# Decadal fluctuations in life history parameters of scamp (Mycteroperca phenax) collected by commercial hand-line vessels from the west coast of Florida

Linda A. Lombardi-Carlson, Melissa Cook, Hope Lyon, Beverly Barnett and Lew Bullock

## SEDAR68-RD09

# Decadal fluctuations in life history parameters of scamp (*Mycteroperca phenax*) collected by commercial hand-line vessels from the west coast of Florida

Linda A. Lombardi-Carlson[1], Melissa Cook[2], Hope Lyon[1], Beverly Barnett[1]
and Lew Bullock[3]

[1]National Marine Fisheries Service
3500 Delwood Beach Road
Panama City, Florida, 32408
Phone: (850) 234-6541 ext. 213

[2] National Marine Fisheries Service
P.O. Drawer 1207
Pascagoula, MS 39568

[3] Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute
100 Eighth Avenue SE
St. Petersburg, Florida 33701

Panama City Laboratory
Library Contribution 11 – 12

## Abstract

Scamp (*Mycteroperca phenax*) were collected from commercial vessels along the west coast of Florida during three decades (1970s, 1990s, and 2000s), allowing for comparisons of life history parameters over time. Differences were found for age and length structure for scamp within these time periods. Fish collected in the 1970s were larger with 48% of the length distribution > 550 mm, compared to only 31% in 1980s and 39% in 2000s. Age interpretations were completed by counting opaque growth increments on thin sectioned otoliths. Scamp were determined to be between age 2 and 24 yrs, 53% of the fish were older than 10 yrs in the 1970s, and 36% and 28% in the 1990s and 2000s, respectively. Comparisons of observed size-at-age data revealed similar growth in scamp collected in the 1970s and 2000s, scamp collected in the 1990s grew slightly faster (age 5 - 10 yr). Gonad tissues were histologically prepared and interpreted for stages of maturity. Data analysis revealed similar size at 50% maturity but younger age at maturity over time for females. Spawning seasons occurred during similar months (March – May) however the 1990s reproductive season was prolonged (five months versus three months). Detecting real differences in life history parameters over several decades can be difficult given changes in fishery management, spatial and temporal changes in habitat, and the size-selective fishing pressures.

## Introduction

The scamp, *Mycteroperca phenax*, is a member of the Family Serranidae, distributed throughout the United States coasts of the Atlantic and the Gulf of Mexico and throughout Mexico (Hoese and Moore 1977). Scamp inhabits ledges or high-relief rocky bottoms in depths of 12 – 73 m along the west Florida shelf (Smith 1976, FMRI 1991). However, there is a limited amount of literature regarding the life history characteristics of scamp throughout its spatial range. The only extensive life history research (age, growth, and reproduction) on scamp has been conducted in the South Atlantic. Scamp were collected (1972-1997) from commercial and recreational vessels, and scientific surveys from the coastal waters of North Carolina, South Carolina and the east coast of Florida (Matheson et al. 1986, Harris et al. 2002). The specific life history characteristics for scamp distributed in the Gulf of Mexico is fairly unknown, with only a minor description of scamp's reproductive behavior and seasonality described (FMRI 1991, Coleman et al. 1996).

Scamp constitutes a small component (< 3%, commercial landings) of the Gulf of Mexico shallow-water grouper commercial landings and is primarily harvested by hand-line gear (e.g. bandit reel, hook and line) (pers. comm., NOAA/Fisheries Statistics Division). This species of grouper is not caught as frequently as the other commercial important grouper species, but normally brings higher dockside prices (FMRI 1991).

The commercial fishery for groupers began in the early 1800s, targeting primarily red grouper, *Epinephelus morio*, with bycatch of numerous species of *Mycteroperca* spp. and *Epinephelus* spp. (Tashiro and Coleman 1977). In 1984, the Gulf of Mexico Fishery Management Council (GMFMC 1981) implemented the first provisions of the Reef Fish Management Unit which included fifteen Lutjanids and eighteen Family Serranids (including scamp). With the increase in reef fish landings throughout the Gulf of Mexico in the late 1980s, the Gulf of Mexico Fishery Management Council established commercial quotas for groupers (Family Serranidae; GMFMC 1989). Also, in 1990, the state of Florida issued a size limit (20 inches total length, 508 mm) for scamp caught within state waters (< 9 nm) (FFWCC 1990). Scamp caught in federal waters (> 9 nm) were not managed under a size limit (16 inches total length, 406 mm) until 1999 (GMFMC 1999).

Given the historical amount of fishing pressure on other members (red grouper and gag grouper, *Mycteroperca microlepis*) of the Family Serranidae and in particular those managed as shallow-water groupers (GMFMC 1989), it is important to investigate the basic life history of these species. It is also pertinent to document any changes in life history traits (such as age and size at maturity, growth rates, etc.) that may have occurred over decades of fishing exploitation (Trippel 1995, McGovern et al. 1998). Scamp is a protogynous hermaphrodite, and like other commercially exploited hermaphrodites, is more vulnerable to overfishing (Armsworth 2001). Currently, scamp are not undergoing overfishing nor overfished in the South Atlantic, however, the status for this species is unknown and has not been assessed in the Gulf of Mexico (NOAA 2008a).

This report's objective is to examine life history characteristics for scamp collected from the west Florida shelf over a period of thirty years. Age, length, growth, size-at-age, mortality, size and age at maturity and transition will be calculated and compared among the decades. We predict scamp collected in the most recent decade from the commercial hand-line industry will be smaller and younger, have a faster growth rate, and smaller size and age at maturity given the impact of commercial and recreational fishing.

## Material and Methods

### *Data Collection*

Scamp otoliths and gonads were collected through the interception of commercial hand-line catches along the west Florida shelf (1977-2002, Figure 1). Measurements of fish lengths (fork or total length, to 1.0 mm), weights (whole or gutted, to 0.1 kg), and removal of otoliths and gonads were completed in the field. Information describing catch location (latitude, longitude, depth, or NMFS statistical shrimp grid) was reported with the otolith samples during routine intercepts of commercial vessels and/or fish houses.

### *Interpretation of Growth Increments*

Growth increments were counted from thin transverse sections of the sagittal otolith. Interpretation of scamp whole sagittal otoliths, the method used for other Serranidae species (Johnson et al. 1993, Johnson and Collins 1994, Fitzhugh et al. 2003, Lombardi-Carlson et al. 2008), was not practical given the scamp's small otolith size (otolith weights (g): 0.016 – 0.516). Growth increments have been validated to be annual through marginal increment analysis of scamp collected in the South Atlantic (Matheson et al. 1986, Harris et al. 2002).

Annual increments were consistently interpreted from the ventral axis (Figure 2) using a stereo microscope (magnification 35 – 70) and reflective fiberoptic light. Otolith readers recorded the number of complete annuli along with the edge type (level of translucency-partial or complete or opaque). Annual age assignment was completed using the date of capture, annuli count, and edge type. The timing of annuli completion for scamp was determined to be July. If the capture date was prior to July 1st and the edge type was classified as complete translucent, then one year was added to the reader count to calculate the annual age else the number of complete annuli equaled the annual age.

### *Reader Agreement-Age*

Two readers interpreted scamp otoliths. The primary reader read all otoliths and the secondary reader completed a 20% overlap of the primary reader's otolith reads. Indices of reader agreement (APE - Average Percent Error, CV - Coefficient of Variation, and percent of readings in agreement ± 1 and 2 bands) were calculated following the procedures as described in Campana 2001.

### *Age and Growth*

Age and growth data were compared statistically among the decades. Differences in age and length distributions between pairs of decades were investigated using a Kolmogorov-Smirnov test for similarities in distributions (Zar 1999). Decadal differences in the size and age data of scamp were examined using single-factor, random-effects analysis of variance. If the null hypothesis is rejected ($P < 0.05$), a Tukey test for multiple comparisons was completed to determined differences between pairs of decades (Zar 1999). In addition, decadal observed mean size-at-age data between pairs of decades were compared using an unpaired Student's t-test with unequal variances. Comparisons were restricted to age classes with sample sizes $\geq 5$. Decadal changes in growth rates were compared using observed fork lengths and annual ages. Due to the lack of small, young scamp all growth models were fixed with age at time- zero ($t_0$) as zero. Predicted asymptotic length ($L_\infty$) and growth coefficients (k) were calculated through the von Bertalanffy growth equation and parameters were compared for each pair of decades using maximum likelihood methodology (Haddon 2001).

### *Mortality Estimates*

Maximum longevity for each decade was used to calculate natural mortality (M) (Hoenig 1983). Hoenig (1983) regression model for teleosts is the recommended model over the rule-of-thumb approach (Hewitt and Hoenig 2005). Catch curves were constructed from age classes vulnerable to fishing for each decade to estimate instantaneous total mortalities (Z) by decade. Estimates of natural and total mortality were compared among the decades.

### *Reproduction*

### *Gonad Processing*

Scamp gonads were weighed to the nearest 0.1 g and fixed in 10% neutral buffered formalin for a minimum of two weeks. Preserved gonads were randomly subsampled along the anterior-posterior axes of the gonad and a small subsample (1 $cm^3$) was removed and placed in a cassette for histological processing. Histological processing of scamp gonads collected during 1977-1980 occurred at the Florida Fish and Wildlife Conservation Commission, and all other samples were prepared by the Louisiana State University School of Veterinary Medicine, Histopathology Laboratory in Baton Rouge, LA. Tissues were embedded in paraffin, sectioned to a thickness of 4-6 µm, mounted on glass slides and stained with hematoxylin-1 and eosin-Y following standard histological procedures.

### *Assigning Maturation Stages*

Histological slides were viewed using a compound microscope at 40 to 400x magnification to determine reproductive class. Gonads were staged using oocyte developmental characteristics (Wallace and Selman 1981, Hunter and Macewicz 1985, Tyler and Sumpter 1996) and assigned to histological classes (Table 1) based on leading gamete stage, indicators of prior spawning and short-term atresia (NOAA 2008b). Specimens with developing, active, spawning or resting gonads were considered sexually mature. Females that possessed only cortical alveoli oocytes were considered mature only if indicators of prior spawning were present (Rideout et al. 2000, Rhodes and Sadovy 2002). Evidence of prior spawning is described by given the number of brown bodies, presence of old hydrated oocytes, stage of atresia, the condition of the muscle bundles, presence of connective tissue, and appearance of lamellae in the gonad tissue (NOAA 2008b). Gonads were considered undergoing sexual transition if at least three male gamete stages (primary spermatocyte to spermatozoa) were observed proliferating throughout the gonad and oocytes were remnant and possibly undergoing atresia (Sadovy and Shapiro 1987).

