Report on Life History of South Atlantic Gray Triggerfish, *Balistes capriscus*, from Fishery-Independent Sources

Kevin J. Kolmos, Tracey Smart, David Wyanski, Amanda Kelly, and Marcel Reichert

SEDAR41-DW16

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Prepared by Kevin J. Kolmos, Tracey Smart, David Wyanski, Amanda Kelly, Marcel Reichert

Marine Resources Research Institute
South Carolina Department of Natural Resources

P. O. Box 12559
Charleston, SC 29422

Executive Summary

Gray Triggerfish analyzed for life history for this report were captured between latitude 27.23^{0}N and 35.10^{0}N and at a depth range of 0 to 93 m between 1973-2013 (n=10,207). Specimens ranged in fork length from 75 to 578 mm and ranged in weight from 11 to 4,064 g (0.02 to 8.96 lbs). Increment counts in the first dorsal spine ranged from 0 to 11. Our recommendation is to use length-length and length-weight conversion equations for males and females combined. Female and male age-at-maturity using increment count concluded both sexes mature within their first year. Analyses of female fork length-at-maturity yielded an L_{50} = 177 mm. Male fork length-at-maturity yielded an L_{50} = 179 mm. The overall sex ratio of 1.2:1 (F:M) was significantly different form a 1:1 ratio. Analyses indicated that female Gray Triggerfish were more abundant than males at smaller lengths, while male Gray Triggerfish were significantly more abundant at lengths $\geq$ 380 mm FL.

Introduction

Gray Triggerfish (*Balistes capriscus*) is a marine species in the family Balistidae that occurs in the tropical and temperate zones across the entire Atlantic Ocean, including the Mediterranean Sea (Robins and Ray 1986, Bernardes 2002). Gray Triggerfish occur in coastal waters of the western Atlantic from Nova Scotia (Canada) to Argentina, including the Gulf of Mexico and off Bermuda (Robins and Ray 1986, Bernardes 2002). Throughout this distribution Gray Triggerfish generally are found at depths of 0-100 m (Harmelin-Vivien and Quéro 1990). In the Gulf of Mexico, they are found commonly at depths between 12 and 42 m among reefs and hard bottom habitat (Harper and McClellan 1997).

Gray Triggerfish are iteroparous gonochorists, building nests and exhibiting bi-parental care (Mackichan and Szedlmayer 2007). Early life stages include demersal eggs and pelagic larvae (Richards and Lindeman 1987). Eggs may not fully hydrate or exhibit the degree of yolk fusion observed in pelagic eggs (Moore 2001). Postovulatory complexes (POCs) are rare in collections possibly due to reduced feeding by spawning females, thereby reducing the chances of females foraging, accepting bait and interacting with collection gear at this phase of the reproductive cycle (Moore 2001). It is unknown if fecundity is determinate or indeterminate. Thus, we know little about female reproductive potential, spawning frequency, and overall ovarian organization.

Male Gray Triggerfish have separate, small, oval-shaped testes that lie close together on the ventral side of the swim bladder. The common spermatic duct is lined with columnar secretory epithelial cells and surrounded by an accessory gland that may function to secrete substances that maintain spermatozoa while they are stored. Spermatic ducts act as a storage system for spermatozoa before release; therefore, both the testes and the spermatic duct/accessory gland complex are needed to accurately assess reproductive condition. A sample from the testes or duct/gland alone is usually only useful to assess sexual maturity (i.e., juveniles vs. adult).

Previous research on the age and growth of Gray Triggerfish has been derived predominately from fish outside the jurisdiction of the South Atlantic Fisheries Management Council (SAFMC). Peer-reviewed and unpublished studies in other regions, using the first dorsal spine as the aging structure, include the southern coast of Africa (Caveriviere et al. 1981, Ofori-Danson 1989, Aggrey-Fynn 2009), Brazil (Bernardes 2002), and the Gulf of Mexico (Johnson and Saloman 1984, Wilson et al. 1995, Hood and Johnson 1997, Ingram 2001, Fioramonti 2012). Along the US South Atlantic, only three projects have focused on the age and growth of Gray Triggerfish in coastal waters (Escorriola 1991, Moore 2001, Kelly 2014). Moore (2001) and Kelly (2014) found that Gray Triggerfish collected among reefs and hard bottom habitat from Cape Fear, North Carolina to Cape Canaveral, Florida ranged in age from 0 to 10 years old, with a maximum observed fork length (FL) of 578 mm. Both studies also found that males were significantly larger than females (Moore 2001, Kelly 2014). To our knowledge, all previous studies conducted on the age and growth of Gray Triggerfish utilized the first dorsal spine as the primary aging structure. The spine has been the accepted structure used to determine ages for Gray Triggerfish. The otoliths extremely small size and irregular shape make routine extraction and examination in this species difficult and time consuming compared to other species. Currently, no published documentation exists of comparisons among potential aging structures (spines, otoliths, vertebrae, etc.) in Gray Triggerfish.

Gray Triggerfish from the US South Atlantic are undergoing an inaugural benchmark stock assessment through the SouthEast Data, Assessment, and Review (SEDAR) process in 2014 (SEDAR 41). This assessment will include data through 2013.

This report describes the data collected by the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program, Southeast Area Monitoring and Assessment Program – South Atlantic (SEAMAP-SA) and Southeast Fishery-Independent Survey (SEFIS) program (for details of these programs see below and Ballenger et al. 2012).

Methods

Workshops were held in Charleston, SC (September 2011) and NOAA Southeast Fisheries Science Center (SEFSC)-Beaufort Laboratory (October 2012) in preparation for SEDAR 32. The goals of the workshops were to (1) compare sample preparation, reading methods and data analysis of the first dorsal spine of Gray Triggerfish, with an emphasis on addressing difficulties and issues previously encountered by Gulf of Mexico and Atlantic labs, and (2) compare reproductive histological assessments and finalize methodology and analyses (see SEDAR DW-03 for results). Considering the cessation of SEDAR 32 Gray Triggerfish Stock Assessment, an additional workshop was held at the NOAA SEFSC-Beaufort Laboratory in November 2013 to assess and resolve issues regarding assessment of age in Gray Triggerfish. As a result of the workshop, a refined aging criterion was put into place for all involved readers (Table 4).

Spines and reproductive tissues were taken from Gray Triggerfish specimens collected from coastal and offshore waters between Cape Hatteras, North Carolina, and Port St. Lucie, Florida, between 1973 and 2013 (n=10,207). The vast majority of specimens were collected during standard sampling by the MARMAP program (fishery-independent, Project ID: P05, P55, & Q26) from 1973 to 2013 and using chevron traps (gear code 324), but over the years other gears collected Gray Triggerfish such as Florida traps (gear code 074), blackfish traps (gear code 053), mini-Antillean "S" traps (gear code 041), 3/4 scale Yankee trawl (gear code 022), snapper/bandit reel (gear code 043), hook and line (gear code 014), spear gun (gear code 065), experimental trap (gear code 073), and Lionfish trap (gear code 540; Collins 1990, Harris and McGovern 1997, Harris et al. 2004, MARMAP 2009). SEFIS also provided samples using fishery-independent chevron traps and hook and line since 2010 (Project T60). The SEAMAP-SA Reef Fish Complement provided fishery-independent specimens from 2009-2013 (Project T59), collected with either hook and line or chevron traps. Thirty-seven Gray Triggerfish were collected during standard sampling by the SEAMAP-SA program (fishery-independent, Project P94), using a Mongoose-type Falcon trawl (gear code 233). Gray Triggerfish specimens also were obtained from commercial catches (fishery-dependent, Project ID: P50) using hook and line (gear code 014), dip net (gear code 019), snapper/bandit reel (gear code 043), and chevron trap (gear code 324). Summary tables were generated for gear deployment, fish collected, and fish aged per gear type and year (Table 1-3).

After collection, catches were sorted by species and processed following standard protocols (see details in MARMAP 2009). Whole Gray Triggerfish were weighed to the nearest gram (g) and pinched, maximum total length (TL), fork length (FL), and standard length (SL) were measured to the nearest mm. Note that fork length was used in all length-based analyses and weight was transformed into pounds (lbs) in this report based on the SEDAR 41 Data Scoping Conference Call. Spines were removed from all fish and stored dry prior to processing. Samples of gonad tissues were removed and stored in 11% seawater-buffered formalin until later processing.

Age

Spine sections were processed using standard methods as discussed and agreed upon by various collaborating fish aging labs that are providing age data to SEDAR 41 (SEDAR32-DW03). MARMAP utilized transverse sections of the dorsal spine immediately distal to the condyle groove for age determination. Spines were cleaned to a degree that surplus skin and muscle tissue were removed prior to sectioning. An Isomet low-speed saw was used to cut 0.4-0.7 mm thick sections from Gray Triggerfish spines.

At the NOAA SEFSC-Beaufort Laboratory, spine sections were examined independently by two readers and re-examined by the other reader if the original reader assigned an age of 6 years or older. Aging was done without knowledge of specimen length or date of capture. In addition, edge type and quality (i.e. readability) were recorded (Table 5). Edge types were coded as either the increment on the edge of the spine or growth beyond the increment. The workshop concluded that the increments as identified by the workshop participants can be considered annuli, and can be used to determine the age of Gray Triggerfish. Therefore, increment count was used in age analyses.

Reproduction

Following capture and dissection, the posterior portion of the gonads were fixed for 7–14 days in an 11% seawater–formalin solution and transferred to 50% isopropanol for an additional 7–14 days. Male Gray Triggerfish are unique in that both testes and the spermatic duct/accessory gland must be collected for complete analysis. For this reason, two different sections of the spermatic duct/accessory gland were taken along with a sample of the testes to ensure accurate staging. Reproductive tissue was processed in an automated and self-enclosed tissue processor and blocked in paraffin. Three transverse sections (6–8 µm thick) were cut from each sample with a rotary microtome, mounted on glass slides, stained with double-strength Gill hematoxylin, and counterstained with eosin-y. Sections were viewed under a compound microscope at 20-400X magnification, and sex and reproductive class were determined without knowledge of capture date, specimen length, or specimen age. Descriptive criteria for reproductive classes with the inclusion of subclasses for male staging were outlined and recommended during the Gray Triggerfish workshops (Table 6 and Table 7). Three readers independently determined sex and reproductive state using histological criteria (Tables 6 and 7). When assignments differed, the readers re-examined the section simultaneously to determine reproductive state. Females were considered to be in spawning condition if they possessed oocytes undergoing maturation (i.e., fusing of yolk globules, germinal vesicle migration and breakdown) or postovulatory complexes (POCs).

