Report to Virginia Marine Resources Commission

Grant F-132-R-2 The Population Dynamics of Blueline and Golden Tilefish, Snowy and Warsaw Grouper and Wreckfish.

Performance Period 10/31/2011-11/30/2014

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The Magnusson-Stevens Fisheries Management Act requires completion of assessments for all fish stocks harvested in United States waters. These assessments are required, regardless of availability or quality of data. For species with more limited data, managers are in turn required to be more cautious, setting more conservative management regulations. These conservative regulations have the potential to be excessive for species that are not overfished, resulting in an unfortunate loss of income to recreational and commercial fisheries.

Prior to this study, the populations of several deepwater, demersal fish species that inhabit the North American Mid-Atlantic continental shelf/slope waters either had not been assessed or had previously been pronounced overfished. Furthermore, data specifically for the portions of these stocks that reside off the coast of Virginia did not include information on vital life history characteristics. This study sought to estimate the population dynamics of blueline tilefish (*Caulolatilus microps*), golden tilefish (*Lopholatilus chamaeleonticeps*), snowy grouper (*Epinephelus niveatus*), Warsaw grouper (*E. nigritus*), and wreckfish (*Polyprion americanus*) off the coast of Virginia. Specifically, our objectives for each species were to: 1) examine the age composition, 2) estimate annual growth rates, 3) estimate annual fishing and natural mortality rates, and 4) evaluate reproductive characteristics. Descriptions and discussions of the fulfillment of each of our objectives are listed below.

Data Collection

We collected groupers and tilefishes off the coast of Virginia using commercial, recreational, and fishery independent sampling techniques from 2009-2014 (Table 1). On 4 occasions commercial samples were purchased, typically as bycatch of fisheries for other species. The bulk of our samples were collected through recreational freezer donations via the Virginia Marine Resources Commission's (VMRC) Marine Sportfish Collection Project. We also conducted 43 fishery independent sampling trips aboard recreational private and headboat charter vessels. The vast majority of specimens were captured in the Norfolk and Washington Canyons.

Despite directed sampling efforts to collect snowy grouper, we were unable to collect enough specimens for a full analysis of life history (n=33). This fact combined with minimal commercial landings of this species is indicative of low abundance of this species at the northern end of its range off Virginia. While we were able to collect a substantial number of wreckfish (n=200), our sample only covered a narrow portion (489-917 mm total length (TL)) of the total size range for this species (max size>2000 mm TL). Therefore, we were unable to develop full age and length compositions for this species as well. We did not encounter any Warsaw grouper during the course of our sampling. During the course of our fishery independent sampling we frequently encountered 2 other species from this deepwater, demersal fishery, blackbelly rosefish (*Helicolenus dactylopterus*) and barrelfish (*Hyperoglyphe perciformis*). As physical changes due to pressure could inhibit survival of released fish, we measured size and collected otoliths (and gonads of rosefish) for these species as well. All of these data are available at the Center for Quantitative Fisheries Ecology (CQFE) for future studies and analyses.

Sagittal otoliths, length measurements (mm), and macroscopic assessments of sex and reproductive stage (using the same Index of Finfish Sexual Maturity as all other species that VMRC collects) were collected from all specimens. In addition, weight (g) was recorded for whole fish and gonads were extracted and weighed (g) for fresh specimens.

Objectives

1. Examine the age composition of tilefish species found off the coast of Virginia.

Blueline Tilefish; Status: Fulfilled

Sagittal otoliths were thin-sectioned and read to determine ages of blueline tilefish. While a previous study had validated the use of otolith thin-sections for aging blueline tilefish (Ross and Huntsman 1982), due to priority placed on aging more commercially significant species since that study, blueline tilefish had not been regularly aged prior to the 2013 Southeast Data Assessment and Review of the Atlantic stock (SEDAR 32). Therefore an aging workshop was held in Beaufort, NC, in which a protocol for aging blueline tilefish was redeveloped and agreed upon by scientists from CQFE, the National Oceanic and Atmospheric Administration’s (NOAA) Beaufort Laboratory, and South Carolina Department of Natural Resources Marine Resources Research Institute (MRRI). This protocol was eventually validated by marginal increment analysis (MIA) of otoliths collected during this study (Figure 1). MIA showed evidence of increment formation in February, which corresponds to the timing observed in a previous aging study of blueline tilefish from the South Atlantic (Ross and Huntsman 1982).

All blueline tilefish collected from 2009-2011 (n=967) were aged, and these data were contributed to SEDAR 32. To avoid redundancy in our age composition, we selected a proportionally allocated subsample (n=517) of blueline tilefish collected in 2012 for aging, based on the total length distribution of the 2009-2011 data (Quinn and Deriso 1999).

As seen in previous studies, blueline tilefish off the coast of Virginia are a long-lived species with ages up to 40 years old and a mean of 9.8 years old (Figure 2). This age range is similar to that observed in the South Atlantic during the 1980s and 90s, although mean age observed during the 1980s (16.9 years) was significantly greater than those observed in our study and in the South Atlantic during the 1990s (Harris 2004). Similarities in age ranges over the temporal development of this fishery suggest that lifespans of Virginian fish are similar to those of the South Atlantic. Observance of nearly the totality of this species' age range throughout the calendar year also suggests a year-round, resident adult blueline tilefish population off the coast of Virginia.

Golden Tilefish: Fulfilled pending further analysis

Sufficient specimens of this species have been obtained for analysis including age and size frequency distribution and growth analysis. Golden tilefish are regularly aged by scientists at MRRI. Therefore, CQFE scientists were trained in sagittal otolith processing and aging protocols for this species through workshops at MRRI. This ensures a consistent aging process throughout the entire US east coast.

All golden tilefish sampled from 2009-2013 have been aged (n=153), and 36 golden tilefish sampled during 2014 will be aged in the upcoming months. Ages ranged from 3 to 30 years with a mean age of 10.7 (Figure 3). Males ranged in age from 7 to 23 years with a mean age of 13.8. Females ranged from 3 to 30 years with a mean age of 12.4.

2. Estimate annual growth rates.

Blueline Tilefish: Fulfilled

Blueline tilefish ranged in size from 283 to 892 mm TL (mean: 533 mm) (Figure 4). Growth was modeled using the von Bertalanffy growth function (VBGF) (von Bertalanffy 1938):

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where is the horizontal asymptote representative of the mean maximum length, is the Brody growth parameter representative of how quickly maximum length is achieved, and is the theoretical age at length=0. Blueline tilefish off the coast of Virginia, similar to those of the South Atlantic, are slow-growing and exhibit sexually dimorphic growth (Figure 5). Limited sample sizes of fish less than 3 years old resulted in a biologically unrealistic estimate of for male growth. Therefore, sex-specific values were fixed at the value estimated from a VBGF based on back-calculated lengths at age of our MIA subsample, =-1.145. Likelihood ratio comparisons of growth curves revealed significant differences between sexes, with males growing faster and to larger total lengths (Table 2).