### *Reader Agreement-Histology*

Two readers interpreted histological slides. The primary reader read all histological slides and the secondary reader completed a 20% overlap of the primary reader's slide readings. Cohen's kappa (Cohen 1960) was used to examine the agreement between the two slide readers (Gerritsen and McGrath 2006). The kappa statistic ranges from -1 to 1, where K = -1 indicates complete disagreement and K = 1 indicates complete agreement.

### *Estimates of Maturity and Sexual Transition*

Size and age at maturity were determined using a logistic regression model:

$$Y_i = 1/(1+ e(-x_i - a)/b),$$

where $Y_i$ = the proportion mature at length or age $x_i$, a is the size or age at maturity, and b is the steepness of the logistic regression. The model provides an estimate of size and age at which 50% of the population is mature. Parameters (a and b) were estimated by maximizing the negative log-likelihood (nLL) for binomial distributions:

$$nLL\ (Y_i|B_i) = \Sigma\,(B_i * Ln(Y_i) + (1 - Y_i) * Ln(1 - Y_i))$$

where $B_i$ is the binomial data (0, 1) at $x_i$ and an Akaike's Information Criterion (AIC) model comparison (using SOLVER in Microsoft EXCEL):

$$AIC = -2 * nLL + 2 * k$$

where k = the number of parameters that varied in the model and δAIC:

$$\delta AIC = AIC - \text{minimum (range of all model AIC values)}$$ were estimated.

The use of AIC and δAIC model selection provides an objective model comparison that estimates the most optimal values of a (length or age at maturity) and b (the steepness of the logistic regression) to test whether or not logistic regressions differed among decades. The above procedure was also used to test for similarities among the decades in size and age at sexual transition, fit to binomial sex data (female = 0, male = 1).

### *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). Monthly mean GSI values were calculated to estimate seasonal reproductive patterns per decade.

### *Fecundity*

Direct measures of fecundity such as batch fecundity could not be calculated due to the small sample size of hydrated females per decade. Therefore, the relationships between gonad weight and fork length, gonad weight and whole weight and whole weight and age were fit using non-linear regression models and used as a proxy for fecundity. Only females with vitellogenic or hydrated oocytes collected during the peak spawning months of March, April and May were included in the analysis. An analysis of co-variance (ANCOVA) was performed to test significant differences in regressions as proxies for fecundity among decades. If significant differences are determined among decades, pair-wise (between decades) ANCOVA will be completed.

## **Results**

### *Data Collection*

Data was grouped into three decades (1970s: 1977-1981, 1990s: 1991-1993, 2000s: 2000-2001). These years were chosen based on two criteria: adequate sampling with similar sample sizes per decade (Table 2) and the establishment of fishery management regulations (1970s: no regulations prior 1990; 1990s: state size limit and commercial annual quota; 2000s: commercial size limit). Only those scamp landed by commercial hand-line vessels and intercepted from ports along the Panhandle south to Tampa were used for further analysis (Figure 1).

### *Interpretation of Otoliths and Reader Agreement*

A total of 1,282 otoliths were sectioned (1970s, n = 509; 1990s, n = 316; 2000s, n = 457). Interpretations of growth increments were difficult and not all otolith sections were readable (1970s, 75%; 1990s, 79%; 2000s, 85%). Two readers completed double reads of 256 otoliths (20% overlap). Based on literature acceptable values of APE, scamp APE was high (APE = 9.49%, n = 178; Campana 2001). Percent agreement values were also low (25%), but agreement increased tremendously ± 1 and ± 2 bands, 65% and 86%, respectively. The primary reader's ages were used for further analysis.

### *Age and Growth Analysis*

Decadal scamp length histograms were normally distributed (Figure 3a-3b). The distributions of lengths and ages were statistically similar for the 1990s and 2000s (Kolmogorov-Smirnov, KS: length, $D = 0.05$, $P = 0.80$; age, $D = 0.07$, $P = 0.42$). Scamp collected in the 1970s were significantly different in length and age distribution for the pair-wise comparisons of 1970s vs. 1990s (KS: length, $D = 0.18$, $P < 0.001$; age, $D = 0.26$, $P < 0.001$) and 1970s vs. 2000s (KS: length, $D = 0.19$, $P < 0.001$; age, $D = 0.22$, $P < 0.001$). A majority of the fish collected in the 1970s were older than 10 yrs (53%) compared to the 1990s and 2000s (36% and 28%, respectively). Furthermore, 48% of the fish collected in the 1970s were > 550 mm (1990s: 31%, 2000s: 39%).

Statistical analysis of decadal size and age data of scamp using a single-factor, random-effects analysis of variance resulted in rejecting the null hypothesis (ANOVA: length, $F = 7.54$, df = 2 , $P < 0.001$; age, $F = 34.89$, df = 2, $P < 0.001$). A Tukey test for multiple comparisons resulted in ranking the decades 1990s and 2000s as more similar compared to the 1970s in regards to both length (mean ± standard error: 1970s: 537 ± 4 mm, 1990s: 517 ± 5 mm, 2000s: 517 ± 4 mm) and age (1970s: 10.0 ± 0.2 yr, 1990s: 8.2 ± 0.2 yr, 2000s: 8.5 ± 0.1 yr).

For a majority of the age classes compared (age 4 -14, sample size ≥ 5), scamp collected in 1990s were larger at age, and grew faster than scamp collected in 1970s and 2000s (Figure 3c). Statistically significant differences of mean lengths were calculated for only a few age classes (age 5, 7, 8, and 10). Scamp age 7 and 10 collected in 1990s (mean ± standard error; age 7: 511 ± 11 mm; age 10: 568 ± 13 mm) were significantly larger than scamp collected in 1970s (age 7: 477 ± 8 mm; age 10: 537 ± 8 mm) and 2000s (age 7: 481 ± 8 mm; age 10: 534 ± 6 mm; Tables 3, 4 and 5).

Scamp annual ages and observed fork lengths were fit to a standard von Bertalanffy growth model to obtain population growth parameters. The standard growth model was fit to all data combined, separate for each decade, and for each pair of decades. Scamp (all data combined) were predicted to have an asymptotic length of 609 mm, growth rate of 0.25 mm $yr^{-1}$ with age at time zero fixed at zero (Table 6). Each decade pair-wise comparison resulted in significant differences in growth curves with statistical differences in parameters (Table 6). The growth model predicted faster growth in 1970s (1970s: $k = 0.21$ mm $yr^{-1}$, 1990s: $k = 0.27$ mm $yr^{-1}$, 2000s: $k = 0.28$ mm $yr^{-1}$) and a larger asymptotic size in 1970s (1970s: $L_\infty = 633$ mm, 1990s: $L_\infty = 604$ mm, 2000s: $L_\infty = 586$ mm; Table 6, Figure 4).

### *Mortality Estimates*

Natural mortality (M) estimates were based on maximum longevity for each decade. The oldest fish was caught in the 1990s (age 24), resulting in a natural mortality (M) of 0.17 (1970s: age 23, M = 0.18; 2000s: age 20, M = 0.21). Total mortality (Z) estimates were based on the age scamp are fully recruited to the fishery (age 9 – 14). It was determined through catch curves that the 1990s had the highest total mortality (1970s: Z = 0.22, 1990s: Z = 0.60, 2000s: Z = 0.43; Figure 5).

### *Interpretation of Histological Slides and Reader Agreement*

A total of 1,917 histological slides were available for analysis (1970s, n = 1,050; 1990s, n = 353; 2000s: 2000-2002, n = 514). Histological class was determined for nearly all slides (1970s, 99%; 1990s, 97%; 2000s, 96%). Initially, both readers completed double reads of 239 histological slides for a 20% overlap. Results from

Cohen's Kappa analysis indicated that reader agreement was substantially good (K = 0.716). Readers had strong agreement (73%) for active and post histological classes and >80 % agreement for fish classified as regressed and spawning. The majority of disagreement occurred in the designation of immature fish, the primarily reader only agreed with 15% of fish that the secondary reader interpreted as immature. Discrepancies between histological readers were resolved by both readers reviewing all fish designated as immature, regressed, regressed skipped and unknown histological classes (n = 355). A second Cohen's Kappa analysis resulted in only fair agreement (K = 0.35) between readers. Due to the difficulty in the designation among these histological classes, both readers reviewed these histological slides together to determine the final histological classification used for further analysis.

### *Analysis of Reproductive Traits*

Females ranged in length from 109 – 878 mm FL whereas males ranged from 404 – 870 mm FL (Table 7). Females were significantly smaller on average than males in all three decades (1970s: F = 475.30, df = 1024, $P < 0.0001$; 1990s: F = 73.38, df = 350, $P < 0.0001$; 2000s: F =175.29, df = 505, $P < 0.0001$). Transitional fish ranged in size and age from 404 – 630 mm FL and 4 – 14 yr, respectively, confirming scamp exhibits characteristics of protogynous hermaphroditism reproductive strategy. Histological examination of scamp ovaries revealed all sexual maturation stages from immature through regressed were present. Immature females ranged in size from 109 – 490 mm FL and varied by time period (1970s: 109 – 435 mm FL; 1990s: 310 – 490 mm FL; 2000s: 196 – 420 mm FL). Ages of immature females ranged from 1-10 years old (1970s: 2 – 8 yr; 1990s: 2 – 10 yr; 2000s: 2 – 7 yr).

### *Estimates of Maturity and Sexual Transition*

The comparisons of sizes and ages at sexual maturity for female scamp among the decades revealed similarities in the size but not the age at maturity (Figure 6, Table 7). Scamp from the 1970s were the largest (390 mm FL) and oldest (age 4.0) at maturity. The comparison of size at maturity logistic regressions among the decades resulted in the lowest log likelihood (LL) and Akaike's Information Criterion (AIC) values when the parameters (steepness of the curve and the size at maturity) varied among decades concluding similar regression (Table 8). Logistic regression comparisons of age at maturity among the decades concluded differences in the age at maturity but similarities in the steepness of the regressions (Table 8).

Sizes and ages at transition were similar among decades (Figure 7, Table 7). Scamp in the 1990s were slightly larger (600 mm FL) and older (age 12) at transition, but comparisons of logistic regressions concluded similarities among decades. Size at transition logistic regressions were best described when the parameters (steepness of the curve and the size at maturity) varied (Table 8). As was concluded for age at maturity, age at transition logistic regression comparisons concluded similarities in the steepness rather than the age at maturity of the regressions.

### *Spawning Season*

Peak gonadosomatic index (GSI) values varied by decade and both sexes followed the same decadal trend (Figure 8). GSI peaked during the same time of year during all decades (1970s: March – May, 1990s: February – May, 2000s: March – April). The 1990s were characterized by an extended reproductive season (5 months, Figure 8).