Statistical Analyses

All analyses were done using R Statistics software. In some instances, the data was subdivided based on depth, latitude and year of capture. The following criteria were used during for these analyses:

Depth:

Inshore:	Sampling depth < 30 m;
Offshore:	Sampling depth >= 30 m

Latitude:

	South:	Latitude < 32 degrees;
	North:	Latitude >= 32 degrees

Period:

	Early:	Year < 1990;
	Mid:	1989 < Year < 2000;
	Late:	Year>1999

Length-length and length-weight conversions were analyzed using linear regression analyses; prior to analyzing length-weight conversions, data were log transformed (ln). As we have no gutted weight data available, no weight-weight analyses were done. Sex ratio data were analyzed using a Chi-square goodness of fit test to determine if observed ratios differed among size classes from an expected 1:1 female:male (F:M) ratio (Zar 1984). R Statistical software was also used to estimate fork length (L_{50}) and age (A_{50}) at which 50% of the population has reached sexual maturity.

<u>Results</u>

Gray Triggerfish analyzed for this report were captured between latitude 27.23^{0}N and 35.10^{0}N and at a depth range of 0 to 93 m. Specimens ranged in fork length from 75 to 578 mm and ranged in weight from 11 to 4,064 g (0.024 to 8.96 lbs). Increment counts ranged from 0 to 11.

<u>Length-length and length-weight conversions.</u>

Linear regression analyses indicated that there were no significant differences in the slopes of various length-length regressions between males and females (Table 8) or in the slopes of length (mm) versus weight (lbs) between males and females (Table 9, Figure 2). In both cases, assuming equal slopes, there was a significant difference in intercepts between males and females. However, these differences were a result of a large data set and have no biological relevance. Our recommendation is to use conversion equations for males and females combined for fishery-independent samples (Table8 and 9).

<u>Length-at-Age</u>

A total of 7,420 fish were used in age analyses (Tables 10a, 10b). Length-at-age data from males, females and all data combined were fitted to the von Bertalanffy growth model (FL = L_∞*(1-*e*(-k*(age-t_0)))) and Gompertz growth model (FL=L_∞**e*((-(lamda/(k))**e*(-(k))*age))to generate estimates of growth parameters for Gray Triggerfish (Table 10a and 10b, Figure 3 and 4). Model selection was performed using Akaike's Information Criterion (AIC; Akaike 1973) and Bayesian Information Criterion (BIC, Schwarz 1978) for growth models of combined sexes. While the Gompertz model was a better fit (Table 10c), the difference was not considered to be biologically significant and perhaps due to a large sample size. Considering that the von Bertalanffy growth model is most commonly used in stock assessments, our recommendation is to use sex-specific von Bertalanffy growth parameters in order to provide comparisons to other stock assessments.

<u>Reproduction</u>

There was a high degree of overlap in the length distributions of definitely mature and regenerating Gray Triggerfish and modest overlap in the lengths of immature and all mature individuals, indicating that individuals were correctly assigned to the immature and regenerating classes (Figures 5 and 6).

Age-based maturity analyses were done using increment count. Predicted length (1 cm length bins) at maturity was based on a logistical model, as it provided the best fit to the data (Logistic, predicted mature = 1 - 1/(1 + exp(a + b*FL)). Predictions of female length-at-maturity yielded an L_{50} = 177 mm FL (Tables 11, 12, and 13). Mature gonads were present in 68% of females at age 0, 83% at age 1, 97% at age 2, 99% at age 3, and 100% at age >3. Male length-at-maturity yielded an L_{50} = 179 mm FL (Table 14, 15, and 16). Mature gonads were present in 64% of males at age 0, 84% at age 1, 97% at age 2, and 100% at age ≥3. The results of all modeling indicate that a large portion (> 60% for males and females) of Gray Triggerfish reach sexual maturity before Age 1.

The overall sex ratio of 1.2 was significantly different from a 1:1 F:M ratio, with the proportion of females being greater than that for males (Table 17 and 19). Analyses also indicated that female Gray Triggerfish were more abundant than males at smaller lengths, while male Gray Triggerfish were significantly more abundant at lengths ≥ 380 mm FL (Table 18, Figure 7, Figure 8).

Literature Cited

Aggrey-Fynn, J. 2009. Distribution and growth of grey triggerfish, *Balistes capriscus* (Family: Balistidae), in western Gulf of Guinea. West African Journal of Applied Ecology 15:3-11.

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Pages 267-281 *in* B. N. Petran, and F. Csaaki, editors. International symposium on information theory, 2nd edition.

Ballenger, J.C., T.I. Smart, and M.J. Reichert. 2012. Trends in relative abundance of reef fishes in waters off the SE US based on fishery-independent surveys. Marine Resources Research Institute. Charleston, SC. 143p.

Bernardes, R. A. 2002. Age, growth and longevity of the Gray Triggerfish, *Balistes capriscus* (Tetraodontiformes: Balistidae), from the southeastern Brazilian coast. Scientia Marina 66:167-173.

Brown-Peterson, N.J., D.M. Wyanski, F. Saborido-Rey, B. J. Macewicz, S.K. Lowerre-Barbieri. 2011. A standardized terminology for describing reproductive development in fishes. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 3:52-70.

Caveriviere, A., M. Kulbicki, J. Konan, and F. Gerletto. 1981. Bilan des connaissances acuelles sur *Balistes capriscus* dans le Golfe de Guinee. Doc. Sci Centre Rech.

Escorriola, J. I. 1991. Age and growth of the Gray Triggerfish *Balistes capriscus* from the southeastern United States. Thesis (MS). University of North Carolina at Wilmington.

Fioramonti, C. 2012. Age validation and growth of Gray Triggerfish, *Balistes capriscus*, of the northern Gulf of Mexico. Thesis (MS). University of West Florida.

Harmelin-Vivien, M.L. and J.C. Quéro. 1990. Balistidae. p. 1055-1060. In J.C. Quéro, J.C. Hureau, C. Karrer, A. Post and L. Saldanha (eds.) Check-list of the fishes of the eastern tropical Atlantic (CLOFETA). JNICT, Lisbon; SEI, Paris; and UNESCO, Paris. Vol. 2.

Harper, D. E. and D. B. McClellan. 1997. A review of the biology and fishery for Gray Triggerfish, *Balistes capriscus*, in the Gulf of Mexico. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory, Contribution Number MIA-96/97-52.

Hood, P.B. and A.K. Johnson. 1997. A study of the age structure, growth, maturity schedules and fecundity of Gray Triggerfish (*Balistes capriscus*), red porgy (*Pagrus pagrus*), and vermilion snapper (*Rhomboplites aurorubens*) from the eastern Gulf of Mexico. MARFIN Final Report. Florida Marine Research Institute, Florida Department of Environmental Protection.

Ingram, Walter. 2001. Stock structure of Gray Triggerfish, *Balistes capriscus*, on multiple spatial scales in the Gulf of Mexico. Ph.D. Dissertation, Department of Marine Sciences, University of South Alabama.

Johnson, A.G. and C.H. Saloman. 1984. Age, growth, and mortality of Gray Triggerfish, *Balistes capriscus*, from the northeastern Gulf of Mexico. Fishery Bulletin 82:485-492.

Kelly, A.M. 2014. Age, growth, and reproduction of Gray Triggerfish, *Balistes capriscus*, off the southeastern U.S. Atlantic coast. Thesis (MS) College of Charleston, South Carolina.

Mackichan, C.A and S.T. Szedlmayer. 2007. Reproductive behavior of the Gray Triggerfish, *Balistes capriscus,* in the northeastern Gulf of Mexico. Gulf and Caribbean Fisheries Institute 59:231-235.

Moore, J.L. 2001. Age, growth and reproductive biology of the Gray Triggerfish (*Balistes capriscus)* from the southeastern United States, 1992-1997. Thesis (MS) University of Charleston, South Carolina.

Ofori-Danson P. K. 1989. Growth of grey triggerfish, *Balistes capriscus*, based on growth checks of the dorsal spine. Fishbyte 7:11–12.

Richards, W.J. and K.C. Lindeman. 1987. Recruitment dynamics of reef fishes: planktonic processes, settlement and demersal ecologies, and fishery analysis. Bulletin of Marine Science 41:392-410.

Robins, C.R. and G.C. Ray. 1986. A field guide to Atlantic coast fishes of North America. Houghton Mifflin Company, Boston, U.S.A. 354 p.

Schwarz, G.E. 1978. Estimating the dimension of a model. Annals of Statistics 6:461-464.

SEDAR32-DW03. Report on Age Determination and Reproductive Classification Workshops for Gray Triggerfish (*Balistes capriscus*), September 2011 and October 2012.

Wilson, C.A., D.L. Nieland, and A.L. Stanley. 1995. Age, growth and reproductive biology of Gray Triggerfish (*Balistes capriscus*) from the northern Gulf of Mexico commercial harvest. Final Report, Coastal Fisheries Institute, Louisiana State University.

Wyanski, D.M., H.S. Meister, O. Pashuk, A.E. Williams, and P.P. Mikell. 2006. Reproductive classification of Gray Triggerfish (*Balistes capriscus*) and female blackbelly rosefish (*Helicolenus dactylopterus*). 3rd Workshop on the Gonadal Histology of Fishes, New Orleans.

Zar, J.H. 1984. Biostatistical analysis, 2nd edition. Prentice Hall, New Jersey. 719 p.

Table 1. Number of positive deployments per gear type for Gray Triggerfish. 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; 540=Lionfish chevron trap.

