Aging procedures and growth curve estimation for gray triggerfish collected from the Gulf of Mexico

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May 8, 2019

ABSTRACT

This report documents problems with current aging procedures and estimation of growth curves for gray triggerfish collected in the Gulf of Mexico. Analyses of edge type distributions of dorsal spine samples for gray triggerfish from different government agencies and academic research labs raise questions about the validity of using the translucent zone of the dorsal fin spine as an annulus for determining the age of gray triggerfish. The edge type distributions for gray triggerfish dorsal spine samples collected from the Gulf of Mexico lack annual peaks and varied significantly between government agencies. These results suggest that age data derived from gray triggerfish dorsal spine samples from the Gulf of Mexico may not be adequate for use in SEDAR stock assessments since any problems with age data may affect the estimation of both age compositions and growth curves. In addition to aging errors, the current study analyzed how gear selectivity influences the length at age estimations for gray triggerfish and discussed the importance of accounting for any gear/sampling effects when comparing lengths at age or growth curves between different regions, seasons, sex, or other variables. Results from this study also suggest that the apparent sexual dimorphism of gray triggerfish reported by several studies was likely caused by sampling differences, gear effects, or aging errors.

INTRODUCTION

The dorsal fin spine has been used as an aging structure for gray triggerfish in several studies (Burton, et al., 2015; Allman, et al. 2016; Kelly-Stormer, et al., 2017). Age data derived from dorsal spine samples was also used for the SEDAR 43 stock assessment for Gulf of Mexico gray triggerfish. However, the usage of the translucent growth zone (TZ) as an annulus for gray triggerfish dorsal spine samples has never been validated (Kelly-Stormer, 2017). Also, edge types distributions for gray triggerfish dorsal spine samples varied considerably among different studies (Jefferson, 2019; also see Fig 1). In one study, the annulus peak for the TZ edge type was identified as occurring in April (Burton, 2015), while in most other cases, the annulus peak for the TZ edge type was not clearly identified (Kelly-Stormer, 2017; Jefferson, 2019). Such inconsistent patterns of edge type distributions and a lack of a definite annual peak for the TZ edge type brings into question the validity of using the dorsal spine as an aging structure for gray triggerfish (Campana, 2001)

Because of the differences in the observed annulus peaks, different age assignment rules were used for aging gray triggerfish in different studies. In the study of Burton et al. (2015), samples collected in the first six months of a year with advanced stage opaque zones were advanced to the next age class. For other studies (Kelly-Stormer, et al., 2017; Allman, et al., 2018 and Jefferson, et al., 2019), no age advancements were made, which indicated that the authors of those studies recognized the lack of a definite annual peak for the TZ edge type in their data.

Problems with aging procedures may influence the accuracy of estimated age compositions and growth parameters for age-structured assessment models. The primary goal of this study was to analyze the edge types distributions for age samples provided for SEDAR 62 from different government agencies and to examine the validity of using age data determined with gray triggerfish dorsal spine translucent zones for stock assessments. A secondary goal of this study was to examine the effects of aging errors, gear selectivity, fishing mode and sampling differences on length at age (LAA) and growth curve estimations for gray triggerfish. In particular, the hypothesis regarding sexual dimorphism of gray triggerfish reported by several studies was examined.

MATERIALS AND METHODS

All age data were from the gray triggerfish age data sets provided for the most recent gray triggerfish stock assessment (SEDAR 62) by the Panama City Laboratory (PC Lab), Southeast Fisheries Science Center (SEFSC), National Marine Fisheries Service (NMFS). These data sets were compiled from age samples originating from the PC Lab and the Gulf States Marine Fisheries Commission as part of the Fisheries Information Network database (GulfFIN).

The coding systems for dorsal spine edge types differ between the two different agencies. Also, GulfFIN samples were provided by different state agencies, each with its own coding system for edge types. Because of this problem, edge types for all samples were described with a common nomenclature based on the data description sheet provided by the PC Lab for their data:

Translucent zone on edge (TZ) –

GulfFIN codes: 1, 2 PC Lab codes: 6_PC or 'T'

Opaque zone on edge (OPZ) –

GulfFIN codes: 3, 4 PC Lab codes: 2_PC or 'O'

The term 'age' refers to age class in this report. The term 'season' is defined as 6 months, so the identifier 'season 1 samples' refers to samples collected from the first 6 months of a year. All lengths are fork lengths in centimeters.

RESULTS AND DISCUSSION

A. Edge type distributions

The monthly distributions of TZ edge types for gray triggerfish dorsal spines samples collected by the PC Lab and GulfFIN differed significantly with each other (Fig 2) and with what was reported previously by other research labs (Fig 1). In particular, the TZ edge type distributions for samples collected by the PC Lab and GulfFIN did not show an annual peak. For PC lab dorsal spine samples, about 50% of samples had TZ on edge throughout the year, while for GulfFIN dorsal spine samples, nearly 90% samples had TZ on edge throughout the year. This means that the TZ edge type, as currently defined by the two labs, may form more than once in a year or not at all. Such edge type distribution patterns bring into question the validity of using the dorsal spine translucent zone as the annulus for gray triggerfish. Moreover, the edge type distribution patterns differed significantly among samples processed by the different state agencies of GulfFIN (Fig 3). In particular, 100% samples processed by Florida had TZ on the edge throughout the year (Fig 3 (a)), which strongly questions whether the TZ, as currently defined in the state of Florida, can be used as the annulus. The pattern of edge type distributions for PC lab samples (Fig 2 (a)) were similar to what was reported previously (Allman, et al. 2016), where percent samples with TZ on edge varied between 35-75% throughout the year.