### *Fecundity*

The relationship of gonad weight of females (with vitellogenic or hydrated ova) verses fork length, gonad weight and whole weight, whole weight and age were used as proxies for fecundity (Figure 9). The relationship between gonad weight and fork length appeared to best represent the data consistently among decades through a non-linear regression (1970s: $r^2 = 0.29$, 1990s: $r^2 = 0.36$, 2000s: $r^2 = 0.30$). There were significant differences among decades for gonad weight and whole weight and gonad weight and length (Table 9). Significances differences for these same fecundity proxies were also determined between the 1990s and 2000s (Table 9).

## Discussion

Decadal fluctuations were detected in life history traits of scamp collected from intercepts of commercial hand line vessels along the west Florida shelf. Changes in size, age and growth rate, size and age at maturity and transition were evident between decade pair-wise comparisons. Scamp collected in the most recent decade were only marginally smaller (20 mm) in average length, slightly younger (1 yr) in average age, grew slower and were similar in size at maturity.

Detecting, understanding, and explaining the mechanism(s) responsible for the fluctuations in life history parameters of scamp harvested from the west Florida shelf can be difficult given the spatial and temporal plasticity of reef fish (Sale 1998, Gust et al. 2002). We attempted to minimize the possibility of misconstruing a spatial pattern with a temporal pattern by drawing samples only from those ports fairly close to the west Florida shelf fishing grounds and only from those years with sufficient observations. Further consideration was made given the reliance on fishery-dependent data. Fishery-dependent data can be biased given the variations in selectivities by gear therefore we limited our data analysis only to those scamp harvested by commercial hand-line (e.g. vertical drop line, bandit rig, etc.) (Begg 2005).

Scamp constitutes a small component (< 3%, commercial landings 154 mt annual average, Figure 10) of the Gulf of Mexico shallow-water grouper commercial and recreational landings but understanding how the population of scamp from the west Florida shelf has been altered by fishing is still of importance. Scamp is managed by a minimum size limit in state waters (20 inches total length, 508 mm, established in 1990; FFWCC 1990), within the annual commercial landings for shallow-water grouper (GMFMC 1989) and a federal size limit (16 inches total length, 406 mm, established in 1999, GMFMC 1999). It is important to note, even with thirty years of fishing pressure on scamp from commercial hand-liners there have been minimal shifts in the scamp's life history parameters (mean size-at-age, growth rate, size at maturity, etc.). Sizes at maturity for all decades (1970s: 390 mm FL; 1990s: 367 mm; 2000s: 376 mm) have remained below the minimal size limit. It is possible that this minimum size limit has provided a refuge for scamp to successfully reproduce and contribute to the population before being harvested (Myers and Mertz 1998).

Fishing typically lowers population density by removing the larger, mature fish first (Rochet 1998). As the level of available resources increases, the smaller, immature fish respond by an increase in growth rate, reaching maturity faster at a younger age.

Natural selection tends to adjust reproductive effort in regards to the amount of resources available for growth (Gadgil and Bossert 1970). Fish populations experiencing increased exploitation, resulting in a lower age at maturity and an increase in growth rate has been documented in exploited commercial fish stocks in the northwest Atlantic, e.g. Atlantic cod, American plaice, and haddock (Trippel 1995) and fish stocks in the south Atlantic, e.g. gag grouper (McGovern et al. 1998) and red porgy (Harris and McGovern 1997). But for scamp caught along the west Florida shelf, minimal differences were detected in the comparison of age, growth, and reproductive traits over the course of thirty years.

Our analysis of reproductive traits was limited to the age and size at maturity and transition, and we were unable to properly examine changes in fecundity and sex ratio among the decades. Comparisons of fecundity proxies (gonad weight and body length and body weight regressions) concluded differences among the decades, as well as, between the decades with the 1990s being the most fecund. The 1990s were also characterized by the longest reproductive season (5 months, compared to 2 – 3 months in 1970s and 2000s). There are several hypotheses why a fish population would alter its reproductive season such as to synchronize spawning with oceanographic conditions, provide offspring with a higher survival given more suitable conditions, and to increase the number of spawnings per season to offset short-term mortality (Wright and Trippel 2009). In addition to these hypotheses, auxiliary factors such as size-selective fishing pressures and environmental conditions (day length, temperature, etc.) can affect the length and timing of reproduction.

Size-selective fishing pressures can alter the composition (age and size) of the spawning stock biomass and effectively cause stock assessments to overestimate a stock's resilience to overfishing (Murawski et al. 2001, Wright and Trippel 2009). As a stock is fished, larger, older more fecund spawners are removed and replaced by smaller, younger, less fecund spawners; size and age at maturity decreases with an increase in the proportion of first time spawners as observed in Western Atlantic groundfish (Murawski et al. 2001) and evident in west Florida shelf scamp population. The proportion of younger (≤ age 4), mature female scamp has increased with the decades (1970s, 4%; 1990s, 13%; 2000s, 47%), as well as, an increase in the percentage of younger (≤ age 4), mature females with indications of prior spawning (1970s, 35%; 1990s, 100%; 2000s, 83%). We measured the degree of prior spawning given the number of brown bodies, presence of old hydrated oocytes, stage of atresia, the condition of the muscle bundles, presence of connective tissue, and appearance of lamellae in the gonad tissue (NOAA 2008b). Therefore, future stock assessment of scamp along the west Florida shelf should be cautions when calculating spawning stock biomass, especially since scamp is a protogynous hermaphrodite.

Total mortality was the highest in the 1990s, which corresponds with the increase in commercial hand-line landings in the Gulf of Mexico (Figure 10). Natural mortality was slightly higher in the more recent decade but given the inaccuracies of age estimations, these differences are more than likely not biological nor significantly different. There are no fishery independent estimates of mortality and so we rely on fishery dependent data to estimate mortality. Catch curve analysis used to calculate total mortality relies on several assumptions, such that survival, natural and fishing mortality and recruitment remain constant for all ages and fishing effort and catchability remains constant over time, as well as, age samples to be routinely and randomly collected (Ricker 1975). We realize the caveats of using fishery dependent data to estimate mortality and the results of the catch curve analysis are used cautiously.

This manuscript provides the first description of detailed population parameters for scamp from the northeast Gulf of Mexico. This data is essential to properly assess this stock. Although we detected some significant differences among age, length, size-at-age, size and age at maturity, it is important to remember reef fish can exhibit small spatial and temporal differences in life history given the quality of habitat, the presence of predators and the availability of prey (Sale 1998). Our decadal data encompasses scamp caught by commercial hand-liners from approximately the same spatial area but within those areas scamp may exhibit site specific population parameters, as detected in *Rhomboplies aurorubens*, vermilion snapper (Allman 2007), *Haemulon plumieri*, white grunt (Murie and Parklyn 2005), and *Pagrus pagrus*, red porgy (DeVries 2006) from the northeastern Gulf of Mexico.

Detecting real differences in life history parameters over several decades may be difficult. Differences in otolith preparation, sampling procedures, and inter-reader variability in band counts and histological interpretation could produce variations that are not real (Caillet et al. 1990). This study attempted to minimize most sources of bias by using the same technique for otolith sectioning and ageing, for the interpretation of the otoliths and histological slides, and for sampling scamp from the commercial hand-line fishery.

## Future Research

To test the mechanisms underlying the response of a species to low densities, a controlled experiment should be conducted. There may be different responses by the species given low population densities and different densities of prey items, as seen in a species of Poeciliopsis (Weeks and Quattro 1991). However, given the logistical problems associated with housing large protogynous hermaphrodites over long periods of time, inferences from natural changes in the population should be considered. Future assessment of scamp should take into account the changes in the composition of the spawning stock biomass by allocating temporal proxies for fecundity and age and size of maturity.

## Acknowledgments

Our sincere gratitude is extended to the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, Florida for providing the data collected in the earliest decade and to Mark Godcharles (NOAA's National Marine Fisheries Service, Southeast Regional Office - retired) as the co-project investigator for that time period. Gary Fitzhugh and Mike Allen provided valuable comments on earlier versions of this manuscript. Opinions expressed herein are of the authors and do not imply endorsement by NOAA Fisheries Service, National Marine Fisheries Service. Financial support was provided by the U.S. Department of Commerce.

## Literature Cited

Allman, R. 2007. Small-scale variation in the population structure of vermilion snapper (*Rhomboplies aurorubens*) from the northeast Gulf of Mexico. Fisheries Research 88:88-89.

Armsworth, P.R. 2001. Effects of fishing on a protogynous hermaphrodite. Canadian Journal of Fisheries and Aquatic Sciences 58:568-578.

Begg, G. A. 2005. Life history parameters. *Pages* 119-150 *in* S. X. Cadrin, K. D. Friedland, and J. R. Waldman, editors. Stock Identification Methods, Applications in Fishery Science. Elsevier Academic Press, Amsterdam.

Caillet, G. M., K. G. Yudin, S. Tanaka, and T. Taniuchi. 1990. Growth characteristics of two populations of *Mustelus manazo* from Japan based upon cross reading of vertebral bands. Pages 167-176 *in* H.L. Pratt, S.H. Gruber, and T. Taniuchi, editors. Elasmobranchs as Living Resources: Advances in the biology, ecology, systematics, and the status of the fisheries. National Oceanic Atmospheric Administration, National Marine Fisheries Service, Technical Report 90. 518 pp.

Campana, S. E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology 59:197-242.

Cohen, J. 1960. A coefficient of agreement for nominal scales. Educational and Psychological Measurement 1960 20:37-46.

Coleman, F. C., C. C. Koenig, and L. A. Collins. 1996. Reproductive styles of shallow-water groupers (Pisces: Serranidae) in the eastern Gulf of Mexico and the consequences of fishing spawning aggregations. Environmental Biology of Fishes 47:129-141.

DeVries, D. A. 2006. The Life History, Reproductive Ecology, and Demography of the Red Porgy *Pagrus pagrus*, in the Northeastern Gulf of Mexico. Ph.D. Thesis. Florida State University, Tallahassee, Florida, 160 pp.

Fitzhugh, G. R., L. A. Lombardi-Carlson, and N. M. Evou. 2003. Age structure of gag (*Mycteroperca microlepis*) in the eastern Gulf of Mexico by year, fishing mode and region. Proceedings of the Gulf and Caribbbean Fisheries Institute 54:538-549.

Florida Marine Research Institute (FMRI). 1991. Memoirs of the Hourglass Cruises. Florida Department of Environmental Protection. St. Petersburg, FL. Volume 8, Part 2. p.243.

Florida Fish and Wildlife Conservation Commission (FFWCC). 1990. Marine Fisheries Commission. Reef Fish Chapter 46-14. Farris Bryant Building, 620 S. Meridian St., Tallahassee, FL, 32399-1600.