Number Gear Deployments (Trips) per Gear Type for Life History													
Year	**014**	**019**	**022**	**041**	**043**	**053**	**065**	**073**	**074**	**233**	**324**	**540**	**Total**
1978	0	0	1	1	2	0	0	0	0	0	0	0	4
1979	0	0	0	0	0	1	0	0	0	0	0	0	1
1980	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	1	0	0	0	8	0	0	0	9
1984	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	1	0	0	0	0	0	0	0	0	56	0	57
1992	0	0	0	0	6	0	0	0	0	4	85	0	95
1993	1	0	0	0	8	0	0	0	0	8	120	0	137
1994	1	0	0	0	9	0	0	0	0	7	151	0	168
1995	0	0	0	0	0	0	0	0	0	3	145	0	148
1996	2	0	0	0	4	0	0	0	0	3	179	0	188
1997	0	0	0	0	11	0	0	0	0	1	185	0	197
1998	0	0	0	0	0	0	0	0	0	0	122	0	122
1999	0	0	0	0	0	0	0	0	0	0	62	0	62
2000	0	0	0	0	1	0	0	0	0	0	89	0	90
2001	0	0	0	0	1	0	0	0	0	0	90	0	91
2002	0	0	0	0	0	0	0	0	0	2	106	0	108
2003	0	0	0	0	0	0	0	0	0	0	34	0	34
2004	1	0	0	0	3	18	0	0	9	0	90	0	121
2005	2	0	0	0	3	5	0	0	5	0	107	0	122
2006	1	0	0	0	0	8	0	0	2	0	75	0	86
2007	0	0	0	0	1	0	0	0	1	1	99	0	102
2008	2	0	0	0	0	0	1	0	0	3	72	0	78
2009	27	0	0	0	0	0	0	1	0	2	81	0	111
2010	10	0	0	0	0	0	0	0	0	0	105	2	117
2011	17	0	0	0	0	0	0	0	0	1	123	0	141
2012	0	0	0	0	0	0	0	0	0	0	206	0	206
2013	0	0	0	0	0	0	0	0	0	0	296	0	296

Total	64	1	1	1	50	32	1	1	25	35	2678	2	2891

Table 2. Number of Gray Triggerfish 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; 540=Lionfish chevron trap.

Number Fish Collected per Gear Type for Life History													
Year	**014**	**019**	**022**	**041**	**043**	**053**	**065**	**073**	**074**	**233**	**324**	**540**	**Total**
1978	0	0	2	1	4	0	0	0	0	0	0	0	7
1979	0	0	0	0	0	2	0	0	0	0	0	0	2
1980	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	1	0	0	0	12	0	0	0	13
1984	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	1	0	0	0	0	0	0	0	0	147	0	148
1992	0	0	0	0	202	0	0	0	0	5	199	0	406
1993	1	0	0	0	159	0	0	0	0	9	298	0	467
1994	3	0	0	0	15	0	0	0	0	7	444	0	469
1995	0	0	0	0	0	0	0	0	0	3	537	0	540
1996	5	0	0	0	244	0	0	0	0	3	843	0	1095
1997	0	0	0	0	484	0	0	0	0	1	823	0	1308
1998	0	0	0	0	0	0	0	0	0	0	509	0	509
1999	0	0	0	0	0	0	0	0	0	0	188	0	188
2000	0	0	0	0	1	0	0	0	0	0	267	0	268
2001	0	0	0	0	1	0	0	0	0	0	247	0	248
2002	0	0	0	0	0	0	0	0	0	2	328	0	330
2003	0	0	0	0	0	0	0	0	0	0	67	0	67
2004	2	0	0	0	43	60	0	0	19	0	255	0	379
2005	7	0	0	0	16	12	0	0	14	0	380	0	429
2006	1	0	0	0	0	8	0	0	10	0	172	0	191
2007	0	0	0	0	1	0	0	0	1	1	299	0	302
2008	2	0	0	0	0	0	1	0	0	3	310	0	316
2009	45	0	0	0	0	0	0	1	0	2	256	0	304
2010	13	0	0	0	0	0	0	0	0	0	219	10	242
2011	38	0	0	0	0	0	0	0	0	1	392	0	431
2012	0	0	0	0	0	0	0	0	0	0	505	0	505
2013	0	0	0	0	0	0	0	0	0	0	1043	0	1043

Total	117	1	2	1	1171	82	1	1	56	37	8728	10	10207

Table 3. Number of Gray Triggerfish 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; 540=Lionfish chevron trap.

Number Fish Aged per Gear Type for Life History													
Year	**014**	**019**	**022**	**041**	**043**	**053**	**065**	**073**	**074**	**233**	**324**	**540**	**Total**
1978	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
1980	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	109	0	109
1992	0	0	0	0	0	0	0	0	0	0	156	0	156
1993	0	0	0	0	0	0	0	0	0	0	253	0	253
1994	0	0	0	0	0	0	0	0	0	0	372	0	372
1995	0	0	0	0	0	0	0	0	0	0	442	0	442
1996	0	0	0	0	0	0	0	0	0	0	736	0	736
1997	0	0	0	0	0	0	0	0	0	0	677	0	677
1998	0	0	0	0	0	0	0	0	0	0	452	0	452
1999	0	0	0	0	0	0	0	0	0	0	167	0	167
2000	0	0	0	0	0	0	0	0	0	0	209	0	209
2001	0	0	0	0	0	0	0	0	0	0	197	0	197
2002	0	0	0	0	0	0	0	0	0	0	287	0	287
2003	0	0	0	0	0	0	0	0	0	0	64	0	64
2004	0	0	0	0	0	0	0	0	0	0	182	0	182
2005	0	0	0	0	0	0	0	0	0	0	322	0	322
2006	0	0	0	0	0	0	0	0	0	0	142	0	142
2007	0	0	0	0	0	0	0	0	0	0	270	0	270
2008	0	0	0	0	0	0	0	0	0	0	272	0	272
2009	0	0	0	0	0	0	0	0	0	0	238	0	238
2010	0	0	0	0	0	0	0	0	0	0	197	0	197
2011	0	0	0	0	0	0	0	0	0	0	338	0	338
2012	0	0	0	0	0	0	0	0	0	0	449	0	449

2013	0	0	0	0	0	0	0	0	0	0	909	0	909
Total	0	0	0	0	0	0	0	0	0	0	7440	0	7440

Table 4. Aging criteria created by the participants at the November 2013 Gray Triggerfish workshop at NOAA Fisheries SEFSC-Beaufort Laboratory. Note: Updated aging criteria can be seen in the final November 2013 Aging Workshop Report.

1. Use magnification ≤ 20x.
2. First obvious, lobate shaped increment is equal to first annulus. Lobate shape needs to be apparent on both sides to include the proposed increment in final count.
3. When applying criteria regarding discreteness of increments, only look at spine structure ventral/posterior to the focus. If two suspected increments merge anywhere posterior to the focus along the spine lateral margin, do not count as separate increments, but rather as doublets (or triplets in rare cases). **Note**: Change in criteria from prior criteria: Line where two lobes come together is cutoff where merge or non-merge to determine doublets, except for first increment in which case the whole spine where visible is allowed to be utilized.
4. Valid increments include all obvious increments, where some obvious increments can appear as dark or "negative" bands.
5. If different counts on each lobe, then go with lower increment count. However, if ages vary ≥3, than sample will not be used.
6. Edge type will now be labeled as 1 or 4 (due to BSD setup) and no longer 1-4 as per otoliths. Generally, define the edge, or margin, type at the tip of the lobes, because you have the most resolution. Annual increments on Gray Triggerfish spines are translucent, thus, 1: increment on the margin: translucent or transparent; 4: opaque. GOM only uses translucent or opaque so biological (or fractional) ages can be back-calculated (based on July 1 birthdate) from increment counts.
7. If cut in condyle groove, use counts more on lateral sides rather than down lobes.
8. When in doubt (such as bubbles presents from mounting medium), try flipping slide over to age.

Table 5. Spine edge type and quality.

EDGE TYPE

Code	Description
1	Presence of the translucent zone on the edge of the spine section
4	Absence of the translucent zone on the edge of the spine section

READABILITY

Code		Description and 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 yrs). Agreement after second reading is expected without much discussion.
E	Excellent readability	Age estimates between readers should be the same.

Table 6. Histological interpretation of female Gray Triggerfish. Most descriptors based on Moore (2001), Wyanski et al. (2006) and Brown-Peterson et al. (2011).

Maturity Class	Description
Uncertain Maturity (Class 0)	Inactive ovaries, primary growth oocytes only; unable to assess maturity
Immature (Class 1)	Primary growth oocytes 20-60 micron diameter (Moore 2001); no evidence of atresia. In comparison to regenerating female, transverse section of ovary is smaller, lamellae lack muscle and connective tissue bundles and are not as elongate, oogonia abundant along margin of lamellae, ovarian wall is thinner
Cortical alveolar oocytes (Class E)	Early Developing; Previtellogenic; cortical alveolar oocytes 140-200 micron diameter
Yolked oocytes (Class F)	Vitellogenic; Most advanced oocytes in yolk-granule or yolk-globule stage; oocyte 170-400 micron diameter
Migratory nucleus oocytes (Class G)	Oocyte maturation; partial coalescence of yolk globules possible; Oocytes 385-500 micron diameter
Postovulatory follicles (POFs): early (Class B), intermediate (Class C), late (Class D)	Vitellogenic oocytes and POFs; Evidence of recent spawn; note that beta-stage atresia cannot always be distinguished from medium to old postovulatory follicles (Hunter and Macewicz 1985)
Regressing (Class 4)	>50% of yolked oocytes undergoing alpha or beta stage of atresia
Regenerating (Class 5)	Primary growth oocytes > 60 micron diameter, with traces of atresia possible. In comparison to immature female, transverse section of ovary is larger, lamellae have muscle and connective tissue bundles and are more elongate and convoluted, oogonia less abundant along margin of lamellae, ovarian wall is thicker and exhibits varying degrees of expansion due to previous spawning
Mature specimen (Class 8)	Mature, but postmortem histolysis or inadequate quantity of tissue prevent assessment of reproductive class
Unknown (Class 9)	Postmortem histolysis or inadequate quantity of tissue prevent assessment of reproductive state

Table 7. Histological interpretation of male Gray Triggerfish. Most descriptors based on Moore (2001), Wyanski et al. (2006) and Brown-Peterson et al. (2011) with the inclusion of sub-classes.