Because of the differences in edge type distributions among samples collected by different labs, different age assignment rules were used by different research labs and government agencies. For gray triggerfish sampled in the South Atlantic area by the Beaufort Lab of SEFSC, an annulus peak was identified in April. As a result, age samples collected in season 1 were converted to the next age class if the edge type was in an advanced stage of opaque growth zone formation (more than 30% of the opaque zone completed). For the PC Lab and GulfFIN, no age advancement was done for any samples. If an annulus peak did occur in season 1 for the gray triggerfish population in the Southeast region, then a portion of the samples collected in season 1 (depending on the actual timing of the annulus peak) should have been advanced to the next age class. Without proper age advancement, the age for the samples collected in the first half of a year may have been underestimated. As shown in Figs 4 & 5, overestimation of LAAs for quarter 1 and quarter 2 samples may have occurred partially due to underestimation of age for season 1 samples.

B. Length at age and growth curve estimation

Aging errors will inevitably change the age-length relationship. Examination of the age-length relationship (i.e., ages at length or LAAs) often can reveal aging problems. The samples sizes for gray triggerfish were not large enough to study the yearly or seasonal changes in ages at length (i.e., ALKs), so LAAs were analyzed in this study to check for any abnormalities in age-length relationships.

Many factors besides aging errors can affect observed LAAs. These factors include sampling differences (Chih, 2009), gear selectivity (Wilson, et al., 2015), seasonal variations (Porch, et al., 2002), and any size-related factors that change the length-frequency distributions of collected samples (e.g., size limits, size-driven regional fish movements, etc.). Comparison of LAAs or growth curves between samples are further complicated by the fact that most fish samples were collected via two stage cluster sampling, which can greatly reduce the effective sample sizes (Chih, 2010). Because of gear selectivity, size limit and other sampling restrictions, it is not possible to perform random sampling for individual ages, which is required for LAAs or growth curve estimations. Any sampling/fishing method that artificially creates differences in length-frequency distributions between investigated fish populations (e.g., regions, sex) may lead to unrealistic differences in estimated LAAs or growth curves. Such sampling differences also violate the assumptions (e.g., randomness) for statistical tests used for comparing growth parameters between different populations. Although the effects of the abovementioned factors are well known (Wilson, et al., 2015), there are still studies that compare LAAs or growth curves from different fish populations (e.g., region, sex) without taking these confounding factors into consideration. In this study, different factors that may influence the estimation of LAAs for gray triggerfish were analyzed to identify problems with aging procedures and growth curve estimations.

(1) Aging errors

The observed seasonal variations in LAAs (Figs 4 & 5) support the conclusion from edge type analyses that gray triggerfish aging procedures may be in error. LAAs estimated for Q1 samples were consistently greater than LAAs estimated for other quarters for fish younger than 7 years old (Fig 4). Similarly, season 1 LAAs were consistently greater than season 2 LAAs for fish younger than 7 years old. As discussed below in B(2), some of these differences may have been due to differences in sample sizes for different gear types between different quarters (Table 2). When the gear effect was removed by analyzing a single gear type, in this case recreational hand line samples, a similar pattern of seasonal differences in LAAs was still observed (Fig 5). Such patterns of seasonal variations in LAAs are biologically unlikely and can be caused by (a) misidentification of age class due to the applied definition of an annulus and (b) lack of adequate age conversion rules if an annulus peak occurred in the first six months of a year (as reported by Burton, et al., 2015). In any case, age data with apparent seasonal variations that appear biologically unrealistic should not be used for estimating age compositions or growth curves.

Because the extent to which and how aging errors affect age data is unclear, the following discussion regarding gear effects and sexual dimorphism does not take the effect of aging errors into consideration.

(2) Effect of gear types and fishing modes

Length frequency distributions estimated from different gear types and fishing modes were very different for gray triggerfish samples (Fig 6). Generally speaking, gray triggerfish samples caught by long line fisheries had the largest size followed by hand line, trap and trawl fisheries (Fig 6(a)). Fishing modes also had a big influence on length frequency distributions (Fig 6(b)), where scientific survey samples (SS, i.e., fisheries-independent samples) were much smaller than the commercial (CM) and recreational (Rec) samples (i.e., fisheries-dependent samples). However, since trawl and trap fishing were only used for scientific surveys, the fishing mode effect can be mostly attributed to differences in gear types between different modes (Fig 6(c)).

