FIRST DRAFT

Golden tilefish (*Lopholatilus chamaeleonticeps*) age, growth, and reproduction from the northeastern Gulf of Mexico: 1985, 1997-2009

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Abstract

Golden tilefish otoliths were collected from fishery dependent and independent sources (n = 4841; 1985, 1997-2005). Fish collected represent a large range of lengths (274-1123 mm TL, mean 653 ± 2 mm std err, se) and ages (2-40, 10 ± 0.06). Most of the fish were 400-899 mm in total length (94%) and age 5-18 (95%). Golden tilefish ages and observed total lengths were fit to a von Bertalanffy growth model to obtain population growth parameters: L_∞ = 830 mm, k = 0.13, t_o = -2.14. Natural mortality was based on longevity (age 40, M = 0.10) and total mortality was calculated as 0.27 from catch curves (age 8-30). Golden tilefish were identified as either female (n = 341) or male (n = 534) through the interpretation of histologically prepared gonad tissue. Reproductively, golden tilefish have an extended spawning season (January to June) in the Gulf of Mexico. Most of the females collected were mature (n = 331, 351-780 mm TL, age 3-27) with very few immature females sampled (n = 4, 301-414 mm TL, age 4-6). A logistic regression was fit to size, age, and binomial data (females either immature-0 or mature-1) to determine the size and age at 50% maturity (344 mm TL and age 2, respectively). Currently, golden tilefish are classified as gonochoristic; however, evidence exists of a possible sex change in golden tilefish from the Gulf of Mexico with both male (68%) and female (11%) gonads containing gonadal tissue of the opposite sex. Sexual dimorphic growth was evident for golden tilefish from the Gulf of Mexico, with males growing faster at each age class additionally, the von Bertalanffy growth model predicted faster growth rate and larger asymptotic size for males. Biological samples collected from the commercial longline fishery were reported from NMFS Statistical Grids 7 – 11 (55%) and from depths of 30-400 m (mean 264 ± 2 m), with a majority (80%) caught between 200-400 m. Fishery dependent and independent data showed an increase in age with depth caught.

Introduction

In the late 1960s, the Bureau of Commercial Fishing Exploratory Fishing and Gear Research conducted research cruises in the Gulf of Mexico investigating the availability of fish stocks and the feasibility of using bottom longline gear in depths 50-200 fathoms (Nelson and Carpenter 1968). The most abundant fish caught was the golden tilefish, an important food fish of the Mid-Atlantic States and at that time, only a few tons were harvested annually from the Gulf of Mexico. By the mid-1980s, hundreds of metric tons of golden tilefish were being landed throughout the Gulf of Mexico (pers com NMFS/FSD).

The golden tilefish, *Lopholatilus chamaeleonticeps*, is a deep-water demersal fish found in the Atlantic from Nova Scotia through the Gulf of Mexico (Dooley 1978). There are only two species of *Lopholatilus* spp. in the Family Branchiostegidae and only one of those two species (*L. chamaeleonticeps*) is found in the Atlantic. *Lopholatilus* spp. are morphometrically different from other species of tilefish due to the presence of a large and elevated predorsal ridge (adipose fin) and a smooth preopercle (Dooley 1978). Golden tilefish are a long-lived fish reaching maximum ages of up to 40 yrs, have a slow growth rate, and mature at fairly large size and age (Turner et al. 1983, Harris and Grossman 1985, Palmer et al. 2004).

The golden tilefish has a unique burrowing behavior and habitat preference. Burrowing construction has been observed through the use of submersibles in the Hudson submarine canyon, southern New England waters (Able et al. 1982), east coast of the United States (Grimes et al. 1986) and waters off of Texas (Jones et al. 1989). Golden tilefish prefer malleable but stable sediments to form burrows, a mixture of clay and silt (Able et al. 1982). In addition to their unique habitat choice, golden tilefish display sexually dimorphic growth with males obtaining larger sizes and are behaviorally dominant (Grimes and Turner 1999). Given the golden tilefish's habitat preference, life history and behavior, these characteristics make this species highly susceptibility to capture and to overfishing (Grimes et al. 1988, Harris and Grossman 1985, Matlock et al. 1991).

Because age, growth, and reproduction information is critical to stock assessment, the goal of this report is to characterize age-length structure and reproductive parameters using data collected from the northeastern Gulf of Mexico. The following are discussed: age and length, growth rates, mortality estimates, and sex-specific age, length, and growth rates, spawning season, age and size at maturity and at transition, and proxy for annual fecundity. This is the first documentation of the golden tilefish life history parameters in the Gulf of Mexico.

Methods

Data Collection

Otoliths were collected (1997-2009) by numerous federal and state sources representing the commercial fisheries (Trip Interview Program – TIP, Alabama Division of Marine Resources – ALMR). Golden tilefish otoliths were first collected in 1985 via a federally funded fishery independent survey (NMFS Pascagoula, MS – MSLAB), which re-established biological sample collection of golden tilefish in 2000. The Cooperative Research Program (CRP) also provided otoliths and gonads and site specific detailed capture locations (2008-2009). At-sea collection of otoliths and gonads were made possible through two observer programs (2008-2009; NMFS Panama City Shark Bottom Longline Observer Program – SBLOP and NMFS Galveston Reef fish Observer Program – GOP). Measurements of fish lengths (total and/or fork), weights (whole or gutted), and removal of otoliths and gonads were completed in the field. Gonads were stored in 10% neutral buffered formalin until histological processing.

Information describing catch location (latitude, longitude, depth, or NMFS statistical sub-areas, further referred as grids; Patella 1975) was often reported with commercial samples. Depth data were either reported as a mean depth or a range of depths for the entire interview. If the range of depth was ≤ 5-fathoms (fm), then an average depth was calculated, otherwise both a start and an end depth were recorded.

Data Quality Control

Each of the data collection sources has separate but similar sampling procedures, data protocols, and reporting methodologies. Our facility uses data quality control guidelines in the interpretation of source-specific datasheets as described by the Procedure Manual for Age, Growth, and Reproduction (AGR) Lab (NOAA 2008). First, each species-specific collection is assigned an annual collection (or tracking) number and all collection-specific data (i.e. source, source number, state, sector, and gear) are proofed and entered in our Annual AGR Access Databases from the original datasheets. If such data are not provided, then the collector (port agent and/or survey leader) is contacted to track down the missing data. Our Annual AGR Access Databases were constructed with field-specific lists of suitable values (e.g. source, state, sector, and gear), validation rules, and user-specific security for data accessibility to enhance our data quality control procedures. Additionally, the source number (or interview number) is a source-specific number (or combination of intercept specific numbers) that permits the cross-referencing of data between databases (original source and Annual AGR Database). Next, after all the individual fish data are entered, proofing sheets are reviewed against the original datasheets and any corrections are made to the Annual AGR Database. Finally, all proofing sheets are initialed, dated and filed for further reference. Prior to 1998, no manual existed to implement these procedures. Therefore, to insure these standards of quality control, all 1997 data were proofed using the TIP original datasheets (archived in Panama City, FL).

Age Validation

Validating the timing of band deposition on otoliths is critical in determining longevity. Marginal increment analysis (Turner et al. 1983) and radiochemical dating with the use of radiocarbon C^{14} (Harris 2005), was attempted for the validation of the timing of band deposition in golden tilefish but provided inconclusive results. A second method of radiochemical dating using the natural decay of lead (^{210}Pb) and radium (^{226}Ra) was explored (Andrews 2009).

Age Determination

The sagittal otolith was used as the primary ageing structure (Turner et al. 1983). Sagittal otoliths were sectioned using a Hillquist thin sectioning saw, and sections were viewed using a stereomicroscope with reflected light. Four readers read the golden tilefish otolith reference collection and indices of precision (Average Percent Error, Percent Agreement, Coefficient of Variation) were calculated (Campana 2001). All fish were assigned an annual age equal to the annulus count by convention. Due to the difficulty in estimating annuls counts, edge types were not reported.

Description of Age, Length and Growth

Age and length data and observed mean size-at-age data are presented for fishery dependent and fishery independent data. Patterns of length and age data were compared among years using a one-factor ANOVA to test for any similarities among years. A growth curve, based on ages and observed total lengths at capture, was modeled using the von Bertalanffy growth function and was fit by non-linear regression (Solver, Microsoft Excel). Since this fishery is not governed by a size limit, all data collected by all sources were used to aid the model to predict growth. Sexual dimorphic growth patterns will be investigated.

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Reproductive Parameters

During gonad processing, all gonads were removed from formalin, blotted dry, and weighed to the nearest 0.1 g. The posterior of one or both lobes of the gonad was cross sectioned and submitted for histological processing. The samples were placed in individual tissue cassettes along with formalin for histological slide preparation at Louisiana State University School of Veterinary Medicine, Department of Pathology. Histological slides were examined microscopically at 40x – 400x magnification to determine oocyte maturation. Using the oocyte maturation characteristics described by Lyon et al. (2008), oocytes were staged accordingly to determine the leading oocyte stage, presence or absence of postovulatory follicles (POFs) and gonad class.

Spawning Season

The gonadosomatic index (GSI) was calculated for males and females using the following formula: $GSI = (GW/(TW-GW)) * 100$; where GW = total fresh gonad weight (g) and TW = total fish weight (g). The value of TW minus GW is also referred to as "somatic weight" for purposes of comparison.

Size and age at maturity and transition

Maturity was based on histological examination of gonad tissue. Females displaying vitellogenic or hydrated oocytes were defined as mature. Females were classified as "spawning" depending upon the presence of hydrated oocytes, indicative of imminent spawning, or POFs, indicative of recent spawning (Hunter and Macewicz 1985). Females with cortical alveoli or primary growth oocytes as the leading stage and with evidence of prior spawning (old, atretic hydrated oocytes, muscle bundles, brown bodies, etc.) were also classified as mature females. Regressed and developing females with few prior indicators of spawning were excluded from the analysis because their maturity was uncertain. A logistic regression model fitted to binomial maturity data (immature=0, mature=1) was used to determine the size and age at which 50% of females in the population reached sexual maturity. The analysis was conducted using females collected during all months of the year. A logistic regression model fitted to binomial data (female=0, male=1) was used to determine the size and age at which 50% of females in the population had transitioned into males.

Proxy for Annual Fecundity

Fecundity analysis was not conducted due to the relatively small number of hydrated gonads available. However, the relationship between gonad weight and age is presented for comparison. Only females with vitellogenic or hydrated oocytes collected during the spawning months (January through June) were used. Ovary weight relationships were compared with somatic weight at age; which in turn is commonly extrapolated by numbers at age to yield estimates of spawning stock biomass. Spawning stock biomass (SSB) for females was the chosen proxy for fecundity in the South Atlantic assessment of tilefish (SEDAR 4).

Mortality Estimates

Natural mortality (M) was estimated for all data and spatially by NMFS Statistical Grids using Hoenig (1983) regression model for teleosts. This regression is the recommended model for estimating natural mortality over the rule-of-thumb approach (Hewitt and Hoenig, 2005). Estimates of instantaneous total mortality (Z) were calculated using catch curve analysis for all data and spatially by grid.

Spatial Patterns

Commercial longline and scientific longline survey data were analyzed by NMFS Statistical Grid and depth bin (grouped by 100 m) to detect any differences between data sources. Patterns of length and age data were compared among NMFS Statistical Grids and depth bins using a one-factor ANOVA to test for any similarities among grids and depth bins by source.

Results and Discussion

Data Collection

A total of 4841 otoliths were collected from fishery dependent and independent sampling (1985, 1997-2005; Table 1). Golden tilefish otoliths were obtained primarily from Florida's federal waters (68%) and 20% collected in Texas' waters (Table 2). Trip Interview Program's port agents collected a majority of the otoliths (79%, Table 3). This fishery is primarily commercial with 92% of otoliths sampled by commercial port agents (Table 4). Ninety-three percent of the golden tilefish otoliths were collected during the more recent years (2003-2009, Table 1).

Age Validation and Determination

Golden tilefish thin sectioned otoliths are difficult to interpret given several different shapes of otolith sections and diverse patterns of growth deposition (Figure 1). Previous validation methods were inconclusive in determining the timing of band depositions. Andrews (1999) determined good agreement between radiometric age and estimated age from growth zone counts for female and unknown age groups, but the oldest male age groups were not in agreement.

