

***AGE & REPRODUCTION IN THREE REEF –  
DWELLING SERRANID FISHES OF THE  
NORTHEASTERN GULF OF MEXICO  
OUTER CONTINENTAL SHELF:***

***Pronotogrammus martinicensis, Hemanthias vivanus &  
Serranus phoebe (with Preliminary Observations  
on the Pomacentrid Fish, Chromis enchrysurus)***



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***Pronotogrammus martinicensis, Hemanthias vivanus &  
Serranus phoebe (with Preliminary Observations  
on the Pomacentrid Fish, *Chromis enchrysurus****

**Undertaken in Response to Gulf of Mexico OCS  
Natural Resource Information Management Needs  
Of the Minerals Management Service**



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*Cover Photograph:* The tattler, *Serranus phoebe*, a small, ecologically important seabass inhabiting deep OCS reefs in the northeastern Gulf of Mexico (photo credit: USGS CEC Research Group).

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CEC Research Group

## Project Cooperation

This study was undertaken to meet information needs identified by the Department of the Interior, U.S. Geological Survey (USGS), Outer Continental Shelf Ecosystem Program in concert with the Minerals Management Service (MMS). It was undertaken collaboratively by USGS and the Florida Marine Research Institute (FMRI).

## Disclaimer

This report was prepared under the direction of, and in collaboration with, the Florida Integrated Science Center, Center for Aquatic Resource Studies, of the USGS. This report has been technically reviewed by USGS and MMS, and has been approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the USGS or MMS, nor does mention of trade names or commercial products constitute endorsement or recommendation for future use.

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With respect to datasets documenting this report, refer to **Metadata** section within.

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**Abstract.** --- Specimens of the four study species were collected during cruises to outer-continental shelf reefs of the northeastern Gulf of Mexico. Age was estimated for all serranid species using whole otoliths and *C. enchrysurus* ages were determined from transverse sections of sagittal otoliths. Ring structure observed on otoliths was validated as having an annual periodicity for *P. martinicensis* using marginal increment analysis. Ring structure on remaining species was assumed to correspond to age (years). *Pronotogrammus martinicensis*, *H. vivanus*, *S. phoebe*, and *C. enchrysurus* exhibited maximum ages of 9, 8, 5, and 11, respectively. Spatial variations in size-at-age were observed in *P. martinicensis* populations. Individuals inhabiting reefs in the Madison-Swanson Reserve area on the West Florida Shelf edge exhibited the fastest growth rates, while the slowest growing *P. martinicensis* were collected from the Alabama Alps Reef, the farthest west study reef.

*Pronotogrammus martinicensis* and *H. vivanus* are both protogynous hermaphrodites. Evidence of active spawning was observed in the months from February through July for *P. martinicensis*, and March and May for *H. vivanus*. *Serranus phoebe* was observed to be a simultaneous hermaphroditic capable of spawning year-round. Batch fecundity estimates for *P. martinicensis* ranged from 149-394 oocytes per fish.

Size selectivity was evident in our primary sampling method, hook and line using small tandem bait hooks. Smaller size-classes of all species examined were under-represented in our samples, hindering accurate growth modeling. Due to the protogynous nature of *P. martinicensis* and *H. vivanus*, hook and line sampling also tended to select for males. Future descriptions of the reproductive biology of both protogynous species would be more complete if less selective sampling methods could be successfully employed.

The data presented here contribute to a better assessment of the fish community of the northeastern Gulf of Mexico. Little information on age and reproduction was previously available for the serranid and pomacentrid species investigated in the present study. These species are important links between both planktonic or benthic food resources and economically-valuable groupers, snappers, and amberjacks. If a catastrophic natural or anthropogenic event occurred in these outer continental shelf reef habitats, the resultant loss of these forage species would immediately impact regional fish production via the food chain. This would be particularly true for reef-resident commercial and recreational fish species that depend extensively upon a diet of small forage fish species. Recovery to a stable community, fully repopulated with small forage fish species, would require at least a decade, possibly longer if the habitat had been substantially degraded during the initial disturbance.

Over the period of 1997-2002, the U.S. Geological Survey (USGS) undertook a program of investigations to develop knowledge of outer continental shelf (OCS) fish community structure. This program of investigations was conducted by the Coastal Ecology and Conservation (CEC) Research Group, Center for Aquatic Resource Studies, Florida Integrated Science Center, Gainesville, Florida under the auspices of the USGS Outer Continental Shelf

Studies Office. This research program responded to the living resource information needs of the Minerals Management Service (MMS) in relation to its ecological stewardship role on the OCS. Investigations conducted by USGS from 1997-1999 emphasized knowledge of sensitive hard-bottom and deep reef ecosystems in areas of hydrocarbon exploration and development. Beginning in 2000, the USGS CEC Research Group began placing

increased emphasis on integrated oceanographic and comparative biological studies of total ecosystem structure and function. Additional research partners with abiding specialized expertise in this regard were solicited to address specific topics requiring a broad oceanographic perspective, or a pre-existing extended time-series of sampling data.

The outer-continental shelf reefs of the NEGOM are home to many large and well-known species, particularly seabasses [i.e., groupers (Serranidae), amberjacks (Carangidae), and snappers (Lutjanidae)]. However, lesser-known small serranids and species of several other families are numerically dominant on NEGOM deep-reef biotopes (Weaver et al. 2002). Of the small serranids inhabiting NEGOM shelf-edge deep reefs (60-120 m), two anthiine planktivores, the rougthead bass, *Pronotogrammus martinicensis* (Guichenot 1868) (Plate I), and the red barbier, *Hemanthias vivanus* (Jordan and Swain 1885) (Plate I), are dominant (Koenig et al. 2000; Weaver et al. 2002). A third serranid, the tattler, *Serranus phoebe* (Poey 1852), and a damselfish (Pomacentridae), the yellowtail reef-fish, *Chromis enchrysurus*, (Jordan and Gilbert 1882) are also abundant on NEGOM OCS reefs (Koenig et al. 2000, Weaver et al. 2002). Together, these four species are of great ecological importance to the deep reef ecosystem, consuming much of the available biomass of plankton and small mobile epibenthos, and in turn forming a substantial portion of the forage base of larger piscivores.

*Pronotogrammus martinicensis*, *H. vivanus*, and *C. enchrysurus* feed mostly on small zooplankton such as copepods and amphipods (Bullock and Smith 1991, Weaver et al. 2002). In contrast, *S. phoebe* feeds on a variety of small epibenthic crustaceans and small fishes (Bullock and Smith 1991, Robins and Starck 1961, Weaver et al. 2002).

All four species are important prey items for larger reef and pelagic predators. Stomach content analyses have revealed that *P. martinicensis* and *H. vivanus* are preyed upon by commercially important species, including red snapper (*Lutjanus campechanus*) and grouper (*Mycteroperca* spp. and *Epinephelus* spp.) (Bullock and Smith 1991, Weaver et al. 2002). In addition to their ecological importance, *P. martinicensis*, *H. vivanus*, and other small deep-reef species are collected by a small but profitable deep-water marine ornamental fishery. These fish are brightly colored (Plate I) and extremely difficult to collect alive, making them valuable to many aquarists. Individual specimens may sell for more than \$100 each in the overseas aquarium market (Chris Cole, Chris's Marine, LLC, personal communication; Forrest Young, Dynasty Marine Associates, personal communication).

Knowledge of the life history of these forage species is not only crucial to ensuring healthy populations of the individual prey species, but is also important to the multi-species management of the larger, more economically-important fishery species (e.g., groupers, snappers, amberjacks). Currently, most fisheries are managed from a single-species approach based solely on abundance and age/size structure. Trophic interactions and fluctuations in prey density are not included in management analyses. However, recent studies indicate a multi-species approach may better explain population dynamics and spatial shifts in abundance (Read and Brownstein 2003). For example, when herring stocks in the Gulf of Maine collapsed during the 1970's, humpback whale numbers also diminished locally as these predators relocated to areas of higher prey abundance (Payne et al. 1990, Weinrich et al. 1997). Some reef-associated predators, however, may exhibit little emigration from their home reefs (Collins et al. 1996) making

them less likely to relocate in the event of prey shortage. As a result, knowledge of the biology of prey populations such as *P. martinicensis*, *H. vivanus*, and *S. phoebe*, as well as the factors influencing abundance and distribution of these species, is useful to the successful management of the larger predators.

Despite the ecological and economic importance of small serranid forage species, comprehensive information concerning their life history remains scarce. Individuals of *P. martinicensis* and *H. vivanus* begin their life as a female, then change into a male at the onset of some biological or sociological cue (Coleman 1981, Hastings 1981). This sequence of sexual change is termed protogynous hermaphroditism. *Serranus phoebe* has been identified as a simultaneous hermaphrodite, with gonads containing simultaneously active male and female gonad tissue (Smith 1959). In each of these three species, however, a detailed description of reproductive biology has not been generated. Neither has the age-structure or size-structure for any of these species been described. In the present study, we report on these aspects of life history (age and reproduction) for *P. martinicensis*, *S. phoebe*, and *H. vivanus*. Data for the fourth study species, *C. enchrysurus*, are limited, but sufficient to provide a preliminary report on longevity at this time. New life history information for these ecologically key species is discussed in relation to the roles these species play in the NEGOM deep-reef ecosystem.

The present investigation is the result of Florida Marine Research Institute (FMRI) collaboration with the USGS in holistic research on fish communities on the OCS in the Northeastern Gulf of Mexico (NEGOM). The St. Petersburg Laboratory of the FMRI has contributed its special expertise in terms of a long-standing program of life history research on resource and forage fish species of the Gulf of Mexico (GOM). Support to the FMRI from the

USGS OCS Ecosystem Studies Program enabled particular attention to determination of key life history parameters (age and reproduction) of three small, highly-abundant fishes of OCS deep reefs. These fishes form a substantial portion of the forage base of economically important resource species, including snappers and groupers. Thus, knowledge of their longevity, age structure, and age at first reproduction is critically important to understanding the ecology, productivity, and repopulation potential of the food base of deep reef ecosystems in the NEGOM. This knowledge may prove valuable in assessing current and future anthropogenic impacts upon deep reef ecosystems due to harvest of both forage base species and their larger predators, and/or due to habitat disturbance from hydrocarbon exploration and development, or other human enterprises.

## Methods

### *Study Area and Sampling Sites Utilized*

Prior to initiation of the USGS biological component of the planned IOS-NEGOM, the MMS had designated a target study area for the overall program of integrated investigations. This target IOS-NEGOM study area is defined as the large irregular polygon shown in Figure 1. Deep reef-fish community structure investigations undertaken by USGS from 1997-1999 (Weaver et al., 2002) were confined to the "Pinnacles" reef tract within this polygon, but the USGS area of interest was extended eastward beginning in 2000. Thus, samples for life history analyses were obtained from a larger geographic area than the original MMS IOS-NEGOM polygon. Small comparative collections from one western Atlantic site off North Carolina, and from the Florida Keys, supplemented material from the primary NEGOM sampling sites (Table 1).

### Sample Collection

Most material of the four study species was collected during USGS cruises to the outer-continental shelf reefs of the NEGOM from 1997 through 2002 (Figure 2, Table 1). Cruise and reef locations pertaining to geographic variations in *P. martinicensis* size-at-age are described in Tables 1 and 2, respectively. Names of reefs used are not official geographic names, but place names of convenience designated by USGS researchers. Fish were primarily collected by hook and line sampling while anchored over reefs. Small multiple unbaited hook rigs (e.g., Hayabusa Sabiki<sup>®</sup>, and Mustad Piscatore<sup>®</sup> rigs) were dropped to the bottom with weights (6-16 ounces depending on water current and depth), fished vertically just off the substrate, and jigged to imitate zooplankton. A variety of miniature hook sizes (nos. 3, 4, 6, 8, 10) were used; all hook sizes were effective in collecting all three serranid study species. Only the smallest hook sizes were effective for *C. enchrysurus*. The same multiple-hook rigs were also fished baited with small bits of squid; these were effective in capturing *S. phoebe*. A 4.9 m semi-balloon trawl with a 3.8 cm mesh body and a 0.6 cm mesh liner was also used to collect specimens inhabiting soft sediments and the reef rubble apron adjacent to the reef. The trawl was equipped with heavy rock-hopper wooden doors, a "Texas" roller rig consisting of a chain surrounded by 7.6 cm rubber disks hanging across the lower edge of the open trawl mouth, and a heavy codend chafing skirt. This type of rock-hopper rigged trawl was used to reduce hang-ups and trawl damage while sampling over rubble substrates. A remote operated vehicle (ROV) (Phantom S2, Deep Ocean Engineering) equipped with a rotenone pump and suction tube sampler (38.1 mm inner diameter) (Weaver et al. 2002) was also used to collect smaller specimens.

Supplementary study material of small *P. martinicensis* was obtained from the Florida Keys and the North Carolina OCS (Table 1). In the report, they were used solely for increasing sample size of small fish for the length-weight regression. Samples were worked up immediately for four cruises (TM 2001-01, TM 2001-02, TM 2002-01, and DMA-02) with both otoliths and gonads taken from most fish. Otoliths were excised, cleaned, and stored dry. Gonads were removed, preserved in 10% formalin, and returned to the laboratory. During the remaining cruises (TM 1997-01, TM 1998-02, TM 1999-01, TM 1999-02, TM 1999-03, TM 2000-01, TM 2000-02, CSA-03, and JSL-01) most of the specimens collected were frozen, and the remainder preserved in 10% formalin. Sagittal otoliths were removed from the frozen specimens and gonads were excised from the formalin preserved specimens in the laboratory. Total body weight was taken from fresh or frozen specimens and weighed to the nearest 0.1 g. Gonad weight was measured to the nearest 0.01 g from gonads fixed in formalin. All lengths were measured to the nearest millimeter (mm).

### Laboratory Methods

#### Age Structure

In order to validate aging procedures, a subset (n=100) of *P. martinicensis* was aged using both whole and sectioned sagittal otoliths. Transverse sections (500  $\mu$ m thick) taken from the left otolith with a low speed saw (Buehler Isomet<sup>®</sup>) were placed on glass slides and mounted with Fbtexx<sup>®</sup> (Fisher Scientific). Whole right otoliths were immersed in water, distal side up to reduce glare. Sectioned and whole otoliths were viewed through a dissecting microscope using reflected light. Age estimates (number of concentric opaque rings counted on otoliths) generated from whole versus sectioned otoliths showed a 96% agreement in *P.*

*martinicensis*. There was no difference (paired t-test,  $\alpha=0.05$ ) in ages between the two methods used. The four fish receiving different age estimates were different only by a single annulus located on the margin. Because no difference was detected, subsequent ages of all serranid species were determined solely from whole otoliths (methods described above). Whole *C. enchrysurus* otoliths were determined to be unsuitable for aging. No ring structure was visible under reflected or transmitted light. As a result, *C. enchrysurus* otoliths were sectioned and aged as described above. Samples of all species for which ages could not easily be estimated were omitted from analyses.