As mentioned above, any artificial differences in length frequency distributions created by gear selectivity will results in differences in estimated LAAs among samples (Fig 7). LAAs estimated from long line and hand line samples were noticeably larger than those estimated for trap and trawl samples (Figs 7(a) & (b)). Since trawl and trap samples were from scientific surveys that did not have size limit restrictions, it is possible that differences in LAAs between long line/hand line samples and trawl/trap samples were due to size limit effects instead of gear effects. To eliminate the size limit factor, LAAs for different gear types were compared for scientific survey samples (i.e., without size limit restrictions). The differences in LAAs between different gear types were also observed for scientific survey samples (Fig 7(c), (d)), which suggests that differences in LAAs between gear types were mostly caused by gear selectivity and not by size limits.

As expected, LAAs estimated from different fishing modes were different (Fig 8 (a), (b)). Differences in LAAs between fishing modes can largely be attributed to differences in proportions of different gear types in different fishing modes (Table 3 (b)). However, fishing modes may also have affected estimated LAAs since LAAs estimated for the hand line gear type were different for different fishing modes (Fig 8 (c),(d)). Such differences may be due to different types of hand lines being used for different fishing modes or to different fishing grounds between different fishing modes.

Although aging errors may have influenced the gear effects observed in Fig 7 and Fig 8, the analyses reveal a general problem in that gear type may affect the estimation of growth curves. Because of the big differences in LAAs between different gear types, any changes in the sampling intensity for different gear types can significantly change estimated LAAs and growth curves. This is particularly a problem for gray triggerfish since overall sample sizes for age samples are small and scientific survey samples (including trap and trawl samples) represent a relatively larger proportion of total age sample sizes as compared to other reef fish species. Thus, how samples from different gear types should be weighted when estimating growth curves is an important issue for gray triggerfish stock assessments.

(3) Sexual dimorphism

Several studies have suggested that sexual dimorphism in size and growth exists for gray triggerfish (Kelly-Stormer, et al., 2017; Allman, et al., 2018, Jefferson, et al., 2019). However, the uncertainties in gray triggerfish aging procedures may have influenced these findings. More importantly, a gear effect on LAA estimation was not taken into consideration in the analyses of sexual dimorphism in these studies, which raises questions about whether the observed sexual dimorphisms in these studies were due to gear effects.

In the current study, sexual dimorphism in size and growth was examined by comparing length frequency distributions and LAAs for female and male samples from different gear types. When all gear types were combined, the sex differences in size were noticeable mostly in the size ranges of 22-30 cm and 38-44 cm (Fig 9(a)). The overall size ranges were similar between female and male fish. Such differences in length frequency distributions between sex groups are very different from the sexual dimorphism observed in other fish species, such as the king mackerel (Fig 9(b)), which showed definite sex differences in all size groups and in an overall range of sizes. When length frequency distributions are separated by sex and gear types, the length distributions for each gear type were similar between the two sex groups (Figs 9 (c), (d)). Since the sample sizes for different gear types and fishing modes were different for different sex groups (Table 4), the observed sex differences in size could be due to sampling differences between female and male fish instead of actual differences in size between the two sex groups.

Analyses of LAAs between female and male fish for different gear types and different quarters for PC Lab samples also suggest that the observed sex differences in LAAs may be due to sampling differences (Fig 10). Although there were distinct sex differences in LAA when PC Lab samples from all gear types were combined (Fig 10 (a)), LAAs estimated for female and male gray triggerfish were similar for samples collected from a single gear type (i.e., recreational hand line, Fig 10 (b)). Also, the estimated LAAs for unknown sex samples were larger than male samples for most age groups (Fig 10 (a)). Normally, the estimated LAAs for the unknown sex group would be expected to be in-between the estimated LAAs for the female and male groups. This observation suggests that factors other than sex are affecting the observed sex differences in LAAs. In addition, unlikely quarterly variations in LAAs (i.e., LAA Q1> LAA Q4, etc.) due to potential aging errors are more obvious among female samples (Fig 10 (c)) than male samples (Fig 10(d)), which means that aging errors may have influenced female fish more than male fish. These results, especially LAAs estimated from PC Lab recreational hand line samples (Fig 10(b), indicate that the observed sex differences in LAAs may be caused by sampling differences between the two sex groups and by aging errors.

In conclusion, the validity of age data derived from gray triggerfish dorsal spine samples provided for SEDAR 62 may be questionable because of (a) the lack of an annual peak for the TZ edge type for both PC Lab and GulfFIN samples, (b) the inconsistencies in edge type distributions between government agencies and between different studies, and (c) the lack of age conversions in the age assignment rules used for the SEDAR 62 gray triggerfish data that could create an underestimation problem for some age samples.

The presence of aging errors is also supported by the observed seasonal variations in LAAs, which are biologically unlikely to occur. Analyses of differences in LAAs among different gear types indicate that growth curve estimations for gray triggerfish need to take gear effects into consideration. Finally, the sexual dimorphism in size and growth reported for gray triggerfish in previous studies may be due to sampling differences between sex groups and aging errors.