Given the difficulty in determining accurate age estimates, an ageing workshop was conducted among several federal and state agencies (NOAA Fisheries Service Panama City, FL; NOAA Fisheries Service Beaufort, NC; South Carolina Department of Natural Resources, Charleston, SC). Each agency provided thin sectioned sagittal otoliths to create a reference collection. Indices of precision were calculated from the reference collection (n = 289) with an overall average percent error of 11%, with percent agreement of 5% increasing to 77% ± 3 years (Table 5).

Description of Age, Length and Growth

Golden tilefish caught from all sources reflected a large range of lengths (274-1123 mm TL, mean 653 ± 2 mm se) and ages (2-40, 10 ± 0.06). A majority of the fish were 400-899 mm in length (94%; Figure 2a) and age 5-18 (95%; Figure 2b). Size-at-age analysis resulted in relatively uniform pattern of increased growth with age (Figure 2c); but at age 17 a decrease in growth is observed. This pattern may be due to the decrease in sample sizes at age and/or the combination of slow growing female and faster growing male fish at older age classes (see below).

Due to the low sample sizes of fish intercepted from the commercial longline fishery, further analysis includes data only collected in 2001-2009. Annual age and length boxplots for commercial longline revealed similarly sized and aged fish by year. Golden tilefish collected through intercepts of the commercial fishery had annual mean lengths of 606-687 mm TL, with an overall mean size of 654 ± 2 (se) mm TL (range = 274-1145 mm; Figure 3a). Mean lengths were significantly different among years (ANOVA, $F = 7.03$, $df = 8$, $p < 0.0001$, $r^2 = 0.01$), 2001 samples were significantly larger than 2002 and 2003 samples (Figure 3a). Golden tilefish collected by the commercial sectors reached an average age of 10 ± 0.1 yrs (range = 2-40 yrs; Figure 3b). Mean ages determined from commercial samples were also significantly different among years (ANOVA, $F = 32.79$, $df = 8$, $p < 0.0001$, $r^2 = 0.06$), with fish collected in 2001 significantly older than all other years (Figure 3b).

Golden tilefish ages and total lengths from the entire time series (1997-2009) were fit to a von Bertalanffy growth model to obtain population growth parameters. The model predicted the following parameters: $L_\infty = 830$ mm, $k = 0.13$, $t_o = -2.14$ (Figure 4). The predicted asymptotic size may seem low given the much larger observed fish. This may be explained in part by size-selectivity of the fishery and in part by the constraints of the von Bertalanffy growth model (Haddon 2001).

Sex-specific Age, Length and Growth

Golden tilefish were identified as either female or male through the interpretation of histologically prepared gonad tissue; totaling 341 females (301-780 mm TL, mean 519 ± 4 mm (se); age 3-27, 10 ± 0.2) and 534 males (397-1109 mm TL, 691 ± 6 mm; age 3-33, 10 ± 0.2; Figure 5a and 5b). Size-at-age data was compared between sexes for only those age classes with sufficient sample sizes ($n \geq 5$) (age 4 – 16; Figure 5c). Males grew faster at each age class compared. Additionally, the von Bertalanffy growth model predicted the males to grow faster and obtain a larger asymptotic size (male: $L_\infty = 767$ mm, $k = 0.15$, $t_o = -1.46$; female: $L_\infty = 613$ mm, $k = 0.13$, $t_o = -4.56$; Figure 6).

Reproductive Parameters

Spawning Season

Female tilefish from the Gulf of Mexico exhibited a spawning season extending from January to June in the 2000-2009 samples reflected both by GSI (Figure 7) and histological assessment (Figure 8). Peak development and spawning was observed in April with elevated gonad development observed from March to June. Males results show seasonal synchrony with females but low male GSI values reveal a much lower level of allocation to reproduction (Figure 7). Atlantic studies suggest a somewhat variable but extended season is possible (up to 9 months) but agree that the peak period occurs in spring-to-summer (Palmer et al. 2004 and citations within). Comparing all studies (ours and cited within Palmer et al. 2004), the only month tilefish spawning has not been detected is December. Thus it is feasible that tilefish may spawn year round to some degree.

Size and Age at Maturity and Transition

Histological examination of tilefish ovaries revealed all sexual maturation stages were present. Immature females were rare among samples (n = 4) and ranged in size 301-414 mm TL and age 4-6 (Figure 9a and 9b). Mature females ranged in size from 351 to 780 mm TL and age 3-27 (n = 331, Figure 9a and 9b). This corresponds reasonably well to the size and age range of females noted to be in spawning condition (389-740 mm TL, age 6-26; Figure 9a and 9b). Based on logistic regression, size and age at 50% maturity for females in the Gulf were 344 mm TL and age 2, respectively (Figure 10a and 10b). The fit of the logistic maturity function may be constrained by the lack of small (and young) tilefish and may not have adequate resolution concerning the onset of maturity. Interestingly, the rarity of immature female tilefish was also noted during the S. Atlantic assessment (Palmer et al. 2004). In the Atlantic analysis, four immature female tilefish were measured at a maximum length of 540 mm TL and maximum age of 6.

During SEDAR4 (US south Atlantic), reproductive information was reviewed including histological assessment of gonads. Although there were 15 males with previtellogenic oocytes (no transitional fish or ovotestes) it was concluded tilefish were to be considered gonochorists. However, more evidence exists of possible sex change in golden tilefish from the Gulf of Mexico. While clearly discernable transitional fish were not detected, 68% (n = 330) of males and 11% (n = 39) of females exhibited gonadal tissue of the opposite sex. Considering the quite apparent larger size at age in males (Figure 5c and Figure 6) and the increasing proportion of males with increasing age (up to age 16 given sufficient sample size >= 15, Figure 5b), the question of protogynous hermaphrodism remains open for discussion (Lyon 2010). Assuming protogny occurs, logistic regression determined the size at transition at 564 mm TL (Figure 11a). Since males and females were present in each age class, age at transition was calculated to be less than age 1 (Figure 11b).

Proxy for Annual Fecundity

Based upon histologically sexed tilefish, 331 females were available to estimate average somatic weight at age (Figure 12). These data (extrapolated to spawning stock biomass, SBB) may be selected as the proxy for fecundity similar to the decision in SEDAR 4. However, the average gonad weight of hydrated females at age suggests that reproductive output is non-proportional to somatic weight with older individuals being much more productive (Figure 12). Since spawning females were not detected until age 6 yet 50% maturity at age is predicted at age 2, there may be an overestimate of the reproductive contribution of the youngest mature fish relative to older ages if an SSB approach is used

Mortality Estimates

Natural mortality (M) estimates ranged from 0.15 to 0.10 based on the maximum age observed (age 28-40) in the respective area (Table 6). One fish was determined to be age 40 (caught 2004, grid 4, commercial longline). The next oldest fish (age 39) was caught in 2009 also from a commercial longline intercept (grid 11). Total mortality (Z) estimates were similar regardless of grid fished (0.26 – 0.29; Table 6). Based on empirical calculations of natural and total mortality, fishing mortality was also similar by area fished (0.14 – 0.16; Table 6).

Spatial Patterns

Providing the golden tilefish's preference of malleable but stable sediments to form burrows (Able et al. 1982), the spatial distribution of age samples was investigated. The majority (55%) of golden tilefish intercepted from the commercial longline fishery were reported from NMFS Statistical Grids 7-11, incorporating the area of the De Soto Canyon (Figure 13a).

These grids also represent the majority of scientific survey caught fish (47%, Figure 13b). Depth of collection was also similar between the two sources (Figure 14a).

Golden tilefish collected through intercepts of the commercial longline fishery and reported with a capture location, i.e. NMFS Statistical Grid, varied in length and age by grid (Figure 15a and 15b). Boxplots revealed similar lengths and ages with adjacent grid locations for commercially caught fish (mean lengths of 591-818 mm TL, overall mean size of 653 ± 2 (se) mm TL; mean ages of 7-11, overall mean age 10 ± 0.05; Figure 15a and 15b). Mean lengths were significantly different among grids (ANOVA, $F = 24.5$, $df = 18$, $p < 0.0001$, $r^2 = 0.10$), with commercial longline data collected in grid 2 significantly different from grids 3, 8, 9, 10, 11, 14, 17 and 19 (Figure 15a). Mean ages were also significantly different among grids (ANOVA, $F = 10.35$, $df = 18$, $p < 0.0001$, $r^2 = 0.04$), with fish collected in grid 2 significantly different from grids 3, 9, 11, 15, 16, 17, 20, and 21 (Figure 15b). For those grids with sufficient sample sizes of both commercial longline and scientific longline survey samples, similar age fish were caught (Figure 16b) with some variation in the size of fish caught by each source within the respective grids (Figure 16a).

Length and age data for commercial longline and scientific longline survey overlapped by upper and lower quartiles (Figure 17a and 17b) for each respective depth bin (1: 101-200 m, 2: 201-300 m, 3: 301-400 m). Mean lengths did not increase with depth bin for either source (CM – depth bin 1: 646 ± 8 (se) mm TL, 2: 633 ± 5, 3: 670 ± 5; SS – 1: 603 ± 14, 2: 653 ± 9, 3: 642 ± 14; Figure 14b), but mean ages did increase with depth (CM – depth bin 1: age 8.9 ± 0.2 , 2: 9.9 ± 0.1, 3: 11.2 ± 0.1; SS – 1: 9.0 ± 0.4, 2: 10.4 ± 0.3, 3: 11.0 ± 0.4; Figure 14c).

Conclusions

This report summarizes the available data for golden tilefish from the Gulf of Mexico. Data were used to characterize the demographics of the landed catch and to estimate growth, reproduction and mortality within the population. Since the analysis of the golden tilefish population is primarily relying on the efforts of fishery dependent port agents, it is important that sampling regiment and protocols are maintained and reviewed. In particular, an increase in age-structure sampling in the commercial fishery would be beneficial.

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Table 1. Summary of the number of golden tilefish collected, read, and determined unreadable (1985, 1997-2009).

Year	Otoliths collected	Otoliths read	Otoliths unreadable
1985	43	40	3
1997	43	43	
1998	4	4	
2000	23	22	1
2001	91	91	
2002	146	143	3
2003	316	307	9
2004	559	546	13
2005	649	614	35
2006	289	271	18
2007	431	405	26
2008	795	775	20
2009	1452	1426	26
Total	4841	4687	154

Table 2. Summary of the number of golden tilefish otoliths aged by state landed (FL – west coast Florida, AL – Alabama, MS – Mississippi, LA – Louisiana, TX - Texas).

Year	FL	AL	MS	LA	TX	Total
1985	40					40
1997	43					43
1998	4					4
2000	16		6			22
2001	65	1	2	11	12	91
2002	106			17	20	143
2003	277			19	11	307
2004	520			22	4	546
2005	576		2	36		614
2006	210	22	1	10	28	271
2007	278	4	5	24	94	405
2008	259	43		155	318	775
2009	773	86		142	425	1426
Total	3167	156	16	436	912	4687
Percent	68%	3%	>1%	9%	20%	

Table 3. Summary of the number of golden tilefish otoliths aged by source (TIP - Trip Interview Program, MSLAB -NMFS Pascagoula MS, CO-OP - Cooperative Research Proposals, SBLOP – Shark Bottom Longline Survey, GOP – Galveston Observer Program, ALMR – Alabama Division of Marine Resources).

Year	TIP	MSLAB	CO-OP	SBLOP	GOP	ALMR	Total
1985		40					40
1997	43						43
1998	4						4
2000	16	6					22
2001	44	47					91
2002	98	45					143
2003	307						307
2004	509	37					546
2005	594	20					614
2006	218	31				22	271
2007	309	60		36			405
2008	609	28	70	25		43	775
2009	941	44	270		98	73	1426
Total	3692	358	340	61	98	138	4687
Percent	79%	8%	7%	1%	2%	3%	

Table 4. Summary of the number of golden tilefish otoliths aged by sector (CM – Commercial, SS - Scientific Survey) and gear (LL - longline, HL - handline).

Year	CM LL	CM HL	SS LL	Total
1985			40	40
1997	43			43
1998	4			4
2000	11	5	6	22
2001	44		47	91
2002	74	24	45	143
2003	273	34		307
2004	507	2	37	546
2005	550	44	20	614
2006	237	3	31	271
2007	337	10	58	405
2008	692	55	28	775
2009	1323	59	44	1426
Total	4095	236	356	4687
Percent	87%	5%	8%	

Table 5. Results of pair-wise and overall reader agreements for reference collection (n = 289): average percent error (APE), coefficient of variation (CV), percent agreement (PA), and percent agreement ± 1, 2, and 3 years.