SEDAR 32 provided an opportunity for the collection and exchange of blueline tilefish growth data from throughout the US Atlantic coast. This enabled us to compare blueline tilefish collected in our study both temporally and spatially with those of the South Atlantic. The growth of modern, Virginian blueline tilefish is similar to that observed off the Carolinas during the 1970s, when the Atlantic stock was considered lightly exploited (Ross and Huntsman 1982, SEDAR 2013) (Table 3). This is significantly different from growth observed in the South Atlantic since the 1980s, when commercial landings peaked at over 500 mt then subsequently crashed to less than 100 mt within 7 years. Modern South Atlantic blueline tilefish grow faster and to smaller maximum sizes than Virginian blueline tilefish (Table 4). This trend is likely reflective of a relatively long-established fishery which has overfished the South Atlantic portion of this stock (increasing the reproductive advantage of faster growth and smaller maximum size due to greater energetic input into reproduction) (SEDAR 32), versus a relatively new fishery that is harvesting a previously unexploited portion of this stock off of Virginia (allowing for a greater abundance of larger and slower-growing individuals).

Golden Tilefish: Fulfilled pending further analysis

Golden tilefish ranged in size from 375 to 1152 mm (total length; TL), with a mean of 759 mm (Figure 6). The fishery-dependent sample ranged in length from 375 to 1152 mm with a mean length of 755 mm. The fishery-independent sample ranged in length from 456 to 1120 mm with a mean length of 766 mm. Through fishery-independent sampling, we were able to approximate the length range of fish caught through the recreational fishery in all but the largest and smallest categories (Figure 7). Size at age estimates indicate that growth may become asymptotic after age 20 at about 1000 mm (Figure 8). The three VBGF parameters were estimated using SAS and allowing the program to estimate without restrictions (Table 5). When allowing the program to estimate for all parameters, a value of -1.75 was returned for. When the VBGF was fit by sex, the female model estimated as -4.88, which is biologically unreasonable. Therefore, was fixed at -0.53 as reported in SARC 58.

Our fishery-independent sampling indicates a lack of small, young golden tilefish in the Norfolk Canyon. This does not seem to be due to gear limitation of smaller individuals as black belly rosefish less than 150 mm TL were collected using the same gear, yet no golden tilefish smaller than 456 mm were found. This lack of smaller individuals can cause difficulty in estimating the x-intercept of the VBGF. In an attempt to obtain smaller fish, we purchased 23 fish (14 juveniles) from a commercial trawl taken off New Jersey. However, the addition of these smaller individuals did not significantly change the estimated parameters.

3. Estimate annual fishing and natural mortality rates.

Blueline Tilefish: Fulfilled

Because there has been no tagging study of tilefishes off the Virginia coast and because catch and effort are likely underreported by this largely recreational fishery, fishing mortality (F) is poorly estimated. Therefore, we combined the use of catch curves to estimate total mortality (Z) with life history approaches to estimate the range of natural mortality (M) and potential ranges of F from the identity Z=F+M. The life history approaches included Alverson and Carney (1975), Pauly (1980) and Hoenig (1983).

Total mortality was calculated as the slope of the descending end of log-transformed numbers at age, or:

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where =numbers at age and =maximum observed age. Z was estimated as 0.165.

Estimates of M were all near 0.1, which was the average of age-specific mortalities estimated during SEDAR 32 (SEDAR 2013). This resulted in corresponding F estimates ranging from 0.05 to 0.072, which are similar to values estimated for 1974-1980, prior to the onset of large-scale commercial fishing for this species (SEDAR 2013).

Golden Tilefish: Fulfilled pending further analysis

Similar problems of underreporting catch and effort also persist for golden tilefish off of Virginia, requiring the use of catch curve analysis to assess mortality in this species as well. Catch curve analysis for golden tilefish estimated Z as 0.11.

Alverson-Carney's and Hoenig's methods estimated M as 0.12 and 0.15, respectively, resulting in negative estimates of F. Pauly's method estimated M as 0.09, resulting in an F estimate of 0.02. Despite the small data collections, natural mortality estimates remained close to that reported by the most recent stock assessment, SARC 58, which estimates natural mortality as ranging from 0.1 to 0.15. Collectively, these results indicate minimal fishing mortality in this portion of the stock, which corresponds to the lack of a commercial fishery and a small recreational fishery in Virginia.

4. Evaluate their reproductive characteristics.

Extracted gonads were fixed in formalin then sent to the Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute (FWRI). There, gonads were histologically sectioned and stained with Periodic-Acid Schiff's reagent (PAS) and Metanil Yellow (MY). Histological sections have been/will be used to microscopically assess reproductive maturity stage. All gonad samples for blueline tilefish have been sectioned, stained, and returned to CQFE. Golden tilefish samples are still being processed by FWRI but should be returned in the near future.

Blueline Tilefish: Fulfilled pending further analysis

Microscopic assessment of sex agreed with 98% of macroscopic assessments for blueline tilefish. Therefore, to increase our sample size, macroscopic sex determinations were used to calculate sex ratios. Overall sex ratio was significantly male skewed (χ^2=32.13, P-value: 1.44E-08). Sex ratios varied with total length as significantly greater proportions of females were observed in the smaller length classes, while greater proportions of males were seen in the larger length classes. Sex ratios also varied among ages with females generally being significantly more prominent than males at the youngest and oldest ages and males being more prominent at intermediate ages. These proportions at size indicate previously discussed sexually dimorphic growth, with males dominating the largest size classes despite a greater proportion of females at old ages. However, this information combined with proportions at age may give some preliminary information on relative age at recruitment. Previous studies have indicated that females mature at younger ages and smaller sizes than males (Ross and Merriner 1983; Harris et al. 2004). If a relationship between age at maturity and age at recruitment is assumed, this seems to be evident in the population off of Virginia as well by the relative abundance of females at small sizes and young ages. By the time males are recruited (~2 years later), female numbers would be relatively lower, reflected by a relative abundance of males at intermediate ages. Finally, the proportion of males would be decreased by lower susceptibility of slower-growing, smaller females of similar age to some of the larger gears used in this fishery, leading to a greater proportion of females in the oldest age classes.