Annual growth rings (annuli) are regions of denser aragonite deposited during periods of slow growth, January through April (Secor et al. 1991). As growth slows in winter months, otolith growth slows and the result is an opaque band observed under reflected light. The ring structure observed on *P. martinicensis* otoliths was confirmed to be annular (deposited annually) with a marginal increment analysis (Geffen 1982). To validate these rings as annual structures, only *P. martinicensis* with a single, completely formed annulus were used for validation. The distance from the otolith core to the outer edge of the rostrum was measured to the nearest 1.0  $\mu\text{m}$  using a videocamera + monitor system and image analysis software (Optimas 6.0®) attached to a dissecting microscope. The distance from the otolith core to the outer edge of the annulus was subsequently measured, followed by the distance from the outer edge of the annulus to the outer edge of the otolith (marginal increment). Marginal increments were averaged monthly and plotted to determine the time of formation and the number of rings formed in a year. To aid in determining the duration of annulus formation, the location of the outermost annulus was recorded (i.e., is the annulus completely laid down or still being formed?). If

this last annulus was on the edge of the otolith (i.e., still being formed), it was not counted. Ring structure on the remaining study species was unable to be validated as annuli due to limited samples during the Fall and Winter months. For these species, ring structure is assumed to correspond to age (years).

Annual survival rate was estimated from abundance of individuals collected in each year-class (Robson and Chapman 1961). Annual survival was determined by this formula:

$$\text{Annual Survival Rate} = \frac{T}{n + T - 1}$$

Where:

$$n = N_0 + N_1 + N_2 + N_3 + \dots$$

$N_0$  = number of individuals in youngest age-class fully sampled.

$N_1$  = number of individuals in next oldest age-class, etc.

$$T = N_1 + N_2 + N_3 + \dots$$

The modal age-class of each species and older individuals were included in the survival estimate to minimize size biases in sampling methods.

### Reproductive Biology

Gonads were preserved in 10% phosphate-buffered formalin for a minimum of four weeks. Gonads were rinsed out of formalin by soaking twice in tap water for one hour and a third time for at least 12 hours, before being transferred to 70% ethyl alcohol (ETOH) for storage and histology. Preserved gonads were dehydrated in a series of increasing concentrations of ETOH, embedded in paraffin, sectioned along the transverse plane (4  $\mu\text{m}$  thick), and stained with



hematoxylin and eosin. Hermaphroditism in each species was defined following Sadovy and Shapiro (1987). Both *P. martinicensis* and *H. vivanus* are protogynous hermaphrodites, where individuals hatch as females and subsequently transition to males. Individuals of these two species were assigned a developmental stage based upon the most advanced oocyte stage present for functional females (perinucleolar, cortical alveolar, vitellogenic, nucleus migration, and nucleus breakdown) or the amount and proliferation of tailed sperm in functional males. Transitional specimens, individuals with gonads undergoing sexual transformation, were characterized by the presence of tailed sperm and non-regressed or regressing oocytes. Temporal variations in the mean size-at-age of *P. martinicensis* and of *H. vivanus* were made by comparing our samples to those of Coleman (1981) and Hastings (1981), respectively. *Serranus phoebe* is a simultaneous hermaphrodite and was staged as both a male and female when both tissue types were present in histological samples. Macroscopically, testicular material in this species is creamy white and is located on the anterior periphery of the gonad, as well as in lobes protruding into the interior of the gonad. Ovarian material is yellowish in color and dominates the posterior two-thirds of the gonad. Testicular tissue was occasionally omitted from histology samples of *S. phoebe* if the transverse section had been taken too close to the posterior end of the gonad. If testicular tissue was missing, *S. phoebe* was staged solely as a female. For all species, female sexual maturity was determined during the spawning season by the presence of vitellogenic oocytes. Vitellogen is a protein secreted by the liver. It accumulates in yolk globules in the cytoplasm of oocytes when the female is reproductively active (Wallace and Selman 1978). During resting periods, female maturity was determined by the presence of atretic oocytes, indicating prior

spawning had occurred. In addition, the presence or absence of post-ovulatory follicles (POFs) was recorded.

Reproductive periodicity was determined using the POF method (Hunter and Macewicz 1985). Post-ovulatory follicles were assumed to become indistinguishable from other atretic bodies after approximately 24 hours, so their presence as collapsed structures with identifiable thecal and granulosa layers indicated that an individual female had spawned within a day of capture.

### Fecundity Estimates

Gonads containing hydrated oocytes were used to assess the reproductive output for a single spawning event (batch fecundity). The left lobe of each *P. martinicensis* gonad was sectioned for histological examination while the right lobe was used for batch fecundity. Lobe fecundity was estimated by separating hydrated oocytes from the tunic using forceps and a low-pressure water stream in a Petri dish. Once hydrated oocytes were isolated, they were stored in 4% phosphate buffered formalin. Hydrated oocytes were placed in a Petri dish, covered with a 2:1 water:glycerin solution to prevent desiccation, and counted with under a dissecting microscope. Lobe fecundity was used to extrapolate batch fecundity using the formula:

*Batch Fecundity* =

$$\frac{\text{Lobe Fecundity} * \text{Total Gonad Weight}}{\text{Lobe Weight}}$$

Where:

*Lobe Fecundity* = average of six counts of number of hydrated oocytes present in a single gonad lobe. Replicates varied less than 4 oocytes (<2%)/lobe.

*Total Gonad Weight = total weight of the whole gonad (0.001 g).*

*Lobe Weight = total weight of right gonad lobe (0.001 g)*

The gonad structure of *S. phoebe* prevents traditional fecundity methodologies from being used. These gonads are undelimited (male and female tissue is not separated by connective tissue) and the two types of germinal tissue cannot easily be isolated. No hydrated *H. vivanus* were collected during the study.

## Results

### *Pronotogrammus martinicensis*

In total 1,278 specimens of *P. martinicensis* were collected for study (Table 1). Study specimens ranged from 31-143 mm SL and 1-90 g total weight (TW) (Table 1, Figure 3). Ages were determined for 667 *P. martinicensis*. Reproductive biology of the species was described from 318 histological samples. The differing sample sizes are a result of the differing preservation methods used for gonad histology versus otolith aging.

Sagittal otoliths from *P. martinicensis* were easily read whole (Figure 4). Opaque rings on *P. martinicensis* otoliths were confirmed as annuli with a marginal increment analysis (Figure 5). Although there is a drop in the mean marginal increment distance during the month of August, the limited sample (n=3) from this month was collected from the Madison-Swanson Reserve, which displayed unique *P. martinicensis* growth characteristics (i.e., higher growth rate) compared to the other NEGOM populations sampled. In addition, none of these individuals contained an annulus on the margin

(newly forming ring), indicating that rings are indeed deposited once per year.

Age estimates for *P. martinicensis* ranged from age-0 to age-IX (Figure 6). The modal age of *P. martinicensis* collected varied somewhat from reef to reef. Scamp Reef and Roughtongue Reef populations have a mode at age-IV, while samples from all other reefs examined exhibited a mode of age-III. Growth was rapid during the first year and the majority of somatic growth was completed by age-IV (Figure 7). Annual survival of *P. martinicensis* age-IV and older was 27% for all reefs combined.

*Pronotogrammus martinicensis* from the northeastern Gulf of Mexico exhibited spatial differences in growth rate and mean size-at-age (Figure 7). The mean size-at-age of *P. martinicensis* from different study reefs varied greatly. Mean size-at-age was most similar among samples from reefs west of DeSoto Canyon, but differed substantially east of DeSoto Canyon. The largest, fastest growing individuals were found in the Madison-Swanson Reserve area while the smallest, slowest growing individuals were from the population inhabiting the Alabama Alps Reef (Figure 7, Figure 8). Growth differences were detectable only in specimens age-II and older. The mean size of age-IV *P. martinicensis* from the Madison-Swanson Reserve was unique among the reefs examined (Figure 8). The sizes of age-IV fish at Catspaw Reef, Porgy Reef, and Yellowtail Reef were not different from each other, but they were larger than *P. martinicensis* from the Alabama Alps, Roughtongue Reef, and Scamp Reef.

*Pronotogrammus martinicensis* is a protogynous hermaphrodite. The size and age distributions for females were smaller/younger than those of transitional samples, which were smaller/younger than males (Figure 9). Most females aged were age-I or younger while male *P. martinicensis* tended to be age-II or older.

Female *P. martinicensis* collected ranged from 31 to 106 mm SL (Figure 9) and spawn during winter and spring months (February through July) (Table 3). Female reproductive samples were unavailable for the months of January, September, and November. During May the frequency of spawning females was declining; most female ovaries were in a state of regression with atretic bodies prevalent throughout the gonad. No active females were collected between August and January. Females mature in their first year and were reproductively active for all age-classes collected (age-0 to age-IV). Spatial variations in the reproductive biology of *P. martinicensis* were not examined as a result of limited sample sizes.

Batch fecundity of *P. martinicensis* ranged from 149-394 oocytes/spawning event. Females with hydrated oocytes (n=3) ranged in size and age from 55 to 62 mm SL and age-I to age-II. Hydrated females were collected during the months of March and May (Table 3), at which time spawning by some females occurred daily, as was indicated by the coexistence of POFs and hydrated oocytes in the ovary (Figure 10). A single female was also collected during March containing POFs, but oocytes were not in final oocyte maturation (i.e., the individual spawned within 24 hours, however spawning was not imminent that day). No relationship was found between number of hydrated oocytes and either standard length or somatic weight, presumably due to low sample size.

The mean size of transitional *P. martinicensis* collected was 85 mm SL and ranged from 71-104 mm SL (Figure 9). Transitional *P. martinicensis* (n=2) aged were age-II. Transitional specimens were collected during the months of March, May, June, and August. The development of seminiferous tissue initiated on the periphery of the gonad and moved inwards. Temporally the mean size at sexual transition of our samples was not

different than that described by Coleman (1981).

The mean size of male *P. martinicensis* collected in the NEGOM was 100 mm SL and ranged from 65-143 mm SL (Figure 9). Males were found as young as age-I and had a mode of age-III. All *P. martinicensis* older than age-IV examined were found to be males. Tailed sperm were present in all male *P. martinicensis* examined and no trend between month and testicular development was detected. No evidence of primary males was detected (i.e., a lumen was evident in all males) (Figure 10).

#### *Hemanthias vivanus*

The largest *H. vivanus* specimens collected from NEGOM reefs were generally smaller the largest specimens of *P. martinicensis*. Standard lengths and weights ranged between 31-107 mm and 0.5-33.0 g, respectively (Figure 11). Ages were recorded for 211 individuals and reproductive stage was assessed for 174 individuals. The differing sample sizes are a result of the differing preservation methods used for gonad histology versus otolith aging.

*Hemanthias vivanus* have relatively large sagittal otoliths, which were easily aged whole (Figure 12). Individual *H. vivanus* were sampled from multiple age-classes with the oldest fish estimated to be age-VIII (Figure 13). The mean age-class of *H. vivanus* collected were in their third year of growth (age-II), while the mode was in their second year of growth (age-I). Young-of-the-year (YOY= age-0) were under-represented as a result of sampling bias from the use of hook and line gear. To account for this under-representation, annual survival estimates were conducted excluding age-0 individuals. Annual survival for *H. vivanus* age-I and older in the NEGOM was estimated to be 48%.

Standard lengths of *H. vivanus* used for age and growth analysis ranged from 50 to 107 mm. Mean SL increased with number of rings on otoliths until age-II when growth slowed (Figure 14), indicating that the majority of somatic growth occurred during the first two years. The mean SL of age-0 and age-I was most likely over-estimated as a result of sampling bias towards larger specimens.

The smallest and youngest individuals collected were females or transitionals, except for two males, 46 and 62 mm SL. Larger specimens (>77 mm) were entirely male (Figure 15). No *H. vivanus* gonads were observed containing simultaneously active male and female reproductive tissue, indicating that the species is a protogynous and not simultaneous hermaphrodite. Female *H. vivanus* may mature as small as 47 mm SL; no females were observed larger than 76 mm SL. Spawning occurs during the winter and spring months, as POFs were observed during the months of March and May (Table 3; Figure 16). Standard lengths of female and transitional *H. vivanus* indicate that all females examined during this study were age-0 (Figure 14). This indicates that *H. vivanus* spend up to one year as a female after which sexual transformation ensues. No females undergoing final oocyte maturation or hydration were collected; as a result no fecundity estimates were generated.

Gonad transformation begins on the periphery of the ovary and progressively moves inward. The smallest and largest transitional *H. vivanus* observed were 49 mm and 77 mm SL, respectively (mean 67 mm SL) (Figure 15). Otoliths were unavailable for transitional *H. vivanus*, however, age at length data (Figure 14) suggest that these individuals are age-0. No evidence of primary males was detected (i.e., a lumen was observed in all males) (Figure 16). The mean size at sexual transition for our samples was not different than that described by Hastings (1981).

Sexual dimorphism was evident in *Hemanthias vivanus* populations. As individuals grew and underwent sexual transformation the fourth dorsal filament (4D) elongated (Figure 17). The 4D length in female *H. vivanus* ranged from 6-30% of the SL (mean 16%). Transitional and male *H. vivanus* 4D lengths ranged from 8-52% SL (mean 29%) and 11-74% (mean 49%) of the fishes SL, respectively.

### *Serranus phoebe*

*Serranus phoebe* is the largest of the three serranid study species. Individuals collected for the present study (n=392) (Table 1) ranged in size from 43-168 mm SL and 2.5-143.4 g TW (Figure 18). Age and growth analysis was completed using age estimates from 290 individuals, and reproductive data were generated from 206 histological samples. The differing sample sizes are a result of the differing preservation methods used for gonad histology versus otolith aging.

Sagittal otoliths from *S. phoebe* were easily read when viewed whole (Figure 19). Multiple age-classes were observed ranging from age-0 to age-V (Figure 20). *Serranus phoebe* grows rapidly during its first year and maximum size is attained during the fourth year of growth (Figure 21). The modal age of *S. phoebe* was age-II in our samples, with the population mean in their second year of growth. However, the modal age estimate from our sample is probably lower than that of the true population due to size-bias from sampling methods. Annual survival of *S. phoebe* age-II and older was 27%.

*Serranus phoebe* is a simultaneous hermaphrodite with un-delimited gonad structure (i.e., male and female tissue is not separated by connective tissue) (Figure 22). The hermaphroditic nature of *S. phoebe* gonads is readily visible macroscopically. Testicular

material is creamy white and is located on the anterior periphery of the gonad, as well as in lobes protruding into the interior of the gonad. Ovarian material is yellowish in color, and dominated the posterior two-thirds of the gonad. Traditional methods for fecundity determination were unsuitable and could not be applied.

Vitellogenic oocytes were observed in *S. phoebe* as small as 83 mm SL, indicating that *S. phoebe* can mature during their first year of life. Otoliths and gonads were removed from 160 specimens of *S. phoebe*. All individuals of *S. phoebe* age-III and older were reproductively active.

The presence of hydrated oocytes and/or POFs in histological samples during the months of March, May, August, and October reveals that *S. phoebe* spawn throughout much of the year. During the months of March and August 96% of *S. phoebe* in final oocyte maturation contained POFs in their gonads, indicating that *S. phoebe* spawns daily throughout much of the spawning season.