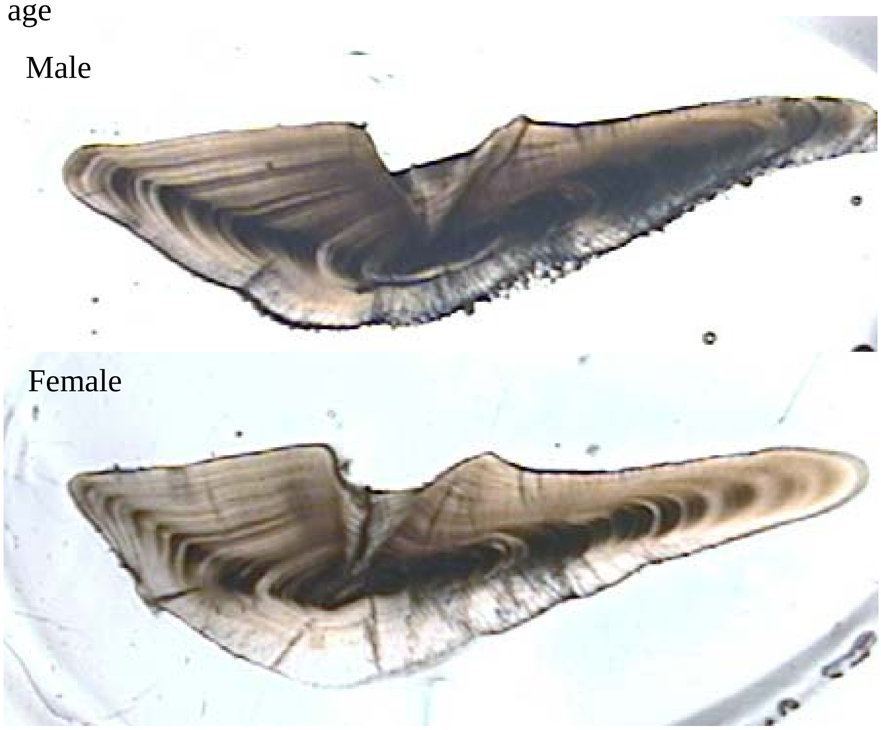
Reader Pair	APE	CV	PA	± 1 yr	± 2 yr	± 3 yr
P. Mikell - K. Kolmos	5.99	8.48	43.6	75.1	57.5	97.2
P. Mikell - D. Berrane	7.21	10.20	32.9	70.6	84.4	94.8
P. Mikell - L. Lombardi	8.95	12.65	20.4	60.9	81.7	90.3
K. Kolmos - D. Berrane	8.23	11.64	30.1	64.0	83.0	92.7
K. Kolmos - L. Lombardi	9.81	13.87	21.1	52.6	77.5	88.6
D. Berrane - L. Lombardi	9.09	12.84	22.2	61.3	79.6	88.6
Overall Agreement	10.58	14.08	5.2	30.4	57.4	77.9

Table 6. Estimates of mortality (natural, fishing, and total) by area (NMFS Statistical Grids) fished and depth bin. Natural mortality (M) was calculated using Hoenig (1983) regression for teleosts based on the maximum aged fish (in parentheses). Total mortality (Z) was calculated using catch curves.

Area Fished	n	M	F	Z
All areas	4647	0.10 (40)	0.17	0.27
East (grids 1 – 11)	2939	0.10 (40)	0.16	0.26
Northeast (grids 6 – 11)	2564	0.11 (39)	0.16	0.27
Southeast (grids 1 – 5)	375	0.10 (40)	0.16	0.26
West (grids 12 – 21)	1390	0.12 (35)	0.16	0.28
Northwest (grids 12 – 19)	627	0.15 (28)	0.14	0.29
Southwest (grids 20 – 21)	763	0.12 (35)	0.16	0.28

Figure 1. Thin sectioned sagittal otoliths from male and female golden tilefish of (a) similar ages 6 yrs and (b) similar lengths 861 mm TL (age 11) and 876 mm TL (age 22), male and female, respectively. All images digitally captured at 15x.

a. age



b. length

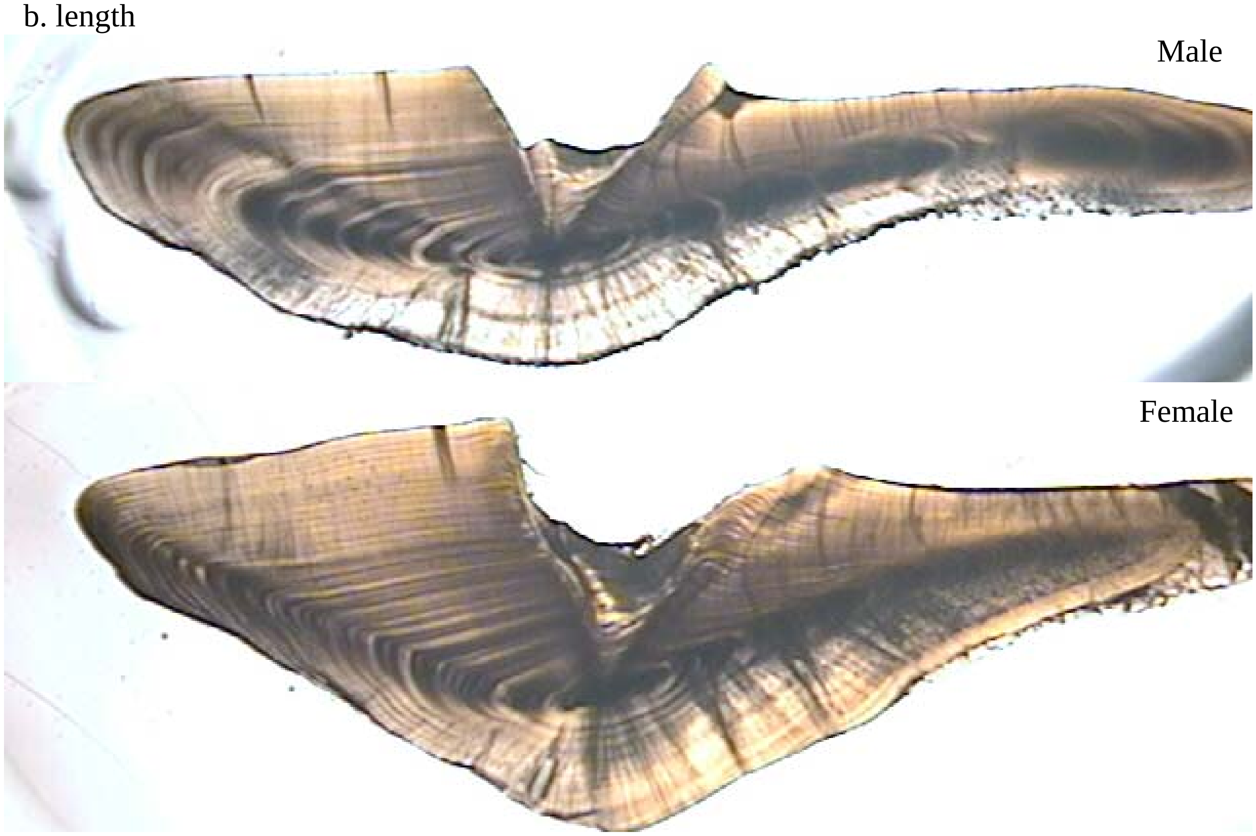


Figure 2. Golden tilefish from the Gulf of Mexico (n = 4647, 1997-2009), description of (a) size, (b) age, and (c) size-at-age (n ≥ 5; mean ± se). Sample sizes above error bars.

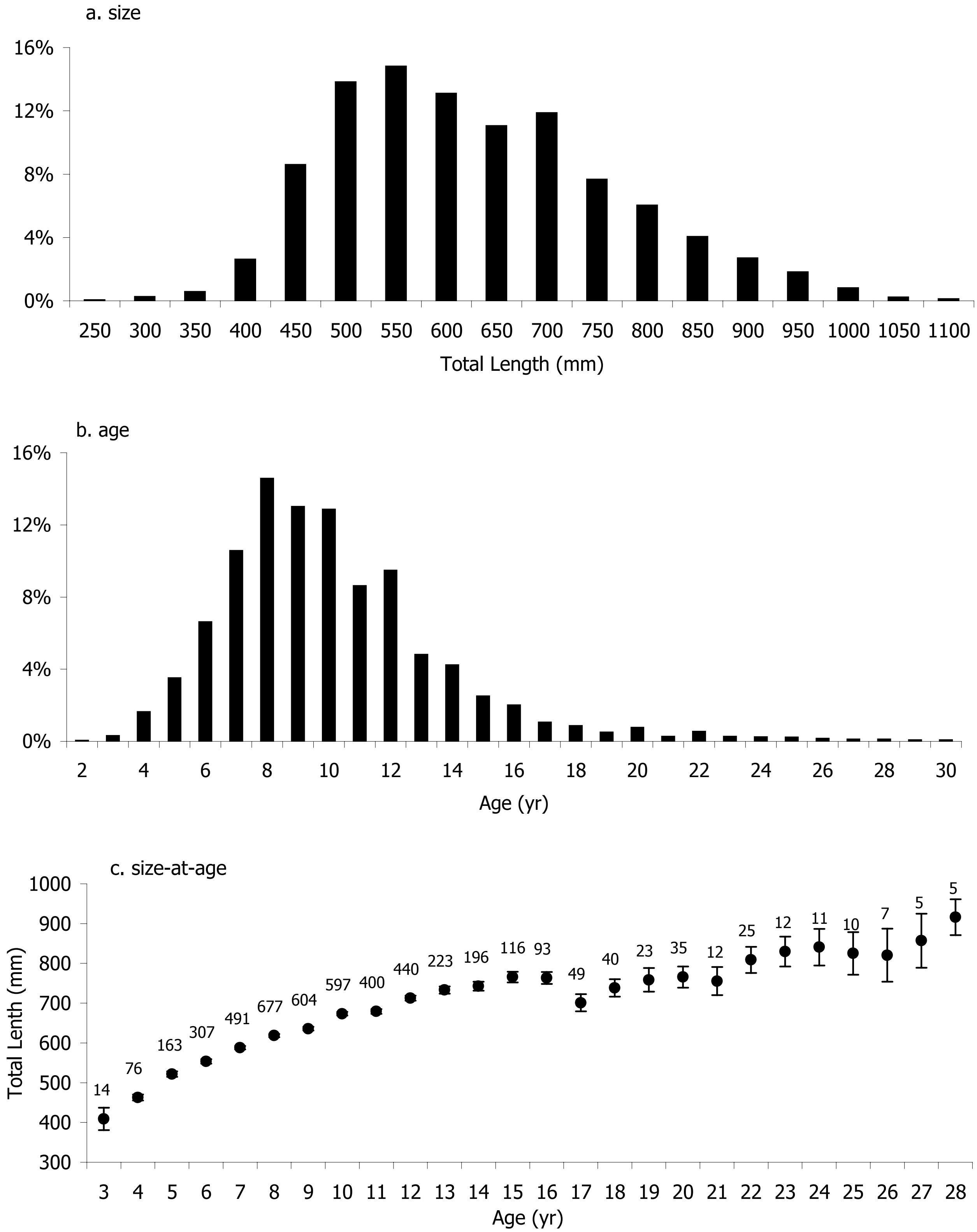
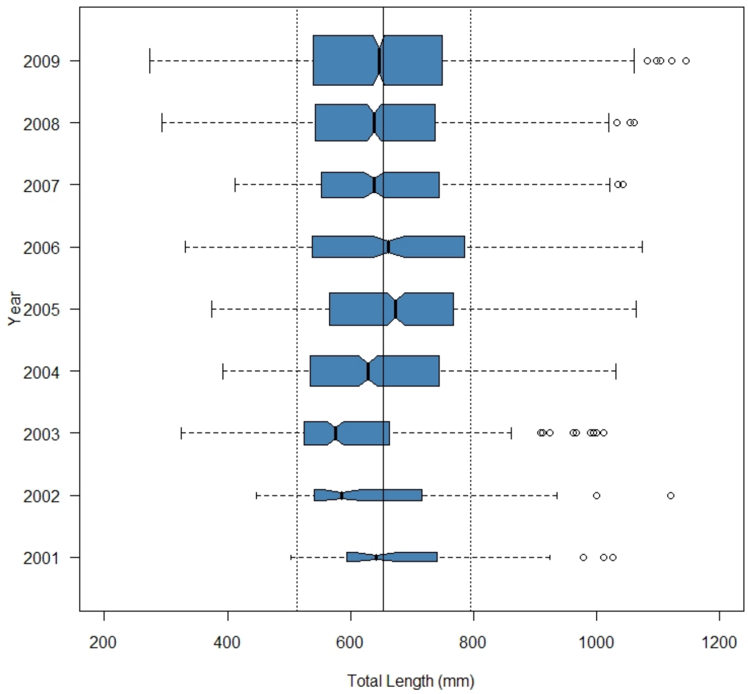