Microscopic assessments of sexual maturity stage have been made for all female blueline tilefish histological slides, according to the Standardized Terminology developed by Brown-Peterson et al. (2011). These assessments revealed that similar to the South Atlantic, the spawning season for blueline tilefish off the Virginian coast begins between February and May (limited sample sizes within these months precludes a more definitive start date) through November, evidenced by spawning capable females (containing late stage vitellogenic or hydrated oocytes) being captured in each of these months (Figure 9). The composition of spawning females varied throughout the spawning season, with increases to both mean age and TL of spawning capable females later into the season (Table 8). By contrast, no spawning capable individuals were captured during the "off" months of December and January. All stages of the female sexual maturity cycle were observed in this high-site fidelity species, indicating that blueline tilefish off the Virginian coast are spawning locally.

Histological slides showed multiple oocyte stages in females, indicative of batch spawning as seen previously in the South Atlantic (Ross and Merriner 1983; Harris et al. 2004). Batch fecundity of spawning capable females will be measured using a gravimetric method as described by Hunter et al. (1985). Total fecundity will be calculated as batch fecundity multiplied by spawning frequency.

Golden Tilefish: Fulfilled pending further analysis

Females significantly outnumbered males across the entirety of our sample (χ^2=6, P-value=0.01). Age-specific sample sizes were not sufficient to calculate meaningful sex ratios. Sex ratios varied with total length, with females being significantly greater than males in the smallest size classes, while males were significantly greater at larger size classes (Table 9).

Spawning season was estimated using female gonadosomatic indices (GSIs) of the form:

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Monthly mean indices were calculated and plotted across the calendar year. Relatively increased mean GSIs, indicative of heavier gonads due to spawning activity, were observed from April through September (Figure 10), corroborating previously observed spawning seasons lasting from March through November (Turner et al. 1983).

Discussion

Blueline Tilefish

Blueline tilefish off the coast of Virginia show similarities in age composition with previously studied South Atlantic blueline tilefish. Both populations contain old individuals, with ages of 40 or more years being observed. However, differences in growth between these populations are evident from distinct lengths at age and length compositions. Blueline tilefish off the coast of Virginia grow more slowly and to larger sizes than those of the South Atlantic, likely due to differences in the fishing histories between these regions. While this larger size may provide incentive for anglers to pursue blueline tilefish off of Virginia, the slow growth of this population could leave it ill-equipped to sustainably support a sizeable fishery.

SEDAR 32 was the first assessment of the Atlantic blueline tilefish stock. In preparation for this assessment, scientists from CQFE and several agencies throughout the South Atlantic collaborated to develop a standardized aging protocol for this species. We were then actively involved in the assessment process, contributing age and growth data as well as anecdotal information to help describe the recreational fishery in Virginia. Although this species is managed by the SAFMC due to its historical spatial range, more recent data reveals that blueline tilefish are now being caught in the Mid-Atlantic as well, with landings as far north as Massachusetts (Personal communication from National Marine Fisheries Service, Fisheries Statistics Division. [08/29/2014]). Thus, this benchmark assessment should mark the beginning of collaborative efforts between scientists from both the South and Mid-Atlantic regions to assess and manage this species throughout the entirety of its range.

A lack of catch, effort, and tagging data from this largely recreational fishery led us to resort to a first order approximation of mortality, namely catch curve analysis and empirically-derived, size-based natural mortality estimates. While these methods offer numerical results that can be inserted into management models, the quality of these estimates must be considered before any regulations are suggested. For long-lived species like tilefish, catch curves can underestimate total mortality (and thus, fishing mortality) due to the division of the change in numbers by a longer than usual time exposed to the fishery. In addition, our age composition shows some indication of bimodality, which would necessitate more sophisticated methods to obtain a more accurate estimate of Z. Thus, while we have estimated mortality of this population, any management decisions based on these estimates should tend towards a more conservative approach.

Age and reproductive data indicate a locally spawning, resident population of blueline tilefish off the coast of Virginia. This local spawning, combined with the high site fidelity observed in other tilefishes and believed to persist in bluelines, creates the potential for a reproductively isolated population of blueline tilefish north of Cape Hatteras, NC. This location marks a change in the physical features of the coastal ocean, with generally cooler waters to the north and warmer waters to the south. A genetic separation has been observed across this boundary in golden tilefish, necessitating the distinction of northern and southern Atlantic stocks (Katz et al. 1983; SEDAR 2011; NEFSC 2009). The differences in growth observed between Virginian and South Atlantic blueline tilefish may be reflective of such a separation. However, local spawning does not necessarily lead to local recruitment. Further studies of larval and juvenile stages as well as genetics of blueline tilefish would be necessary to determine whether this stock can or does exhibit a genetic separation.

Golden Tilefish

Golden tilefish are managed as two stocks separated by the North Carolina-Virginia border. Each population has distinct life history characteristics. Preliminary results indicate that growth of the Norfolk Canyon portion of the northern stock of golden tilefish may vary from that of Southern New England. However, this result may be impacted by additional ages from our 2014 sample, so no definitive conclusions should be drawn until this analysis is fully complete.

The small sample size, lack of complete age distribution, and lack of effort estimates left us with only a catch curve analysis to estimate age-based mortality. This method did provide numerical values that are plausible, but they should be looked at with caution. The lack of samples in all age classes leaves a high degree of uncertainty to the estimates.

Reproductive estimates are inconclusive at this point. Further analysis will be conducted once the microscopic gonad samples have been received. When male golden tilefish reach maturity, they postpone spawning for two to three years (McBride et al. 2013). Because of this delay, macroscopically immature individuals may in fact be young males. Microscopic analysis may change some of the sex-specific von Bertalanffy parameters.

Golden tilefish high have site fidelity and do not move more than a few meters from their burrows (Grimes 1983). Although we collected older, larger individuals, we were unable to find any young, small juveniles. We know our sampling gear did not exclude these smaller sizes as we collected small black belly rosefish with the same gear. Further analysis is needed to determine if this lack of small individuals is due to a social hierarchical structure, or if the Norfolk Canyon population may be supplying new individuals to the southern New England population.

Publications based on this grant are in draft and will be submitted for peer-review. Two Ph.D. students (Schmidtke & Kirch) will also provide dissertations based on these collections upon completion of their degrees.

Presentations

Schmidtke, M. A., and C. Jones. 2013, August. Age and growth of blueline tilefish from the Mid-Atlantic Bight. Oral Presentation. American Fisheries Society 143rd Annual Meeting, Little Rock, AR.

Schmidtke, M. A., and C. Jones. 2014, January. Differential growth within a stock: a case study of blueline tilefish. Oral Presentation. Southern Division of the American Fisheries Society 2014 Spring Meeting, Charleston, SC.

Schmidtke, M. A., C. Jones, and S. Lowerre-Barbieri. 2015, January. Reproductive characteristics of blueline tilefish off the coast of Virginia. Oral Presentation. Southern Division of the American Fisheries Society 2015 Spring Meeting, Savannah, GA.