#### *Chromis enchrysurus*

All *Chromis enchrysurus* collected for age and growth analysis (n=56) came from the NEGOM (Table 1). These deep-living planktivores are extremely difficult to capture except with Sabiki-type rigs. Prior to the USGS Pinnacles and NEGOM programs, only a handful of preserved museum specimens were available for study. Standard lengths of NEGOM sampled *C. enchrysurus* ranged from 62-90 mm and TW from 12.4-32.3 g (Figure 23). Total weight was not obtainable from all samples due to variability in sample quality (fins and abdominal cavities were occasionally missing). Reproductive data were not taken since all samples were frozen.

No ring structure was visible on whole otoliths; therefore, age estimates were derived

from sectioned otoliths. Age estimates from *C. enchrysurus* sectioned sagittal otolith (Figure 24) ranged from age-I to age-XI (Figure 25). Standard length was not a good indicator of age for our samples. Little variation was seen in the SL of *C. enchrysurus*, regardless of age, indicating the majority of growth occurs during the first year of life (Figure 26).

## Discussion

### *Age and Growth Rates*

Small prey species are often presumed to be relatively short-lived. A perhaps surprising and significant finding from the present study is that the small serranids dominant on NEGOM reefs were older than their typical inshore forage-fish counterparts. The oldest specimens of *P. martinicensis*, *H. vivanus*, and *S. phoebe* examined were age-IX, age-VIII, and age-V, respectively. Many comparative small prey species from inshore waters, such as ballyhoo (*Hemiramphus brasiliensis*), bay anchovy (*Anchoa mitchilli*), and scaled sardine (*Harengula jaguana*), rarely live beyond one year (Lapolla 2001, McBride and Thurman 2003, Pierce et al. 2001). Other, much larger serranid species such as scamp (*Mycteroperca phenax*), gag (*Mycteroperca microlepis*), and red grouper (*Epinephelus morio*) are relatively long-lived, with maximum observed ages of 30, 21, and 48 years, respectively (Harris et al. 2002, Hood and Schlieder 1992, Johnson and Collins 1994). Age estimates from otoliths of other small serranid species have yielded results similar to ours. Black seabass (*Centropristis striata*) and sand perch (*Diplectrum formosum*) attain maximum ages of seven and six, respectively (Bortone 1971, Hood et al. 1994). Known maximum ages of other reef families (Lutjanidae, Labridae and Pomacentridae) exceed seven years (Burton 2001, Dulcic and Draljevic 1995, Fowler and Doherty 1992, Hood

1999, McBride 2001). Thus, our age estimates for the three serranid species analyzed in the present study are consistent with those for other small reef-fish species.

The spatial variations observed in *P. martinicensis* growth rates for different reef populations deserve further inquiry. Similar variations have also been observed in other serranid species. Populations of *C. striata* off the southeastern United States exhibited latitudinal variations in size-at-age (McGovern et al. 2002). Regional variations have also been observed in the size at sexual transition in another protogynous anthiine, *Anthias squamipinnis* (Fishelson 1975, Popper and Fishelson 1973, Shapiro 1979). In these studies the minimum size at transition for *A. squamipinnis* ranged from 65-100 mm total length. Low sample sizes of female and transitional *P. martinicensis* prevented spatial comparisons of reproductive data.

The factors responsible for spatial variations in *P. martinicensis* growth rates are unknown. However, there are most likely a number of factors influencing this trend. In other aquatic ecosystems, predation, food availability, and quality of the environment have been shown to influence the size structure of fish populations (Paukert et al. 2002). Unfortunately, sufficient coordinated physical and biological habitat parameter data do not exist to determine what factors influence *P. martinicensis* demographics.

An alternative explanation of differential modal fish size for different NEGOM reefs may be the effects of varying anthropogenic impacts from fishing pressure. All NEGOM reefs have been exploited for decades by both the commercial and recreational fisheries. Differential rates of removal of large piscivores may result in differences in abundance, modal size, and behavior of small serranid planktivores.

Whole otoliths proved preferable for use in aging the serranid samples available in the present study. The relatively small size of otoliths examined permitted sufficient reflected light to penetrate the otolith and allowed the denser annuli to be viewed. In sectioned serranid otoliths, the annuli tend to split into two or more rings, which could lead to an over-estimation of age. In whole otoliths, these small imperfections are blended together making the annuli more visible. Most other serranid age estimates available in the literature have been derived from sectioned otoliths. However, previous serranid aging studies have dealt mostly with large species from the commercial fishery (e.g., *E. morio*, *M. phenax*, *M. microlepis*, and *C. striata*) (Harris et al. 2002, Hood and Schlieder 1992, Hood et al. 1994, Johnson and Collins 1994). The much larger otoliths in these species have generally required otolith sectioning in order to count annual rings. Whole sagittal otoliths have been used to age another small serranid, *D. formosum*, in Florida waters (Bortone 1971). Scales have been shown to be less reliable than otoliths because they underestimate ages of fish older than age-VI (Lowerre-Barbieri et al. 1994).

In contrast to the relative ease of identifying annuli on serranid otoliths, *C. enchrysurus* otoliths were considered difficult to age. While concentric rings were visible, they were more difficult to distinguish from one another. Moreover, the limited sample size and lack of *C. enchrysurus* specimens from throughout the year prevented otolith validation in our study. Nonetheless, our age estimates (maximum age=XI) correspond closely with validated ages of other pomacentrids. For example, maximum validated ages for *Pomacentrus moluccensis* and *P. wardi* have been reported as age-IX and age-X, respectively (Fowler and Doherty 1992). Specimens of *C. enchrysurus* of different ages also displayed little variation in SL (Figure 26). Presumably this is a result of sampling bias

from hook and line sampling. As was evident for the other species aged, young *C. enchrysurus* (age-0, age-I, and age-II) are under-represented in our samples. In order to complete an accurate length versus weight regression and validate *C. enchrysurus* otoliths more sampling of this species is needed.

The longevity exhibited by *P. martinicensis*, *H. vivanus*, *S. phoebe*, and *C. enchrysurus* enables an estimate of post-disturbance recovery time for dominant prey fish species and the overall deep-reef ecosystem. For example, if a natural disaster (i.e., hurricane or red tide) or human impact suddenly removed all species from a deep OCS reef, it would take a minimum of nine years for *P. martinicensis* populations to return their previous demographics. This assumes that habitat quality was not fundamentally impaired by the disturbance. However, in the case of an oil spill, recovery may take longer. For example, following an oil spill in a temperate coastal bay, oil residues were still present after six years, and contamination still evident in fish tissue after eight years (Keizer et al. 1978, Stegeman 1978).

### Reproduction

*Pronotogrammus martinicensis* and *H. vivanus* are both protogynous hermaphrodites, as are many other anthiine serranids such as *Anthias squamipinnis*, and *Hemanthias peruanus* (Coleman 1983, Fishelson 1975, Popper and Fishelson 1973, Shapiro 1979). Although previous research had described both species as protogynous (Coleman 1981, Hastings 1981), our study describes the reproductive biology of both species in more detail, and presents one contrary finding. Coleman (1981) described a single *P. martinicensis* as having a gonad with spermatogenesis and oogenesis occurring simultaneously, but in our large sample, we

found no evidence of simultaneous hermaphroditism in this species.

Our determinations of the mean SL of transitional *P. martinicensis* and *H. vivanus* corresponded closely with the lengths at transitions previously reported. Coleman (1981) described transitional *P. martinicensis* as ranging from 73-94 mm SL (mean = 81.6 mm). In our study, transitional *P. martinicensis* from the NEGOM ranged from 71-104 mm SL (mean SL = 85 mm). The mean SL of *H. vivanus* in the NEGOM has not changed in the past 20 years. Hastings (1981) observed transitional specimens ranging from 65-74 mm SL (mean SL = 68.6). Transitional *H. vivanus* collected in our study ranged in SL from 49-77 mm (mean SL = 67 mm).

Our limited fecundity data suggests that body size and weight are not useful indicators of batch fecundity for *P. martinicensis*. Further sampling is required to verify this lack of a trend. The hydrated females collected indicated a potentially narrow size range among spawning females. Together with a limited number of data points, this makes it difficult to model a statistically significant regression. We did not determine batch fecundity estimates for *H. vivanus* or *S. phoebe*. During this study, no hydrated *H. vivanus* were collected, presumably the result of the small size of *H. vivanus* females (< 77 mm SL). *Serranus phoebe* gonads are undelimited and the male tissue is located on the anterior periphery of the gonad. As a result, female and male tissue cannot be easily separated in order to make accurate oocyte counts.

*Serranus phoebe* is a simultaneous hermaphrodite. We found no indications of alternative reproductive modes. *Serranus baldwini* and *S. fasciatus* populations have been described to contain both simultaneous hermaphrodites and larger terminal males (Hastings and Petersen 1986, Petersen and Fischer 1986, Petersen 1987). In contrast, we

found no indication of a terminal male stage in *S. phoebe* populations in the NEGOM. Although all histological samples examined contained ovarian tissue, testicular material was not visible in all histological samples. Nonetheless, *S. phoebe* populations do not appear to contain a solely female reproductive stage. The testicular tissue is located on the anterior section of the gonad and was visible macroscopically in all gonads. During histological processing, male tissue was occasionally, but inadvertently omitted. This depended on the size of the gonad and which side of the transverse section was used for histological slide preparation.

The more detailed knowledge of species life histories developed during the present study provides a better understanding of outer-continental shelf reef ecology. This knowledge also provides insights that may prove useful in fisheries management and conservation. As a result of fishing pressure, many deep-reef ecosystems have experienced temporal changes in the relative abundance of the benthic predators that probably control community structure to a large extent. Benthic predators (e.g., *M. phenax*, *M. microlepis*, *C. striata*, and *Epinephelus niveatus*) declined in relative abundance from 50% to 5% of total observed fish species on Jeff's Reef from 1980-1995, while prey species (*P. martinicensis* and *H. vivanus*) increased in relative abundance from 6% to 71% (Koenig et al. 2000). In recent years, declines in economically-important benthic predators have resulted in a variety of management regulations, ranging from increased size of minimum harvest to the establishment of marine protected areas. By further understanding the interactions between predator and prey species, researchers are better able to predict the causes and effects of these changes in species abundance, thereby facilitating more effective management of marine ecosystems.

## Recommendations and New Research Directions

The most notable problem encountered during this study was the size-selective nature of the sampling methods used. This was evident for all four study species. The youngest age-classes of each species were uniformly under-represented in our samples, biasing attempts to model growth and estimate mortality rates. The protogynous nature of *P. martinicensis* and *H. vivanus* resulted in both size-selective and sex-selective sampling biases. Female and transitional individuals of both species were considerably under-represented in our samples. Since female and transitional specimens are required for assessing the reproductive biology of each species, our reproductive data are not as robust as they might ideally be.

In order to apply conventional growth models (i.e., the von Bertalanffy growth equation) and to further explore the reproductive biology of each species, it will be necessary to sample a broader size range of each target species. Future research should attempt to collect the entire range of lengths exhibited during entire life cycle of each species, specifically young-of-the-year juveniles recently settled to the substrate from the planktonic larvae stage. Many different gears were successfully employed to collect specimens during these cruises (i.e., Sabiki-type angling rigs, otter trawl, ROV suction, hand collection during mixed gas diving, and recovery from predator stomach contents). To increase the numbers of younger stages and smaller sizes, we recommend more sampling with the ROV suction sampler, and the development of small mesh trawling along with large-mesh plankton sampling. We have also found the use of mixed-gas diving to be an effective (if expensive) way to hand collect small stages in the Florida Keys (P. Thurman and R. McBride, FMRI, unpublished data). These techniques





could be applied in future work in the Gulf of Mexico.

The seasonal coverage of our age and reproductive samples was not as complete, or as evenly distributed as would ideally be desired. Sampling cruises tended to focus on the spring and summer months (Table 1), leaving many months inadequately sampled. Better distribution of seasonal sampling would enhance all aspects of this study. Further winter sampling combined with less size-specific sampling methods would collect fish of all species, vastly improving our knowledge of the reproductive biology of all species.

New questions have arisen during the course of the present study. Further investigation of growth rate differences among populations of *P. martinicensis* should address potential genetic differences among these populations – in addition to addressing differential ecological factors. Such a comprehensive approach might determine what genetic, oceanographic, or habitat-specific parameters to the growth rate variation we have documented. In addition, larger sample sizes of *H. vivanus*, *S. phoebe*, and *C. enchrysurus* from individual reefs would permit investigation of spatial differences, as has been possible for *P. martinicensis* in the present study.

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Serranid life history research undertaken by P. Thurman during the present investigation forms a portion of his Master of Science thesis at the University of South Florida, St. Petersburg, FL.

### Metadata & Voucher Material

The USGS NEGOM project study plan, cruise reports, sampling station data, and taxonomic voucher specimens and images documenting this investigation are maintained at the USGS Center for Aquatic Resource Studies, Gainesville, FL: Contact scientist – Kenneth J. Sulak. Otolith preparations, gonad slide preparations, and data documenting this investigation are vouchered at the Florida Marine Research Institute, St. Petersburg, FL: Contact scientist - Richard McBride. An FMRI format metadata file documenting the research resulting in this report is found in Appendix I.

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- Table 1. Data for sampling cruises from which specimens of *P. martinicensis*, *H. vivanus*, *S. phoebe*, and *C. enchrysurus* were collected. Number of specimens indicated for each species is total number from all sampling activities and gear types (Sabiki-type rigs, ROV, predator stomach contents, and mixed gas diving) combined. Key to cruise designations: TM = USGS RV “Tommy Munro” missions, CSA = Continental Shelf Associates RV “Tommy Munro” mission; JSL = DSRV “Johnson-Sea-Link” submersible mission; DMA = Dynasty Marine Associates.
- Table 2. Locations and depth ranges (m) of specific sampling areas investigated for *P. martinicensis* growth rates. Coordinates are for a general reference position within each sampling area. Ranges are for depths from which specimens of *P. martinicensis* were collected.
- Table 3. Spawning seasonality of the Serranidae study species *P. martinicensis*, *H. vivanus*, and *S. phoebe* collected in the NEGOM in the present study and one comparative literature study. Key: X = present study - mature female gonads determined from histological observation of oocytes in final maturation (sexually mature) or post-ovulatory follicles (spent); O = present study – mature or spent female gonads not found; Y = mature females reported in Bullock and Smith (1991); nd = no data, female samples unavailable for the months indicated.

Table 1. Data for sampling cruises from which specimens of *P. martinicensis*, *H. vivanus*, *S. phoebe*, and *C. enchrysurus* were collected. Number of specimens indicated for each species is total number from all sampling activities and gear types (Sabiki-type rigs, ROV, predator stomach contents, and mixed gas diving) combined. Key to cruise designations: TM = USGS RV "Tommy Munro" missions, CSA = Continental Shelf Associates RV "Tommy Munro" USGS contract mission; JSL = DSRV "Johnson-Sea-Link" submersible mission; DMA = Dynasty Marine Associates.