Figure 3. Graphical representation of (a) length and (b) age of golden tilefish caught from commercial longlines by year (2001-2009). Box plots include the median, upper and lower quartiles (boxes: drawn in proportion to the square root of the sample size by year, if notches do not overlap then this indicates significant differences in median values, upper and lower range (dashed line), and outliers (open circles); solid line annual average ± standard deviations (vertical dotted lines).

a. length



b. age

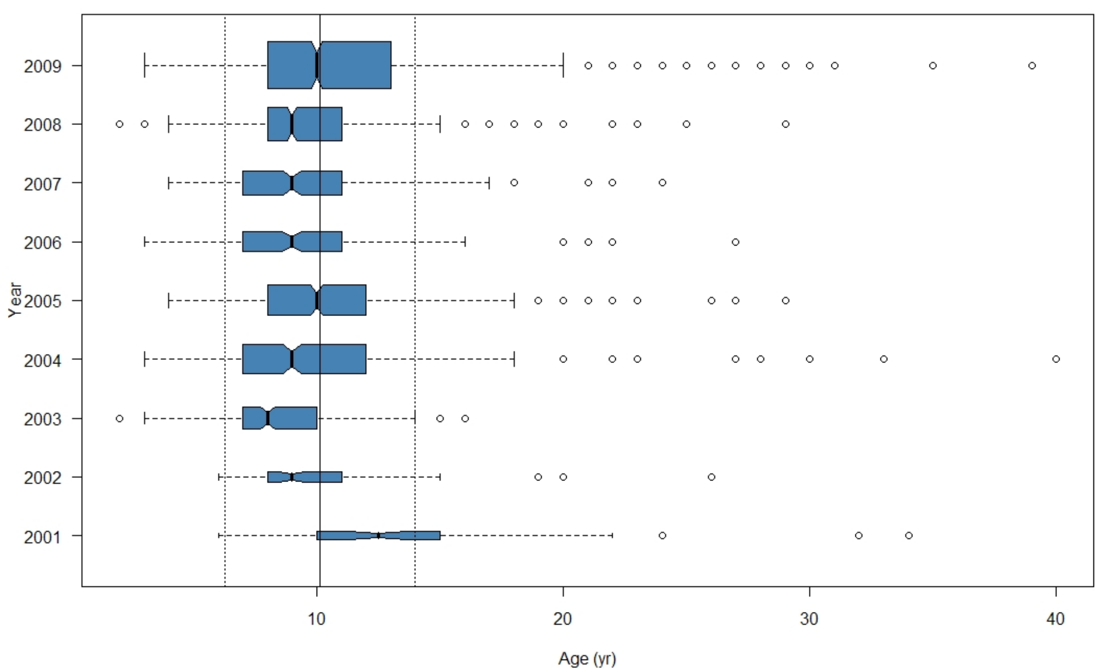


Figure 4. Results of von Bertalanffy growth model for all data combined fit to observed total length and ages for golden tilefish collected 1997-2009 from the Gulf of Mexico.

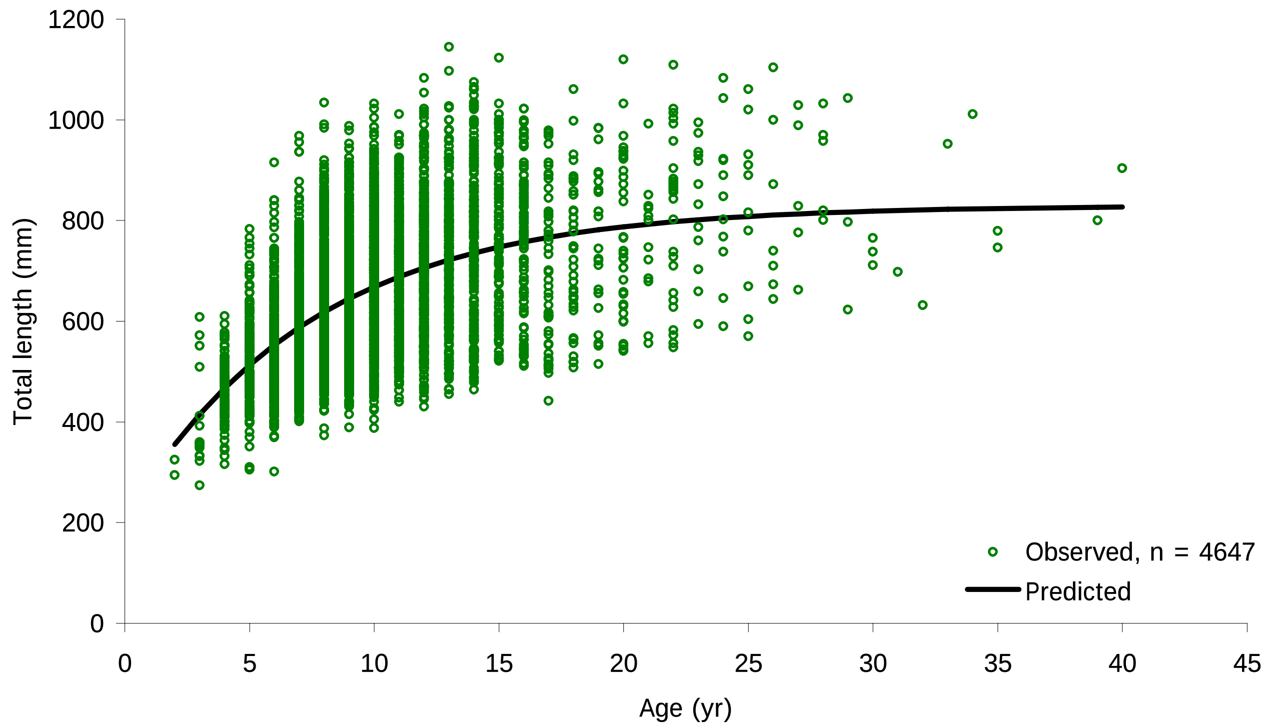


Figure 5. Sex-specific description of (a) size, (b) age, and (c) size-at-age (n ≥ 5; mean ± se) of golden tilefish from the Gulf of Mexico (2000-2009). Sample sizes above and below error bars by sex, respectively.

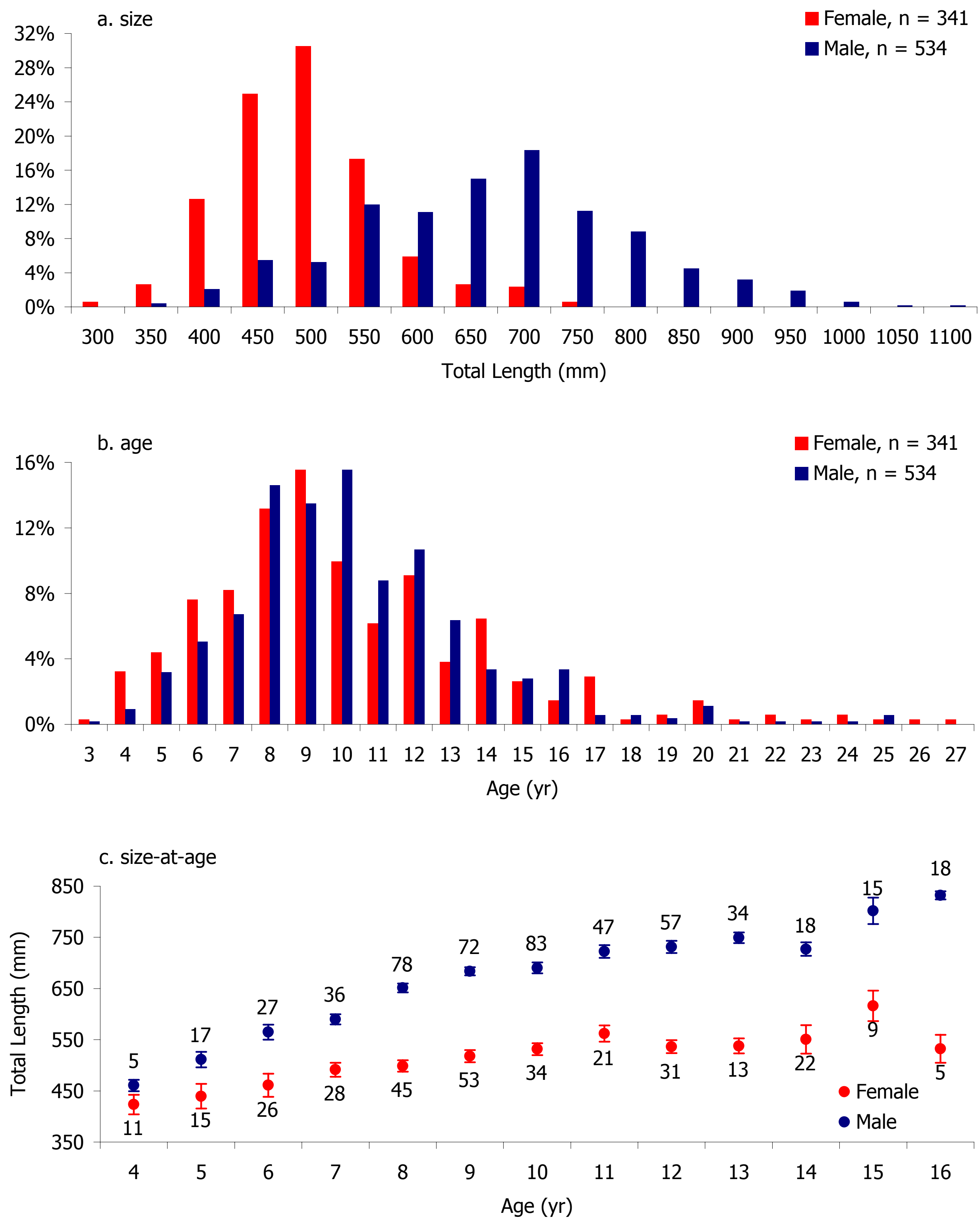


Figure 6. Results of von Bertalanffy growth model for sex-specific data fit to observed total length and ages for golden tilefish collected 2000-2009 from the Gulf of Mexico.