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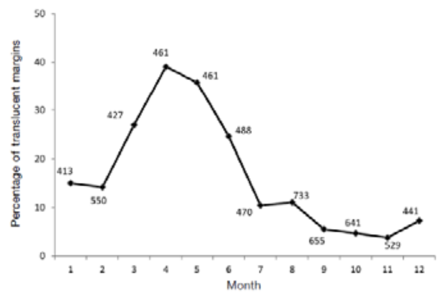
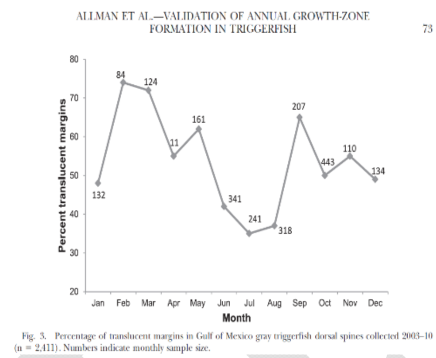
Wilson, K.L., Matthias, B.G., Barbour. A.B., Ahrens, R.N.M., Tuten, T., and Allen, M.S., 2015. Combining samples from multiple gears helps to avoid fishy growth curves. 35(6): 1121-1131.

Fig 1. Monthly edge type distributions (percent translucent edge) for gray triggerfish dorsal spine samples from four previous studies (see References for citation).

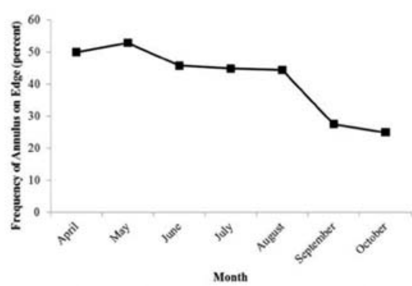
(a) Burton et al. 2015 (n=6419)



(b) Allman, et al., 2016 (n=2411)



(c) Kelly-Stormer, et al., 2017 (n=7685)



(d) Jefferson, et al., 2019 (n=1135)

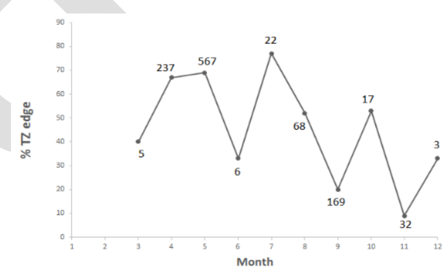
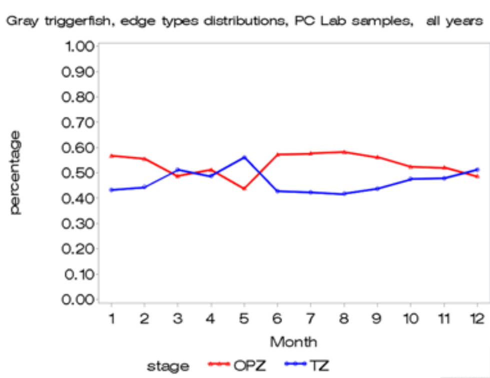


Fig 2. Monthly edge type distributions for gray triggerfish dorsal spine samples used for the SEDAR 62 stock assessment: (a) Panama City Lab (PC Lab) samples (b) GulfFIN samples. (TZ - translucent zone, OPZ - opaque zone).

(a)Panama City Lab samples (n=7834)



(b) GulfFIN samples (n=3041)

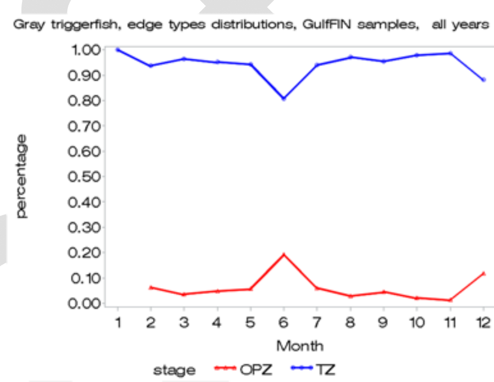
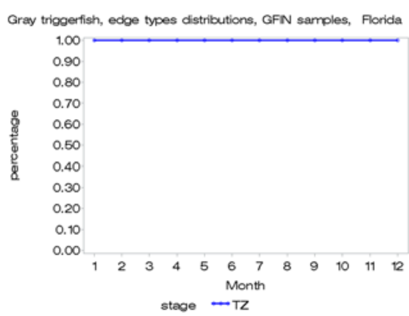
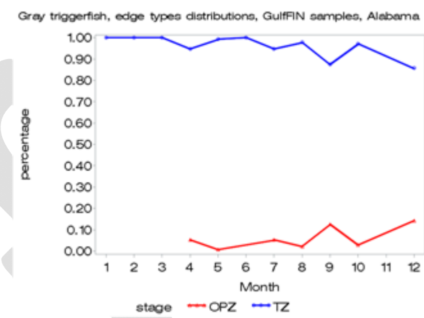


Fig 3. Monthly edge type distributions for gray triggerfish samples processed by different GulfFIN state agencies (TZ -translucent zone, OPZ - opaque zone).