Cruise Designation	Date	Location	<i>P. martinicensis</i>	<i>H. vivanus</i>	<i>S. phoebe</i>	<i>C. enchrysurus</i>
<b>USGS Missions:</b>						
TM 1997-01	August 1997	NEGOM	98	34	51	0
TM 1998-02	October 1998	NEGOM	64	22	23	6
TM 1999-01	February 1999	NEGOM	226	137	22	6
TM 1999-02	May-June 1999	NEGOM	342	71	65	6
TM 1999-03	August 1999	NEGOM	1	0	0	31
TM 2000-01	March 2000	NEGOM	79	41	31	0
TM 2000-02	September 2000	NEGOM	92	64	0	0
TM 2001-01	May 2001	NEGOM	278	134	54	7
TM 2001-02	August 2001	NEGOM	0	0	188	0
TM 2002-01	August 2002	NEGOM	66	18	56	0
Subtotals			1,246	521	490	56
<b>Other Missions:</b>						
CSA-03	August 1998	NEGOM	17	18	2	0
JSL-01	September 2001	Western Atlantic	9	0	0	0
DMA-02	December 2002	Florida Keys	6	0	0	0
Subtotals			32	18	1	0
<b>All Missions:</b>			<b>1,278</b>	<b>539</b>	<b>493</b>	<b>56</b>



Table 2. Locations and depth ranges (m) of specific sampling areas investigated for *P. martinicensis* growth rates. Coordinates are for a general reference position within each sampling area. Ranges are for depths from which specimens of *P. martinicensis* were collected.

Sampling Area Designation*	Latitude N	Longitude W	Depth Range (m)
“Alabama Alps Reef”	29° 15.4’	88° 20.3’	67-73
“Catspaw Reef”	29° 26.4’	87° 35.1’	64-69
Unnamed Low Profile Reef	29° 26.3’	87° 35.2’	64
Madison-Swanson Reserve	29° 11.3’	85° 40.7’	71-83
“Porgy Reef”	29° 26.3’	87° 37.1’	65
“Scamp Reef”	29° 19.4’	87° 46.6’	99-102
“Yellowtail Reef”	29° 27.1’	87° 35.5’	66-99
“Roughtongue Reef”	29° 26.2’	87° 34.5’	62-76

\* Reef names indicated in quotations are USGS names of convenience for designation of long-term study reefs. These are not official geographic place names.

Table 3. Spawning seasonality of the Serranidae study species *P. martinicensis*, *H. vivanus*, and *S. phoebe* collected in the NEGOM in the present study and one comparative literature study. Key: X = present study - mature female gonads determined from histological observation of oocytes in final maturation (sexually mature) or post-ovulatory follicles (spent); O = present study – mature or spent female gonads not found; Y = mature females reported in Bullock and Smith (1991); nd = no data, female samples unavailable for the months indicated.

Species	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<i>P. martinicensis</i>	nd	Y	XY	Y	X	O	Y	O	nd	nd	nd	nd
<i>H. vivanus</i>	nd	nd	X	Y	X	Y	nd	Y	nd	nd	nd	nd
<i>S. phoebe</i>	nd	Y	X	Y	nd	Y	Y	XY	nd	X	nd	nd

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- Figure 3. Standard length (mm) versus weight (g) relationship for *P. martinicensis* collected from the northeastern Gulf of Mexico, Florida Keys, and western Atlantic Ocean from 1997 through 2002 (n=931). Relationship was generated using only fresh and frozen specimens of *P. martinicensis*.
- Figure 4. Digital images of *P. martinicensis* otolith preparations from an individual specimen (SL=116 mm) collected in the NEGOM. A – whole otolith shown distal side up, and B - transverse section of same otolith taken through the dotted line in 'A'. Arrows indicate ring structure representing annual growth rings, or annuli.
- Figure 5. Mean marginal increment in mm ( $\pm 95\%$  confidence intervals) of age-I *P. martinicensis* from NEGOM waters. Data are pooled from multiple years (1997-2002) and locations sampled (Table 3) throughout the study period. The shaded region indicates the period of annulus formation.
- Figure 6. Histogram (percent frequency of individuals aged) of *P. martinicensis* age-classes from NEGOM samples (n=667). Ages are based on number of opaque rings resolved in whole sagittal otoliths viewed beneath a dissecting microscope using reflected light.
- Figure 7. Mean standard length (SL) in mm,  $\pm 95\%$  confidence intervals, at age for *P. martinicensis* from NEGOM reef habitats. Age estimates are derived from whole sagittal otoliths viewed with reflected light. Age-0 *P. martinicensis* were not included in the analysis since daily ages were not available (curves have been extended back to a theoretical zero origin). Mean SL of age-IV *P. martinicensis* (shaded region) is presented in Figure 8.

Figure 8. Mean standard length in mm of age-IV *P. martinicensis* from NEGOM reefs. Error bars are  $\pm 95\%$  confidence intervals. Reefs are listed in order of increasing mean SL in *P. martinicensis*.

Figure 9. Percent frequency of female, transitional, and male *P. martinicensis* classes from the NEGOM (all reefs combined): A - standard length classes in 10 mm increments; B - age-classes is years estimated from reading of whole sagittal otoliths. Sex was determined through histological examination of gonad tissue.

Figure 10. Histological features of *P. martinicensis* gonad development. Partial cross section from (A) mature female; (B) transitional, and (C) mature male. Major stages of gonad development are indicated by capital letters; cortical alveolar (C), hydrated oocyte (H), perinucleolar (P), post-ovulatory follicle (POF), tailed sperm (T), vitellogenic oocyte (V). All scale bars are 0.250 mm.

Figure 11. Standard length (mm) versus weight (g) relationship for *H. vivanus* collected in the NEGOM from 1997 through 2002 (n=279). Relationship was generated using only fresh and frozen specimens of *H. vivanus*.

Figure 12. Digital image of whole sagittal otolith (shown distal side up) from an age-VI specimen of *H. vivanus* (SL = 84 mm) collected in the NEGOM. Arrows indicate ring structure representing annual growth rings, or annuli.

Figure 13. Histogram (percent frequency of individuals aged) of *H. vivanus* age-classes from NEGOM samples (n=211). Ages are based on number of opaque rings resolved in whole sagittal otoliths viewed beneath a dissecting microscope using reflected light.

Figure 14. Mean standard length (SL) in mm,  $\pm 95\%$  confidence intervals, at age for *H. vivanus* from NEGOM reef habitats (n=211). Age estimates are derived from whole sagittal otoliths viewed with reflected light.

Figure 15. Percent frequency of female, transitional, and male *Hemanthias vivanus* standard length classes (in 10 mm increments) from the NEGOM (all reefs combined). Sex was determined through histological examination of gonad tissue.

Figure 16. Histological features of *H. vivanus* gonad development. Partial cross-section from (A) mature female; (B) transitional, and (C) mature male. Major stages of gonad development are indicated by letters in white boxes + arrows: cortical alveolar (C), hydrated oocyte (H), perinucleolar (P), post-ovulatory follicle (POF), tailed sperm (T), vitellogenic oocyte (V). All scale bars are 0.250 mm.

Figure 17. Secondary sexual expression in *H. vivanus*: Length of 4<sup>th</sup> dorsal filament expressed as proportion of standard length for NEGOM collected specimens. Sex was determined by histological examination of gonad tissue.

Figure 18. Length-weight relationship for *S. phoebe* collected in the NEGOM from 1997 through 2002 (n=392). Relationship was generated using only fresh and frozen specimens of *S. phoebe*.

Figure 19. Digital image of whole sagittal otolith (shown distal side up) from an age-V specimen of *S. phoebe* (SL = 141 mm) collected in the NEGOM. Arrows indicate ring structure representing annual growth rings, or annuli.

Figure 20. Histogram (percent frequency of individuals aged) of *S. phoebe* age-classes from NEGOM samples (n=290). Ages are based on number of opaque rings resolved in whole sagittal otoliths viewed beneath a dissecting microscope using reflected light.

Figure 21. Mean standard length (SL) in mm,  $\pm 95\%$  confidence intervals, at age for *S. phoebe* from NEGOM reef habitats (n=290). Age estimates are derived from whole sagittal otoliths viewed with reflected light.

Figure 22. Histological features of *S. phoebe* gonad development. Partial cross section from a mature active individual. Major stages of gonad development are indicated by capital letters; cortical alveolar (C), hydrating oocyte (H), perinucleolar (P), post-ovulatory follicle (POF), tailed sperm (T). Scale bar is 0.250 mm.

Figure 23. Standard length (mm) versus total weight (g) relationship for *C. enchrysurus* collected in the NEGOM (n=48). Relationship was generated using only fresh and frozen specimens of *C. enchrysurus*. No regression was generated as a result of the very limited length distribution available for analysis.

Figure 24. Digital image of sectioned sagittal otolith (shown distal side up) from an age-VI specimen of *C. enchrysurus* (SL = 78 mm) collected in the NEGOM. Arrows indicate ring structure representing annual growth rings, or annuli.

Figure 25. Histogram (percent frequency of individuals aged) of *C. enchrysurus* age-classes from NEGOM samples (n=31). Ages are based on number of opaque rings resolved in transverse sections (500  $\mu\text{m}$  thickness) of sagittal otoliths viewed beneath a dissecting microscope using reflected light.

Figure 26. Distribution of SL (mm) versus age-class for *C. enchrysurus* collected in the NEGOM. Age-class was derived from number of opaque rings (= presumed annuli) observed on transverse sections (500 $\mu\text{m}$  thickness) of sagittal otoliths.

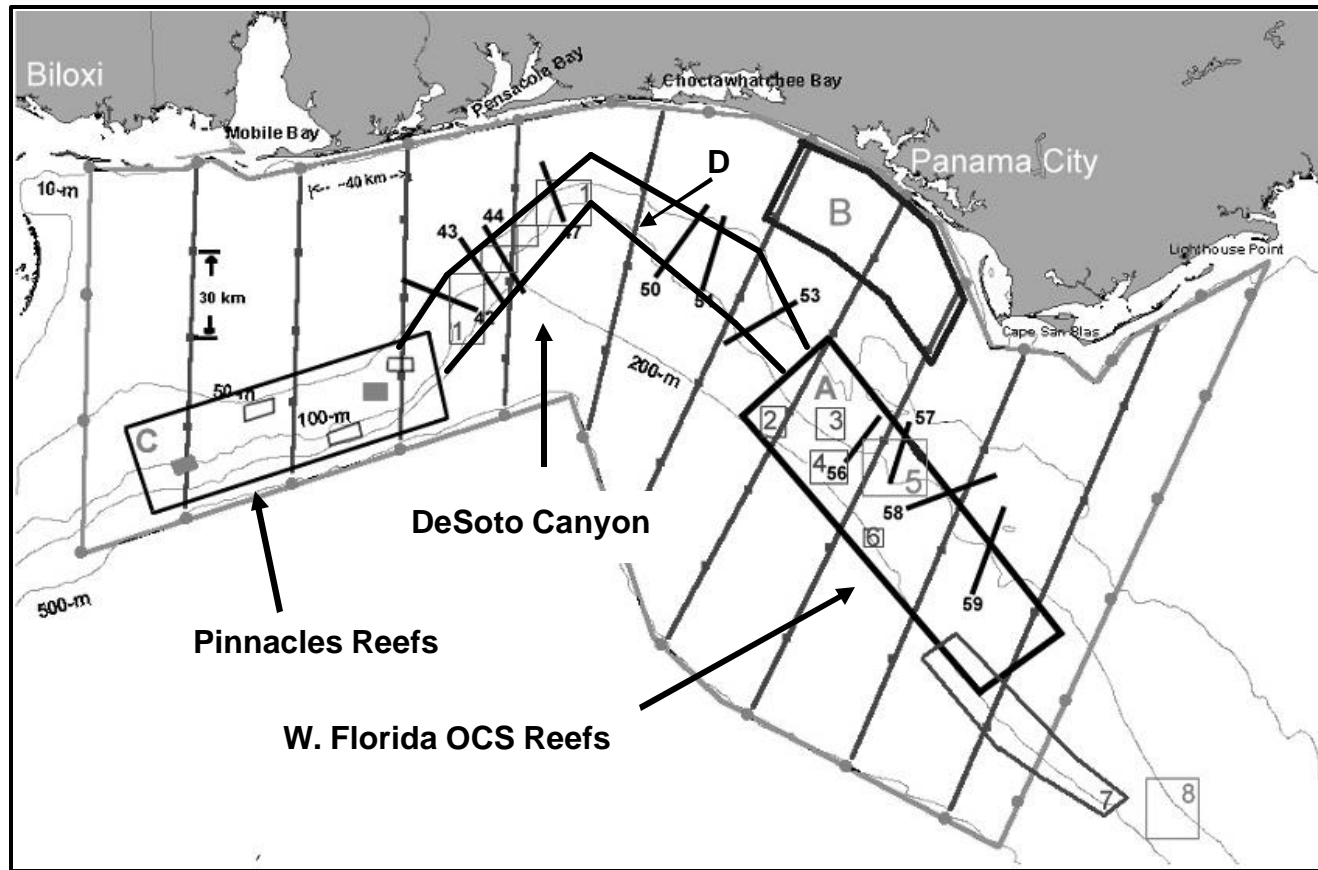


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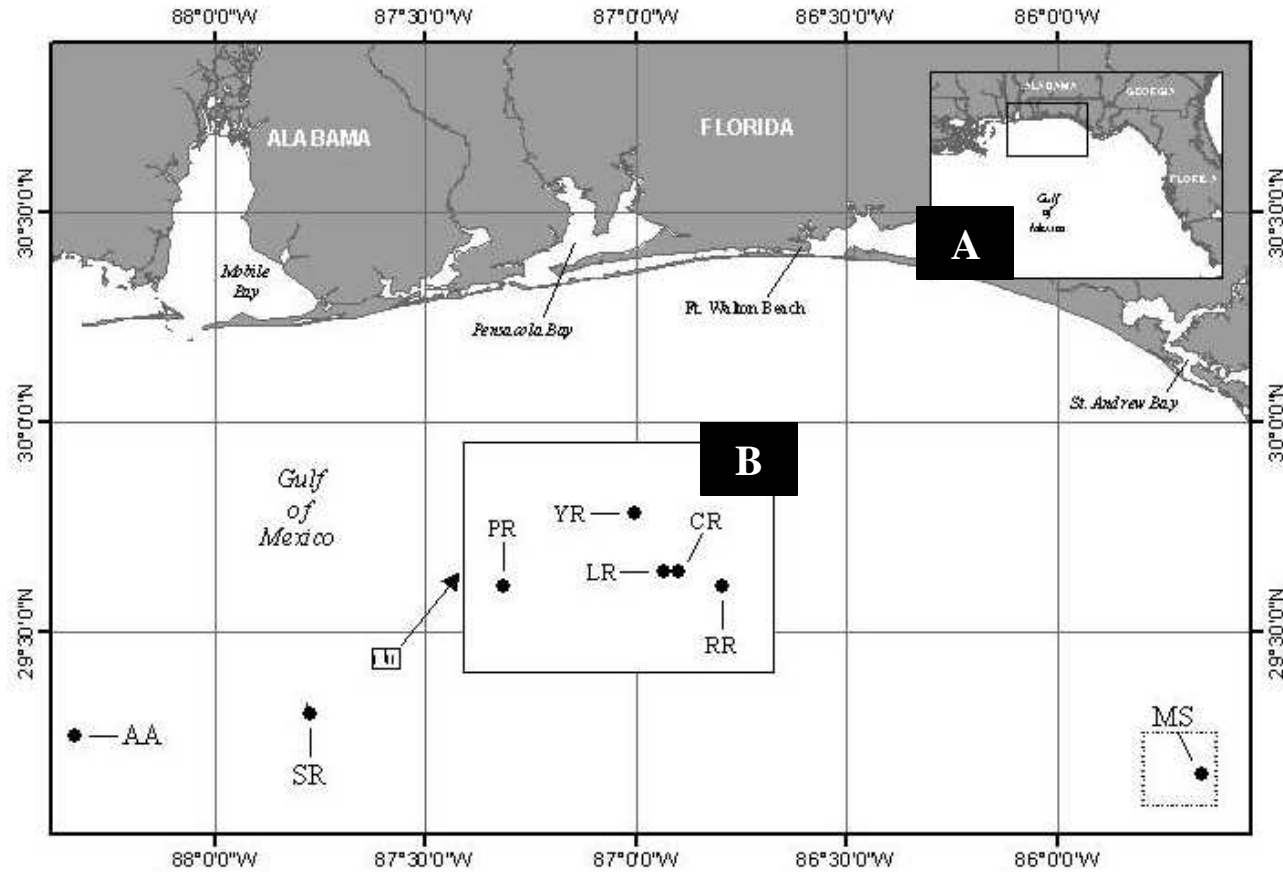