Figures and Tables

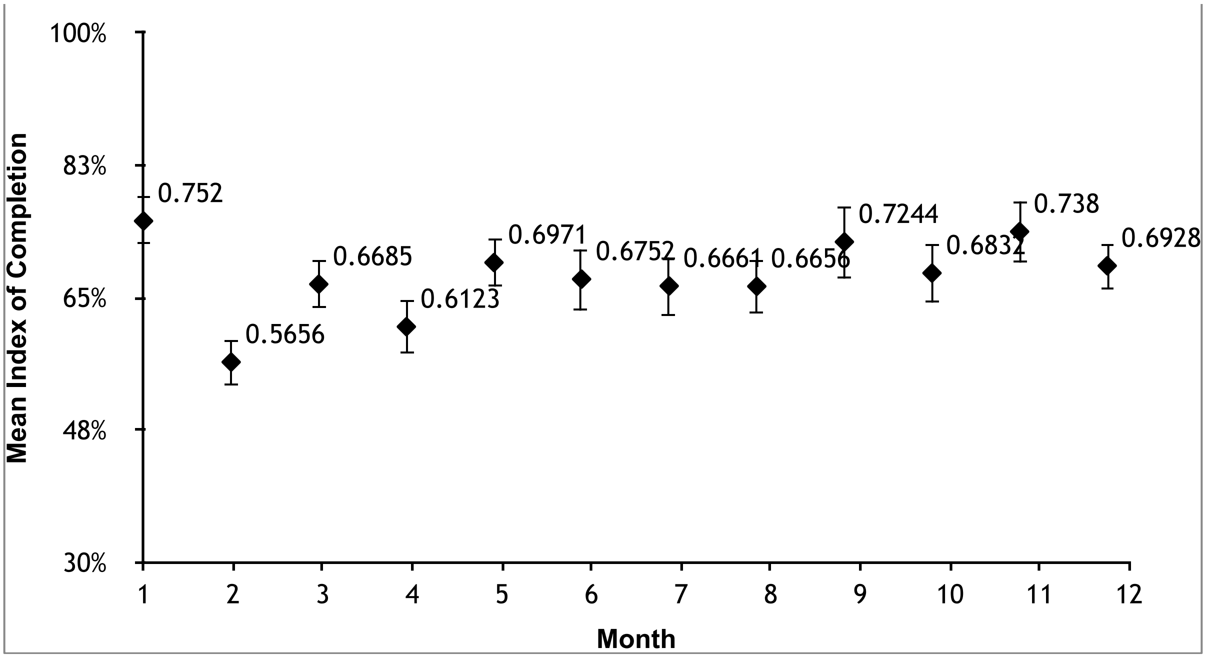

Figure 1. Means and standard errors of indices of completion for marginal increments of blueline tilefish sagittal otoliths. Sample sizes are shown to the right of each month's mean.

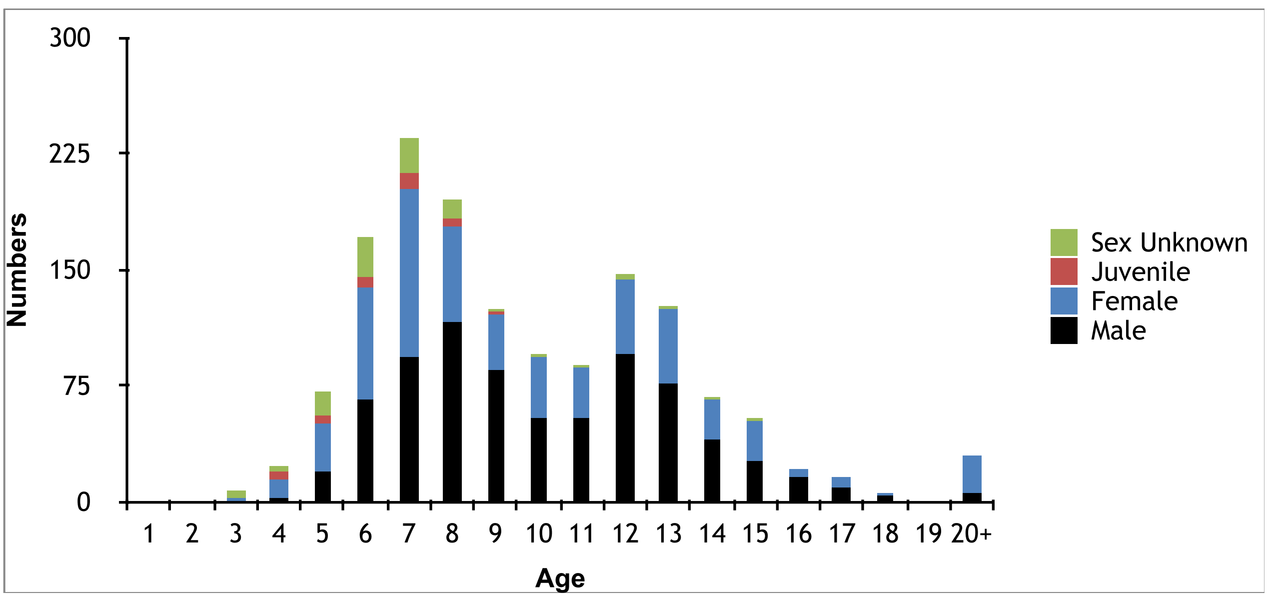

Figure 2. Age distribution for blueline tilefish sampled from 2009-2012 sorted by sex as determined by macroscopic gonad identification.