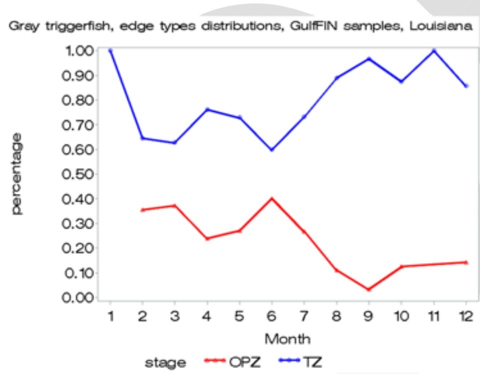
(a) Florida (n=1702)



(b) Alabama (n=657)



(c)Louisiana (n= 500)



(d) Texas (n=177)

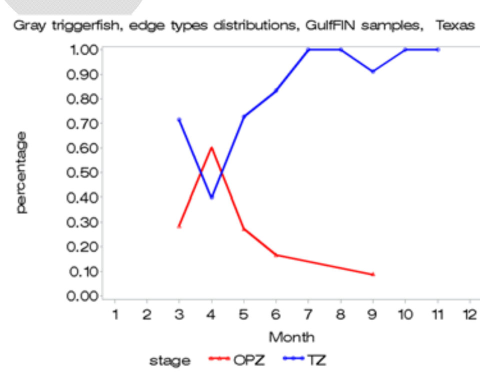
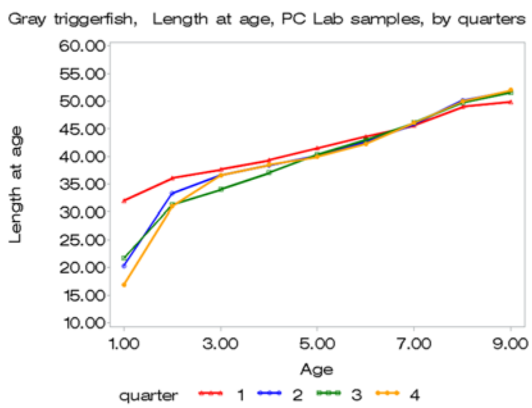
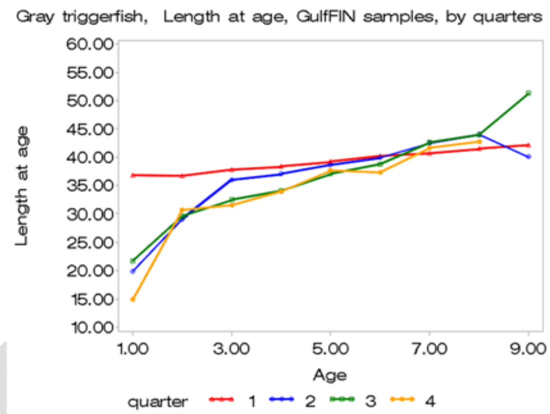


Fig 4. Comparisons of quarterly and seasonal lengths at age (LAAs) for different ages of gray triggerfish samples processed by different labs (season 1: months 1-6, season 2: months 7-12). Note that the values of LAAs do not follow the normally expected pattern that Q1-LAA < Q2-LAA < Q3-LAA < Q4-LAA.

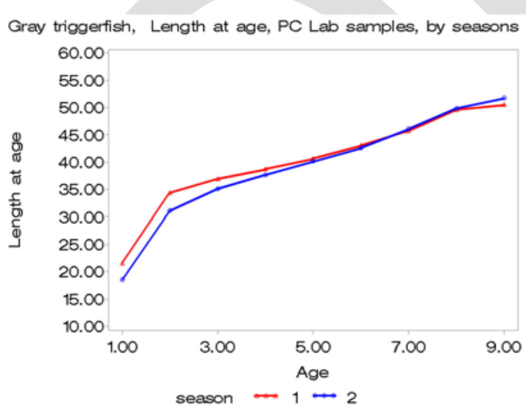
(a) Quarterly LAAs, PC Lab samples



(b) Quarterly LAAs, GulfFIN samples



(c)Seasonal LAAs, PC Lab samples



(d) Seasonal LAAs, GulfFIN samples

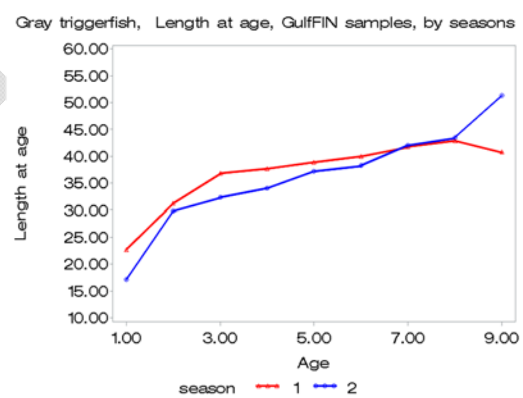
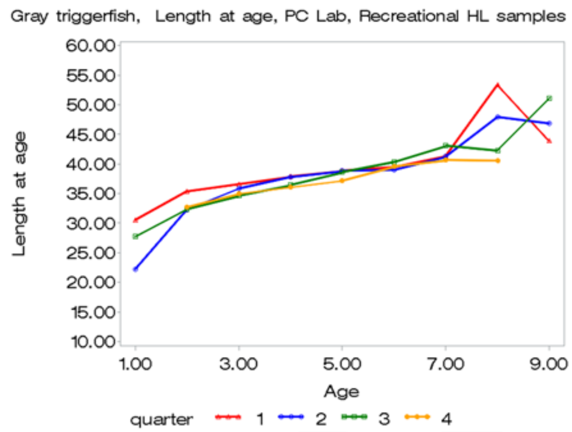