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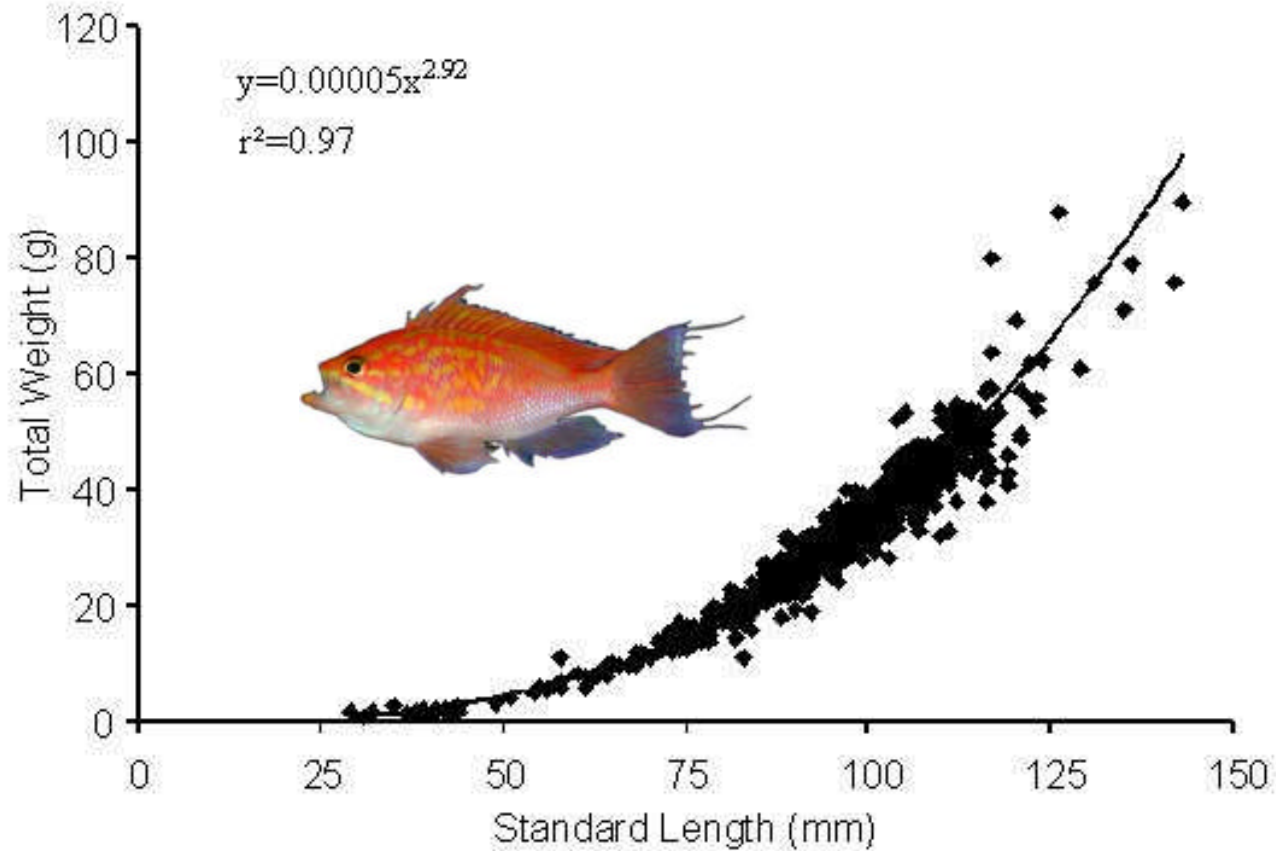


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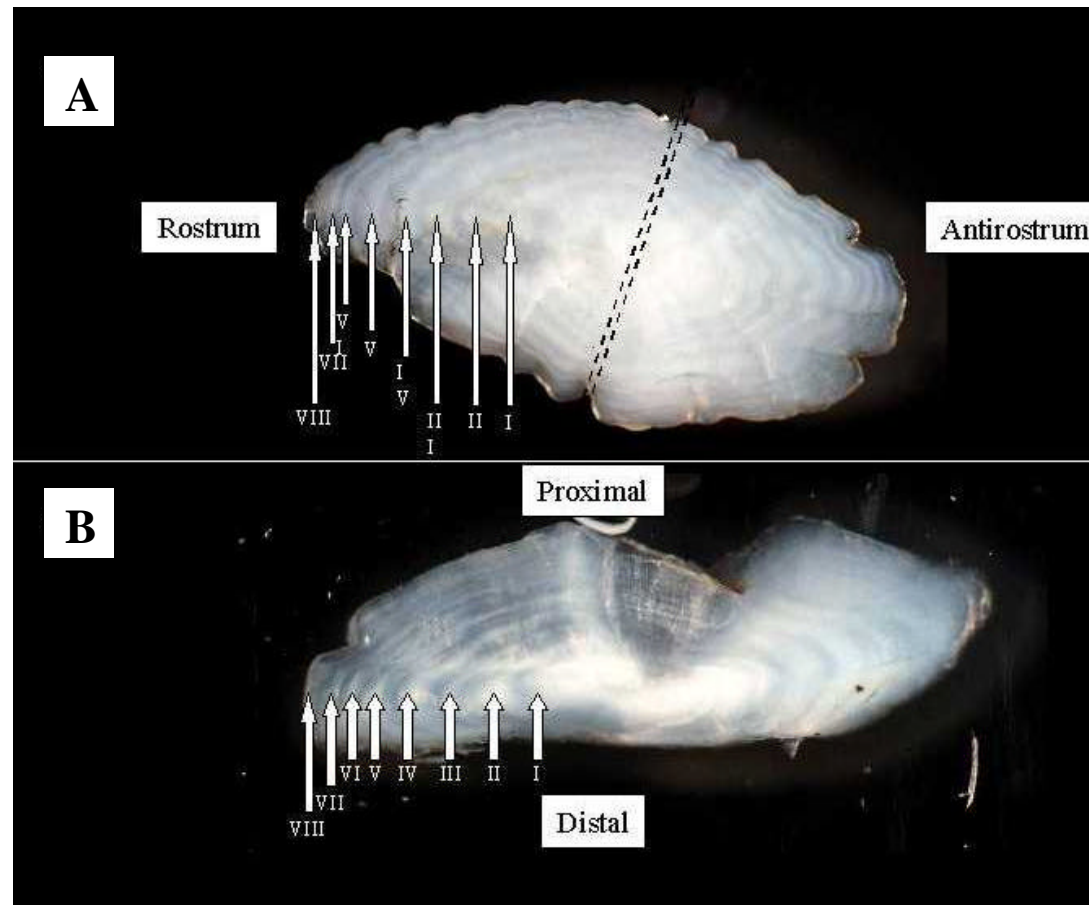


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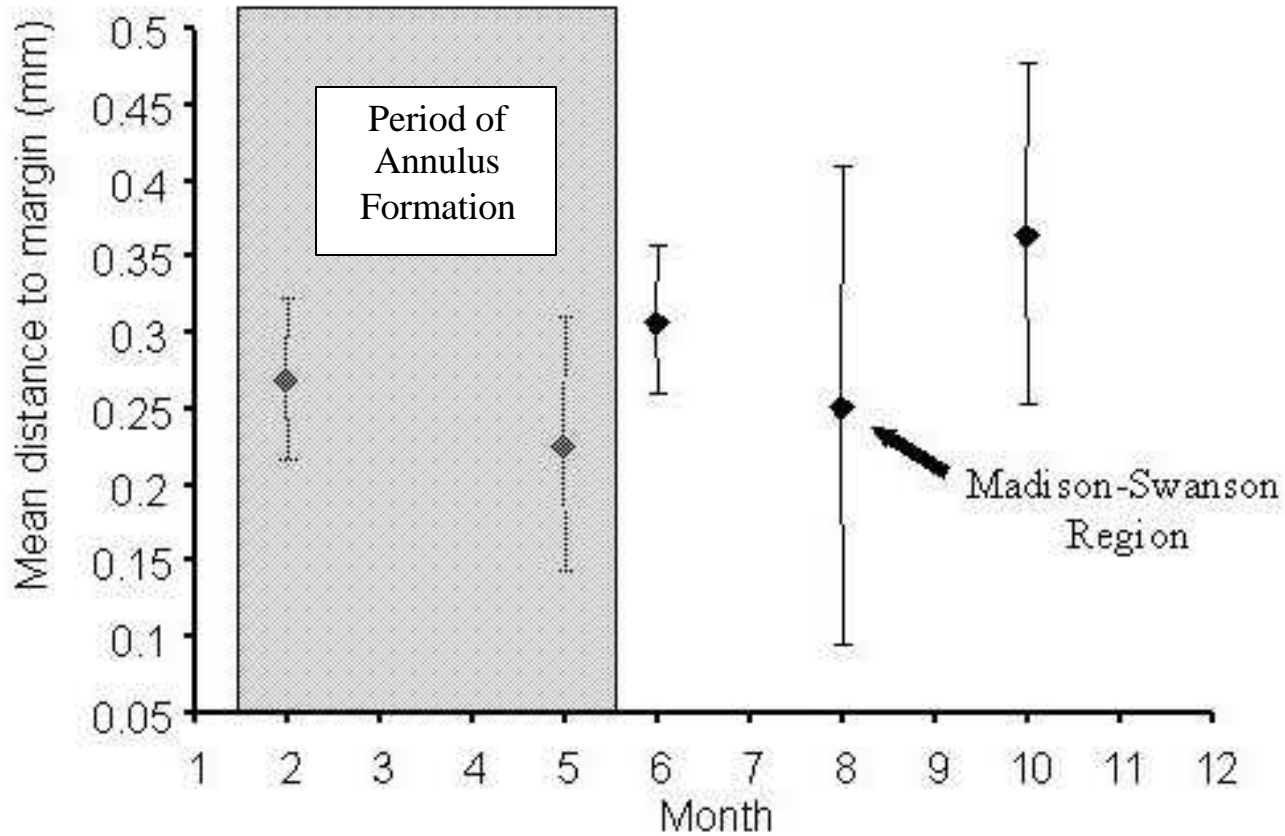


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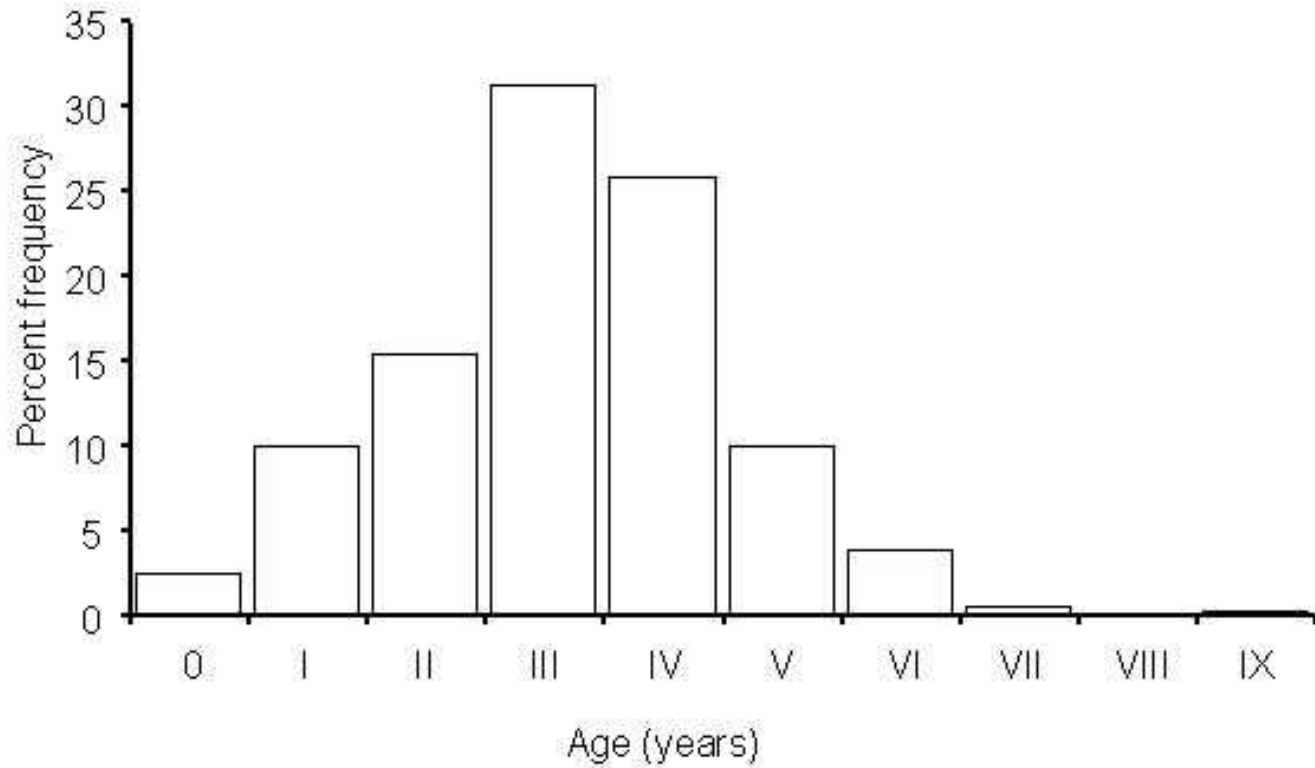