Maturity Class	Sub-Class	Description
Uncertain Maturity (Class 0)		Inactive testes; unable to assess maturity
Immature (Class 1)		Small transverse section compared to regenerating male; little or no spermatocyte development
Developing (Class 2)		Limited spermatogenesis in testes; elongation of lobules and some accumulation of spermatozoa (SZ) in testes BUT no accumulation in lobules, efferent ducts (within testes), and spermatic ducts
Spawning Capable (3 sub-classes)	Early Spawning Capable (Subclass ESC)	Spermatozoa evident in ducts; amount of spermatogenesis in testes ranges from limited to extensive; in ducts, greater area of structural tissue compared to sinuses
	Storage (Subclass H)	Spermatozoa storage within expanding ducts; >50% of area of sinuses densely packed with spermatozoa; amount of spermatogenesis in testes ranges from limited to extensive
	Recent Spawn (Subclass 7)	Large, expanded ducts not as densely packed with spermatozoa; area of sinuses greater than that of structural tissue; usually has empty lobules toward center of testes
Regressing (Class 4)		Limited spermatogenesis in testes; shrinking ducts/lobules with residual spermatozoa present; overall number of ducts containing spermatozoa also small; increase of connective tissue in testes, proliferating from center; may have enlarged cells lining sinuses
Regenerating (Class 5)		Larger transverse section compared to immature male; very limited or no spermatogenesis in testes; little or no residual spermatozoa in ducts
Mature Specimen (Class 8)		Postmortem histolysis or inadequate quantity of tissue prevent assessment of reproductive class
Unknown (Class 9)		Postmortem histolysis or inadequate quantity of tissue prevent assessment of reproductive state

Table 8. Gray Triggerfish length versus length relationships. TL= maximum total length, FL=fork length, SL=standard length. All lengths are in mm. n=number of specimen. R^2 is adjusted for degrees of freedom.

	equation	n	a	b	R2
All	TL=a+b*FL	9003	-17.50	1.205	0.9684
	TL=a+b*SL	9012	2.31	1.372	0.9551
	FL=a+b*SL	9009	16.60	1.138	0.9845
Males	TL=a+b*FL	3862	-19.986	1.213	0.9666
	TL=a+b*SL	3863	0.698	1.381	0.9538
	FL=a+b*SL	3866	17.590	1.137	0.9845
Females	TL=a+b*FL	4643	-15.376	1.198	0.9640
	TL=a+b*SL	4648	5.210	1.358	0.9481
	FL=a+b*SL	4644	17.586	1.132	0.9815

Table 9. Gray Triggerfish length (mm) versus weight (lb) relationships. WT=fish wet weight in pounds, TL=total length, FL=fork length, SL=standard length. All lengths are in mm. n=number of specimens. a= ln(α) in the untransformed $WT=\alpha L^{\beta}$ R^2 is adjusted for degrees of freedom.

	equation	n	a	β	R^2
All	ln (WT) = a + β *ln(TL)	8939	-15.722	2.751	0.9626
	ln (WT) = a + β *ln(FL)	8953	-16.498	2.951	0.9861
	ln (WT) = a + β *ln(SL)	8946	-15.141	2.805	0.9774
Males	ln (WT) = a + β *ln(TL)	3843	-15.720	2.749	0.9607
	ln (WT) = a + β *ln(FL)	3847	-16.558	2.960	0.9864
	ln (WT) = a + β *ln(SL)	3850	-15.196	2.814	0.9778
Females	ln (WT) = a + β *ln(TL)	4615	-15.763	2.759	0.9581
	ln (WT) = a + β *ln(FL)	4610	-16.560	2.964	0.9838
	ln (WT) = a + β *ln(SL)	4617	-15.137	2.805	0.9732

Table 10a. Estimates of von Bertalanffy growth parameters base on non-linear regression analysis using available fork length (mm) and increment count data. n=number of aged fish used in analysis. L_∞ = asymptotic FL, SE= standard error, k= growth coefficient. t0= parameter for age at theoretical length=0.

	n	L_∞	SE	k	SE	t0	SE
All Fish	7420	437	5.80	0.270	0.0139	-2.03	0.115
Males	3262	469	10.21	0.261	0.0203	-1.88	0.161
Females	3951	421	8.02	0.245	0.0185	-2.54	0.191

Table 10b. Estimates of Gompertz growth parameters base on non-linear regression analysis using available fork length (mm) and Increment count data. n=number of aged fish used in analysis. L_∞ = asymptotic FL, SE= standard error,lamda/ k= growth parameters.

	n	L_∞	SE	lamda	SE	k	SE
All Fish	7420	420	4.29	0.297	0.014	0.373	0.015
Males	3262	448	7.19	0.323	0.022	0.374	0.022
Females	3951	406	6.00	0.238	0.015	0.334	0.020

Table 10c. Model selection of length at age using Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) for growth models of combined sexes.

	von Bertalanffy	**Gompertz**
AIC	**79302.729**	**79290.198**
BIC	**79330.378**	**79317.847**

Table 11. Results of various regression model analyses for age and length at maturity for female Gray Triggerfish. Data for all years and all gears were combined. Age as Increment Count and length is fork length in mm. N=number of fish used in analyses, a= coefficient, b= coefficient, A_{50}= age at 50% maturity, L_{50}=length at 50% maturity. AIC=Akaike's Information Criterion. Parameters in bold represent the best fit models.

	Model	N	a	SE	b	SE	**A_{50}/ L_{50}**	AIC
Age	**Logistic Logit**	**3820**	**0.361**	**.200**	**1.455**	**0.116**	**-0.248**	**749.91**
	Logistic Probit	3820	0.419	0.108	0.659	0.055	-0.635	752.26
Length	**Logistic Logit**	**4480**	**-9.794**	**0.742**	**0.055**	**0.004**	**177**	**500.09**
	Logistic Probit	4480	-4.846	0.377	0.028	0.002	175	505.91

Table 12. Female fork length (cm) at maturity using Logistic-Logit model. % Mature= Percent Mature, Prop. Mat. = projected proportion mature using Logit model.

Length	Immature	Mature	Total	% Mature	Prop. Mat.
8	2	0	2	0	0.005
9	0	0	0	NA	0.008
10	4	0	4	0	0.014
11	2	0	2	0	0.024
12	1	0	1	0	0.041
13	3	0	3	0	0.069
14	8	1	9	0.111	0.114
15	10	1	11	0.091	0.183
16	17	3	20	0.15	0.28
17	18	15	33	0.455	0.404
18	13	24	37	0.649	0.541
19	13	30	43	0.698	0.672
20	12	46	58	0.793	0.781
21	6	46	52	0.885	0.861
22	10	79	89	0.888	0.915
23	5	72	77	0.935	0.949
24	7	119	126	0.944	0.97
25	0	127	127	1	0.983
26	1	182	183	0.995	0.99
27	1	137	138	0.993	0.994
28	1	244	245	0.996	0.997
29	1	208	209	0.995	0.998
30	1	342	343	0.997	0.999
31	0	271	271	1	0.999
32	0	333	333	1	1
33	0	270	270	1	1
34	0	316	316	1	1
35	0	277	277	1	1
36	0	310	310	1	1
37	0	217	217	1	1
38	0	214	214	1	1
39	0	143	143	1	1
40	0	134	134	1	1
41	0	76	76	1	1
42	0	46	46	1	1
43	0	21	21	1	1
44	0	16	16	1	1
45	0	8	8	1	1
46	0	7	7	1	1
47	0	4	4	1	1
48	0	1	1	1	1
49	0	2	2	1	1
50	0	1	1	1	1
51	0	0	0	NA	1
52	0	0	0	NA	1
53	0	0	0	NA	1
54	0	0	0	NA	1
55	0	0	0	NA	1
56	0	1	1	1	1

Table 13. Female age at maturity using Logistic-Logit. Female age at maturity using Logistic-Logit. % Mature = Observed proportion mature, Pred. Mat. = predicted proportion mature using Logit model.

Inc Count	**Immature**	**Mature**	**Total**	**%. Mature**	**Pred. Mat.**
0	13	28	41	0.683	0.589
1	59	295	354	0.833	0.860
2	25	835	860	0.971	0.963
3	9	1051	1060	0.992	0.991
4	3	771	774	0.996	0.998
5	0	436	436	1	1.000
6	0	121	121	1	1.000
7	0	100	100	1	1.000
8	0	46	46	1	1.000
9	0	17	17	1	1.000
10	0	5	5	1	1.000
11	0	6	6	1	1.000

Table 14. Results of various regression model analyses for age and length at maturity for male Gray Triggerfish. Data for all years and all gears were combined. Age is expressed in Increment Count and length is fork length in mm. n=number of fish used in analyses, a= coefficient, b= coefficient , 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. AIC=Akaike's Information Criterion. Parameters in bold represent the best fit models.

	Model	N	a	SE	b	SE	**A_{50}/ L_{50}**	AIC
Age	**Logistic Logit**	**3222**	**0.118**	**0.232**	**1.614**	**0.141**	**-0.073**	**597.41**
	Logistic Probit	3222	0.298	0.125	0.735	0.067	-0.406	598.76
Length	**Logistic Logit**		**-8.400**	**0.740**	**0.047**	**0.003**	**179**	**504.36**
	Logistic Probit		-4.056	0.383	0.023	0.002	176	509.44

Table 15. Male fork length (cm) at maturity using Logistic Logit model. % Mature= Percent Mature, Prop. Mat. = projected proportion mature using Logit model.

Length	Immature	Mature	Total	% Mature	Prop. Mat.
13	1	0	1	0	0.09
14	3	0	3	0	0.136
15	6	0	6	0	0.202
16	8	2	10	0.2	0.287
17	16	6	22	0.273	0.392
18	14	20	34	0.588	0.507
19	18	27	45	0.6	0.622
20	14	43	57	0.754	0.724
21	6	41	47	0.872	0.807
22	7	71	78	0.91	0.87
23	2	50	52	0.962	0.914
24	6	85	91	0.934	0.945
25	6	73	79	0.924	0.965
26	3	77	80	0.963	0.978
27	2	93	95	0.979	0.986
28	2	117	119	0.983	0.991
29	2	115	117	0.983	0.994
30	0	165	165	1	0.996
31	0	146	146	1	0.998
32	0	182	182	1	0.999
33	0	187	187	1	0.999
34	0	272	272	1	0.999
35	0	162	162	1	1
36	0	277	277	1	1
37	0	192	192	1	1
38	0	217	217	1	1
39	0	144	144	1	1
40	0	201	201	1	1
41	0	151	151	1	1
42	0	181	181	1	1
43	0	93	93	1	1
44	0	97	97	1	1
45	0	76	76	1	1
46	0	50	50	1	1
47	0	27	27	1	1
48	0	27	27	1	1
49	0	10	10	1	1
50	0	11	11	1	1
51	0	3	3	1	1
52	0	4	4	1	1
53	0	3	3	1	1
54	0	1	1	1	1
55	0	0	0	NA	1
56	0	0	0	NA	1
57	0	0	0	NA	1
58	0	1	1	1	1

Table 16. Male age at maturity using Logistic Logit model. % Mature= Observed Percent Mature, Prop. Mat. = projected proportion mature using Logit model.