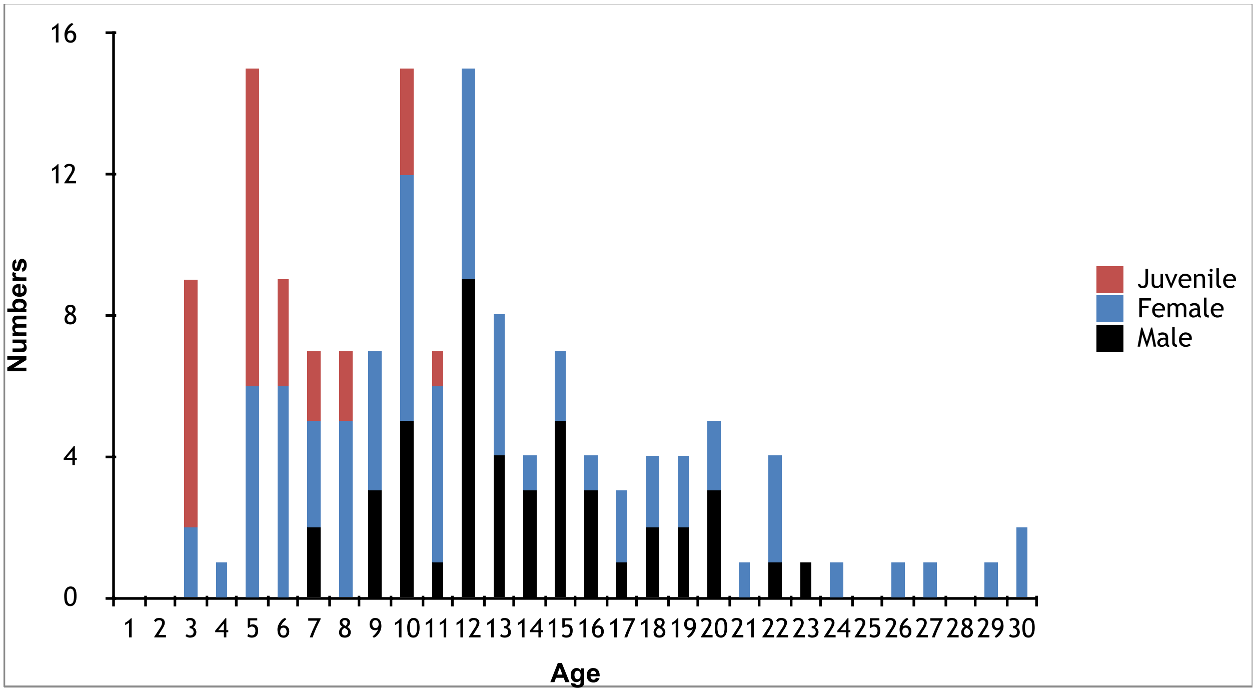

Figure 3. Age distribution for golden tilefish sampled from 2009-2013 sorted by sex as determined by macroscopic gonad identification.

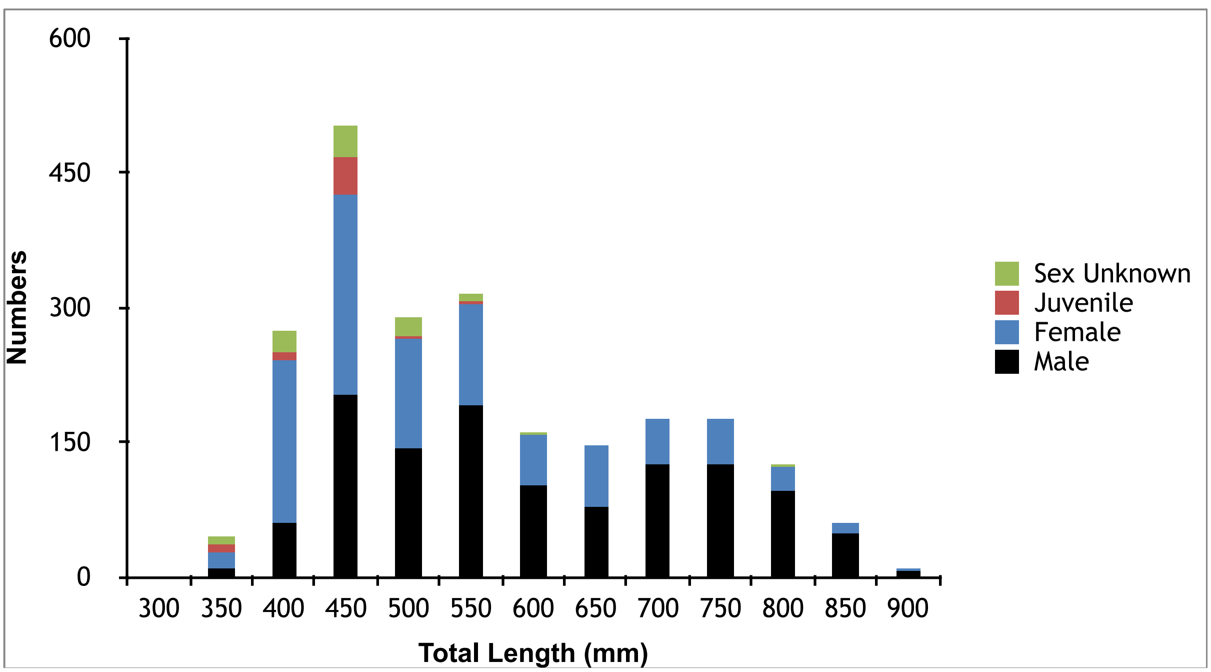

Figure 4. Length distribution of blueline tilefish collected from 2009-2012 sorted by sex as determined by macroscopic gonad identification (bins span ranges of the form: less than 300, 301-350, 351-400, etc.).

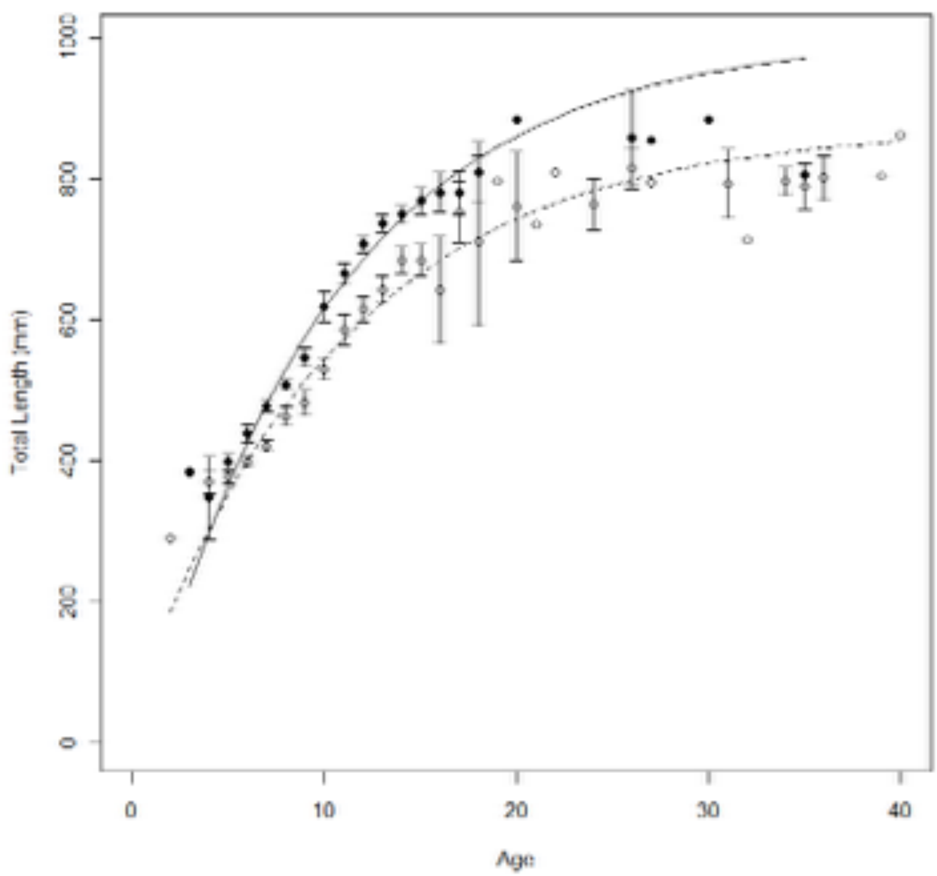

Figure 5. Von Bertalanffy growth curves regressed upon observed lengths at age (with fixed at -1.145) and data points indicating mean lengths at age with 95% confidence intervals for male (solid line, filled circles) and female (dashed line, open circles) blueline tilefish landed in VA from 2009-2012.