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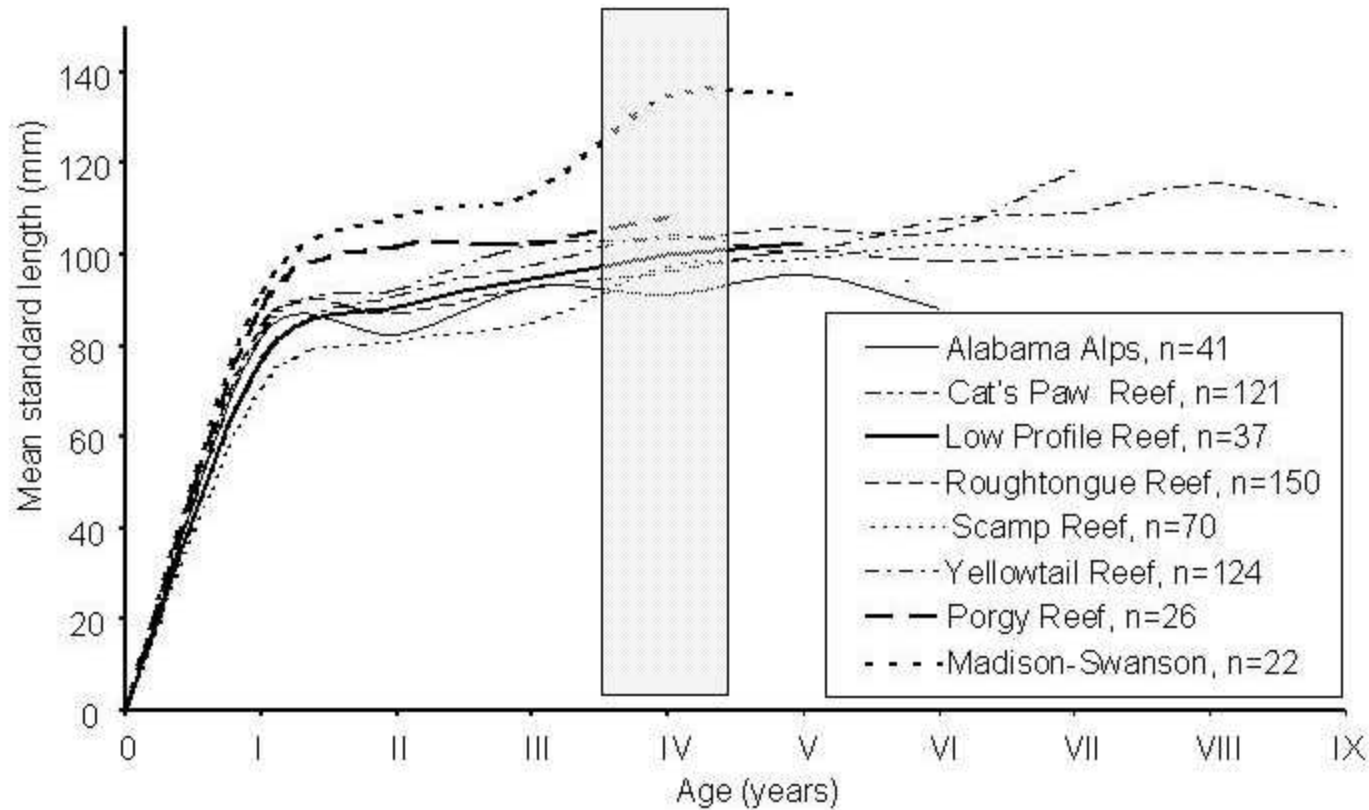


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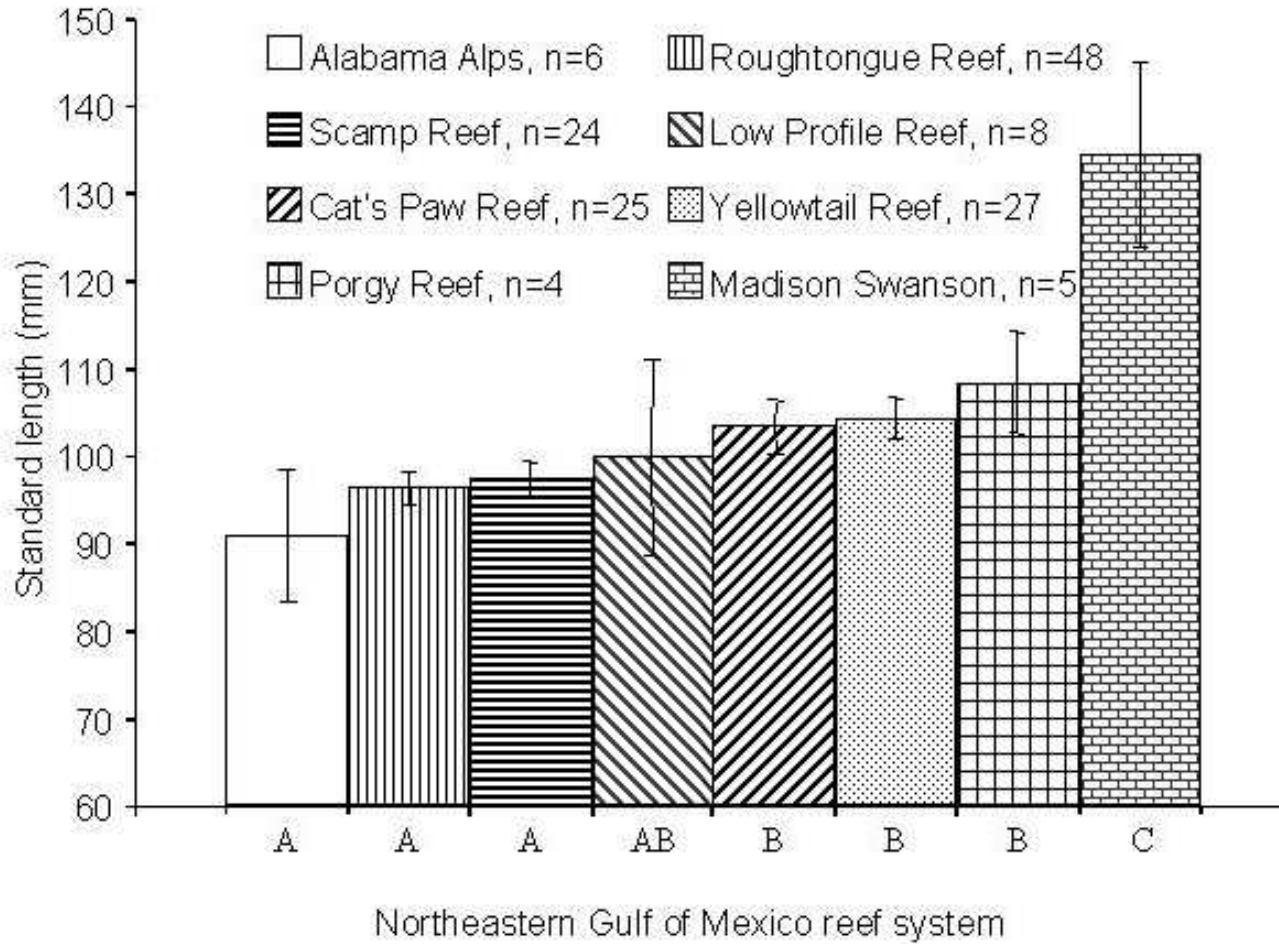


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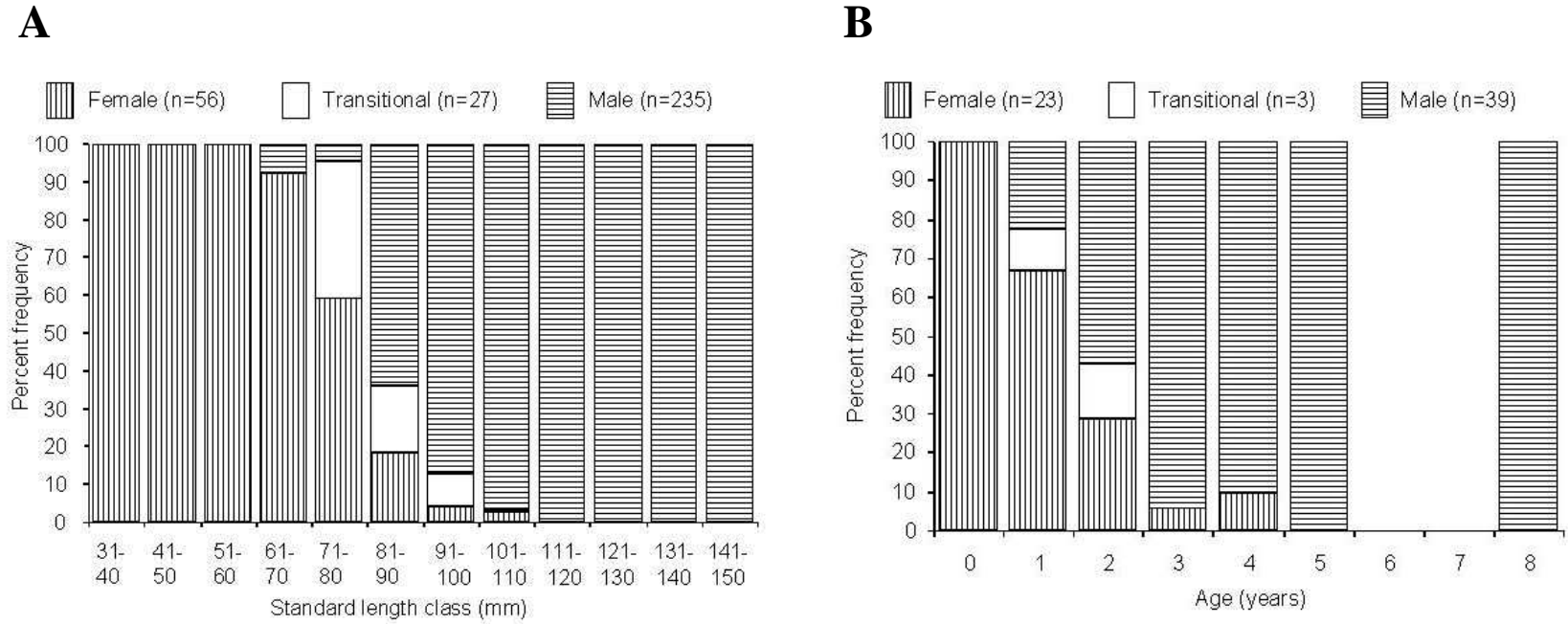


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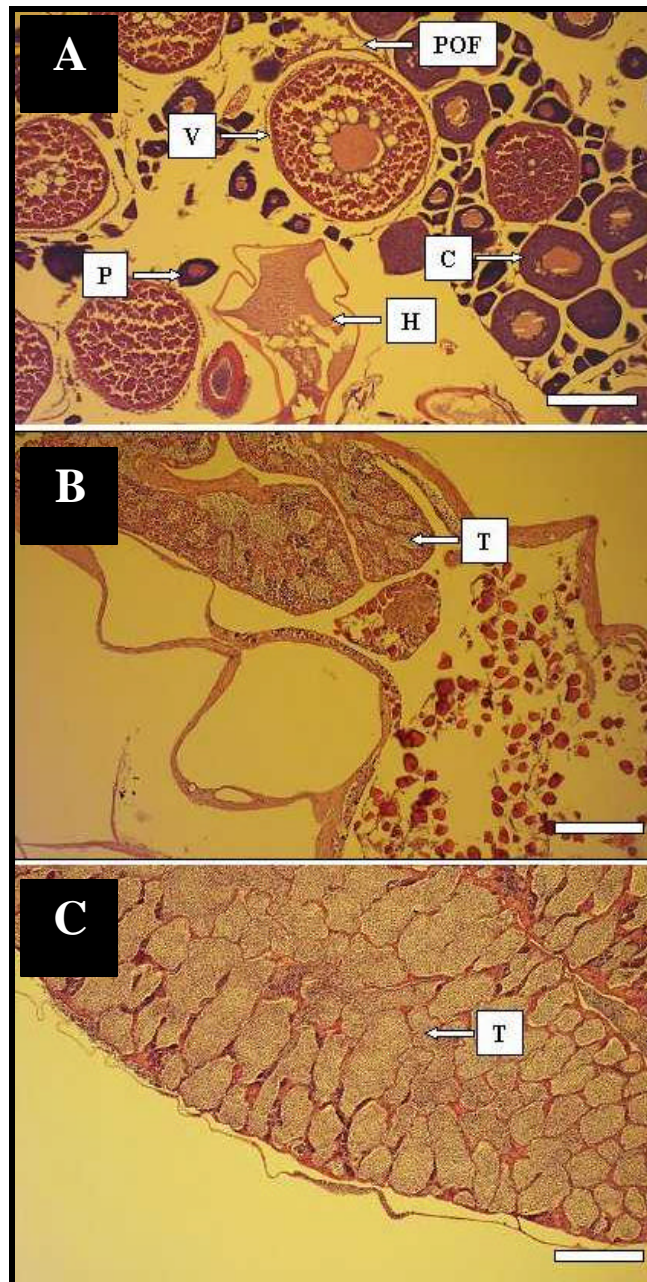


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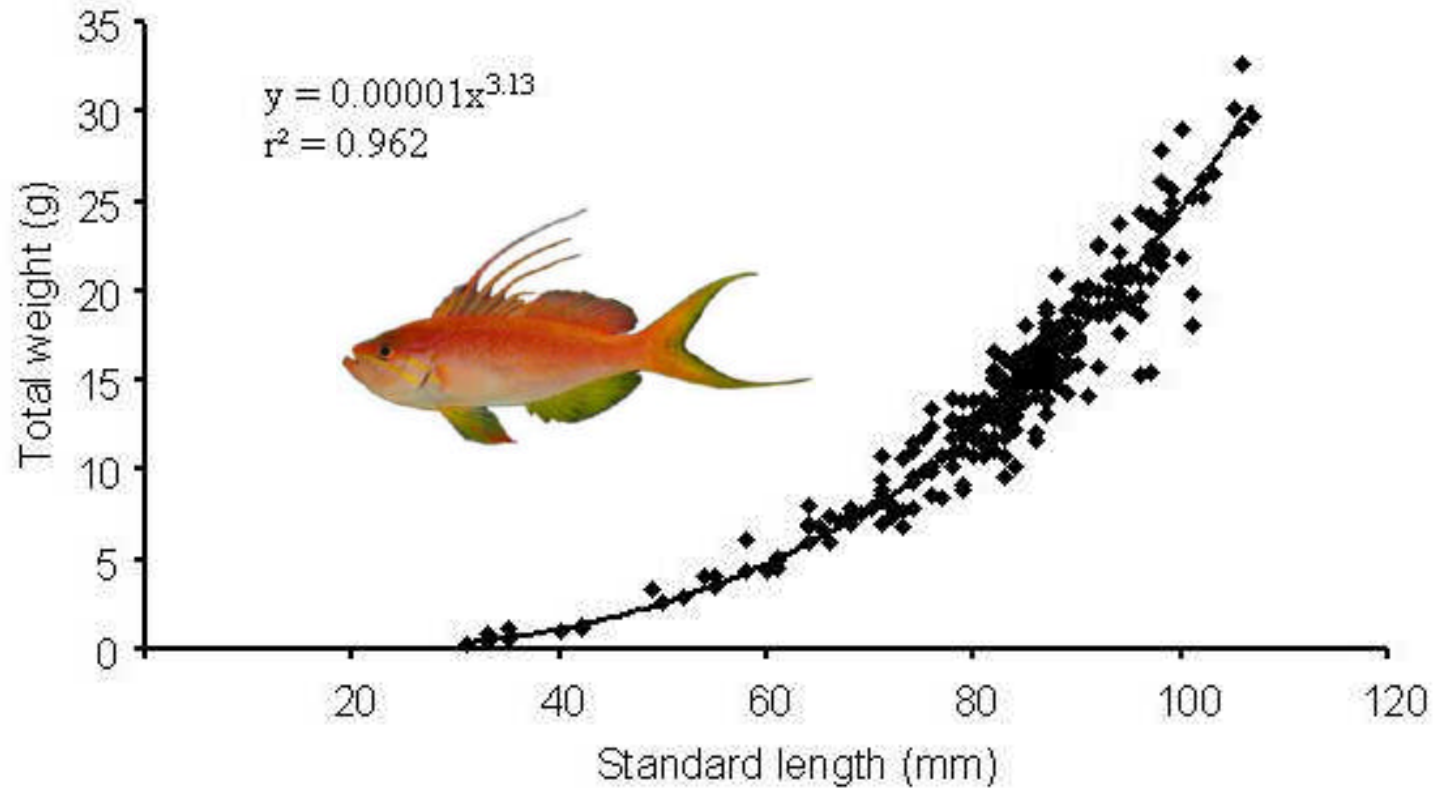