Inc Count	Immature	Mature	Total	% Mature	Prop. Mat.
0	9	16	25	0.640	0.529
1	50	255	305	0.836	0.850
2	25	684	709	0.965	0.966
3	4	880	884	0.995	0.993
4	0	671	671	1.000	0.999
5	1	403	404	0.998	1.000
6	0	118	118	1.000	1.000
7	0	75	75	1.000	1.000
8	0	23	23	1.000	1.000
9	0	7	7	1.000	1.000
10	0	1	1	1.000	1.000

Table 17. Gray Triggerfish overall sex ratio.

	Ratio: Female:Male	# Male	# Female	Proportion Female	Chi-squared	P-value
Overall	1.200	3765	4520	.546	68.802	<0.0001

Table 18. Length based sex ratio by one centimeter bins.

Fork Length (cm)	Female:Male	# Male	# Female	Proportion	Chi-square	P-value
14		0	2	1		
15	2	1	2	0.6667		
16	2.8	5	14	0.7368	4.263	0.039
17	4.167	6	25	0.8065	11.645	0.001
18	1.76	25	44	0.6377	5.232	0.022
19	1.364	33	45	0.5769	1.846	0.174
20	1.25	52	65	0.5556	1.444	0.229
21	1.277	47	60	0.5607	1.579	0.209
22	1.164	73	85	0.538	0.911	0.34
23	1.386	57	79	0.5809	3.559	0.059
24	1.547	86	133	0.6073	10.087	0.001
25	1.75	76	133	0.6364	15.546	<0.0001
26	2.333	81	189	0.7	43.2	<0.0001
27	1.553	94	146	0.6083	11.267	0.001
28	2.075	120	249	0.6748	45.098	<0.0001
29	1.819	116	211	0.6453	27.599	<0.0001
30	2.085	165	344	0.6758	62.949	<0.0001
31	1.877	146	274	0.6524	39.01	<0.0001
32	1.841	182	335	0.648	45.279	<0.0001
33	1.439	190	273	0.5896	14.879	0.0001
34	1.165	272	317	0.5382	3.438	0.064
35	1.716	162	278	0.6318	30.582	<0.0001
36	1.13	277	313	0.5305	2.197	0.138
37	1.13	192	217	0.5306	1.528	0.216
38	0.986	217	214	0.4965	0.021	0.885
39	0.993	144	143	0.4983	0.004	0.953
40	0.673	202	136	0.4024	12.888	<0.001
41	0.407	152	77	0.3362	24.563	<0.0001
42	0.254	181	46	0.2026	80.286	<0.0001
43	0.226	93	21	0.1842	45.474	<0.0001
44	0.165	97	16	0.1416	58.062	<0.0001
45	0.105	76	8	0.0952	55.048	<0.0001
46	0.14	50	7	0.1228	32.439	<0.0001
47	0.185	27	5	0.1563	15.125	0.0001
48	0.037	27	1	0.0357	24.143	<0.0001
49	0.2	10	2	0.1667	5.333	0.021
50	0.091	11	1	0.0833	8.333	0.004
51		3	0	0		
52		4	0	0		
53		3	0	0		
54		1	0	0		
55		0	0			
56		0	1	1		
57		0	0			
58		1	0	0		

Table 19. Age based sex ratio by increment count.

Inc Count	Female:Male	# Male	# Female	Proportion	Chi-square	P-value
0	1.524	21	32	0.6038	2.283	0.131
1	1.237	278	344	0.5531	7.003	0.008
2	1.275	698	890	0.5605	23.214	<0.0001
3	1.208	886	1070	0.5470	17.309	<0.0001
4	1.162	672	781	0.5375	8.177	0.004
5	1.087	404	439	0.5208	1.453	0.228
6	1.042	118	123	0.5104	0.104	0.747
7	1.333	75	100	0.5714	3.571	0.059
8	2.000	23	46	0.6667	7.667	0.006
9	2.429	7	17	0.7083	4.167	0.041
10	5.000	1	5	0.8333	N/A	N/A
11	N/A	0	6	1.0000	N/A	N/A

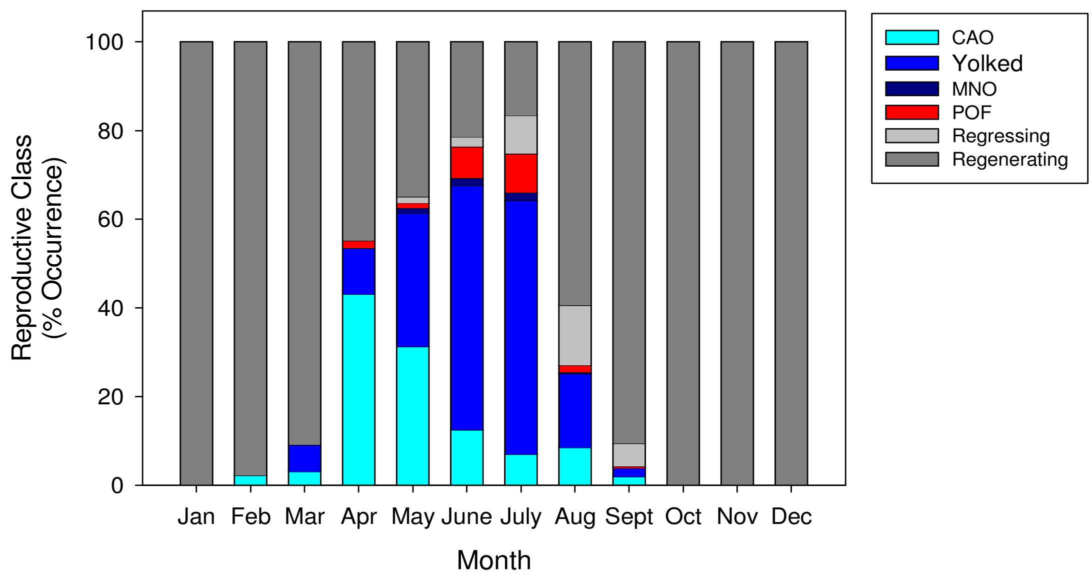

Figure 1. Female Gray Triggerfish spawning seasonality. CAO= cortical alveolar oocytes, Yolked= Yolked oocytes, MNO= migratory nuclear oocytes, POF= postovulatory follicle (also referred to as post ovulatory complexes).

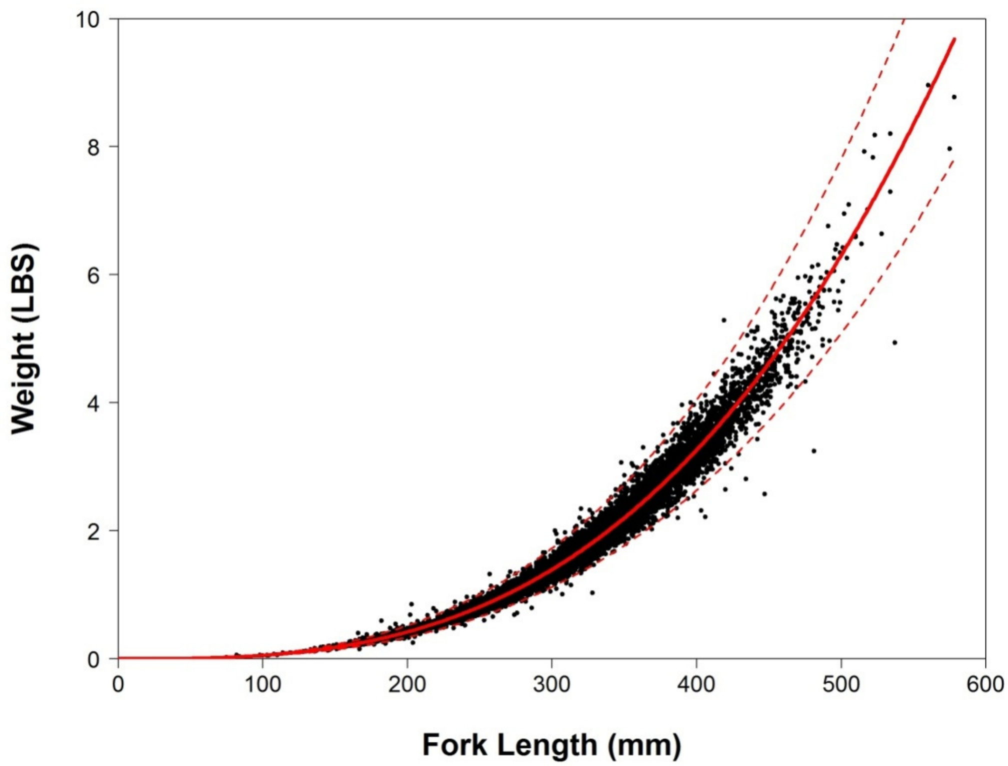

Figure 2. Regression lines of analyses of Gray Triggerfish fork length (mm) versus whole wet weight (lbs).

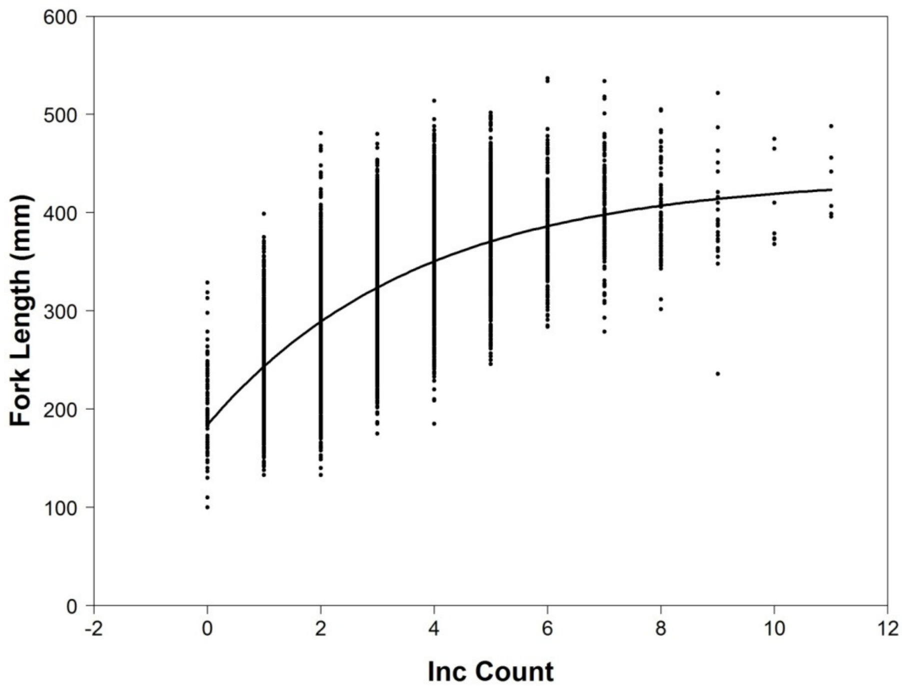

Figure 3. Gray Triggerfish von Bertalanffy additive base analysis model using all fish (n=7,420), fork length (mm) and increment count. L_{50}= 437 mm FL, k = 0.270, t_0 = -2.03.