Gadgil, M. and W. H. Bossert. 1970. Life historical consequences of natural selection. American Naturalist 104:1-24.

Gerristen, H. D. and D. McGrath. 2006. Variability in the assignment of maturity stages of plaice (*Pleuronectes platessa* L.) and whiting (*Merlangius merlangus* L.) using macroscopic maturity criteria). Fisheries Research 77:72-77.

Gulf of Mexico Fishery Management Council (GMFMC). 1981. Fishery Management Plan for the Reef Fish Fishery of the Gulf of Mexico. 5401 West Kennedy Boulevard, Suite 881. Tampa, Florida 33609.

GMFMC. 1989. Amendment number 1 to the Reef Fish Fishery Management Plan. 5401 West Kennedy Boulevard, Suite 881. Tampa, Florida 33609.

GMFMC. 1999. Amendment number 16B to the Fishery Management Plan for the Reef Fish Resources of the Gulf Of Mexico. The Commons at Rivergate, 3018 U.S. Highway 301 North, Suite 1000, Tampa, Florida 33619-2266

Gust, N., J. H. Choat, and J. L. Ackerman. 2002. Demographic plasticity in tropical reef fish. Marine Biology. 140:1039-1051.

Haddon, M. 2001. Modelling and Quantitative Methods in Fisheries. Chapman and Hall/CRC Press, Boca Raton, FL.

Harris, P. J., and J. C. McGovern. 1997. Changes in the life history of red porgy, *Pagrus pagrus*, from the southeastern United States, 1972-1994. Fishery Bulletin. 95:732-747.

Harris, P. J., D. M. Wyanski, D. B. White, and J. L. Moore. 2002. Age, growth, and reproduction of scamp, *Mycteroperca phenax*, in the southwestern North Atlantic, 1979-1997. Bulletin of Marine Science 70:113-132.

Hewitt, D. A., and J. M, Hoenig. 2005. Comparison of two approaches for estimating natural mortality based on longevity. Fishery Bulletin 103: 433-437.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate natural mortality rates. Fishery Bulletin 82: 898-903.

Hoese, H. D. and R. H. Moore. 1977. Fishes of the Gulf of Mexico, Texas, Louisiana, and Adjacent Waters. Texas A and M University Press. College Station, Texas.

Hunter, J. R., and B. J. Macewicz. 1985. Measurement of spawning frequency in multiple spawning fishes. *Pages* 79-94 *in* R. Lasker, editor. An egg production method for estimating spawning biomass of pelagic fish: an application to the northern anchovy, *Engraulis mordax*. National Oceanographic Atmospheric Administration, National Marine Fisheries Service Technical Report 36.

Johnson, A. G., and L. A. Collins. 1994. Age-size structure of red grouper, (*Epinephelus morio*), from the eastern Gulf of Mexico. Northeast Gulf Science 13:101-106.

Johnson, A. G., L. A. Collins, and J. J. Esley. 1993. Age-size structure of gag, *Mycteroperca microlepis*, from the northeastern Gulf of Mexico. Northeast Gulf Science 13: 59-63.

Lombardi-Carlson, L., G. Fitzhugh, C. Palmer, C. Gardner, R. Farsky, and M. Ortiz. 2008. Regional size, age, and growth differences for red grouper (*Epinephelus morio*) along the west Florida shelf. Fisheries Research 91:239-251.

Matheson, R.H, III, G.R. Huntsman, and C.S. Manooch, III. 1986. Age, growth, mortality, food, and reproduction of the scamp, *Mycteroperca phenax*, collected off North Carolina and South Carolina. Bulletin of Marine Science 38:300-312.

McGovern, J. C., D. M. Wyanski, O. Pashuk, C. S. Manooch, II, and G. R. Sedberry. 1998. Changes in the sex ratio and size at maturity of gag, *Mycteroperca microlepis*, from the Atlantic coast of the southeastern United States during 1976-1995. Fishery Bulletin 96:797-807.

Murawski, S. A., P. J. Rago, and E. A. Trippel. 2001. Impacts of demographic variation in spawning characteristics on reference points for fishery management. ICES Journal of Marine Science 58:1002-1014.

Murie, D. J. and D. C. Parkyn. 2005. Age and growth of white grunt (*Haemulon plumieri*): a comparison of two populations along the west coast of Florida. Bulletin of Marine Science 76:73–93.

Myers, R. A., and G. Mertz. 1998. The limits of exploitation: a precautionary approach. Ecological Applications. 8: S165-S169.

National Oceanographic Atmospheric Administration (NOAA). 2004. Fisheries of the Caribbean, Gulf of Mexico, and South Atlantic; Reef Fish Fishery of the Gulf of Mexico; Red Grouper Rebuilding Plan. 50 CFR Part 622.

NOAA. 2008a. National Marine Fisheries Service 2007 Report to Congress, The Status of U.S. Fisheries. Office of Sustainable Fisheries, Silver Springs, MD.

NOAA. 2008b. Procedural Manual for Age, Growth, and Reproductive Lab, 3rd Edition. Editors: L. Lombardi-Carlson, C. Fioramonti, and M. Cook. Southeast Fisheries Science Center, Fisheries Biology Group, Panama City Laboratory, 3500 Delwood Beach Road, Panama City, Florida 32408. Panama City Laboratory Contribution 08-15. p. 250.

Rhodes, K. L. and Y. Sadovy. 2002. Reproduction in the camouflage grouper (Pisces: Serranidae) in Pohnpei, Federated States of Micronesia. Bulletin of Marine Science 70:851-869.

Ricker, W. E. 1975. Chapter 2. Estimation of survival rate and mortality rate from age composition. Computation and Interpretation of Biological Statistics of fish Populations. Bulletin of the Fisheries Research Board of Canada. 191:1-382.

Rideout, R. M., M. P. M. Burton and G. A. Rose. 2000. Observations of mass atresia and skipped spawning in northern Atlantic cod, from Smith Sound, Newfoundland. Journal of Fish Biology 57:1429-1440.

Rochet, M-J. 1998. Short-term effects of fishing on life history traits of fishes. ICES Journal of Marine Science 55: 371-391.

Sadoovy, Y. and D. V. Shapiro. 1987. Criteria for the diagnosis of hermaphroditism in fishes. Copeia 1:136-156.

Sale, P. F. 1998. Appropriate spatial scales for studies of reef-fish ecology. Australian Journal of Ecology 23:202-208.

Smith, G. B. 1976. Ecology and distribution of eastern Gulf of Mexico reef fishes. Florida Department of Natural Resources, Marine Research Laboratory Publication No. 19:1-78.

Tashiro, J. E. and S. E. Coleman. 1977. The Cuban grouper and snapper fishery in the Gulf of Mexico. Marine Fisheries Review 39:1-6.

Trippel, E. A. 1995. Age at maturity as a stress indicator in fisheries. Bioscience 45:759-771.

Tyler, C. R. and J. P. Sumpter. 1996. Oocyte growth and development in teleosts. Reviews in Fish Biology and Fisheries 6:287-318.

Wallace, R. A. and K. Selman. 1981. Cellular and dynamic aspects of oocyte growth in teleosts. American Zoologist 21:325-343.

Weeks, S. C. and J. M. Quattro. 1991. Life-history plasticity under resource stress in a clonal fish (Poeciliidae: Poeciliopsis). Journal of Fish Biology 39:485-494.

Wright, P. J. and E. A. Trippel. 2009. Fishery-induced demographic changes in the timing of spawning: consequences for reproductive success. Fish and Fisheries 10: 283-304.

Zar, J.H. 1999. Biostatistical Analysis. Prentice Hall, Inc., Englewood Cliffs, NJ. 663 pp.

Table 1. Description of female and male scamp maturation classes based on histological preparation of gonad tissue.

| Maturation Class | Description |
|---|---|
| Immature, inactive | Female – Primary growth oocytes only, no evidence of prior spawning.<br>Male – Includes males with spermatogonia and no evidence of spermatogenesis. Difficult to distinguish from regressed, except immature males do not have residual spermatozoa. |
| Inactive, uncertain | Female – Only primary growth oocytes present, not capable of spawning in distant future and any evidence of prior spawning unclear.<br>Male – This phase has not been observed for males. |
| Developing virgin | Female – Cortical alveolar oocytes dominate and no prior indicators of maturity.<br>Male – Spermatogenesis begins, spermatocytes present and no prior indicators of maturity. |
| Developing | Female – Cortical alveolar oocytes present. Prior spawning indicators confirm maturity.<br>Male – Spermatogenesis and the formation of spermatocytes begins. Little or no spermatozoa. |
| Active, mature | Female – Vitellogenic oocytes present and fish should spawn within days or weeks.<br>Male – This phase is not used for males since it is essentially the same as developing, except discontinuous germinal epithelium is present at either the periphery or ducts. |
| Spawning, hydrated | Female – Early or late hydrated oocytes. Spawning now or within hours. Also, includes gonads with any stage of post-ovulatory follicles present. |
| Spawning capable | Male – Fish is reproductively active and capable of spawning. All stages of spermatogenesis may be present. Spermatozoa evident and filling lobules and sperm ducts. |
| Post-ovulatory, spent | Female – All oocytes stages may be present, majority of oocytes (>50%) experiencing atresia. |

| Maturation Class | Description |
|---|---|
|  | Male – Spermatogenesis ceasing, some residual spermatozoa present, spermatogonia proliferation common. |
| Regressed, inactive, mature | Female – Primary growth oocytes only, evidence of sexual maturity and recently spawned. |
|  | Male – Spermatogonia dominate, no active spermatogenesis, and some residual spermatozoa may be present. |
| Regressed, skipped, mature | Female – Sexually mature but will not spawn in current season, development ended prematurely. |
|  | Male – This phase has not been observed for males |

Table 2. Annual numbers of gonads and otoliths (plus the number of ages determined) from intercepts of commercial hand-line vessels fishing on the west Florida shelf. Data was grouped into three decades (1970s: 1977-1981, 1990s: 1991-1993, 2000s: 2000-2001) to obtain similar sample sizes per decade for proper statistical analysis and to signify changes in the fishery management regulations.

| Year | Gonads | Otoliths | Ages |
|---|---|---|---|
| 1977 | 28 | 26 | 20 |
| 1978 | 223 | 23 | 14 |
| 1979 | 314 | 220 | 149 |
| 1980 | 267 | 138 | 96 |
| 1981 | 271 | 106 | 102 |
| 1991 | 175 | 146 | 119 |
| 1992 |  | 10 | 10 |
| 1993 | 168 | 160 | 121 |
| 1994 | 119 | 110 | 81 |
| 1995 | 115 | 134 | 108 |
| 1996 | 47 | 77 | 64 |
| 1997 | 5 | 11 | 10 |
| 1998 | 9 | 35 | 28 |
| 1999 | 22 | 27 | 24 |
| 2000 | 13 | 55 | 49 |
| 2001 | 42 | 402 | 348 |
| 2002 | 106 | 340 | 284 |