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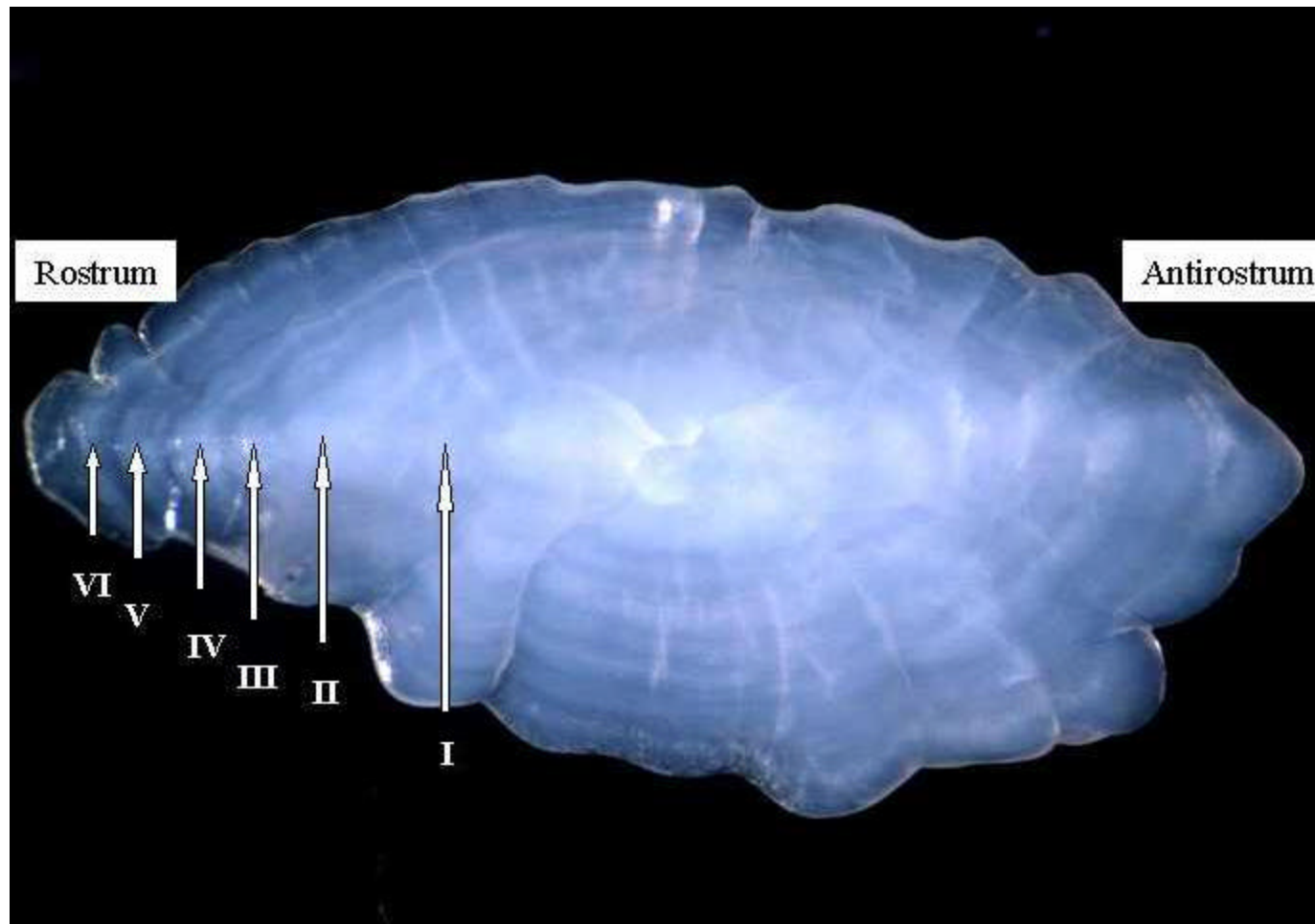


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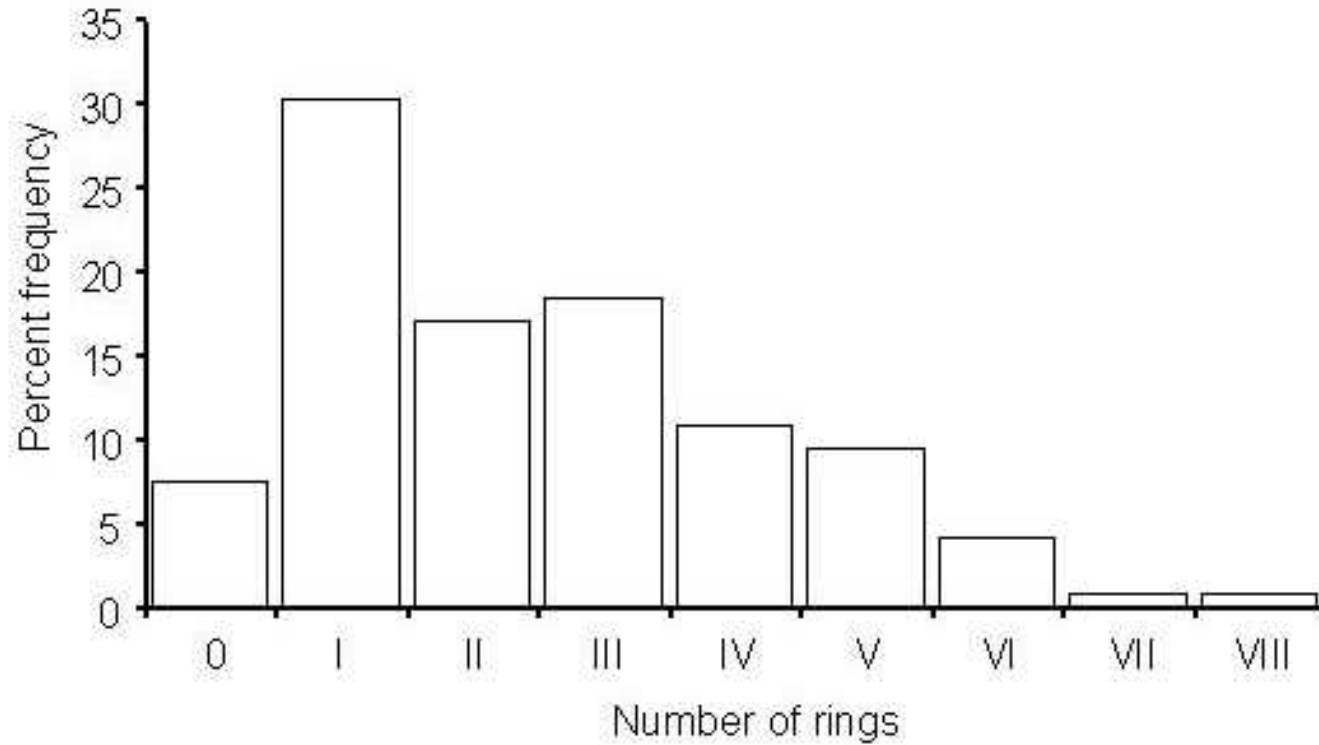


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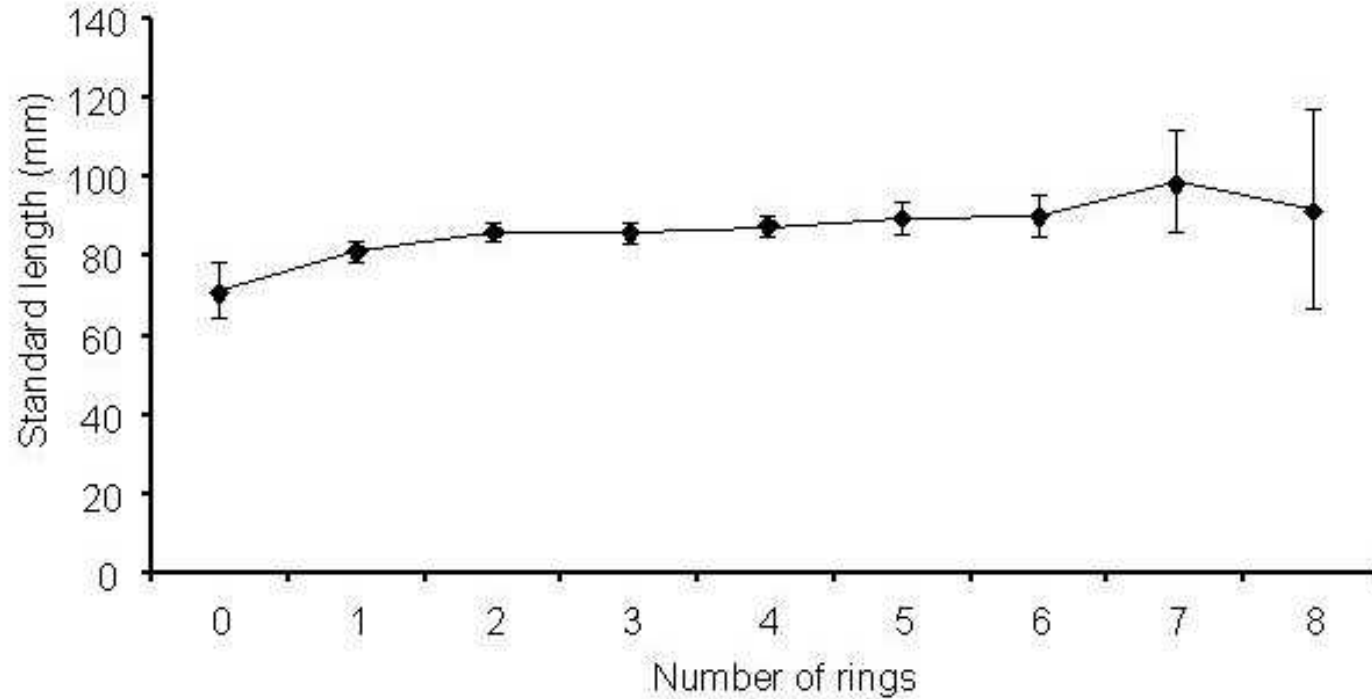


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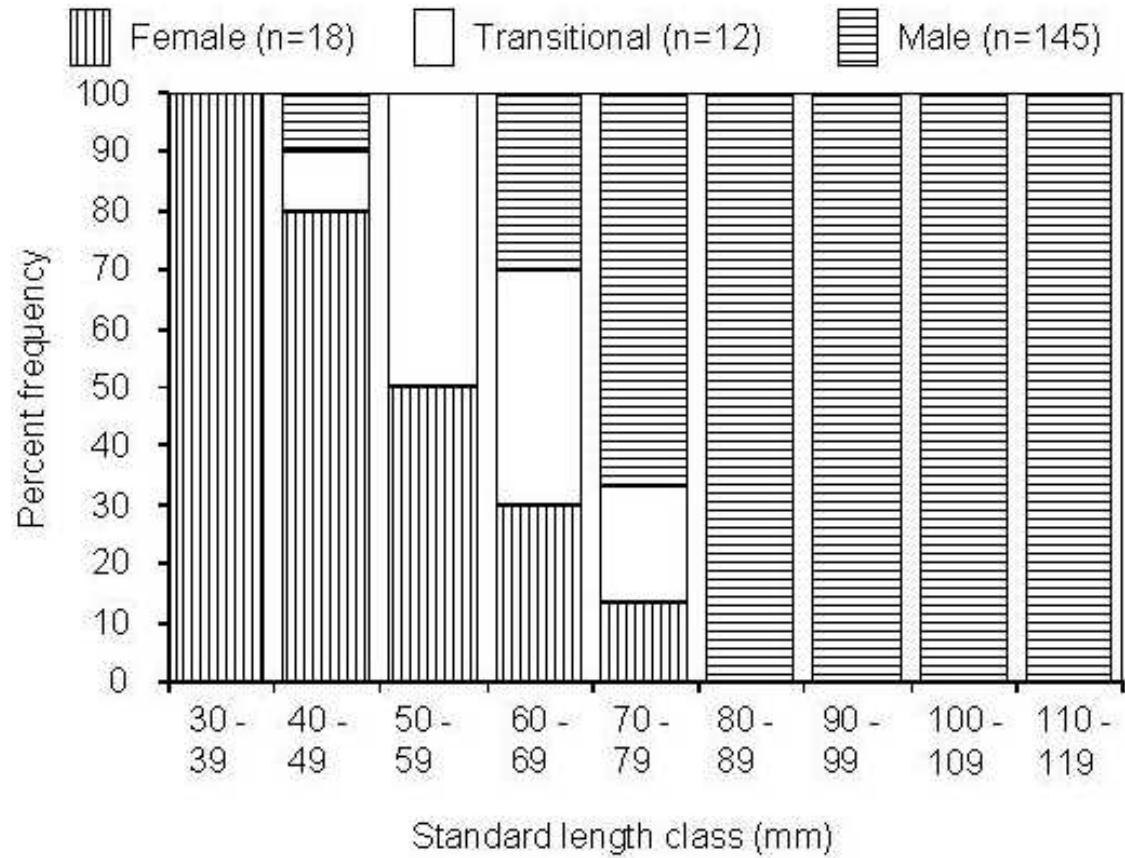


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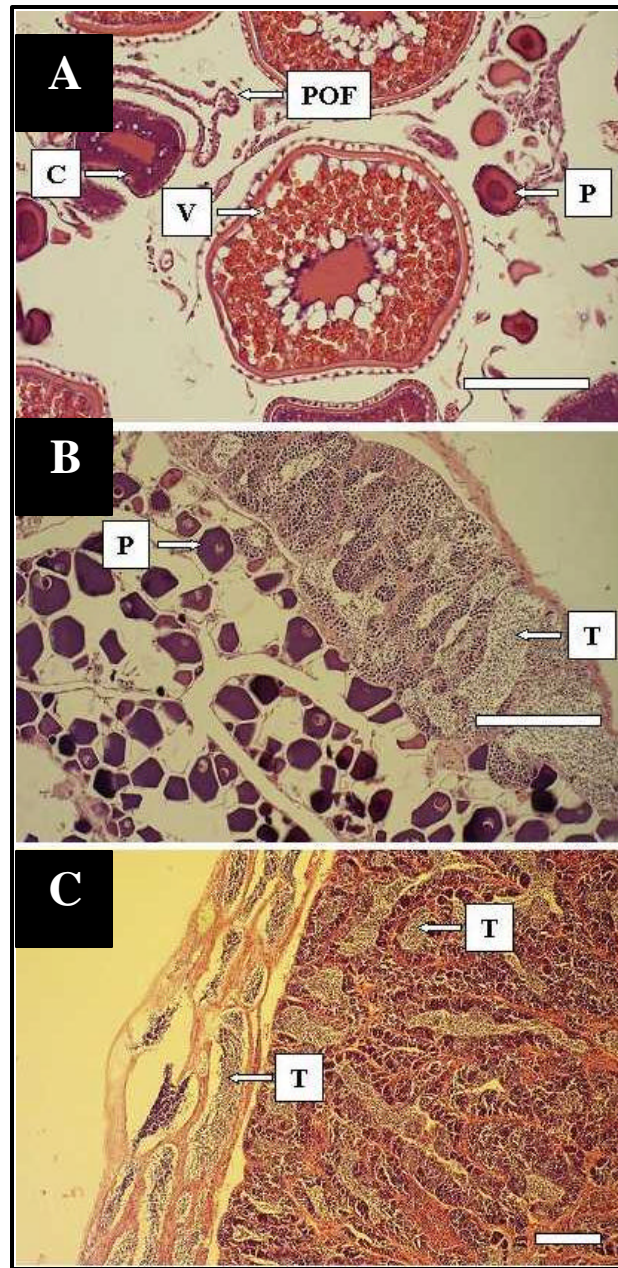


