(-exp(-(-3.54+2.32E-02*FL))). R^2(McFadden) = 0.172. Based upon records from June July and August for

histological maturity (all available records) and macroscopic maturity from scientific surveys.

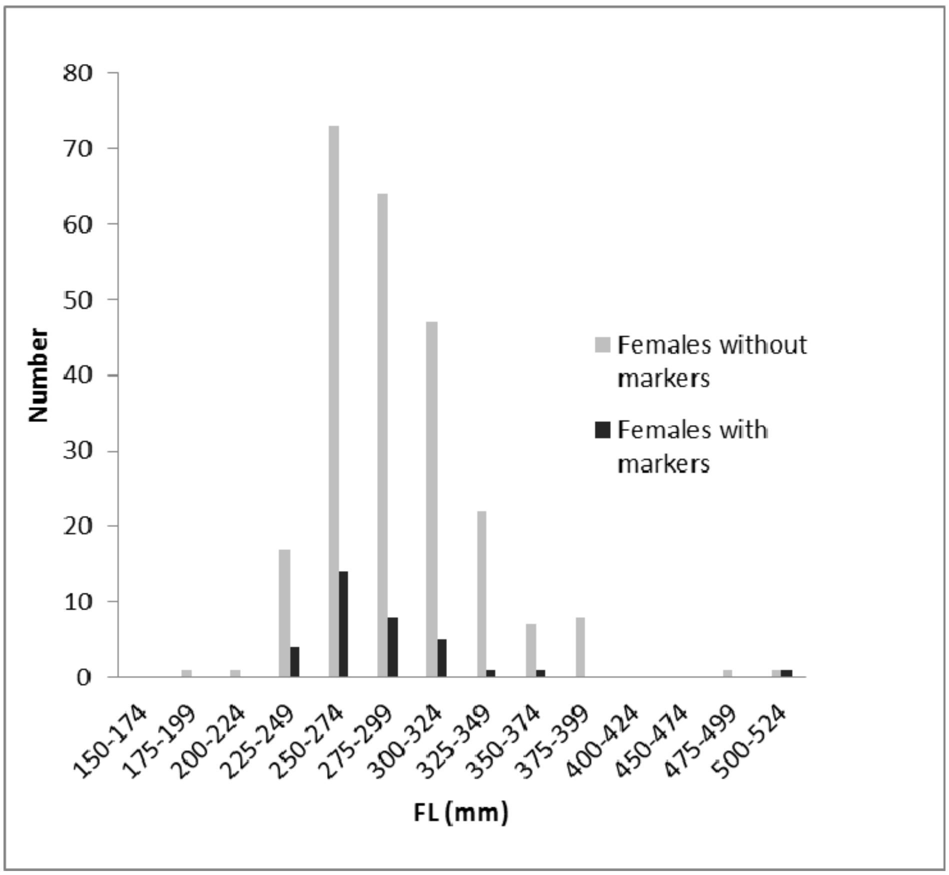

Figure 5. Females observed with and without spawning markers (postovulatory follicles) during June, July and August. Overall fraction = 34/242 = 0.14.