Table 3. Decade comparisons (1970s vs. 1990s) of scamp collected by commercial hand-line vessels fishing on the west Florida shelf observed size-at-age data and results of paired *t-tests*. Abbreviations are samples sizes (n), standard error (s.e.), t-statistic (t), degree of freedom (d.f.). Significant levels for pair-wise comparisons as determined by t-test, $^{NS}$ – not significant; *, $P < 0.05$; ** $P < 0.01$, ***, $P < 0.001$.

| Age class | decade | n | mean ± s.e. | *t* | d.f. |
|---|---|---|---|---|---|
| 4 | 1970s | 6 | 426 ± 17 | $1.70^{NS}$ | 6.95 |
| | 1990s | 17 | 395 ± 7 | | |
| 5 | 1970s | 23 | 416 ± 10 | $-1.48^{NS}$ | 35.83 |
| | 1990s | 19 | 439 ± 12 | | |
| 6 | 1970s | 30 | 464 ± 6 | $-1.37^{NS}$ | 60.15 |
| | 1990s | 35 | 478 ± 8 | | |
| 7 | 1970s | 28 | 477 ± 8 | $-2.51^{*}$ | 45.68 |
| | 1990s | 26 | 511 ± 11 | | |
| 8 | 1970s | 39 | 545 ± 8 | $-1.30^{NS}$ | 73.98 |
| | 1990s | 37 | 530 ± 8 | | |
| 9 | 1970s | 45 | 532 ± 8 | $-1.24^{NS}$ | 81.92 |
| | 1990s | 40 | 546 ± 8 | | |
| 10 | 1970s | 42 | 537 ± 8 | $-2.07^{*}$ | 52.26 |
| | 1990s | 30 | 568 ± 13 | | |
| 11 | 1970s | 37 | 570 ± 8 | $1.07^{NS}$ | 36.74 |
| | 1990s | 18 | 555 ± 11 | | |
| 12 | 1970s | 41 | 578 ± 9 | $1.63^{NS}$ | 17.57 |
| | 1990s | 9 | 552 ± 13 | | |
| 13 | 1970s | 17 | 596 ± 11 | $-0.06^{NS}$ | 6.17 |
| | 1990s | 5 | 597 ± 22 | | |

Table 4. Decade comparisons (1990s vs. 2000s) of scamp collected by commercial hand-line vessels fishing on the west Florida shelf observed size- at-age data and results of paired *t-tests*. Abbreviations are samples sizes (n), standard error (s.e.), t-statistic (t), degree of freedom (d.f.). Significant levels for pair-wise comparisons as determined by t-test, $^{NS}$ – not significant; *, $P < 0.05$; ** $P < 0.01$, ***, $P < 0.001$.

| Age class | decade | n | mean ± s.e. | *t* | d.f. |
|---|---|---|---|---|---|
| 4 | 1990s | 17 | 395 ± 7 | -3.63 $^{***}$ | 25.94 |
| | 2000s | 15 | 440 ± 10 | | |
| 5 | 1990s | 19 | 439 ± 12 | -1.13 $^{NS}$ | 31.50 |
| | 2000s | 34 | 455 ± 7 | | |
| 6 | 1990s | 35 | 478 ± 8 | -0.04 $^{NS}$ | 71.82 |
| | 2000s | 51 | 479 ± 7 | | |
| 7 | 1990s | 26 | 511 ± 11 | 2.19 $^{*}$ | 49.47 |
| | 2000s | 38 | 481 ± 8 | | |
| 8 | 1990s | 37 | 530 ± 8 | 2.17 $^{*}$ | 79.72 |
| | 2000s | 51 | 506 ± 7 | | |
| 9 | 1990s | 40 | 546 ± 8 | 1.51 $^{NS}$ | 89.48 |
| | 2000s | 57 | 529 ± 8 | | |
| 10 | 1990s | 30 | 568 ± 13 | 2.39 $^{*}$ | 44.47 |
| | 2000s | 57 | 534 ± 6 | | |
| 11 | 1990s | 18 | 555 ± 11 | -1.20 $^{NS}$ | 36.09 |
| | 2000s | 41 | 571 ± 8 | | |
| 12 | 1990s | 9 | 552 ± 13 | -1.37 $^{NS}$ | 17.50 |
| | 2000s | 11 | 581 ± 17 | | |
| 13 | 1990s | 5 | 597 ± 22 | 0.53 $^{NS}$ | 8.94 |
| | 2000s | 13 | 582 ± 17 | | |

Table 5. Decade comparisons (1970s vs. 2000s) of scamp collected by commercial hand-line vessels fishing on the west Florida shelf observed size- at-age data and results of paired *t-tests*. Abbreviations are samples sizes (n), standard error (s.e.), t-statistic (t), degree of freedom (d.f.). Significant levels for pair-wise comparisons as determined by t-test, $^{NS}$ – not significant; *, $P < 0.05$; ** $P < 0.01$, ***, $P < 0.001$.

| Age class | decade | n | mean ± s.e. | *t* | d.f. |
|---|---|---|---|---|---|
| 4 | 1970s | 6 | 426 ± 17 | $-0.72^{NS}$ | 8.91 |
|  | 2000s | 15 | 440 ± 10 |  |  |
| 5 | 1970s | 23 | 416 ± 10 | $-3.22^{**}$ | 45.58 |
|  | 2000s | 34 | 455 ± 7 |  |  |
| 6 | 1970s | 30 | 464 ± 6 | $-1.61^{NS}$ | 76.40 |
|  | 2000s | 51 | 479 ± 7 |  |  |
| 7 | 1970s | 28 | 477 ± 8 | $-0.35^{NS}$ | 63.07 |
|  | 2000s | 38 | 481 ± 8 |  |  |
| 8 | 1970s | 39 | 545 ± 8 | $0.78^{NS}$ | 82.22 |
|  | 2000s | 51 | 506 ± 7 |  |  |
| 9 | 1970s | 45 | 532 ± 8 | $0.27^{NS}$ | 98.29 |
|  | 2000s | 57 | 529 ± 8 |  |  |
| 10 | 1970s | 42 | 537 ± 8 | $0.26^{NS}$ | 83.51 |
|  | 2000s | 57 | 534 ± 6 |  |  |
| 11 | 1970s | 37 | 570 ± 8 | $-0.14^{NS}$ | 75.45 |
|  | 2000s | 41 | 571 ± 8 |  |  |
| 12 | 1970s | 41 | 578 ± 9 | $-0.18^{NS}$ | 46.38 |
|  | 2000s | 11 | 581 ± 17 |  |  |
| 13 | 1970s | 17 | 596 ± 11 | $0.66^{NS}$ | 21.68 |
|  | 2000s | 13 | 582 ± 17 |  |  |

Table 6. Growth curve parameters ($L_\infty$ – asymptotic length, k – growth coefficient, $t_0$ – size at time zero) and associated residuals for annual ages and observed fork lengths at capture provided for a standard von Bertalanffy growth curve with age at time zero fixed at zero for scamp collected by commercial hand-line vessels fishing on the west Florida shelf for all data combined, by decade (1970s, 1990s, and 2000s) and for each pair of decades. Significant levels for pair-wise comparisons as determined by maximum likelihood, $^{NS}$ – not significant; *, $P < 0.05$; ** $P < 0.01$, ***, $P < 0.001$.

| | n | $L_\infty$ | k | Sum of squares |
|---|---|---|---|---|
| All data | 1075 | 609 | 0.25 | $3.39 \times 10^6$ |
| 1970s | 381 | 633 | 0.21 | $9.88 \times 10^5$ |
| 1990s | 250 | 604 | 0.27 | $7.07 \times 10^5$ |
| 2000s | 444 | 586 | 0.28 | $1.61 \times 10^6$ |
| 1970s vs 1990s | 631 | $621^{*}$ | $0.23^{**}$ | $1.74 \times 10^{6*}$ |
| 1990s vs 2000s | 694 | $593^{NS}$ | $0.27^{NS}$ | $2.33 \times 10^{6*}$ |
| 1970s vs 2000s | 825 | $611^{***}$ | $0.24^{***}$ | $2.66 \times 10^{6*}$ |

Table 7. Reproductive parameter estimates for scamp from the northeastern Gulf of Mexico from three decades: 1970s, 1990s, and 2000s. Length reported as fork length (mm) and sample sizes appear in parenthesis.

| Parameters | 1970s | 1990s | 2000s |
|---|---|---|---|
| Female length range | 109 – 752 (638) | 310 – 710 (255) | 196 – 878 (313) |
| Male length range | 440 – 752 (388) | 430 – 740 (97) | 404 – 870 (194) |
| Female age (yr) range | 2 – 17 (223) | 2 – 15 (178) | 1 – 19 (268) |
| Male age (yr) range | 6 – 23 (160) | 5 – 18 (68) | 3 – 24 (160) |
| Median length at maturity | 390 (632) | 367 (247) | 376 (247) |
| Median age (yr) at maturity | 4.0 (223) | 1.0 (177) | 2.8 (210) |
| Median length at transition | 564 (1033) | 600 (353) | 561 (514) |
| Median age (yr) at transition | 11.5 (386) | 12.0 (247) | 10.3 (433) |

Table 8. The results of statistically testing for similarities in logistic regressions (size and age and maturity and transitions) among the decades using maximum negative log-likelihood (nLL), Akaike's Information Criterion (AIC) and delta AIC (δAIC) for model comparisons. The parameters of the logistic regression (a = size or age at maturity, b = steepness of the logistic regression) were manipulated (kept constant or varied) to determine the best fit of the data.

| Comparison | a | b | nLL | AIC | δAIC |
|---|---|---|---|---|---|
| Size at Maturity | varied | varied | -132.37 | 276.73 | 0.00 |
| | constant | varied | -136.91 | 281.81 | 5.08 |
| | varied | constant | 140.95 | 289.89 | 13.16 |
| Age at Maturity | varied | varied | -105.75 | 223.51 | 0.00 |
| | constant | varied | -112.20 | 232.41 | 8.09 |
| | varied | constant | -108.22 | 224.44 | 0.93 |
| Size at Transition | varied | varied | -922.54 | 1857.08 | 0.00 |
| | constant | varied | -928.64 | 1865.27 | 8.19 |
| | varied | constant | -936.45 | 1880.89 | 23.81 |
| Age at Transition | varied | varied | -563.16 | 1138.32 | 0.00 |
| | constant | varied | -566.36 | 1140.72 | 2.40 |
| | varied | constant | -565.64 | 1139.28 | 0.96 |

Table 9. Results of analysis of covariance (ANCOVA) for fecundity proxies (gonad weight (g) and fork length (mm), and whole weight (g), and age) among (1970s, 1990s 2000s) and between decades. Significant levels for comparisons as determined by ANCOVA, $^{NS}$ – not significant; *, $P < 0.05$; ** $P < 0.01$, ***, $P < 0.001$.

| Comparison | Proxy for Fecundity | *F* |
|---|---|---|
| among decades | gonad weight and length | 5.43** |
| among decades | gonad weight and whole weight | 36.25*** |
| among decades | gonad weight and age | 2.54 $^{NS}$ |
| | | |
| 1970s vs 1990s | gonad weight and length | 4.58* |
| 1970s vs 1990s | gonad weight and whole weight | 2.64 $^{NS}$ |
| | | |
| 1990s vs 2000s | gonad weight and length | 8.32** |
| 1990s vs 2000s | gonad weight and whole weight | 58.06*** |
| | | |
| 1970s vs 2000s | gonad weight and length | 0.01 $^{NS}$ |
| 1970s vs 2000s | gonad weight and whole weight | 12.08*** |

Figure 1. Scamp were intercepted from commercial hand-line vessel landings from commercial ports along the Florida Panhandle south to Tampa. The primary area of harvest was the west Florida Shelf.