Fig 5. Comparisons of quarterly and seasonal lengths at age (LAAs) for different ages of gray triggerfish samples collected from the recreational hand line fishery and processed by Panama City Lab.

(a) Quarterly LAAs



(b) Seasonal LAAs

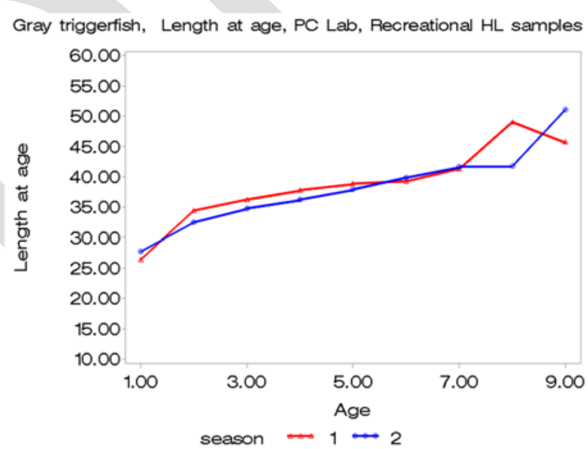
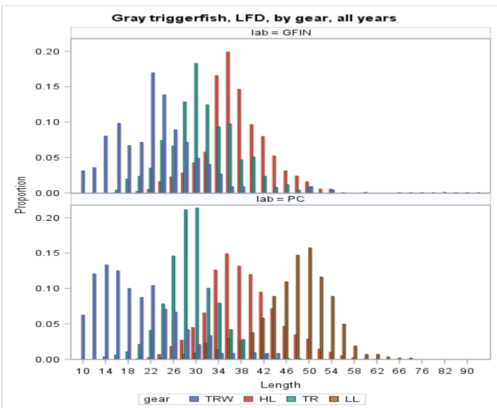
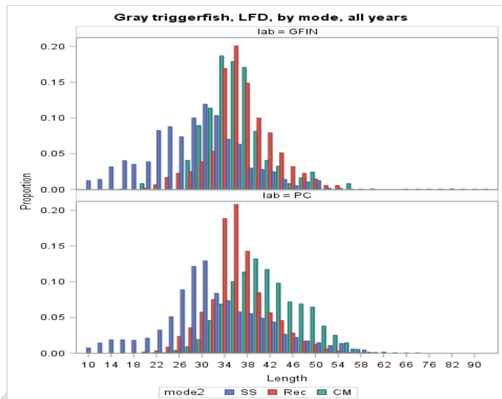


Fig 6. Length-frequency distributions for gray triggerfish samples collected from different fisheries and by different gear types (fishing modes: CM-commercial, Rec-recreational, SS-scientific survey; gear types: TRW-trawl, TR-trap, HL-hand line, LL- long line, Labs: PC- Panama City Lab, GFIN- GulfFIN) (note: only 4 major gear types are included in this figure)

(a) gear types



(b) fishing modes



(c)fishing modes and gear types

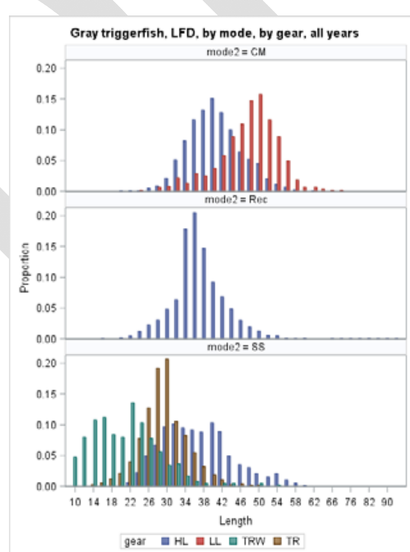
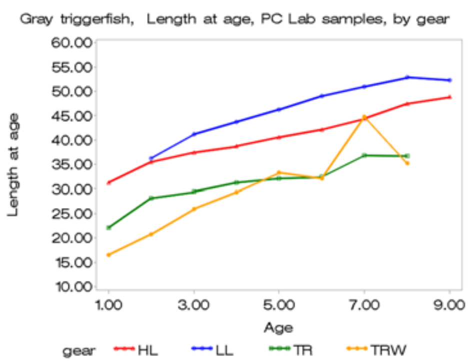


Fig 7. Effect of gear types on length at ages (LAAs): (a) PC Lab samples, (b) GulfFIN samples, (c) PC Lab scientific survey (SS) samples, and (d) GulfFIN scientific survey samples (gear types: TRW-trawl, TR-trap, HL-hand line, LL- long line).