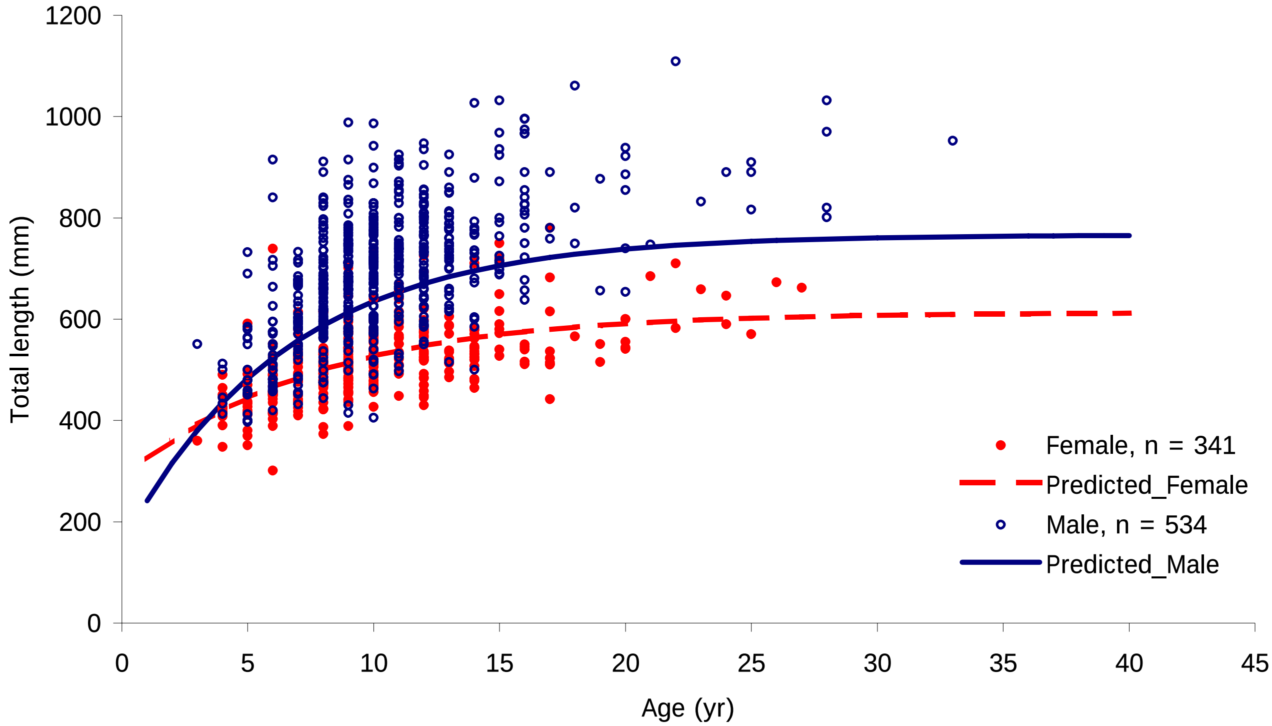


Figure 7. Tilefish monthly Gonadosomatic Index (GSI) mean ± se for males and females.

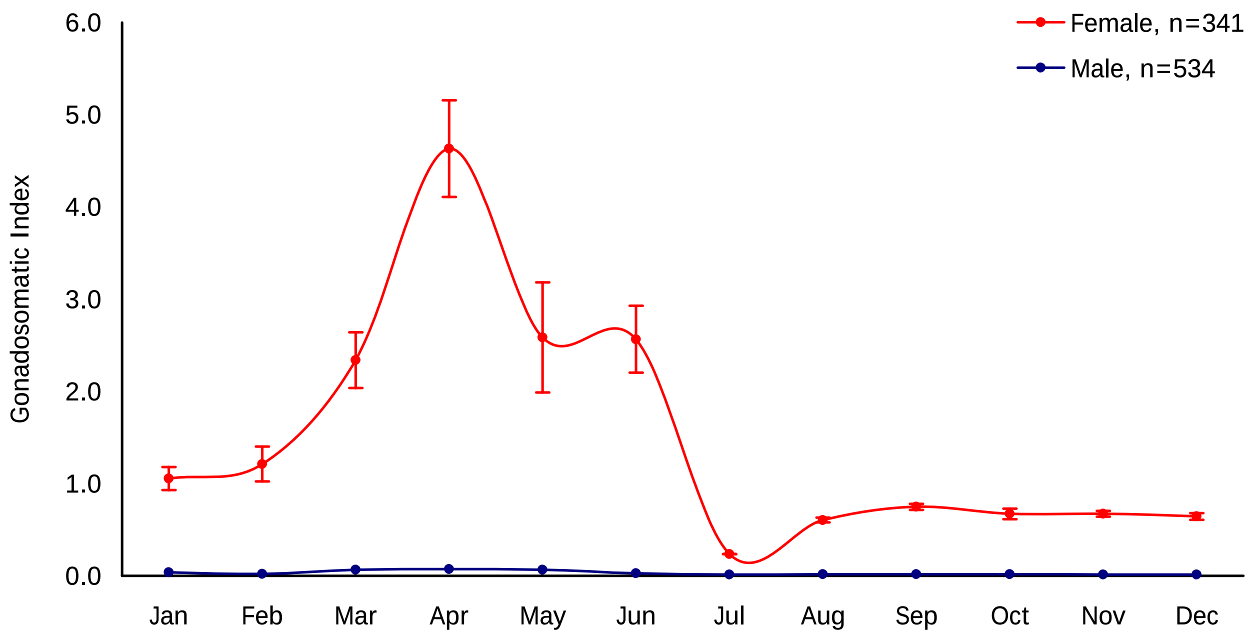


Figure 8. Percent of tilefish females classified as inactive or active/spawning per month. Based on histology, females with vitellogenic or hydrated oocytes were considered active and all other females were considered inactive.

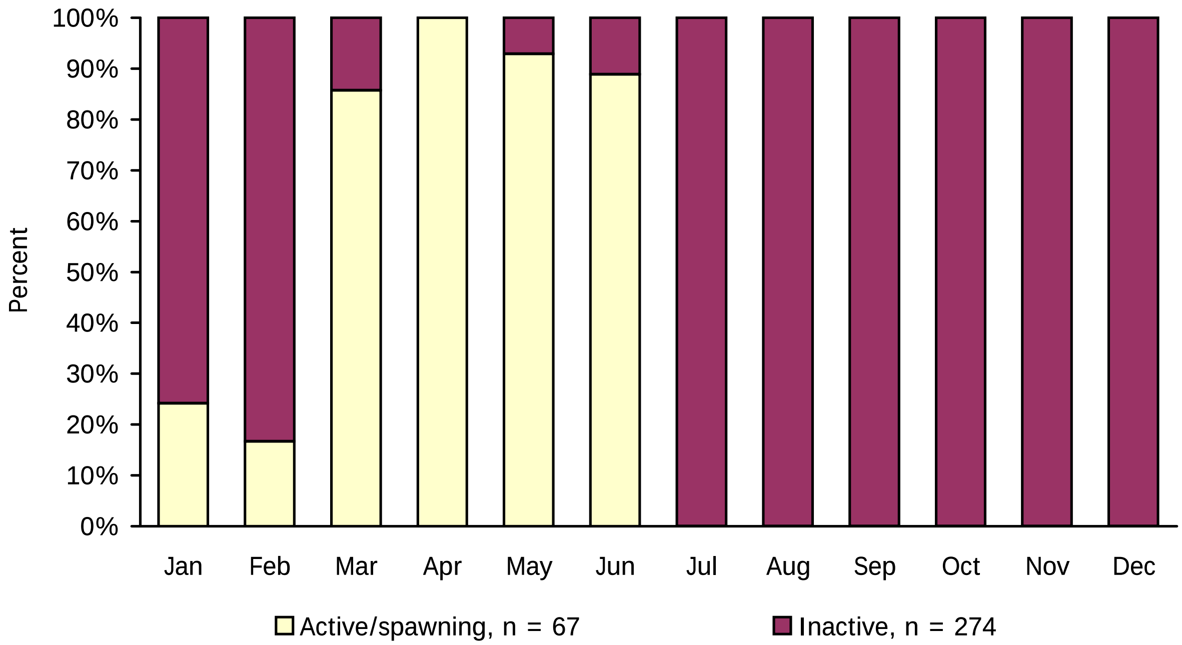
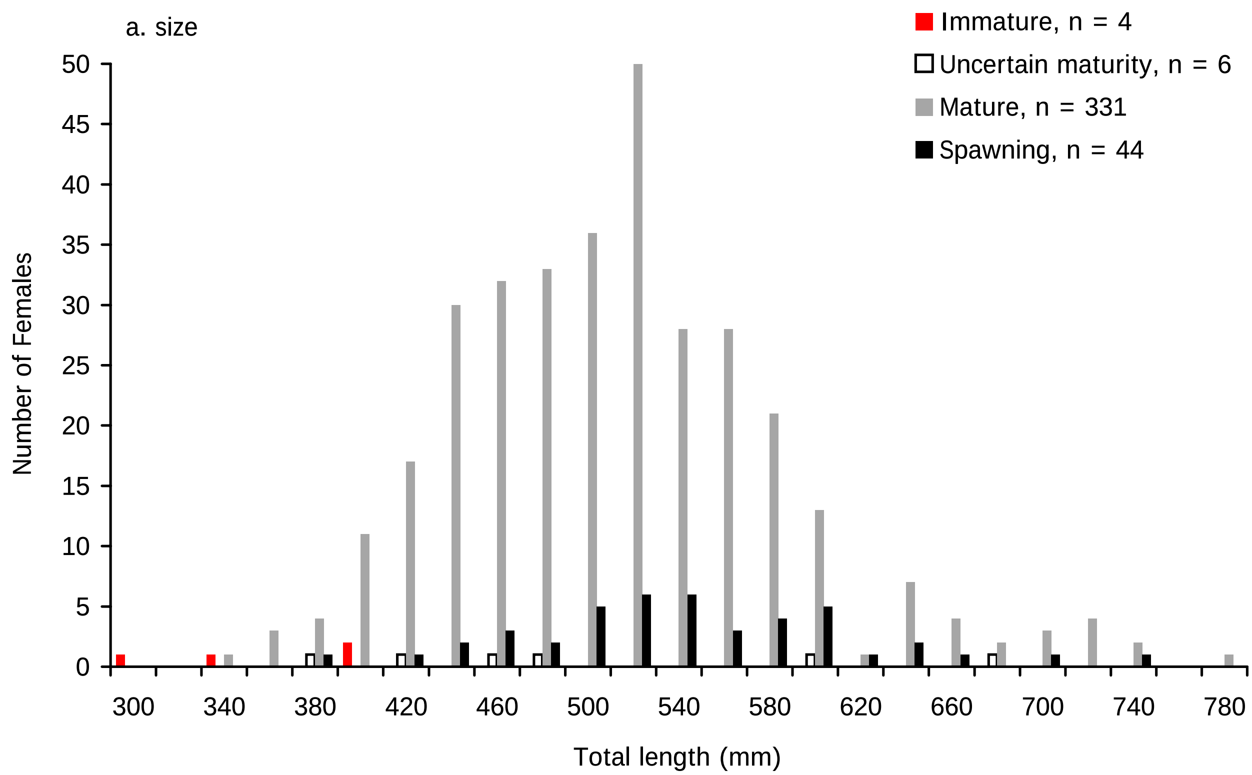


Figure 9. Description by (a) size and (b) age of immature, mature, and mature spawning females. Females with uncertain sexual maturity were excluded from statistical analysis.