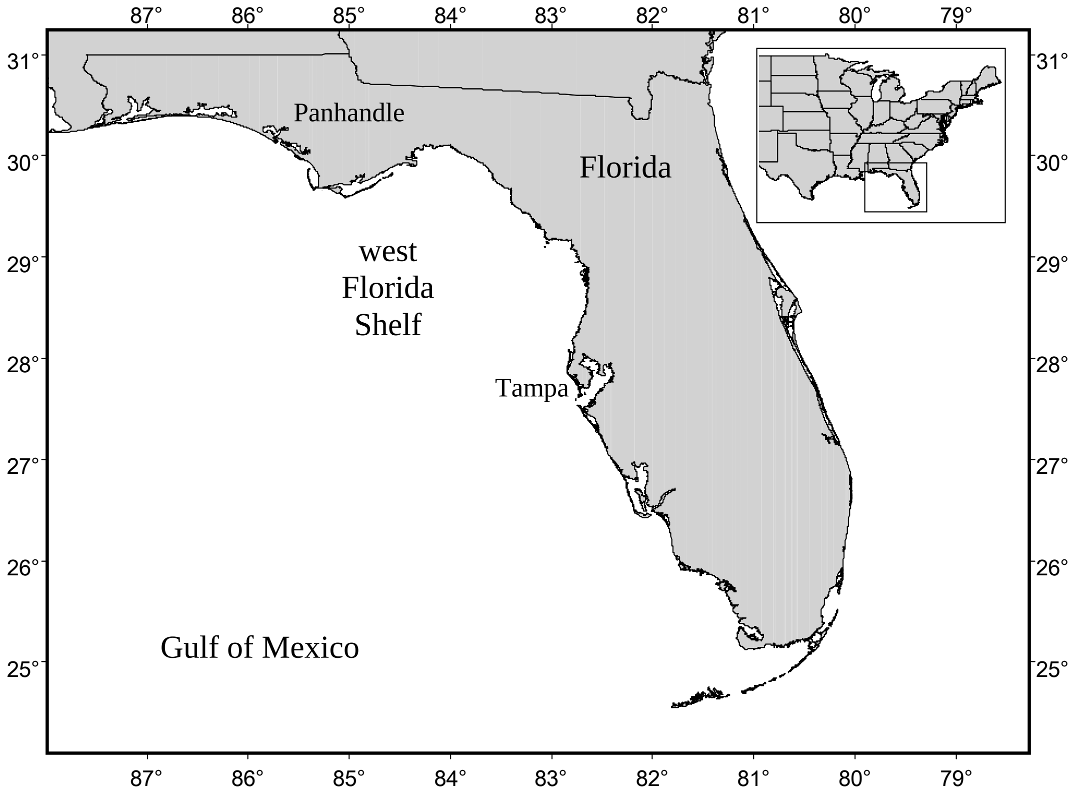

Figure 2. Sectioned otolith of a scamp (500 mm FL, female). Age was determined by interpreting opaque increments along ventral sulcus and axis (solid lines) using reflected light (35x).

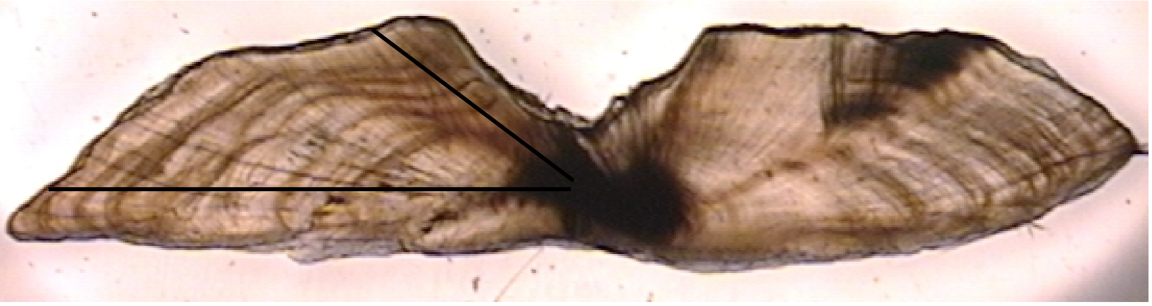

Figure 3. Scamp from the northeastern Gulf of Mexico (**a**) length and (**b**) age distributions and (**c**) size-at-age data by decade (1970s, 1990s, and 2000s).

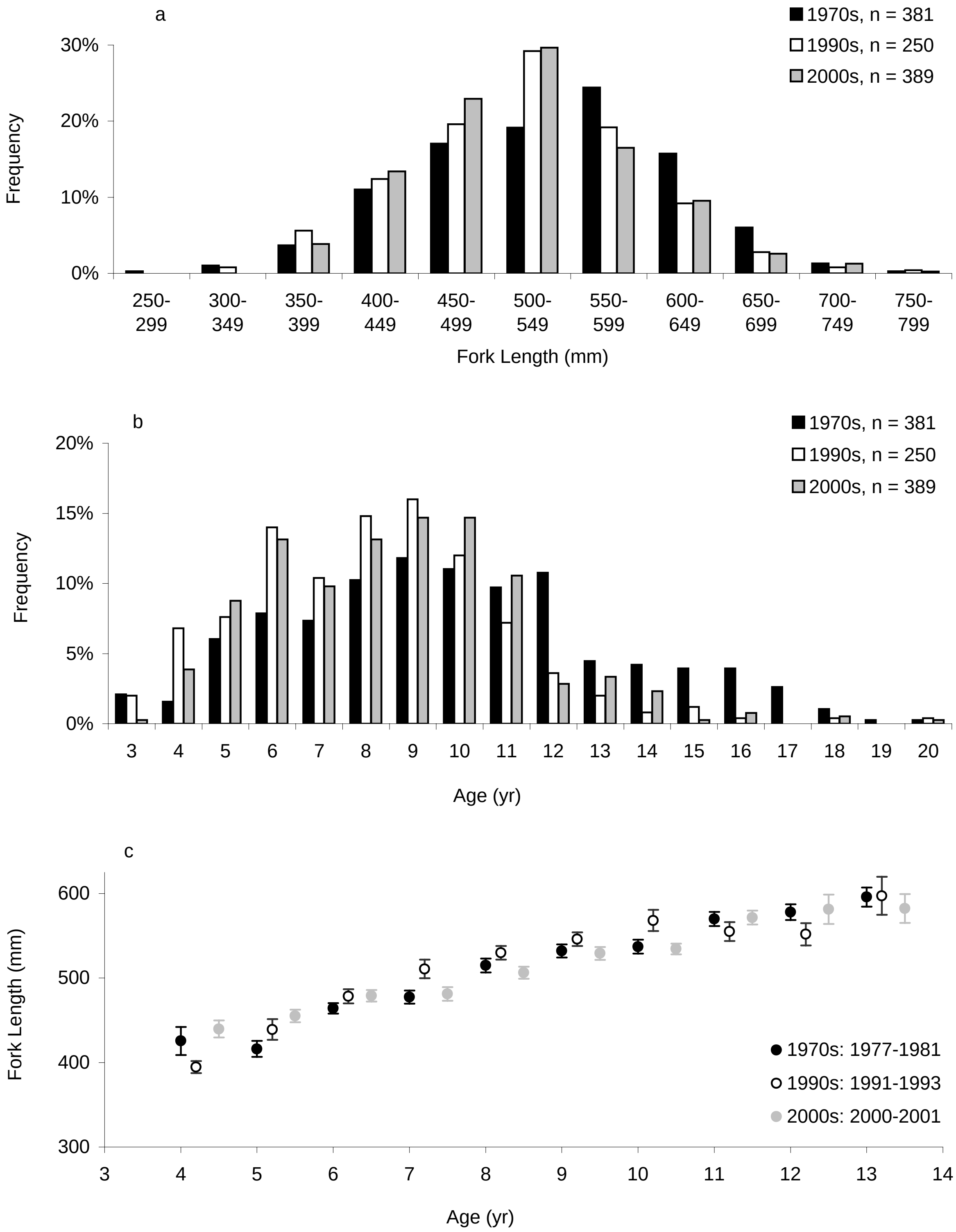

Figure 4. Observed size-at- age data and von Bertalanffy growth curves for scamp from the northeastern Gulf of Mexico by decade: 1970s (solid black line), 1990s (dashed black line), and 2000s (solid grey line).