(a) PC Lab samples



(b) GulfFIN samples

(c)PC lab scientific survey samples

(d) GulfFIN scientific survey sample

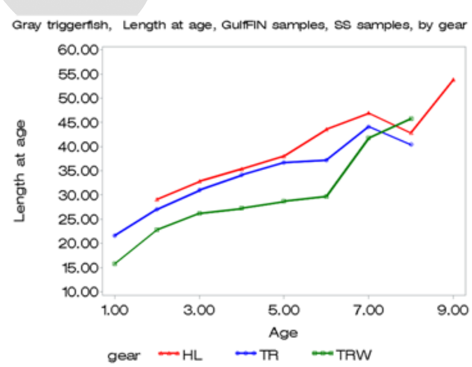
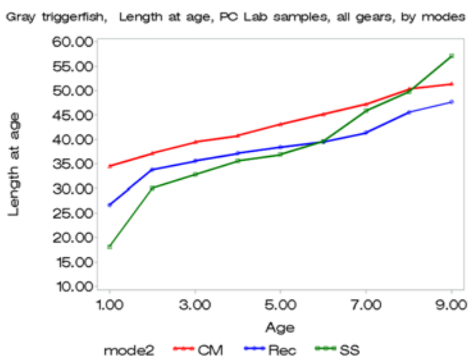
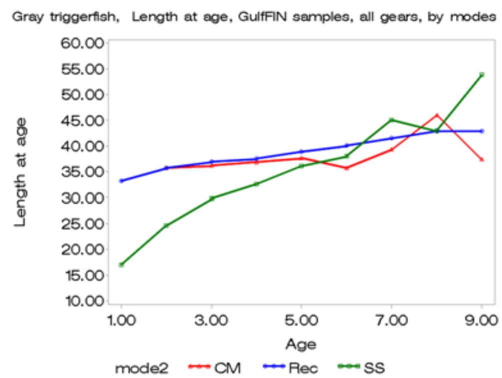


Fig 8. Effects of fishing modes on lengths at age (LAAs): (a) PC Lab samples, (b) GulfFIN samples, (c) PC Lab hand line (HL) samples, and (d) GulfFIN hand line samples (fishing modes: CM-commercial, Rec-recreational, SS-scientific survey)

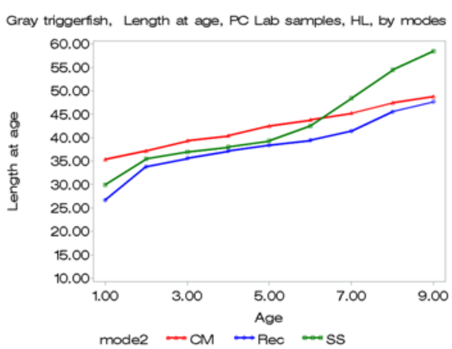
(a) PC Lab samples



(b) GulfFIN samples



(c) PC Lab hand line samples



(d) GulfFIN hand line samples

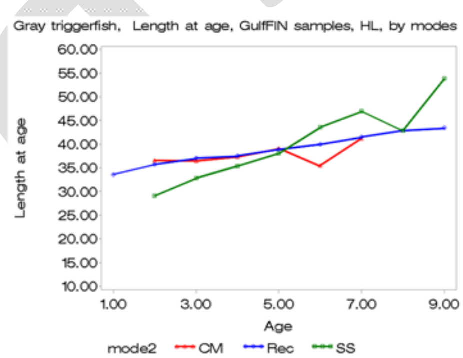
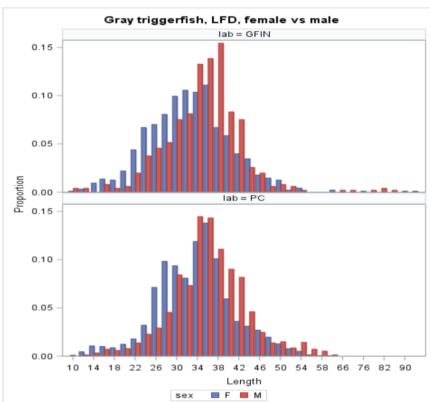
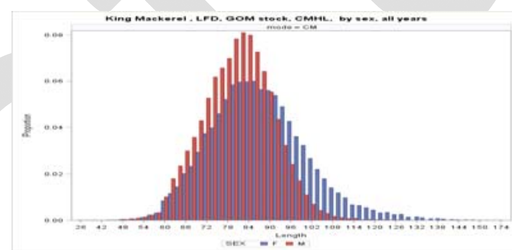


Fig 9. Length frequency distributions (LFDs) for gray triggerfish with known sex identifications: (a) comparison of LFDs between male and female fish collected from PC Lab and GulfFIN, (b) sexual dimorphism in LFDs for king mackerels (note: this figure is included for the purpose of comparison), (c) LFDs for different gears and sex for PC Lab samples and (d) LFDs for different gears and sex for GulfFIN samples