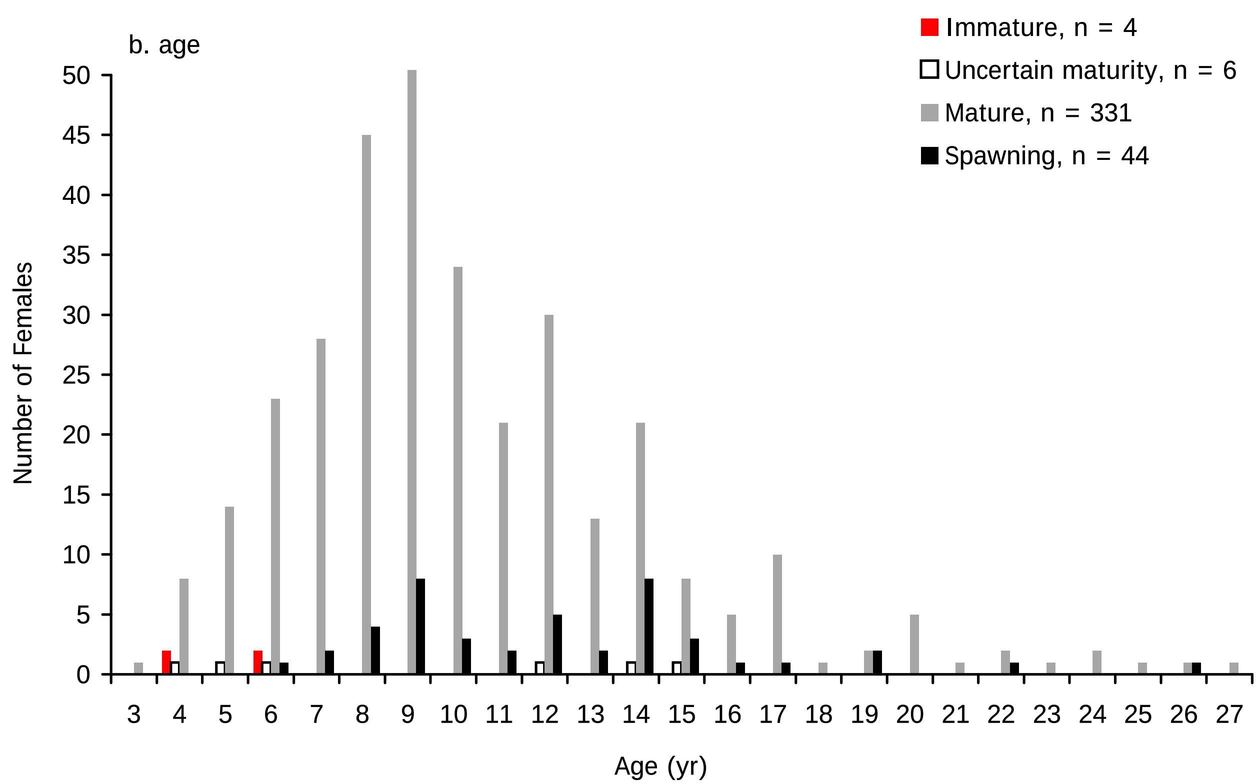
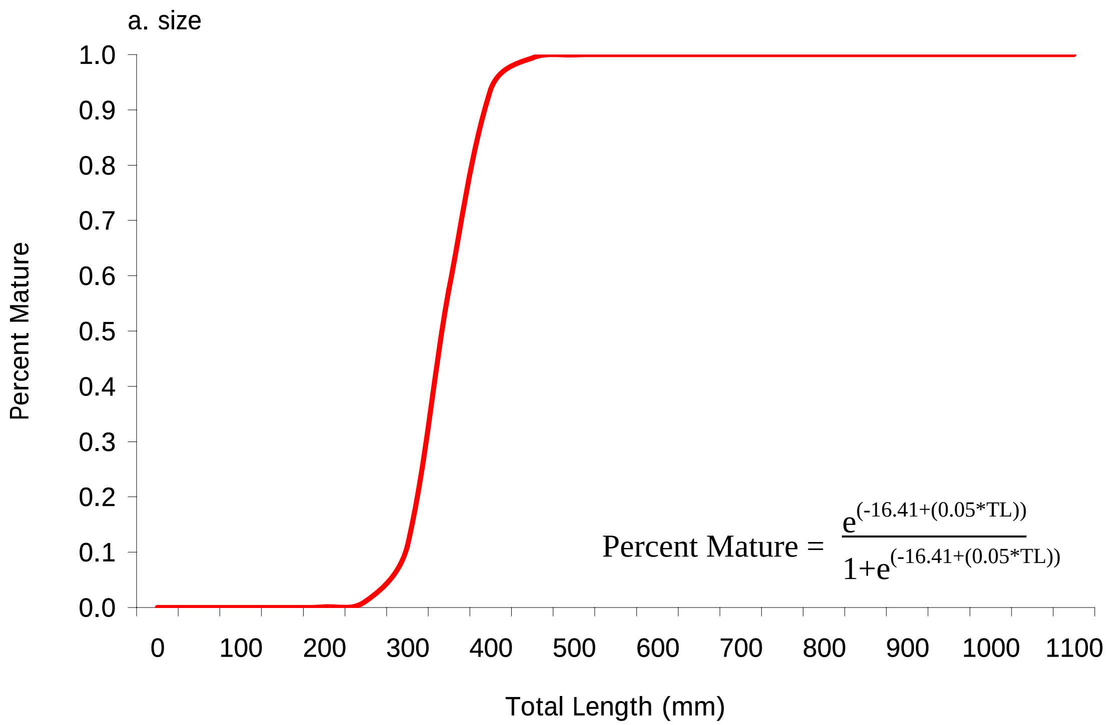


Figure 10. Logistic regressions for (a) size (344 mm) and (b) age (2 yr) at maturity for golden tilefish from the Gulf of Mexico.



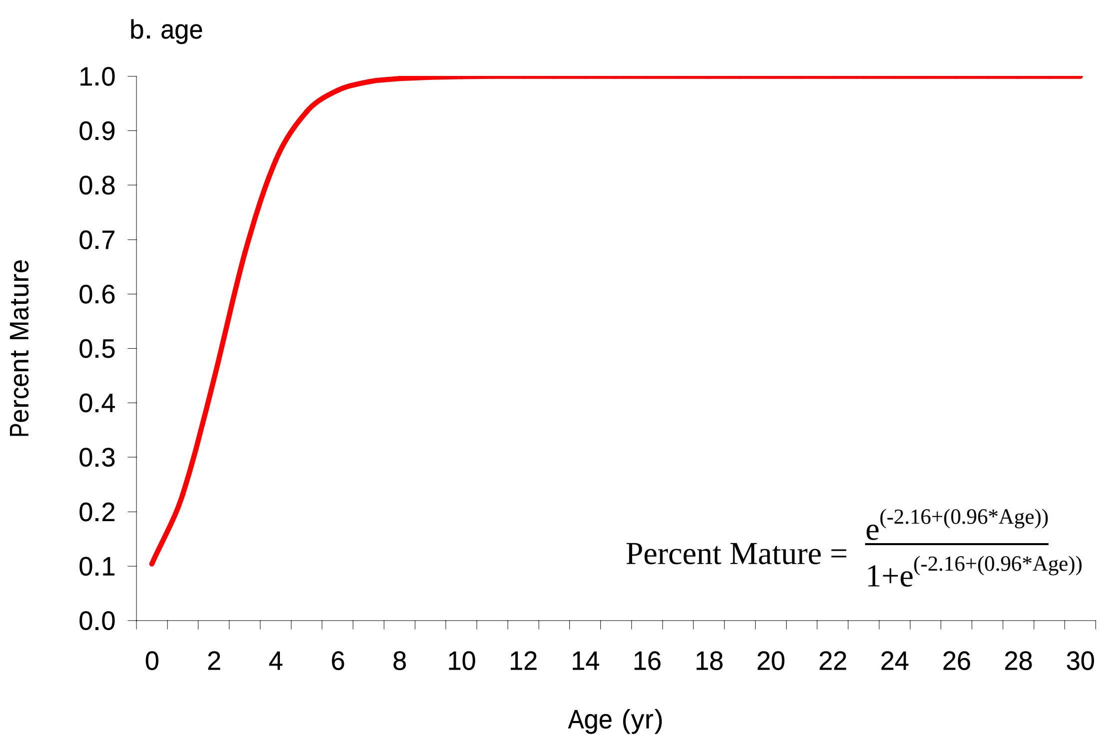


Figure 11. Logistic regressions for (a) size (564 mm) and (b)age (-yr) at transition for golden tilefish from the Gulf of Mexico, assuming protogyny (transition from female to male) occurs .

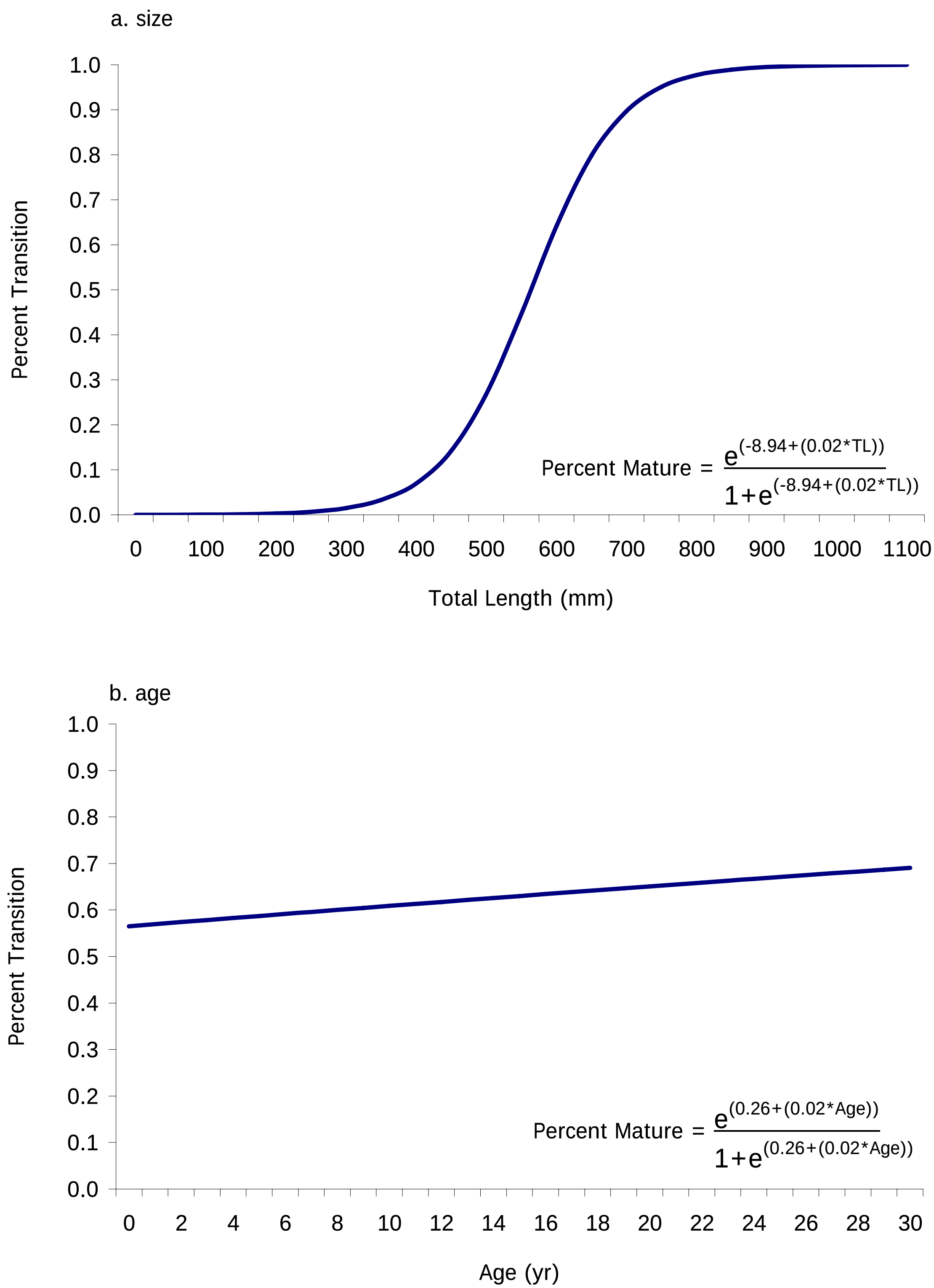


Figure 12. Comparison of mean ± se female somatic weight (total whole weight minus gutted weight, n = 341, primary vertical axis), and mean ovary weights of spawning (hydrated, n= 44) and active (vitellogenic, n= 19) females by age.