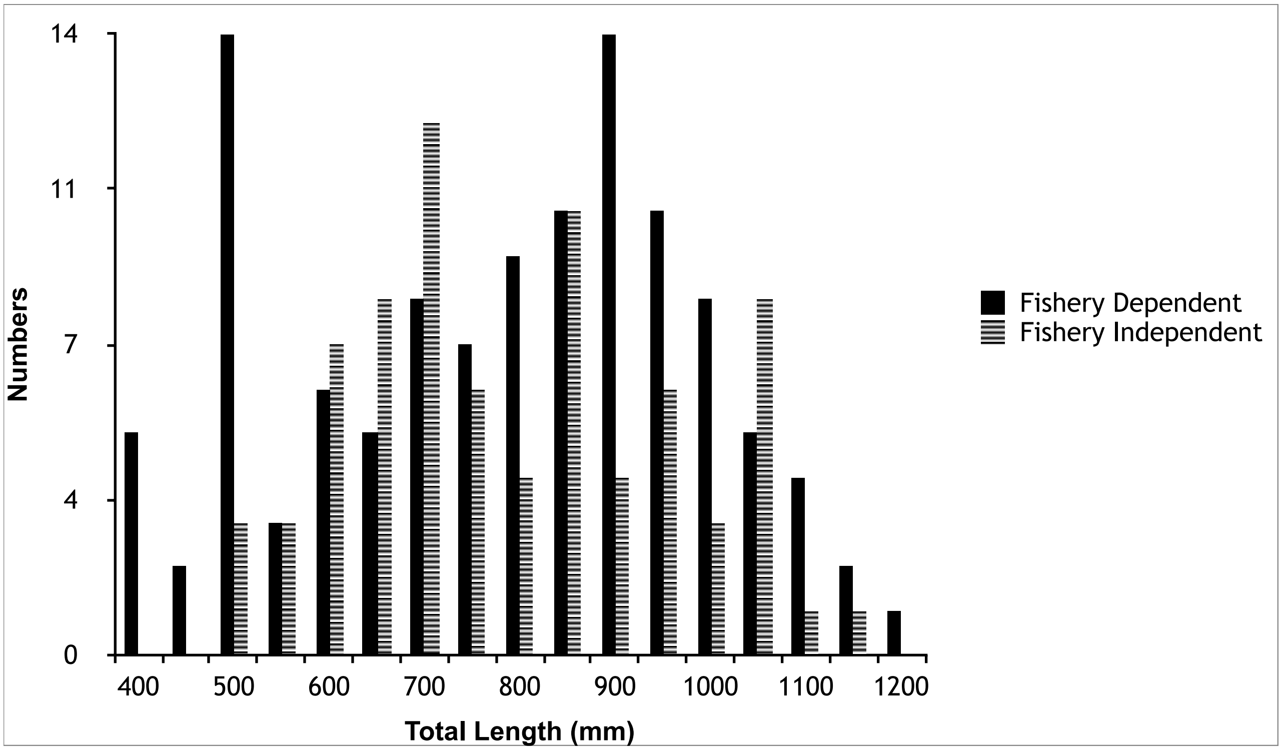

Figure 6. Length distribution for fishery-independent and fishery-dependent golden tilefish samples in mm TL (bins span rages of the form: less than 400, 401-450, 451-500, etc.).

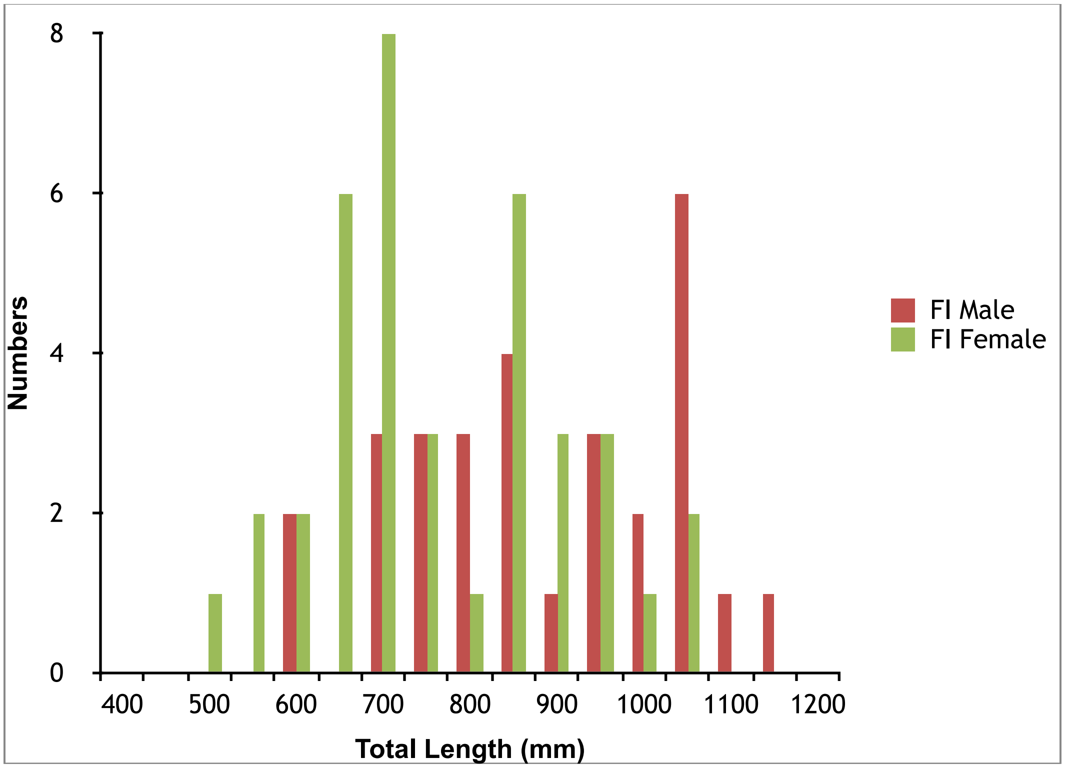

Figure 7. Length distribution of male and female golden tilefish in mm TL sampled by fishery independent methods.