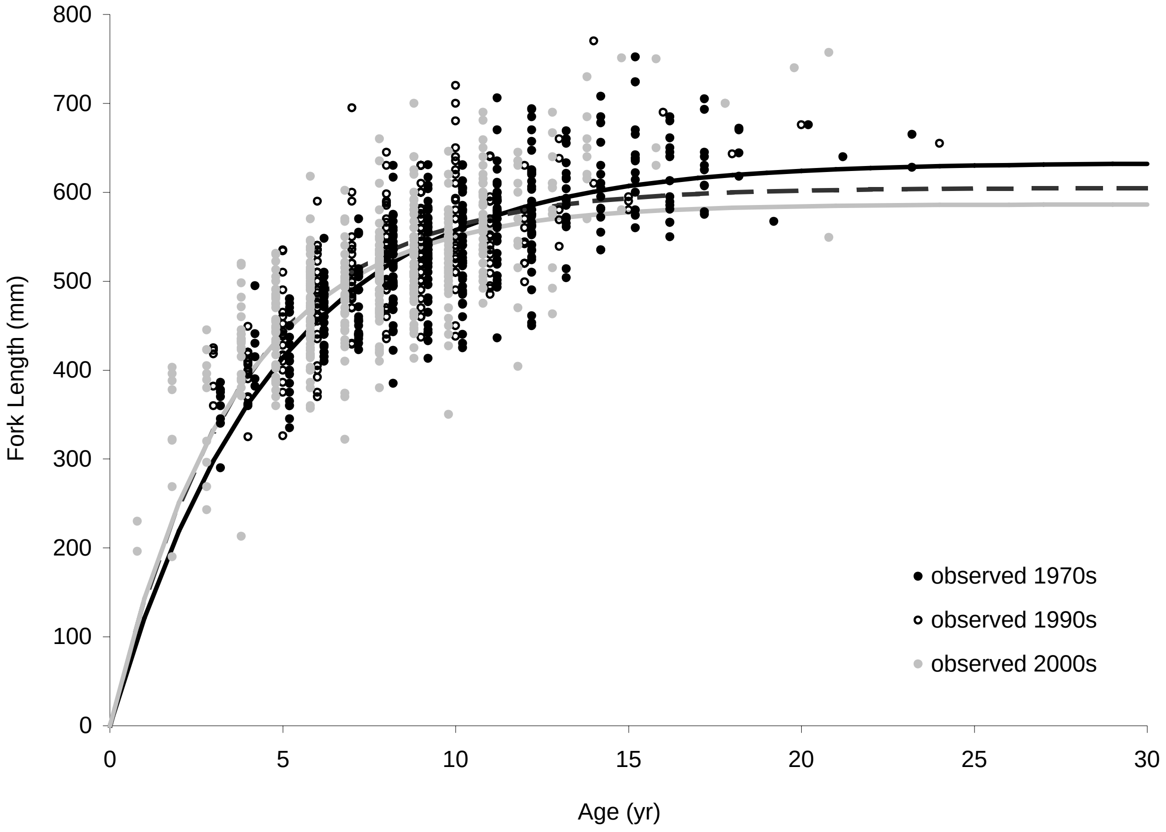

Figure 5. Catch curves for commercially caught scamp by decade (1970s, 1990s, 2000s) from the northeastern Gulf of Mexico.

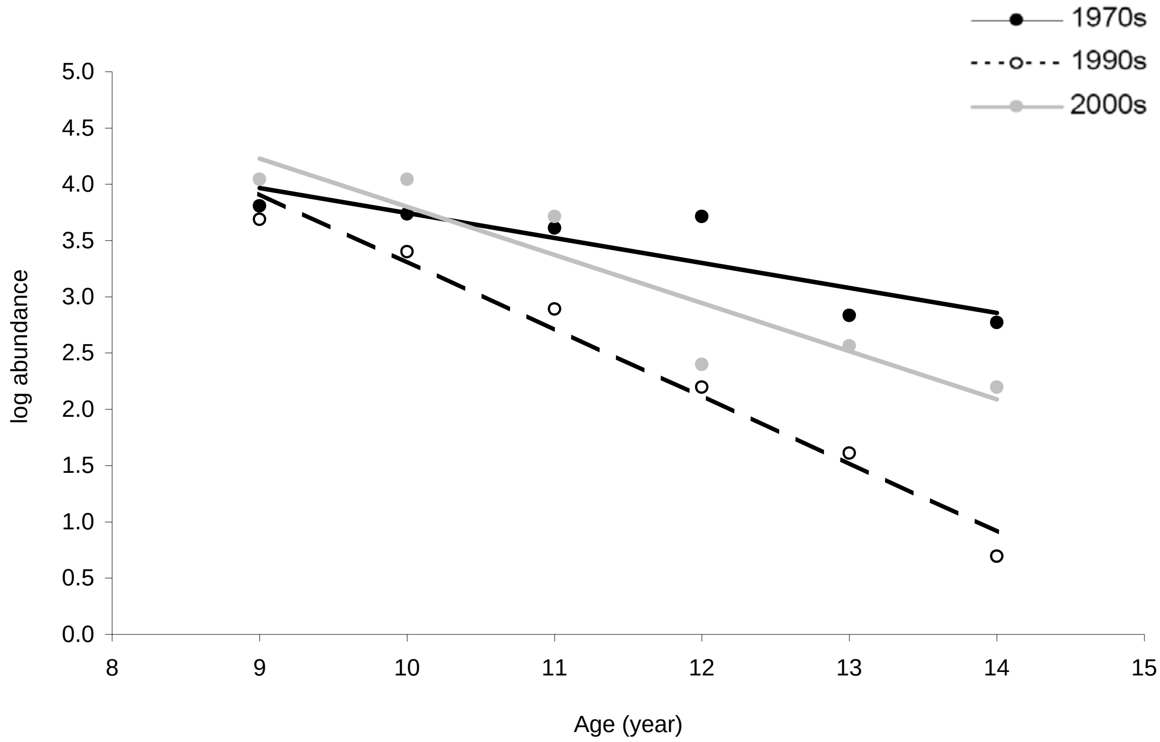

Figure 6. Maturity estimates for the (**a**) size and (**b**) age of scamp by decade (1970s, 1990s, 2000s) from the northeastern Gulf of Mexico. Reference line is the 50% proportion mature.

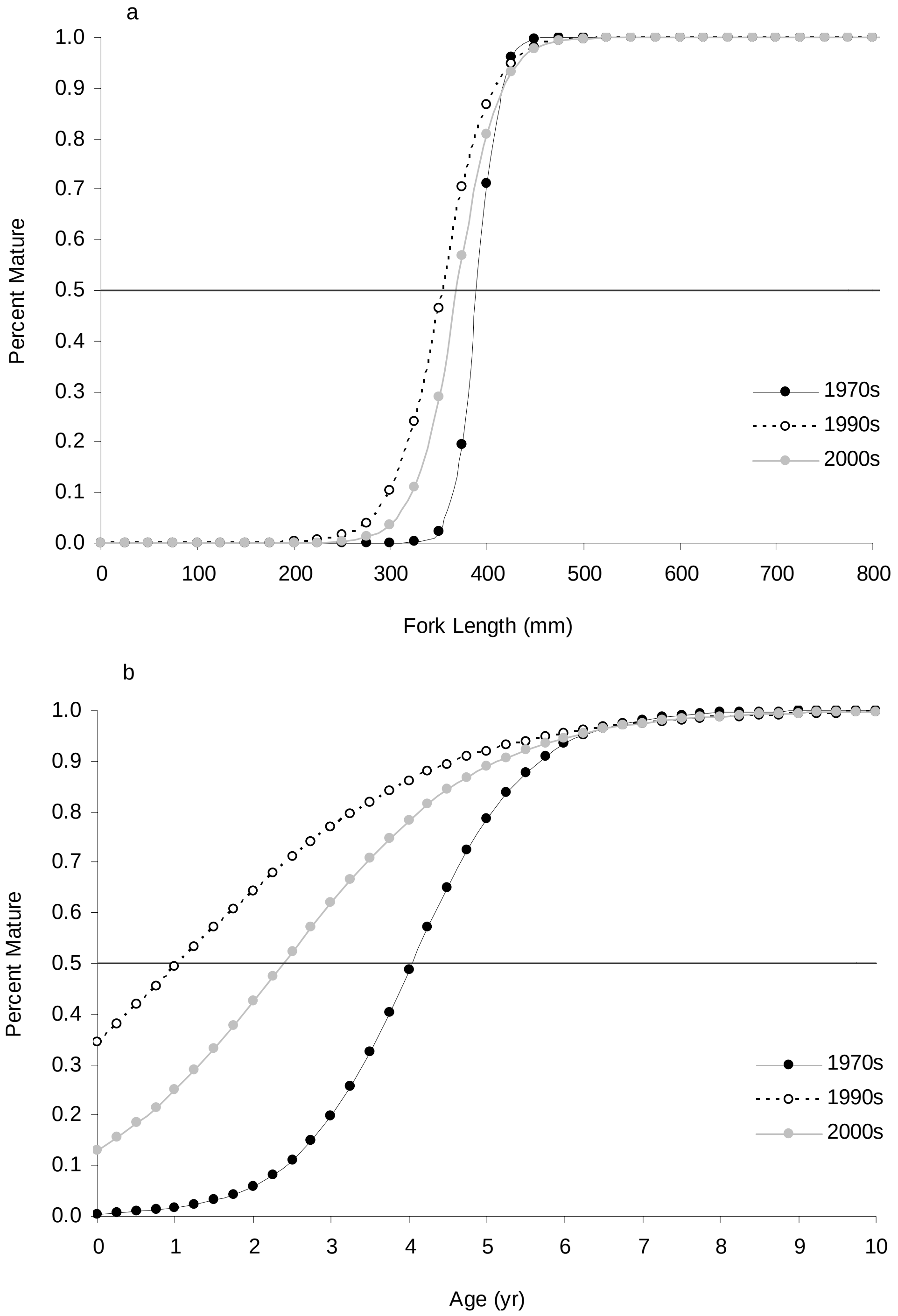

Figure 7. Results of logistic functions for binominal sex data to determine the (**a**) size and (**b**) age at transition of scamp by decade (1970s, 1990s, 2000s) from the northeastern Gulf of Mexico. Reference line is the 50% proportion transitioned.