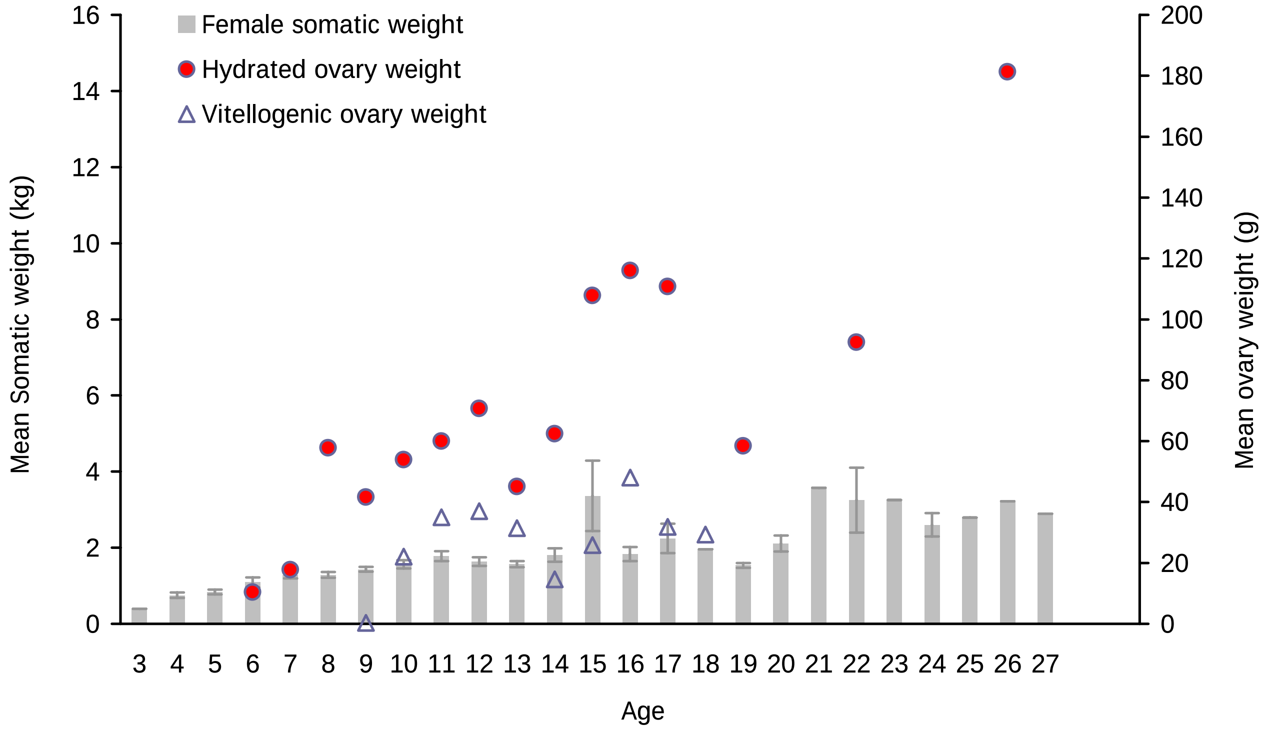
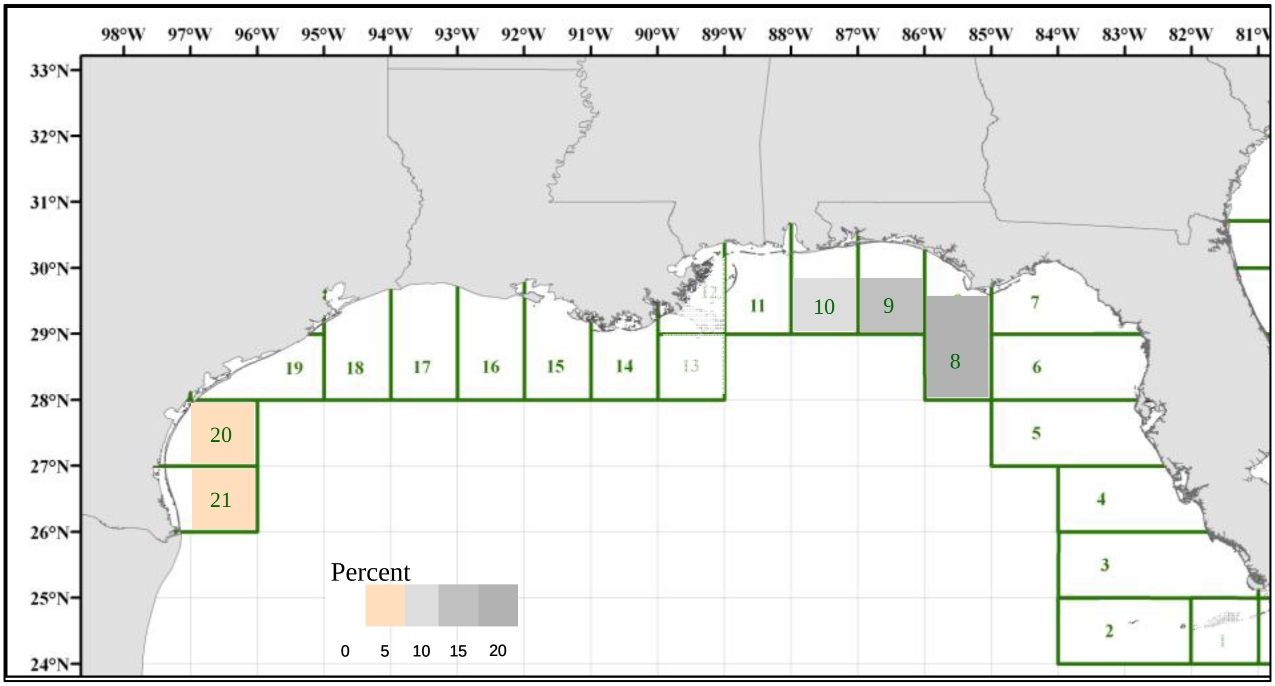


Figure 13. Description of the capture locations of golden tilefish from the Gulf of Mexico as reported through dockside interview for the commercial longline fishery and through reported latitude and longitude of scientific longline surveys: (a) map of the Gulf of Mexico displaying the NMFS Statistical Grids, shaded areas represent the percentage of commercial longline fish caught; (b) frequency of occurrence by source and NMFS Statistical Grid.

a. Gulf of Mexico



b. frequency of occurrence

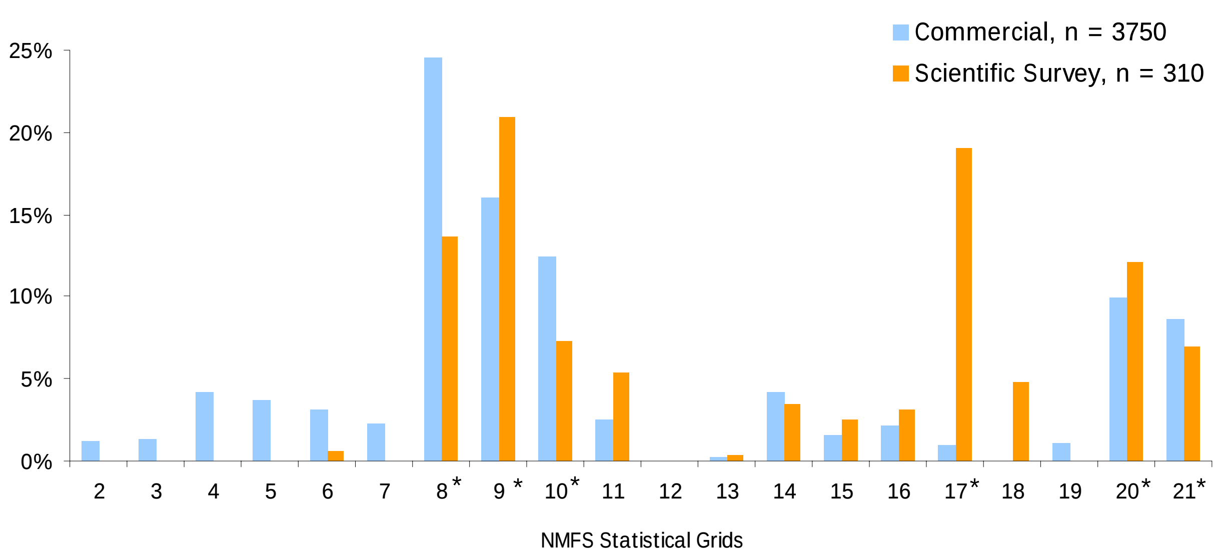


Figure 14. Description of the depths golden tilefish were caught in the Gulf of Mexico by the commercial longline fishery and scientific longline surveys; (a) frequency of occurrence, (b) mean length ± se (c) mean age ± se. * sample sizes per source ≥ 20.

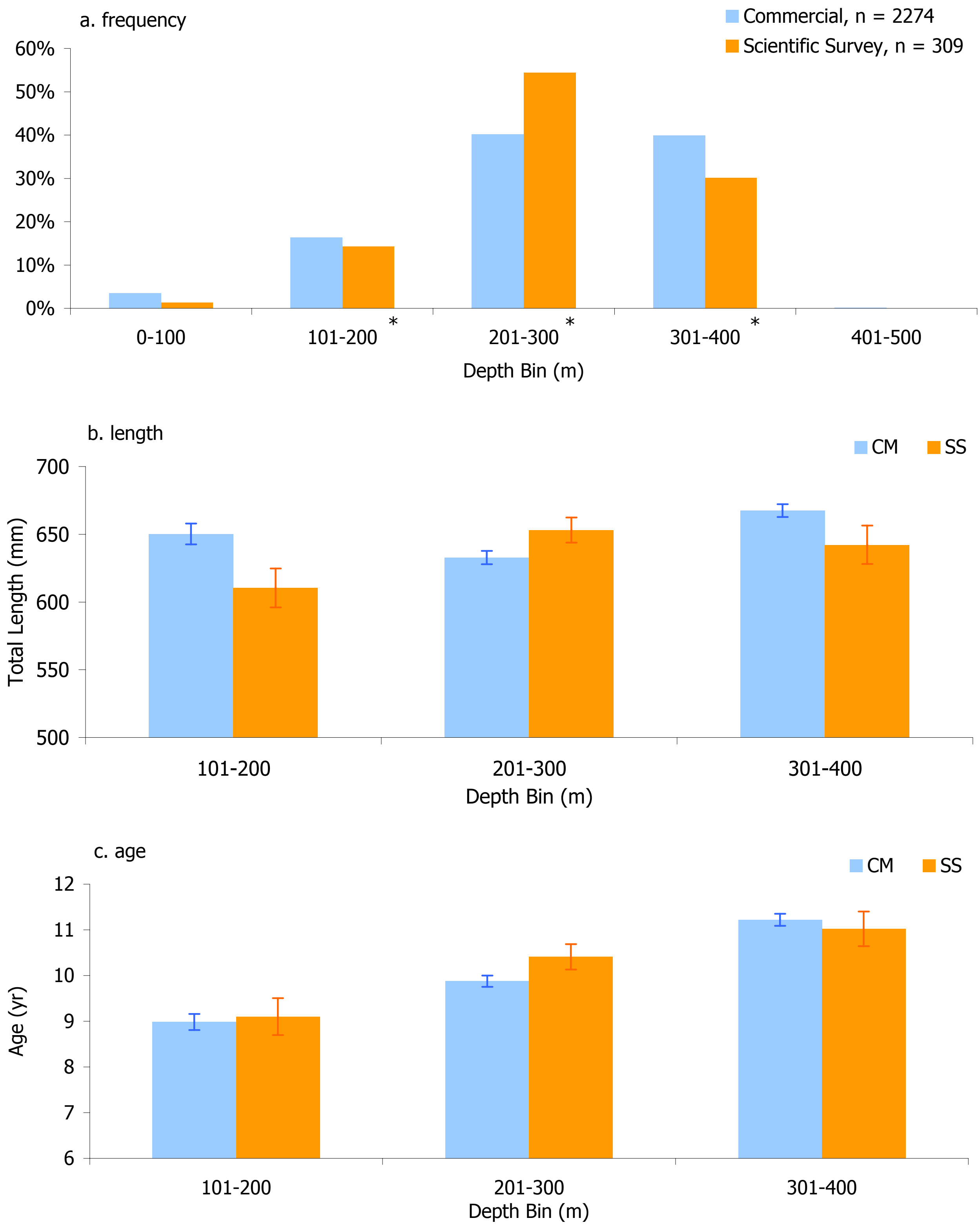
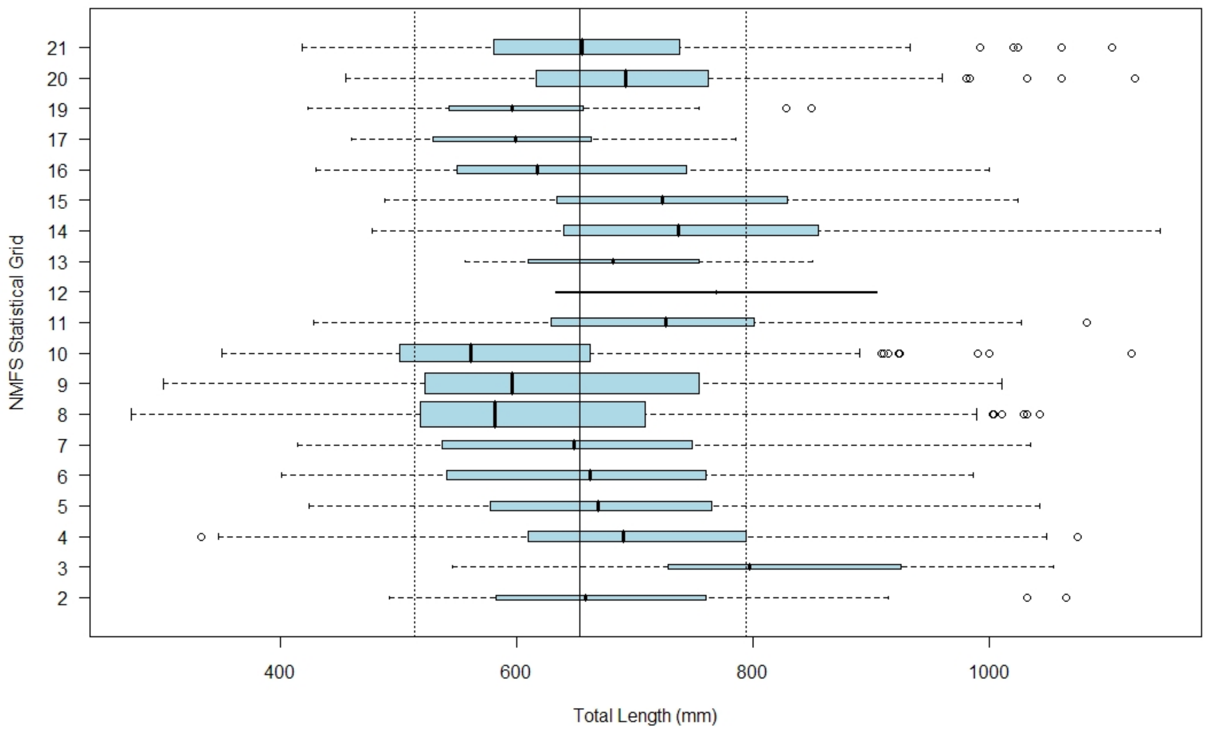