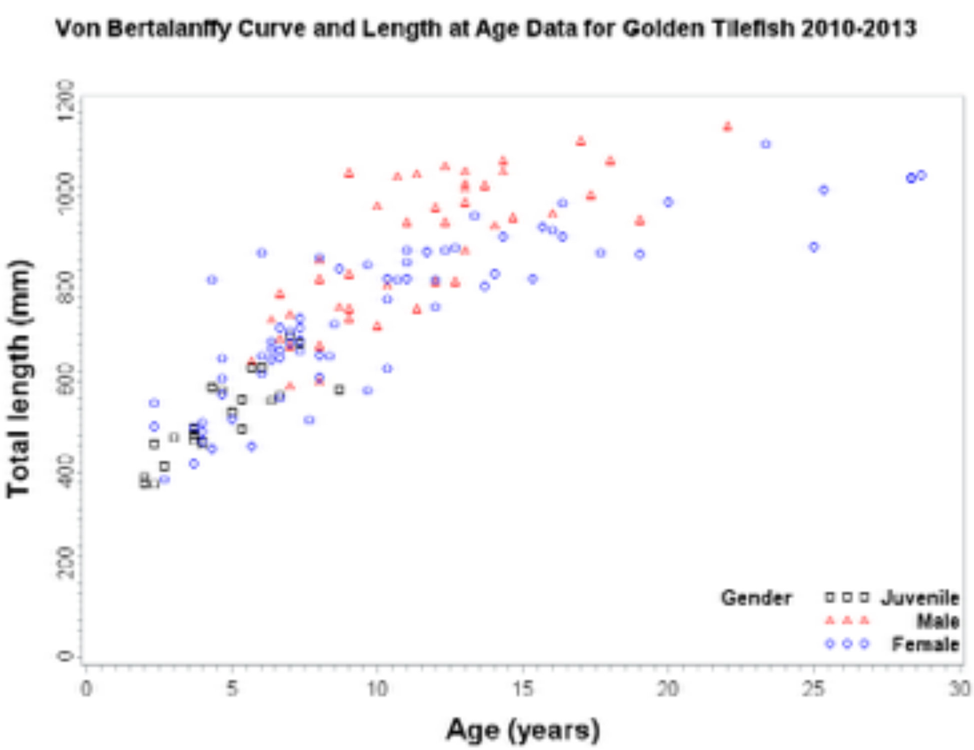

Figure 8. Von Bertalanffy growth curve for golden tilefish sampled from 2010-2013.

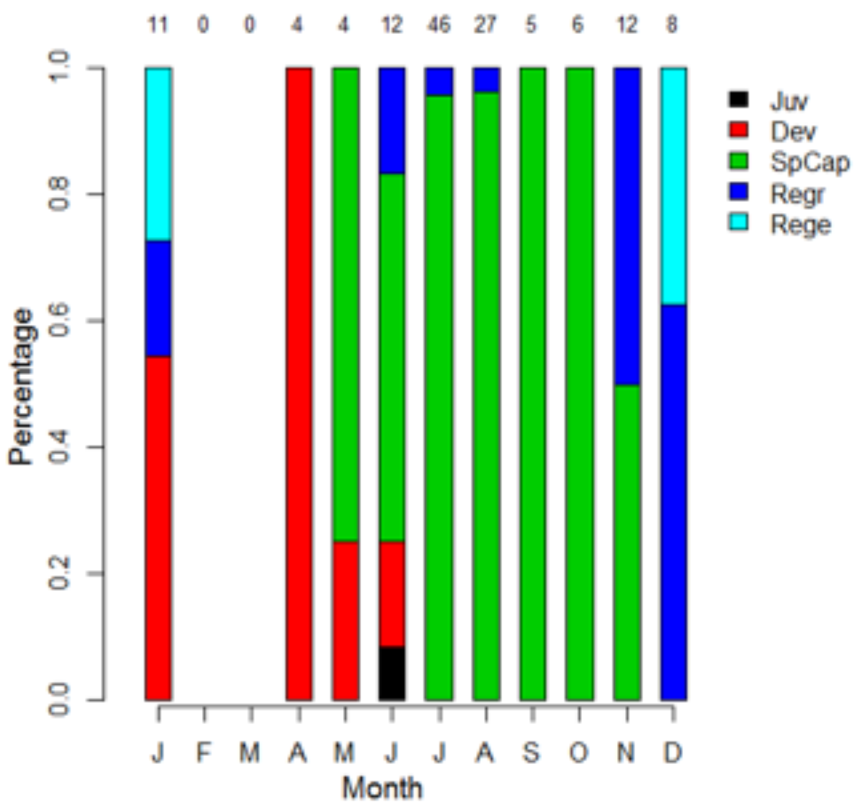

Figure 9. Proportions of reproductive maturity phases observed in blueline tilefish collected of the coast of Virginia, as determined by examination of histological sections. Phases were designated according the standardized terminology of Brown-Peterson et al. (2011) (Juv=Juvenile; Dev=Developing; SpCap=Spawning Capable; Regr=Regressing; Rege=Regenerating). Sample sizes are listed above each month.

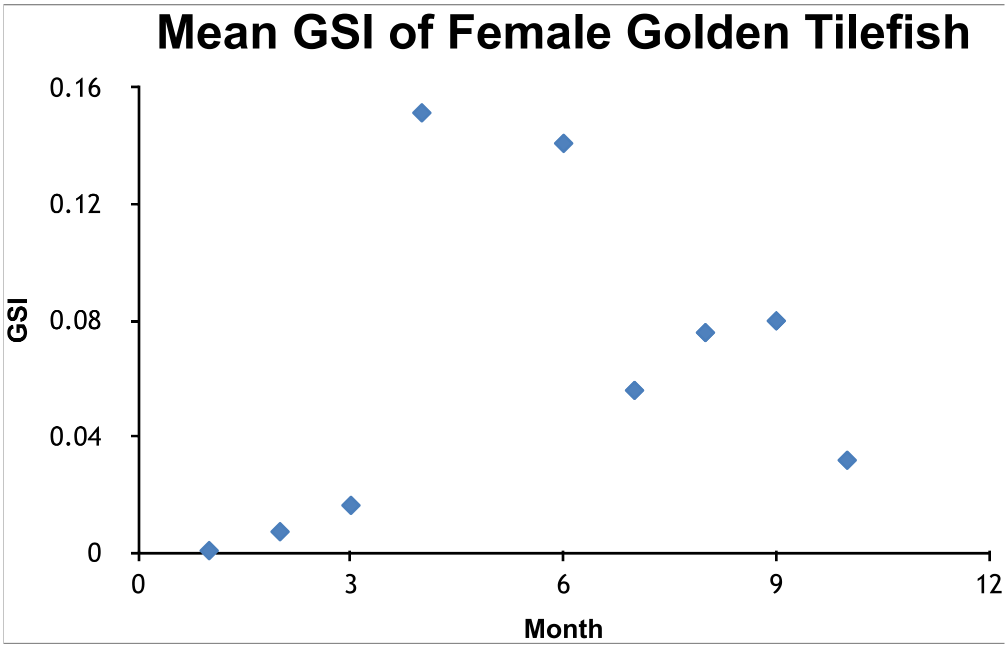

Figure 10. Mean gonadosomatic index (GSI) for female golden tilefish by month. GSI was calculated by dividing the gram weight of whole gonad by gram weight of whole fish.