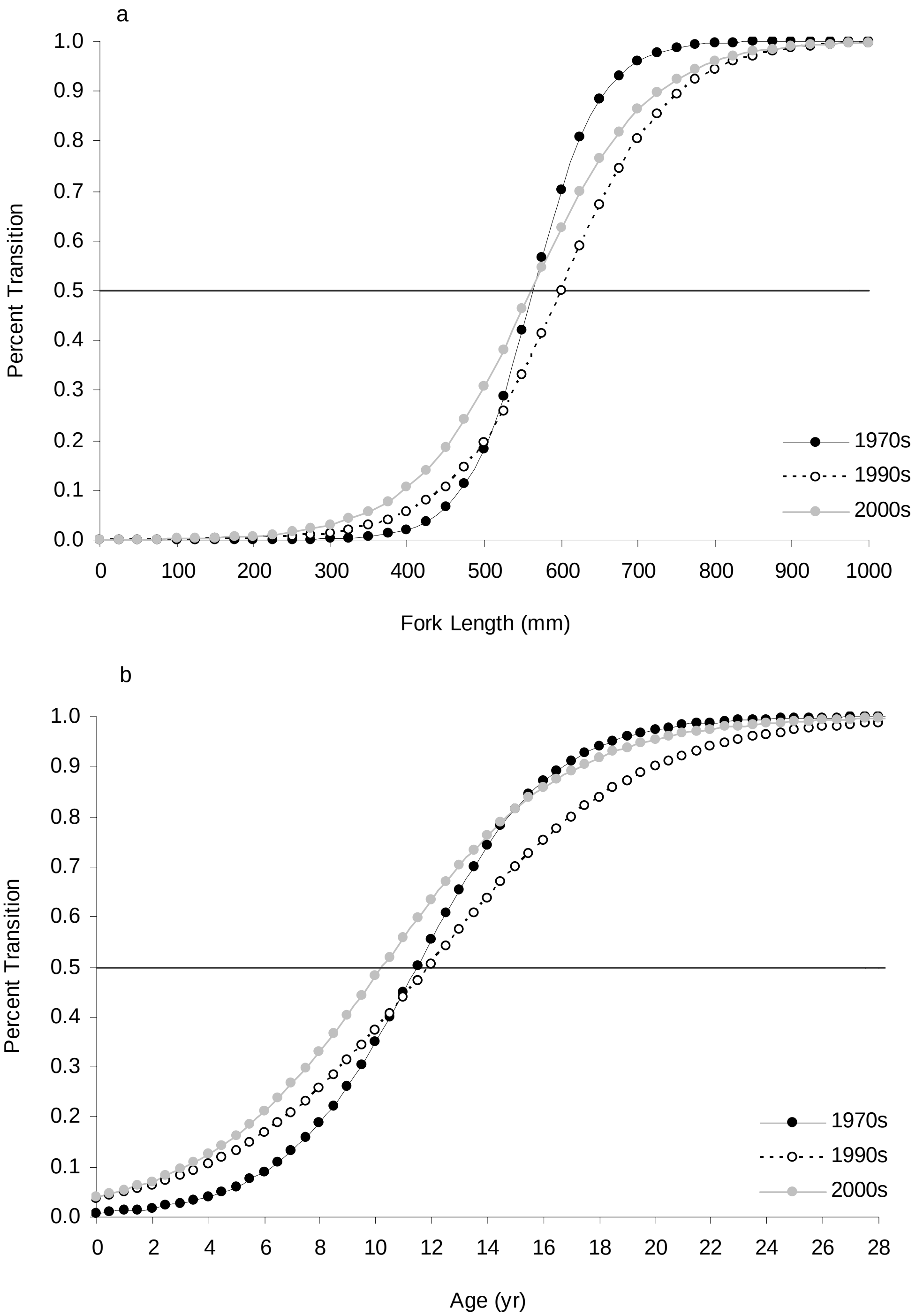

Figure 8. Gonadosomatic Index (GSI) mean ± standard error for (**a**) female and (**b**) male scamp by month and by decade (1970s, 1990s, and 2000s). Note figures have difference scales on the y-axis.

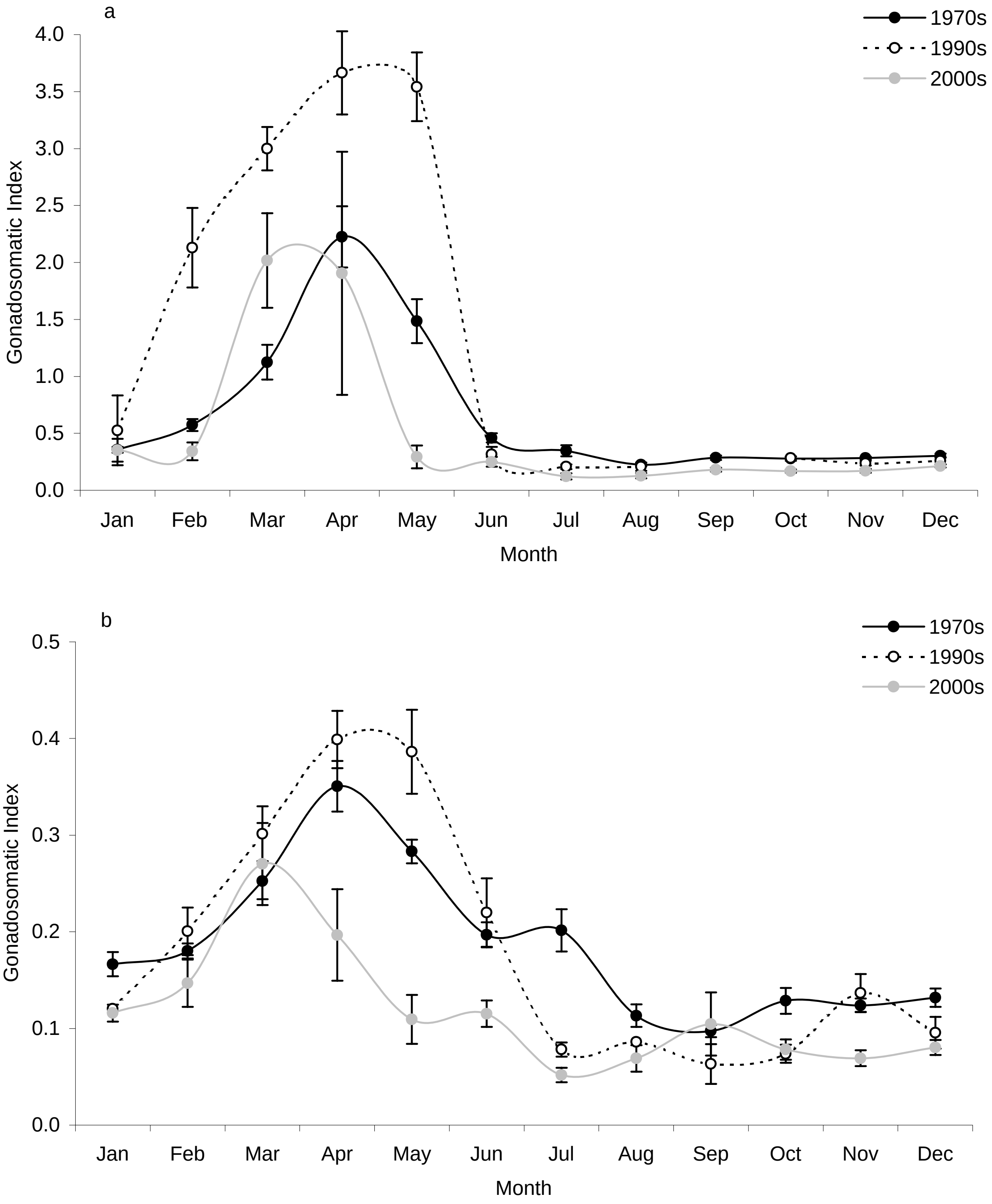

Figure 9. Proxies for fecundity for scamp given the relationship between gonad weights and (**a**) fork lengths, (**b**) whole weights, (**c**) ages by decade (1970s, 1990s, and 2000s).

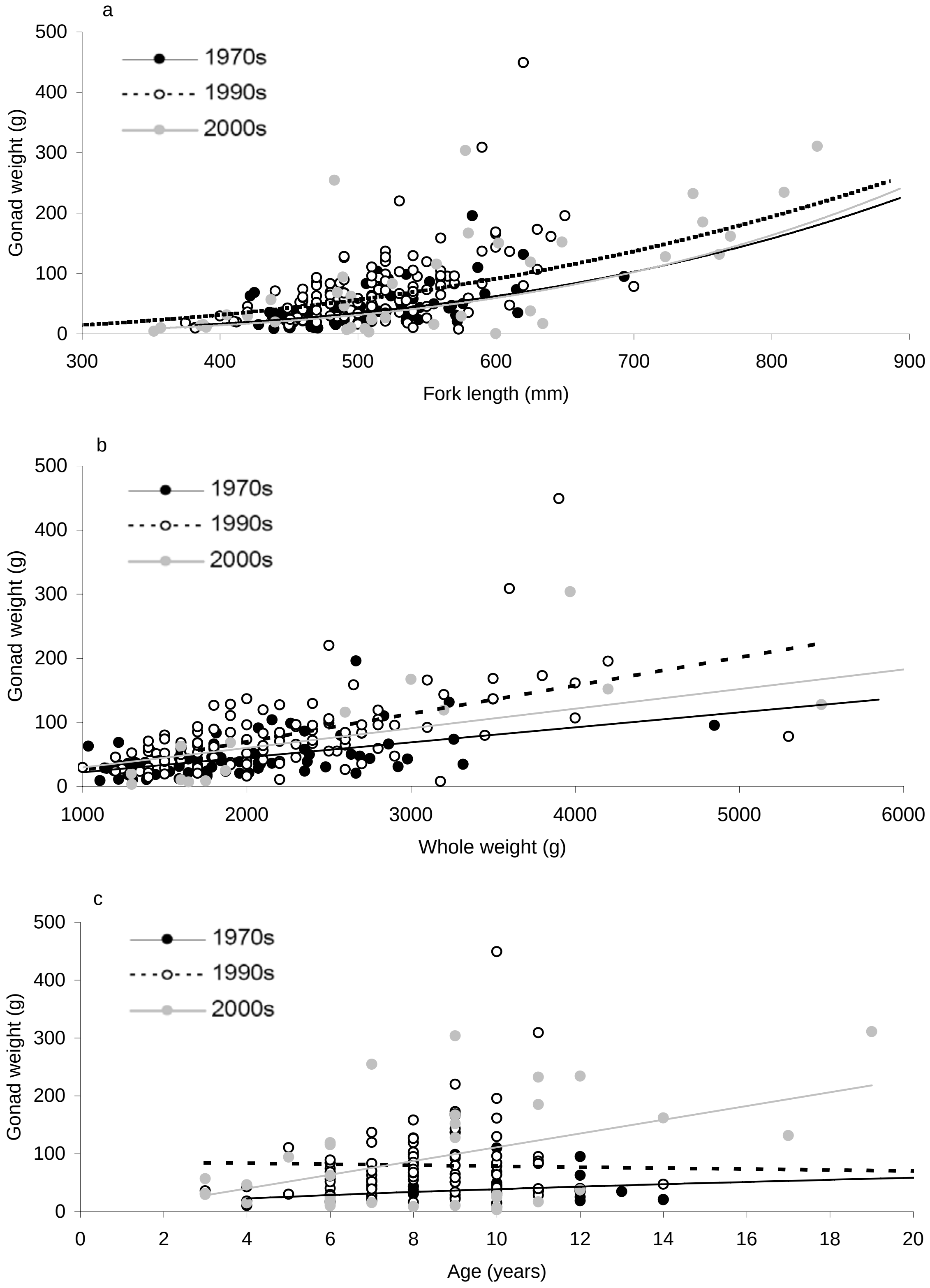

Figure 10. Commercial and recreational landings (1986-2002) of scamp from the northeastern Gulf of Mexico (pers. comm. NOAA/ Fisheries Statistics Division). Commercial landings were not designated by grouper species until 1986.