Figure 15. Graphical representation of (a) length and (b) age of golden tilefish caught from commercial longlines within NMFS Statistical Grids. Box plots include the median, upper and lower quartiles (boxes: drawn in proportion to the square root of the sample size by year, if notches do not overlap then this indicates significant differences in median values, upper and lower range (dashed line), and outliers (open circles); solid line overall grid average ± standard deviations (vertical dotted lines).

a. length



b. age

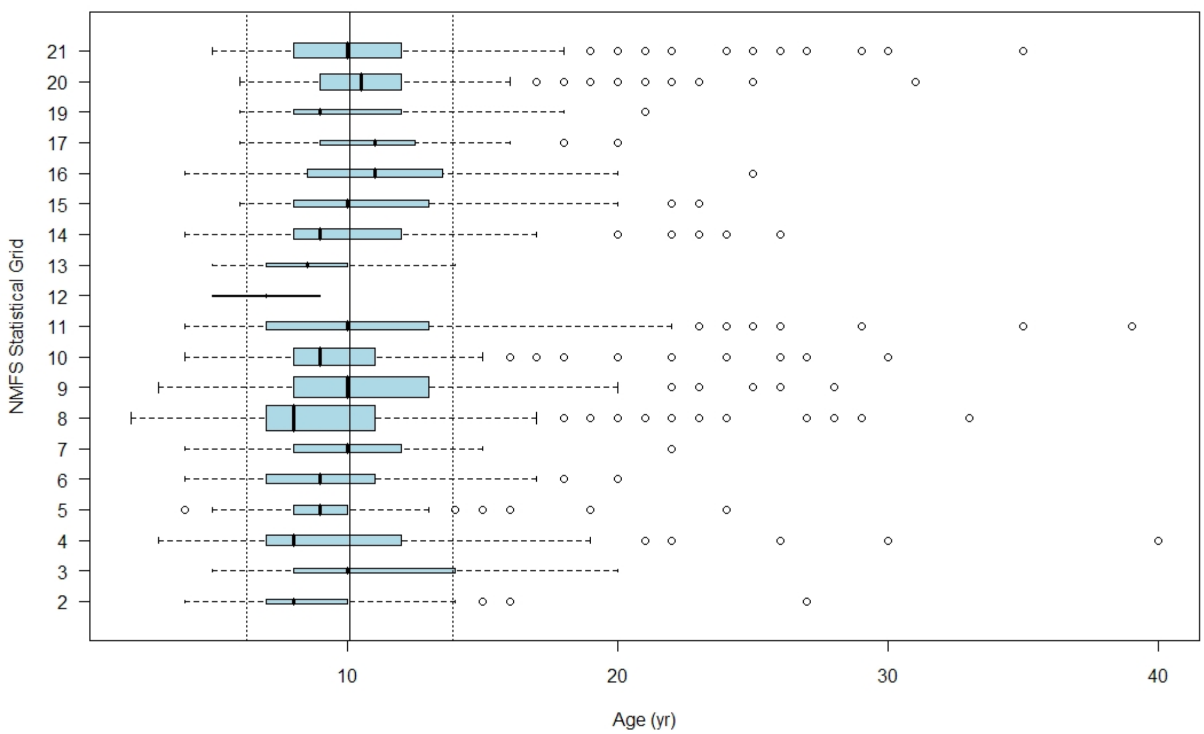
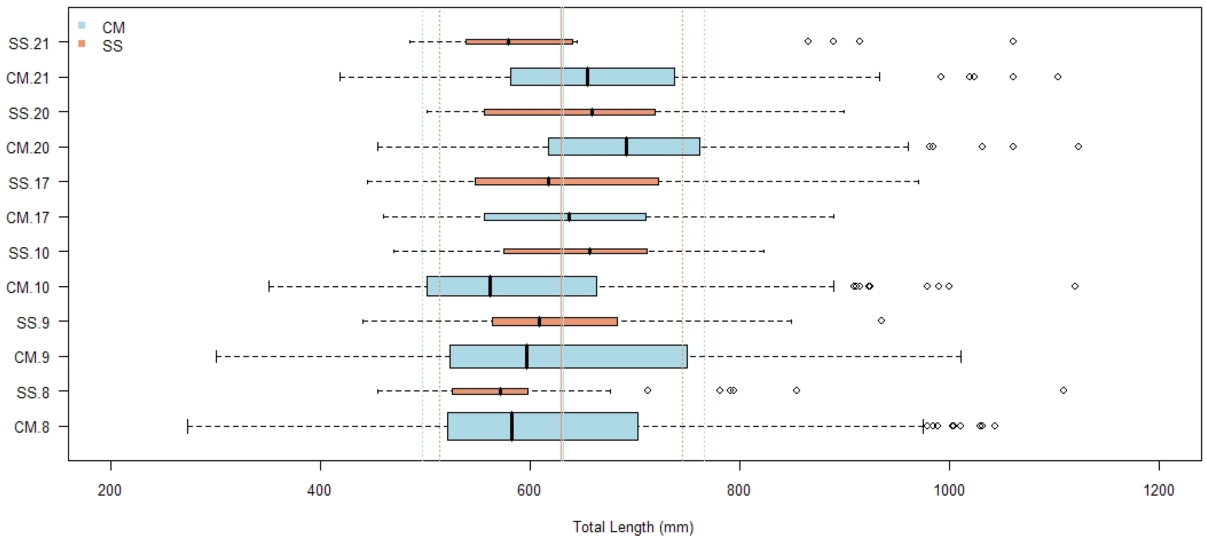


Figure 16. Graphical representation of (a) length and (b) age of golden tilefish caught from commercial longline and scientific longline surveys within NMFS Statistical Grids (sample size ≥ 20). Box plots include the median, upper and lower quartiles (boxes: drawn in proportion to the square root of the sample size by year, if notches do not overlap then this indicates significant differences in median values, upper and lower range (dashed line), and outliers (open circles); solid line grid per source average ± standard deviations (vertical dotted lines).

a. length



b. age

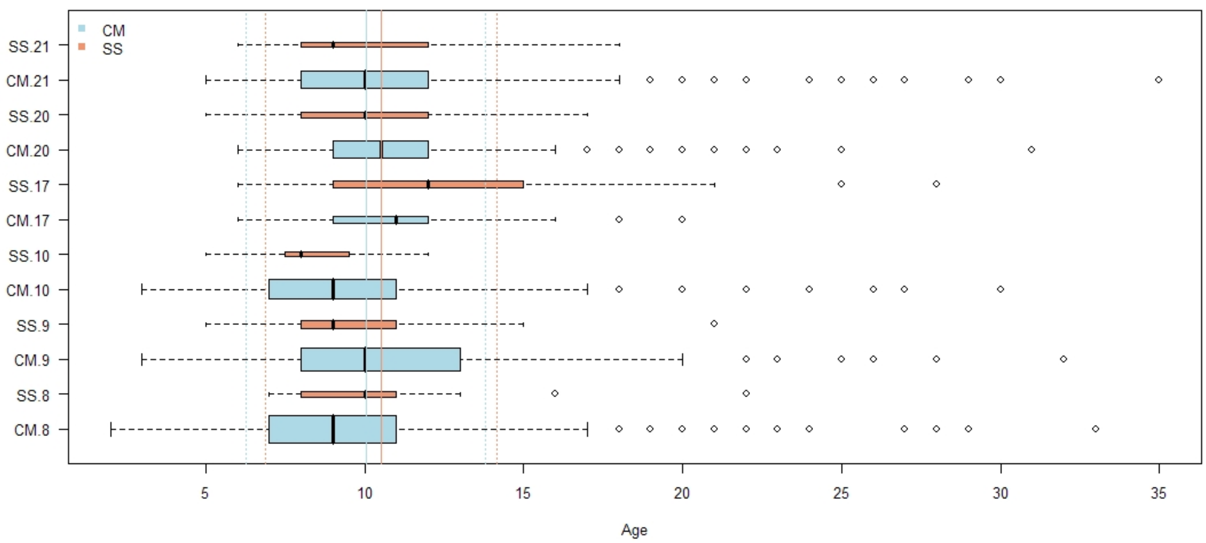
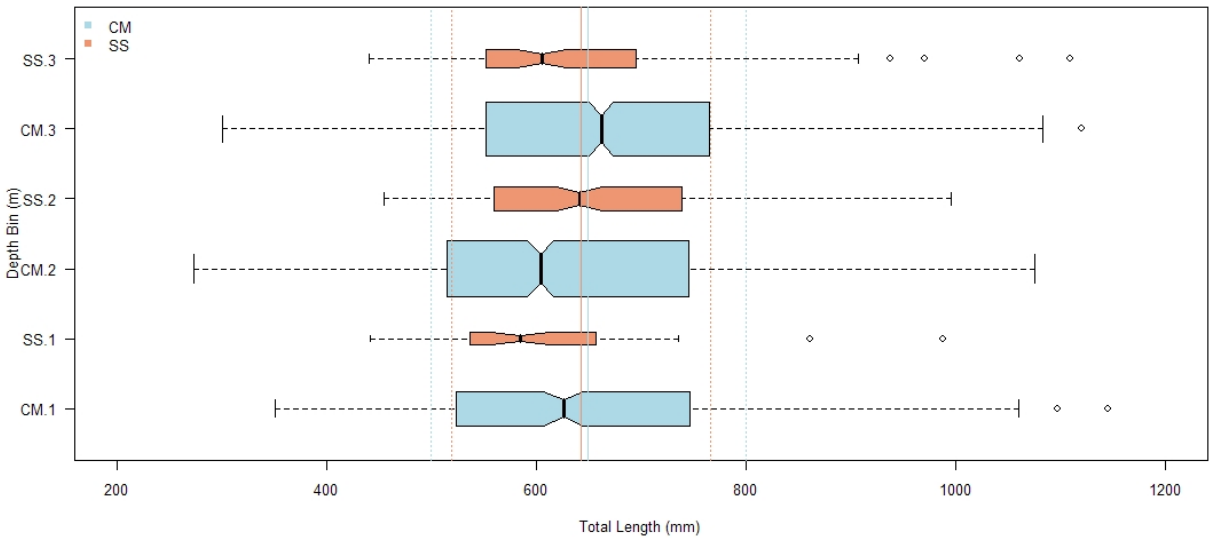


Figure 17. Graphical representation of (a) length and (b) age of golden tilefish caught from commercial longline and scientific longline surveys by depth bin (sample size ≥ 20; 1:101-200 m, 2:201-300 m, 3:301-400 m). Box plots include the median, upper and lower quartiles (boxes: drawn in proportion to the square root of the sample size by year, if notches do not overlap then this indicates significant differences in median values, upper and lower range (dashed line), and outliers (open circles); solid line depth bin per source average ± standard deviations (vertical dotted lines).

a. length



b. age