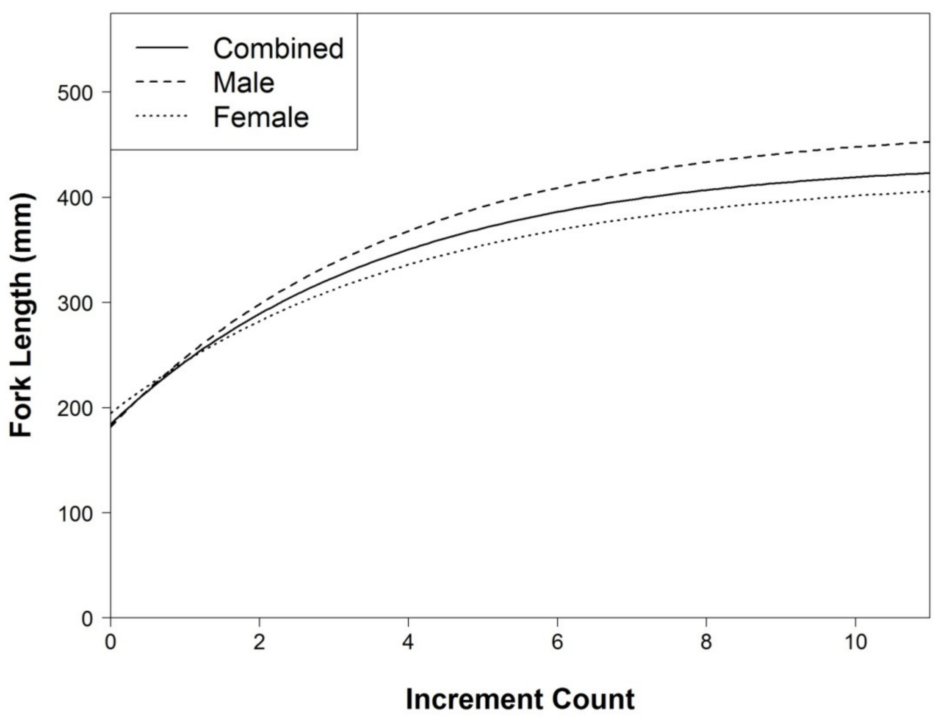

Figure 4. Non-linear regression lines of the von Bertalanffy growth model analyses of all Gray Triggerfish combined, males, and females fork length (mm) and increment count.

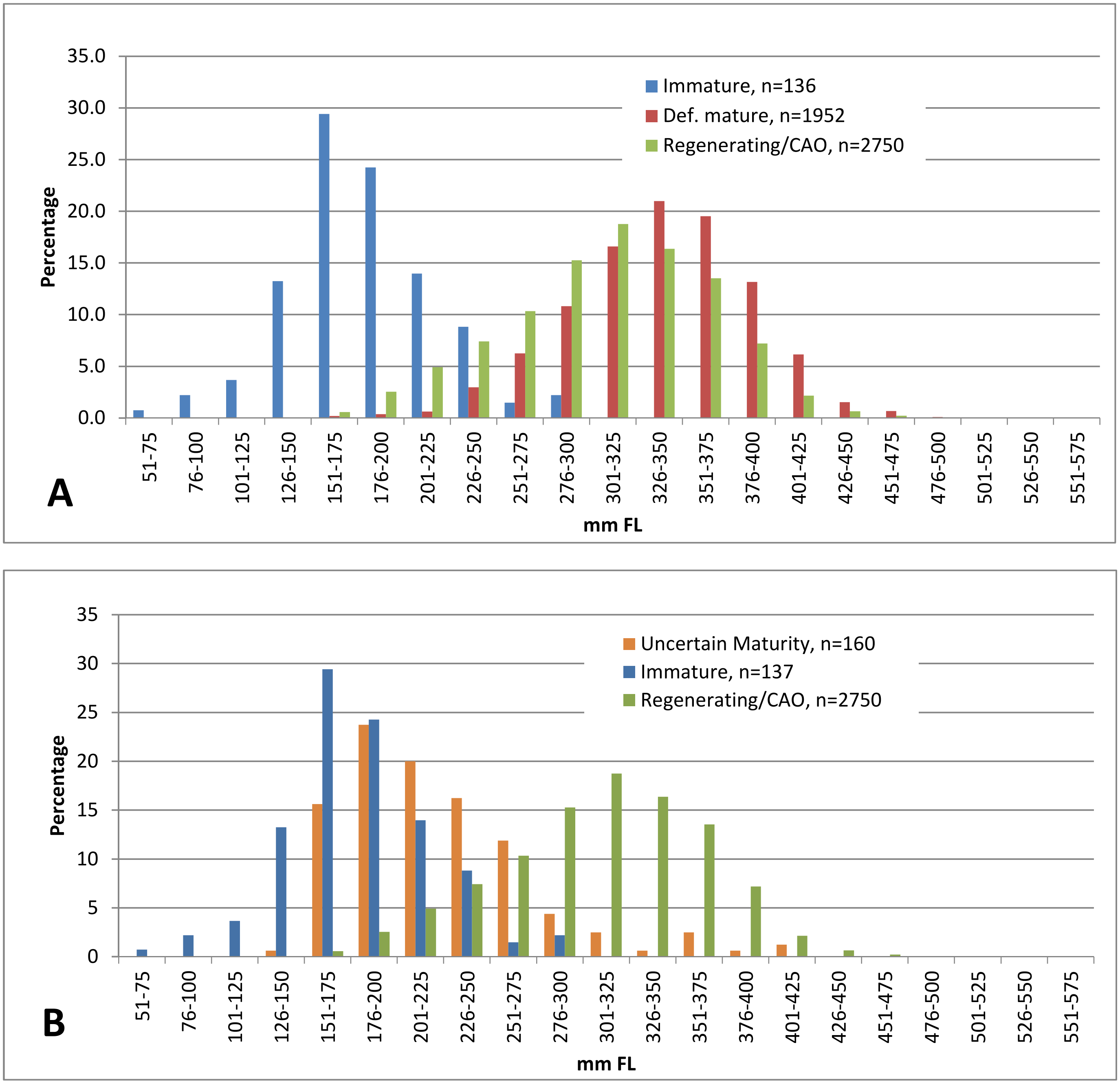

Figure 5. **A**. A comparison of female Gray Triggerfish length-frequency histograms specimens that were categorized as immature, definitely mature (Def. mature), or Regenerating. Definitely mature specimens were developing, spawning capable, or regressing. **B**. Female Gray Triggerfish histological staging of immature, regenerating and uncertain maturity. Both graphs provide data from all years and all gears. CAO= cortical alveolar oocytes, n= number of fish.

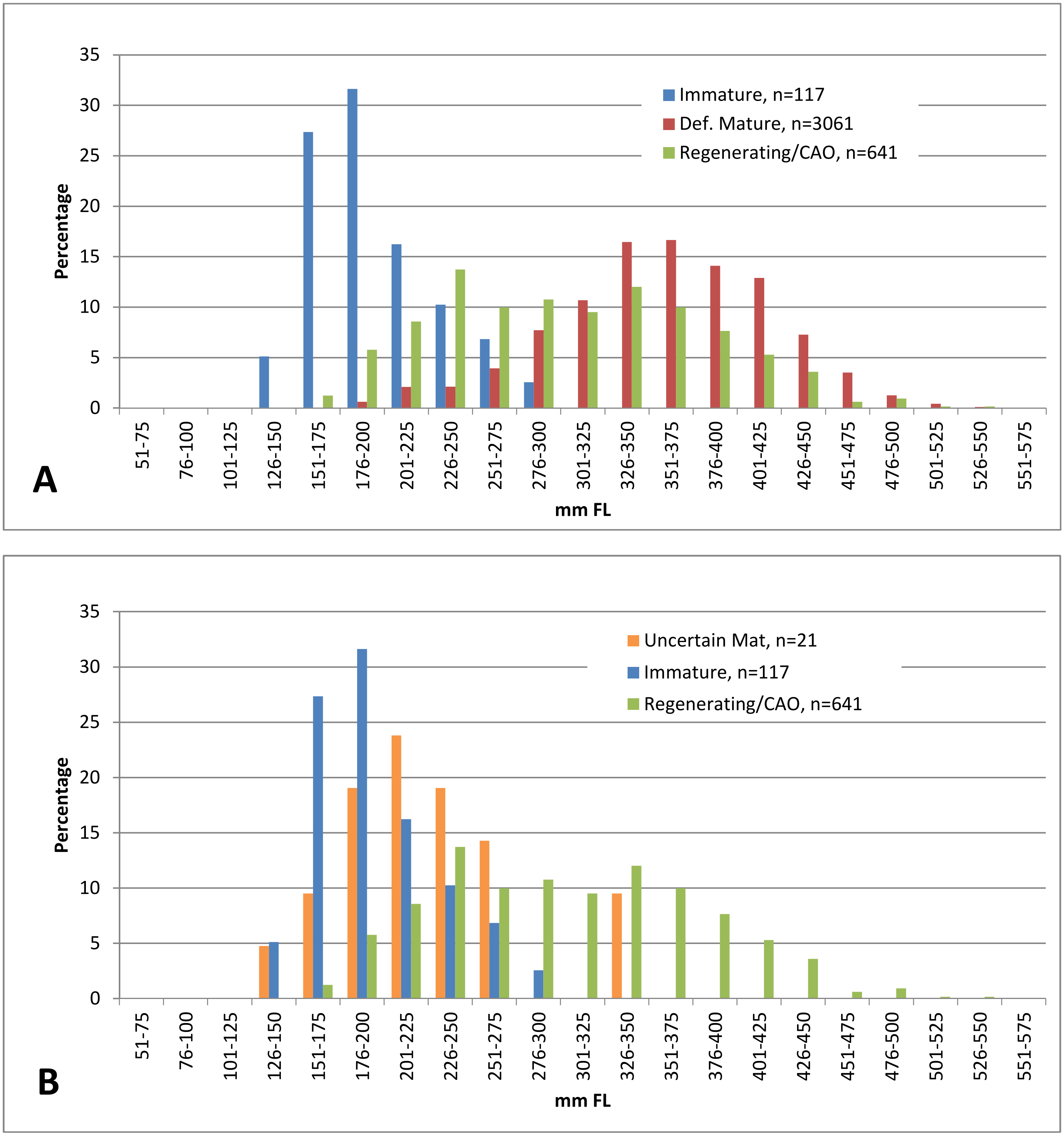

Figure 6. **A.** A comparison of male Gray Triggerfish length-frequency histograms specimens that were categorized as immature, definitely mature, or resting. Definitely mature specimens were developing, spawning capable, or regressing. **B**. Male Gray Triggerfish histological staging of immature, regenerating and uncertain maturity. Both graphs provide data from all years and all gears. n= numbers of fish.