Fishery	Species	2009	2010	2011	2012	2013	2014	Totals
Commercial	Blueline tilefish	0	0	53	5	0	0	58
	Golden tilefish	0	0	0	23	0	0	23
Recreational donations	Blueline tilefish	90	195	445	1022	72	87	1911
	Golden tilefish	2	18	9	17	8	36	90
	Snowy Grouper	4	4	7	6	1	7	29
	Wreckfish	0	3	8	58	10	3	82

CQFE Sampling	Blueline tilefish	0	75	125	96	40	0	336
	Golden tilefish	0	2	5	47	22	0	76
	Snowy Grouper	0	0	0	2	2	0	4
	Wreckfish	0	0	22	94	2	0	118

Table 1. Numbers of fish collected in fishery-dependent (Commercial and Recreational) and fishery-independent (CQFE) sampling.

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Male	1001	0.101	0.506	1163	0.067	-1.145
Female	872	0.093	-0.570	894	0.084	-1.145
Chi Sq (P-value)	18.41 (<0.001)	0.78 (0.377)	8.47 (0.004)	23.69 (<0.001)	85.75 (<0.001)	

Table 2. Parameter estimates for sex-specific VB growth models of individual observed lengths at age. Chi square and p-values resulting from likelihood ratio tests of equality between parameter estimates are shown in the bottom row.

	Parameter Estimates			VA Parameter Estimates (fixed) and VRT Statistics				
Study; Time Period							F (df=31)	P-value
Present Study; 2009-2012	837	0.12	-0.84					
Ross and Huntsman 1982; 1972-1977	810	0.14	-1.64	848	0.10	-1.64	1.91	0.077
Harris et al. 2004; 1982-1987	643	0.15	-3.88	879	0.08	-3.88	7.77	<0.001
Harris et al. 2004; 1996-1999	651	0.08	-11.77	1026	0.04	-11.77	4.49	<0.001

Table 3. Parameter estimates for VB growth models of unweighted mean lengths at age for current VA and past SA data sets. Models were compared by variance ratio tests between each of the past models and a refit current VA model with fixed at the values estimated by each of the past models.

State	N						
VA	1619	926	0.098	-0.368	968	0.083	-1.145
NC	2451	742	0.229	-1.068	744	0.224	-1.145

SC	260	635	0.296	-2.279	628	0.367	-1.145
FL	232	732	0.228	-0.919	742	0.213	-1.145

Table 4. State VB parameter estimates for blueline tilefish landed in FL, SC, NC, and VA from 2003-2012. Models were fit with estimated (left) and fixed (right) values for .

	Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits		Skewness	Bias	Percent Bias
Entire Sample	L inf	1108.1	61.3534	986.8	1229.3	0.7758	8.9102	0.80
	K	0.0942	0.0173	0.0600	0.1284	0.1895	0.000546	0.58
	to	-1.7512	0.8984	-3.526	0.0242	-0.6174	-0.0801	4.57
Males	L inf	1172.9	166.0	838.1	1507.6	3.0966	91.9331	7.84
	K	0.1094	0.0652	-0.022	0.2408	0.1583	0.00172	1.57
	to	0.1514	3.5542	-7.016	7.3191	-2.2884	-1.2772	-844
Females	L inf	1112.0	118.7	875.1	1349.0	1.8017	38.7675	3.49
	K	0.0689	0.0255	0.0181	0.1197	0.2046	0.000868	1.26
	to	-4.8831	2.6319	-10.13	0.3687	-1.2590	-0.5102	10.4
NJ Removed	L inf	1412.6	294.7	829.1	1996.0	2.8780	146.1	10.3
	K	0.0423	0.0222	-0.001	0.0863	0.1203	0.000446	1.05
	to	-8.6780	3.9606	-16.51	-0.837	-1.5082	-0.9400	10.8

Table 5. Von Bertalanffy growth parameters for golden tilefish. The parameters were calculated for the entire sample, males and females only, and the entire sample with those collected from New Jersey removed.

Method	Description	M	F
Alverson-Carney (1975)	, where , = maximum observed age, and is the VB growth parameter.	0.098	0.067
Hoenig (1983)		0.115	0.05
Pauly (1980)	), where is the VB mean maximum age parameter, and is the environmental water temperature, =13.034°C.	0.093	0.072

Table 6. Estimates of natural mortality (M) and corresponding fishing mortality (F) of blueline tilefish as a result of Z=F+M. Z was estimated as 0.165 from catch curve analysis. Water temperature for Pauly's method was calculated as the mean of bottom temperatures for locations at which we caught blueline tilefish during fishery-independent sampling trips.

Method	Description	M	F
Alverson-Carney (1975)	, where , = maximum observed age, and is the VB growth parameter.	0.12	-0.01
Hoenig (1983)		0.15	-0.04
Pauly (1980)	), where is the VB mean maximum age parameter, and is the environmental water temperature,=10.749°C.	0.09	.02

Table 7. Estimates of natural mortality (M) and corresponding fishing mortality (F) of golden tilefish as a result of Z=F+M. Z was estimated as 0.11 from catch curve analysis. Water temperature for Pauly's method was calculated as the mean of bottom temperatures for locations at which we caught golden tilefish during fishery-independent sampling trips.

Spawning Capable Females		
Month	**Mean Age**	**Mean TL (mm)**
May	8.00	502
June	8.14	435
July	8.45	501
August	7.92	456

September	14.80	612
October	11.60	579
November	13.67	569

Table 8. Mean ages and total lengths of spawning capable female blueline tilefish captured off the coast of Virginia.

Sex Ratio by Total Length (mm)				
Length Range	n	M/F	x	P
< 600	18	0.13	10.89	9.67E-04
601-700	27	0.17	13.37	2.56E-04
701-800	24	1.00	0	1
801-900	34	0.55	2.94	8.63E-02
901-1000	26	1.17	0.15	0.695
1001-1100	17	3.25	4.76	2.90E-02
1101-1200	4	3.00	1	0.317

Table 9. Sex ratios of golden tilefish by length.

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