(a) LFDs by sex and by labs

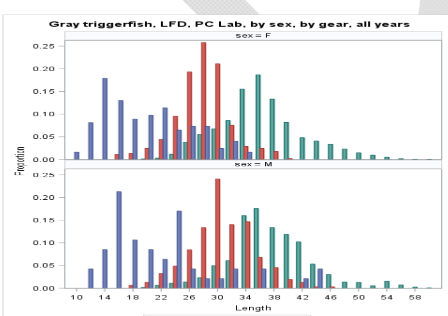
(b) sexual dimorphism in King Mackerels





(c)PC Lab samples

(d) GulfFIN samples



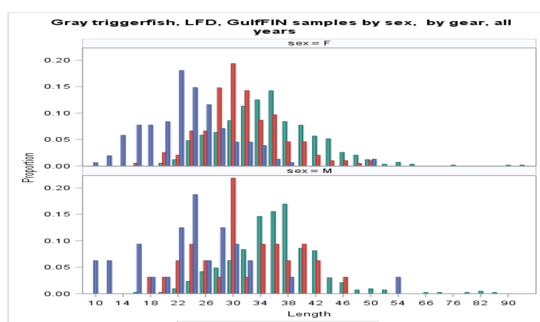
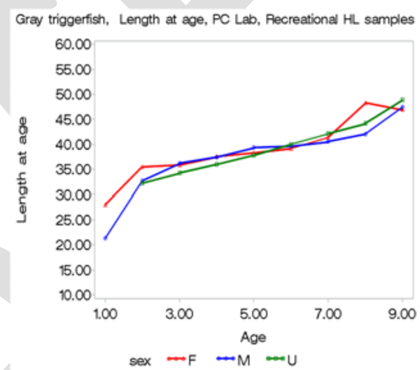


Fig 10. Lengths at age (LAAs) for gray triggerfish with different sex IDs that were processed by the PC lab: (a) LAAs for all samples and different sexes, (b) LAAs for recreational hand line samples and different sexes, (c) quarterly LAAs for female samples and (d) quarterly LAAs for male samples (sex: F- female, M- male, U-unknown).

(a) PC Lab samples

(b) PC Lab recreational hand line samples



(c)Quarterly LAAs for female samples

(d) Quarterly LAAs for male samples

Table 1. Sample sizes for gray triggerfish samples used for edge type analysis.

Month	GulfFIN	PC Lab
1	138	384
2	176	530
3	620	696
4	376	791
5	626	1172
6	313	621
7	222	456
8	208	786
9	152	758
10	117	758
11	76	416
12	17	466

Table 2. Sample sizes for gray triggerfish samples collected by different gear types (gear types: TRW-trawl, TR-trap, HL-hand line, LL- long line) (note: only these four major gear types are included in this table).

GulfFIN	HL	LL	TR	TRW
1	883			
2	1083		29	156
3	367		171	30
4	103		58	38
PC Lab				
1	1414	176		
2	2063	132	266	41
3	1191	107	500	82
4	1208	170	99	136

Table 3. Sample sizes for gray triggerfish samples collected from different fisheries and by different gear types (a) sample sizes for different fishing modes for each quarter and (b) samples sizes for different fishing modes and gears (fishing modes: CM-commercial, Rec-recreational, SS-scientific survey; gear types: TRW-trawl, TR-trap, HL-hand line, LL- long line) (note: only four major gear types are included in this table).

(a) sample sizes by fishing modes and by quarters

GulfFIN	Com	Rec	SS
Q1	62	872	
Q2	27	1099	189
Q3	24	286	272
Q4	10	90	110
PC Lab			
Q1	920	660	29
Q2	1000	812	767
Q3	598	439	952
Q4	834	477	329

(b) sample sizes by fishing modes and by gear types

GulfFIN	**HL**	**LL**	**TR**	**TRW**
Com	42			
Rec	2306			
SS	88		258	224
PC Lab				
Com	2739	585		
Rec	2367			
SS	770		865	259

Table 4. Sample sizes for gray triggerfish samples caught by different fisheries and by different gear types (a) sample sizes for different gear types for different sex groups and (b) samples sizes for different fishing modes for different sex groups (fishing modes: CM-commercial, Rec-recreational, SS-scientific survey; gear types: TRW-trawl, TR-trap, HL-hand line, LL- long line; sex: F- female, M- male, U-unknown).

(a) sample sizes by gear types and by sex groups

	HL	LL	TR	TRW
GulfFIN				
F	583		197	155
M	431		32	32
U	1422		29	37
PC Lab				
F	1545		455	135
M	1090		308	52
U	3241	585	102	72

(b) sample sizes by fishing modes and by sex groups

	CM	Rec	SS
GulfFIN			
F	28	535	393
M	13	421	71
U	82	1391	107
PC Lab			
F	13	1143	1056
M	5	722	815
U	3334	523	206