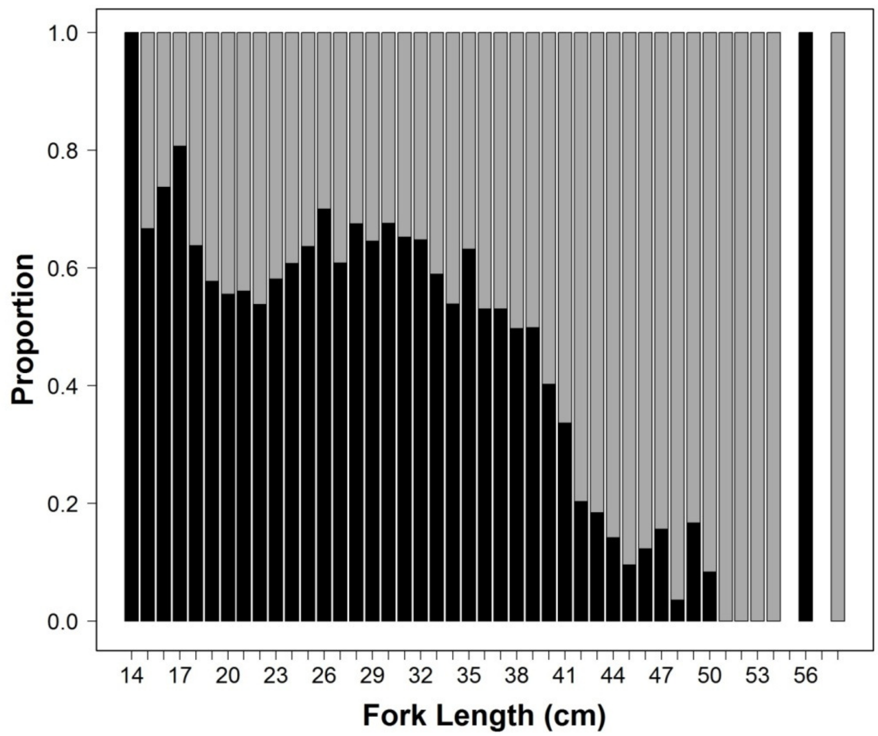

Figure 7. Gray Triggerfish length-based sex ratio. Black bars represent females (total n = 4511), gray bars represent males (total n = 3757).

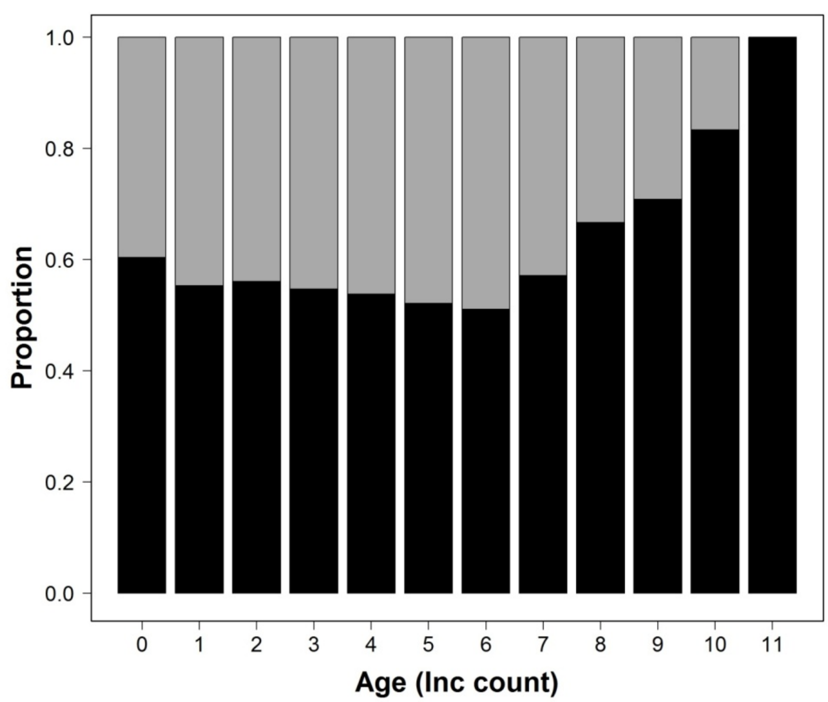

Figure 8. Gray Triggerfish age based sex ratio. Black bars represent females (n = 3853), gray bars represent males (n = 3183).

ADDENDUM

UPDATE: Life History of South Atlantic Gray Triggerfish, *Balistes capriscus*

SEDAR 41-DW16-B
MARMAP Technical Report 2015-007
July 2015

Prepared by Kevin J. Kolmos, Tracey Smart, David Wyanski, and Marcel Reichert

Marine Resources Research Institute
South Carolina Department of Natural Resources

P. O. Box 12559
Charleston, SC 29422

This report is an update to SEDAR41-DW16 in preparation for the ongoing SEDAR41 on Gray Triggerfish. One additional year of data (2014) was included in the following life history analyses and included lengths, ages and macroscopic staging of gonadal tissue. Standard operating procedures were followed in accordance to the techniques in SEDAR41-DW16. The following are the bulleted methods and results with the additional year of data. Maturity analyses were not performed since no new maturity data was collected. Updates were made only to relevant sex ratio graphs and tables when new data from 2014 were available. Note that the measure of age in the original version of this report is increment count. All ages in this update refer to calendar age (see 18 December 2014 draft of SEDAR41 Life History Working Group report).

Methods:

- 1076 new individuals caught from fishery-independent sources (South East Reef Fish Survey; SERFS)
- 976 of 1076 individuals were aged
- 1053 of 1076 individuals were macroscopically sexed

Results from Fishery-Independent and Fishery-Dependent Sources (1978-2014)

- Overall sex ratio was 1.19:1 females to males, significantly different from 1:1 (Table 1)
- Overall 54.3% of the population female (Table 1)
- Analyses were run on sex ratio by year (Figures 1 & 2), by age (Figures 3 & 4), and by FL (Figures 5 & 6).

The overall (Fishery Independent and Dependent) sex ratio of 1.19:1 was significantly different from 1:1 F:M ratio, with the proportion of females being greater than males. Although analyses revealed an overall sex ratio favoring females and trends related to age and size, we do not believe there is strong evidence for using a sex-specific stock assessment model. The difference may be driven by large sample size.

Table 1. Sex ratio in Gray Triggerfish population. SERFS: South East Reef Fish Survey (fishery-independent). Under 7 is sex ratio of all individuals under age 7. Overall dataset includes fishery-independent (94 %) and fishery-dependent (6 %) data.

	Ratio: Female:Male	# Male	# Female	Proportion Female	Chi-squared	P-value
SERFS	1.19	4,883	5,789	0.542	76.91	<0.0001
Age < 7	1.21	3,551	4,290	0.547	69.65	<0.0001
Overall	1.20	5,174	6,220	0.546	96.03	<0.0001

Table 2. Age specific sex ratios calculated to estimate total egg production.

Cal Age	Males	Females	Total	PropMale	PropFemale
0	0	3	3	0.00	1.00
1	317	398	715	0.44	0.56
2	815	1042	1857	0.44	0.56
3	1115	1382	2497	0.45	0.55
4	883	1059	1942	0.45	0.55
5	527	584	1111	0.47	0.53
6	175	236	411	0.43	0.57
7	94	136	230	0.41	0.59
8	31	67	98	0.32	0.68
9	10	24	34	0.29	0.71
10	3	6	9	0.33	0.67
11	0	5	5	0.00	1.00
12	0	4	4	0.00	1.00

Figure 1. Overall sex ratio by Year for adult Gray Triggerfish.

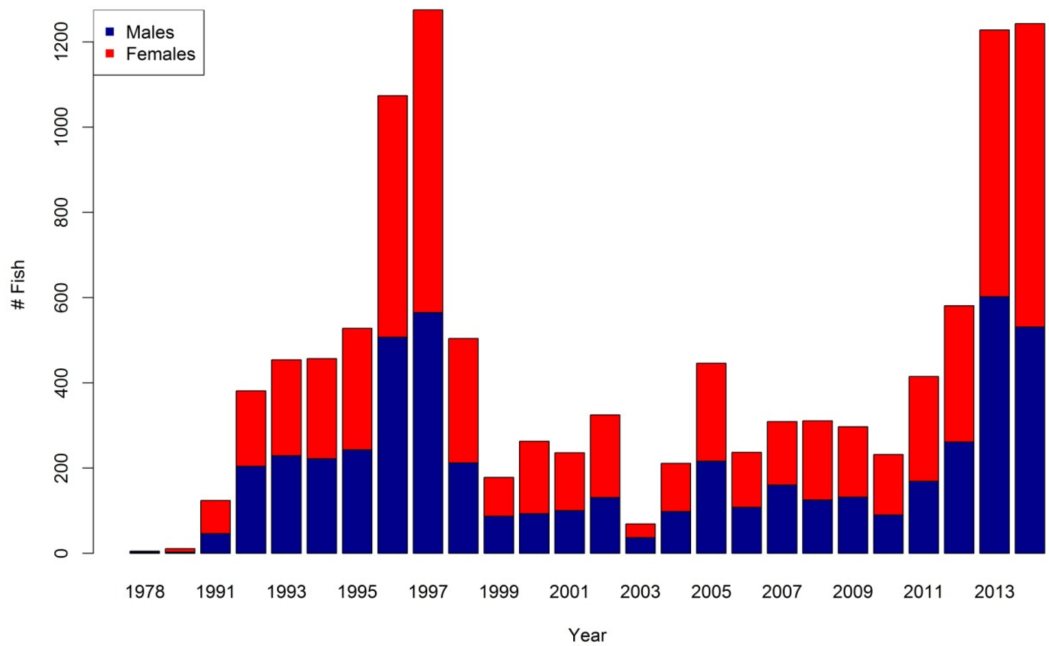

Figure 2. Overall proportion of females and males by year for adult Gray Triggerfish.

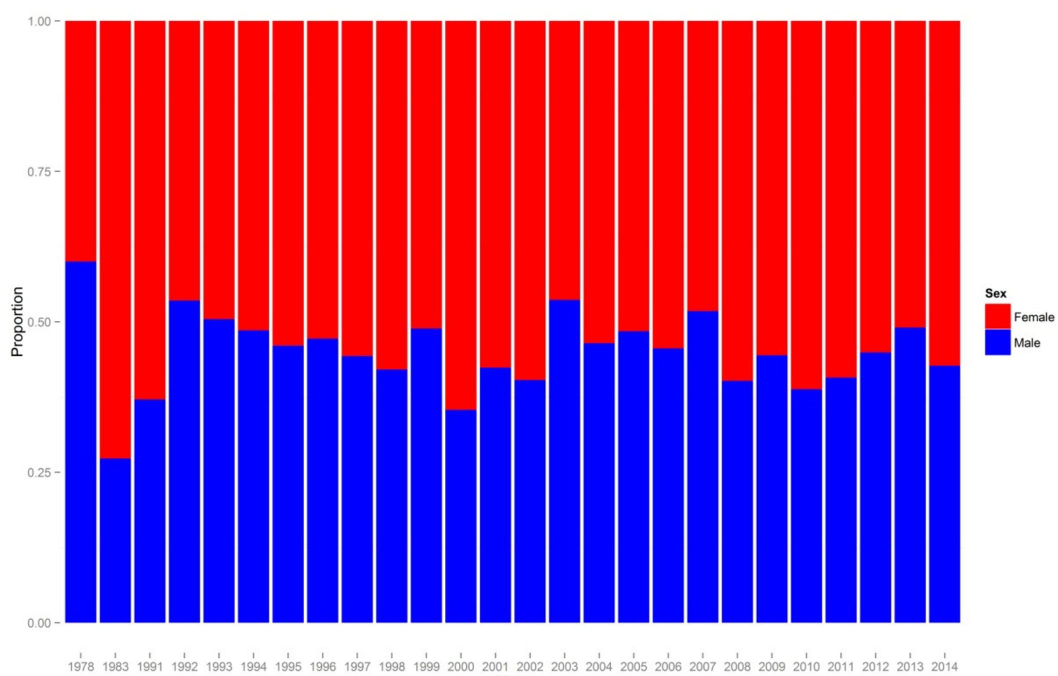

Figure 3. Overall sex ratio by calendar age (Cal Age in years) for adult Gray Triggerfish.

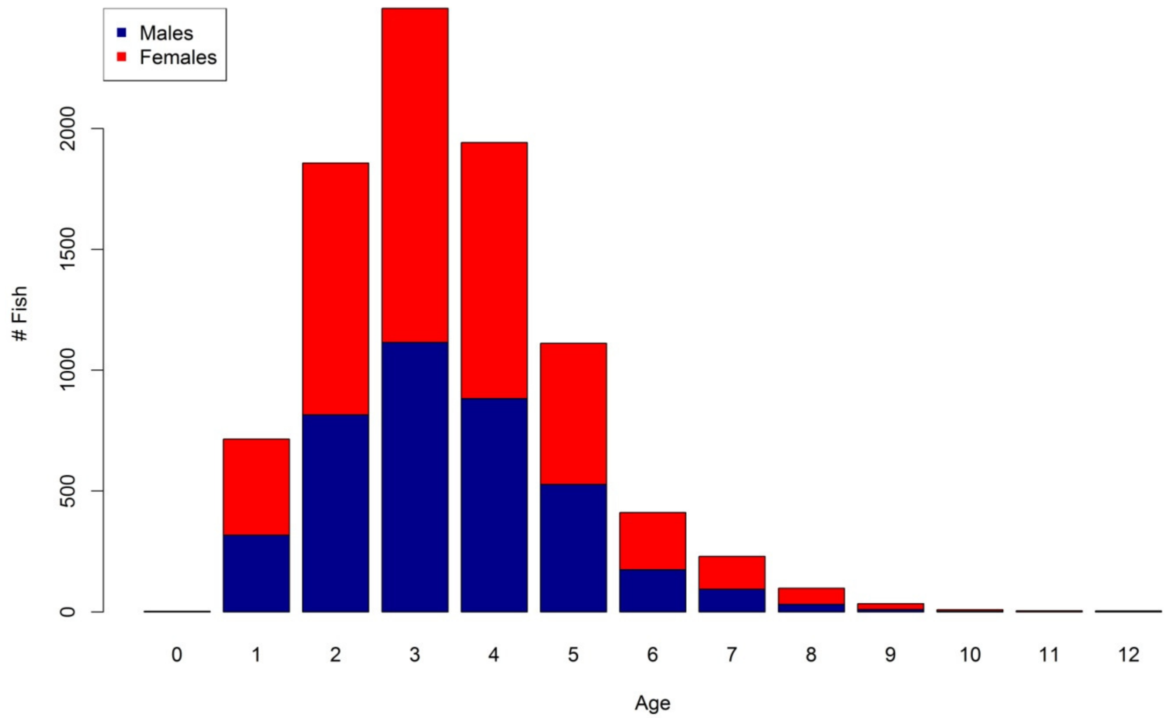

Figure 4. Overall proportion of females and males by calendar age (in years) for adult Gray Triggerfish.

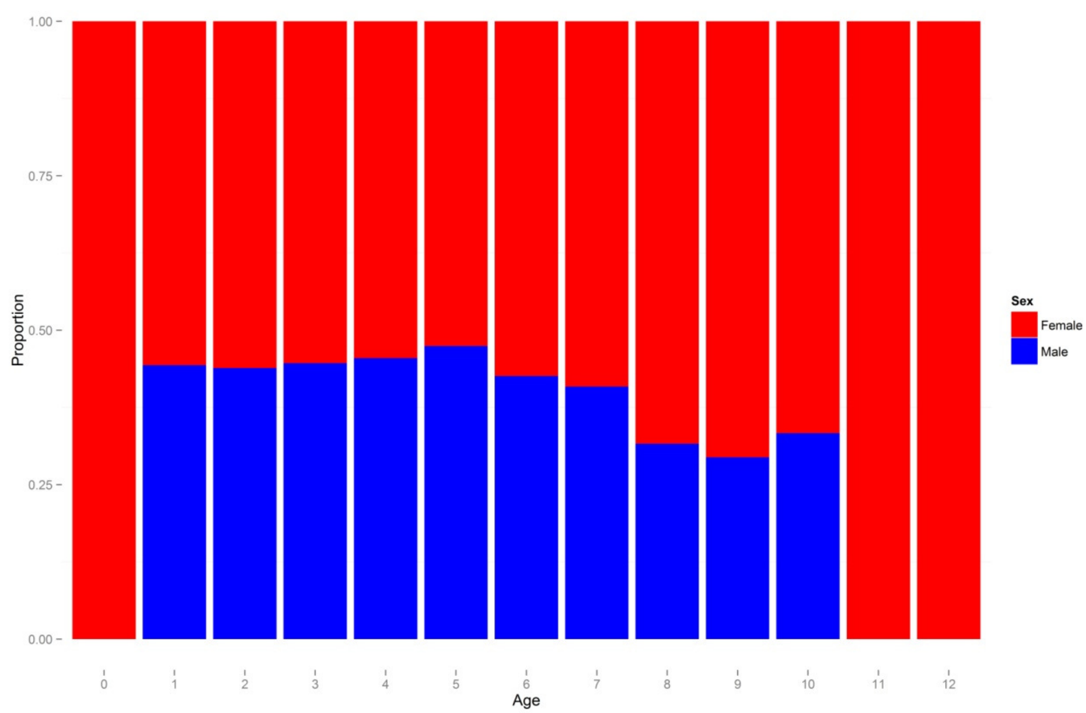

Figure 5. Overall sex ratio by fork length (cm) for adult Gray Triggerfish.

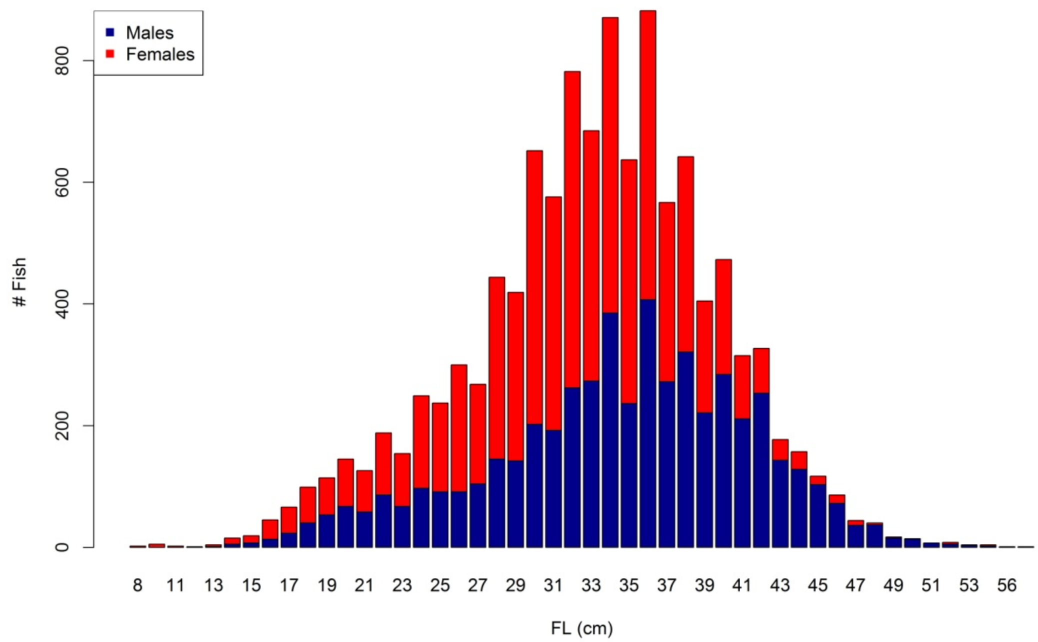

Figure 6. Overall proportion of females and males by fork length (cm) for adult Gray Triggerfish.