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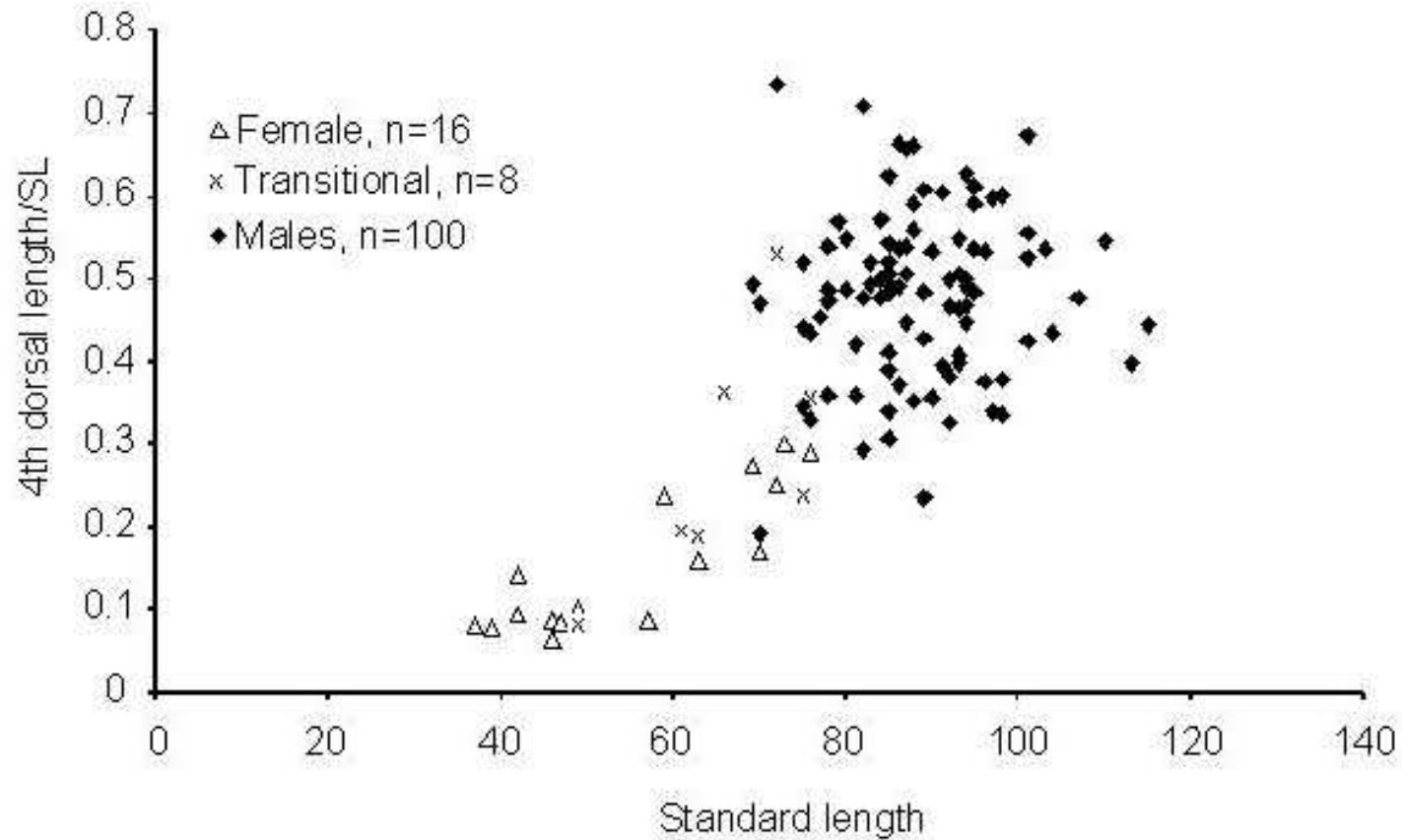


Figure 17. Secondary sexual expression in *H. vivanus*: Length of 4<sup>th</sup> dorsal filament expressed as proportion of standard length for NEGOM collected specimens. Sex was determined by histological examination of gonad tissue.

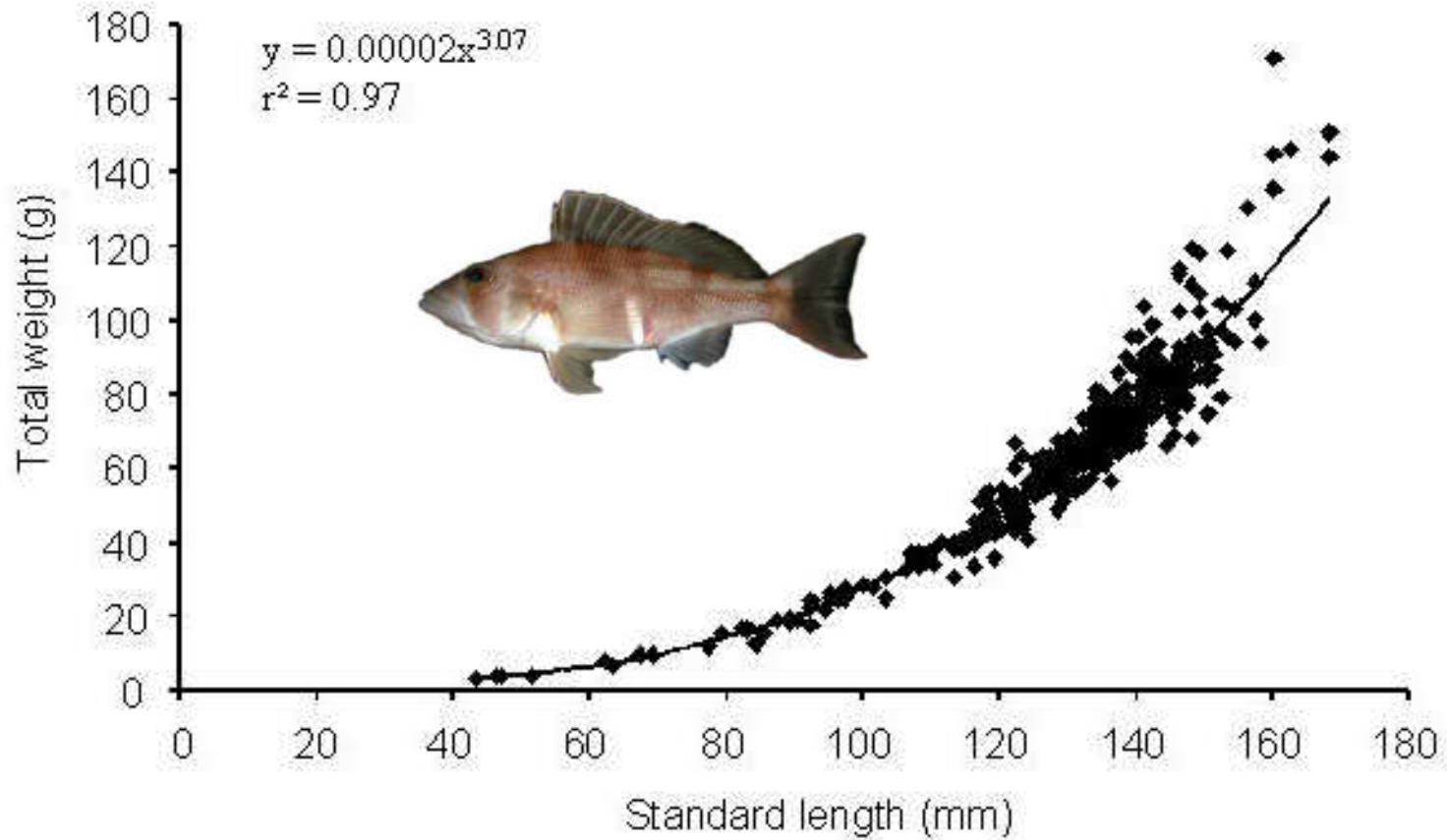


Figure 18. Length-weight relationship for *S. phoebe* collected in the NEGOM from 1997 through 2002 (n=392). Relationship was generated using only fresh and frozen specimens of *S. phoebe*.



Figure 19. Digital image of whole sagittal otolith (shown distal side up) from an age-V specimen of *S. phoebe* (SL = 141 mm) collected in the NEGOM. Arrows indicate ring structure representing annual growth rings, or annuli.



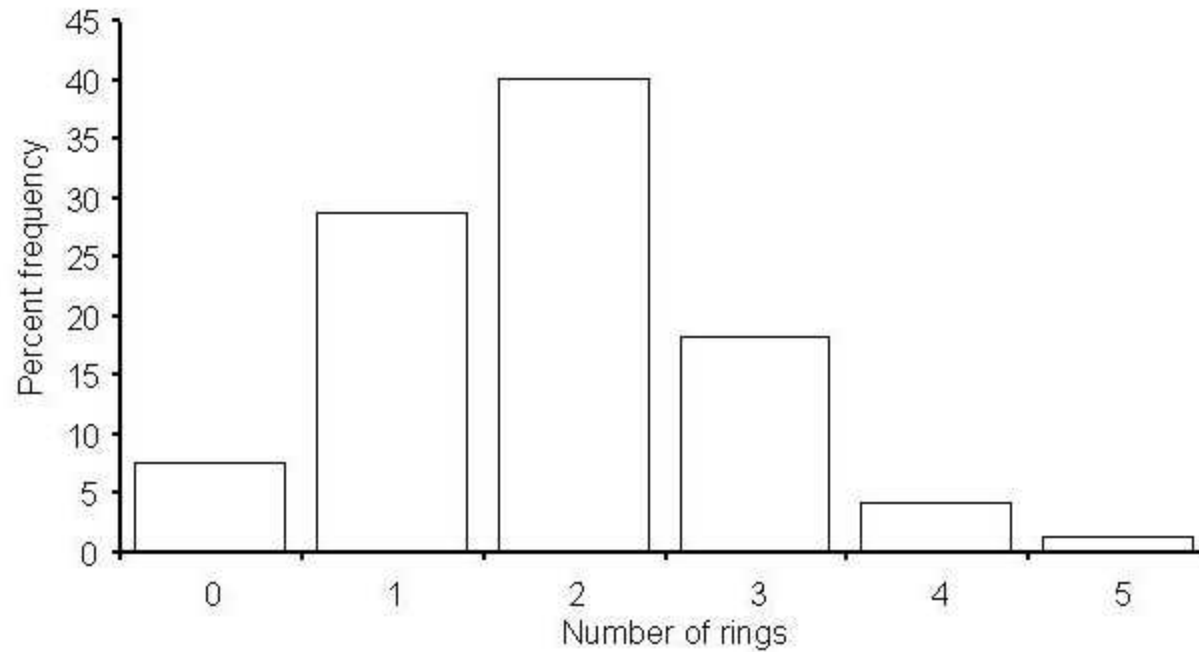


Figure 20. Histogram (percent frequency of individuals aged) of *S. phoebe* age-classes from NEGOM samples (n=290). Ages are based on number of opaque rings resolved in whole sagittal otoliths viewed beneath a dissecting microscope using reflected light.

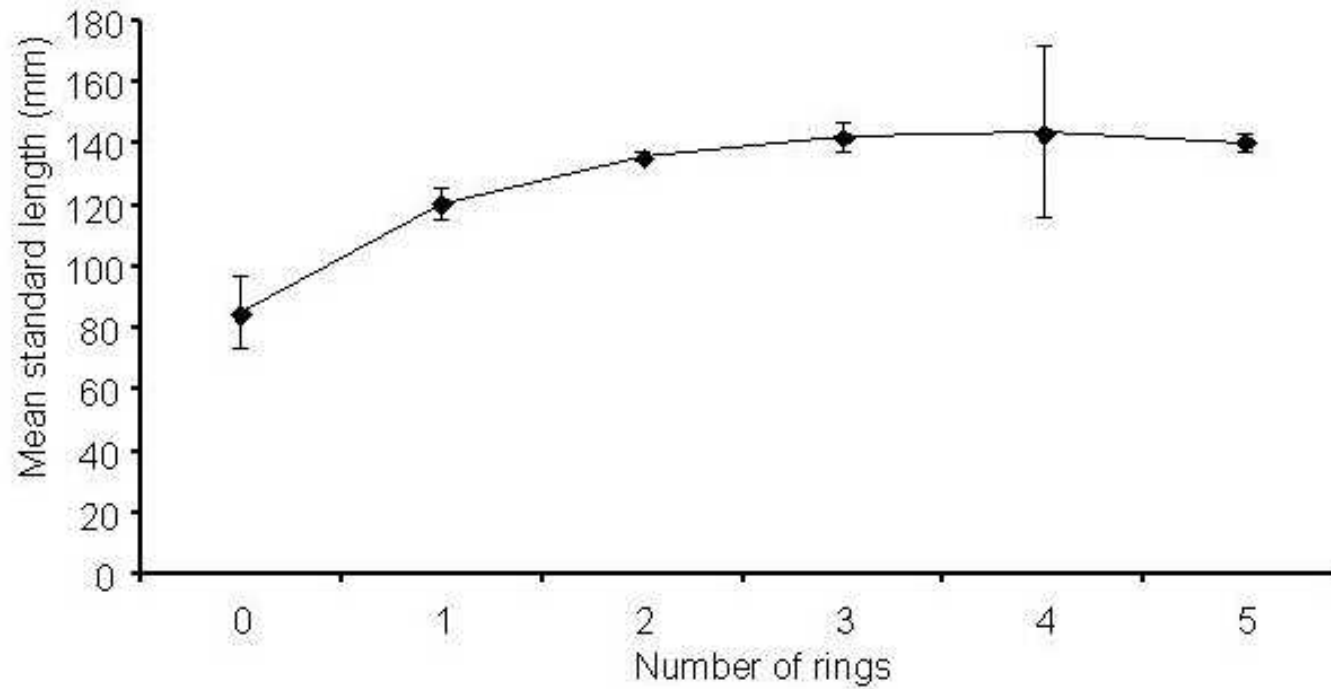


Figure 21. Mean standard length (SL) in mm,  $\pm 95\%$  confidence intervals, at age for *S. phoebe* from NEGOM reef habitats (n=290). Age estimates are derived from whole sagittal otoliths viewed with reflected light.

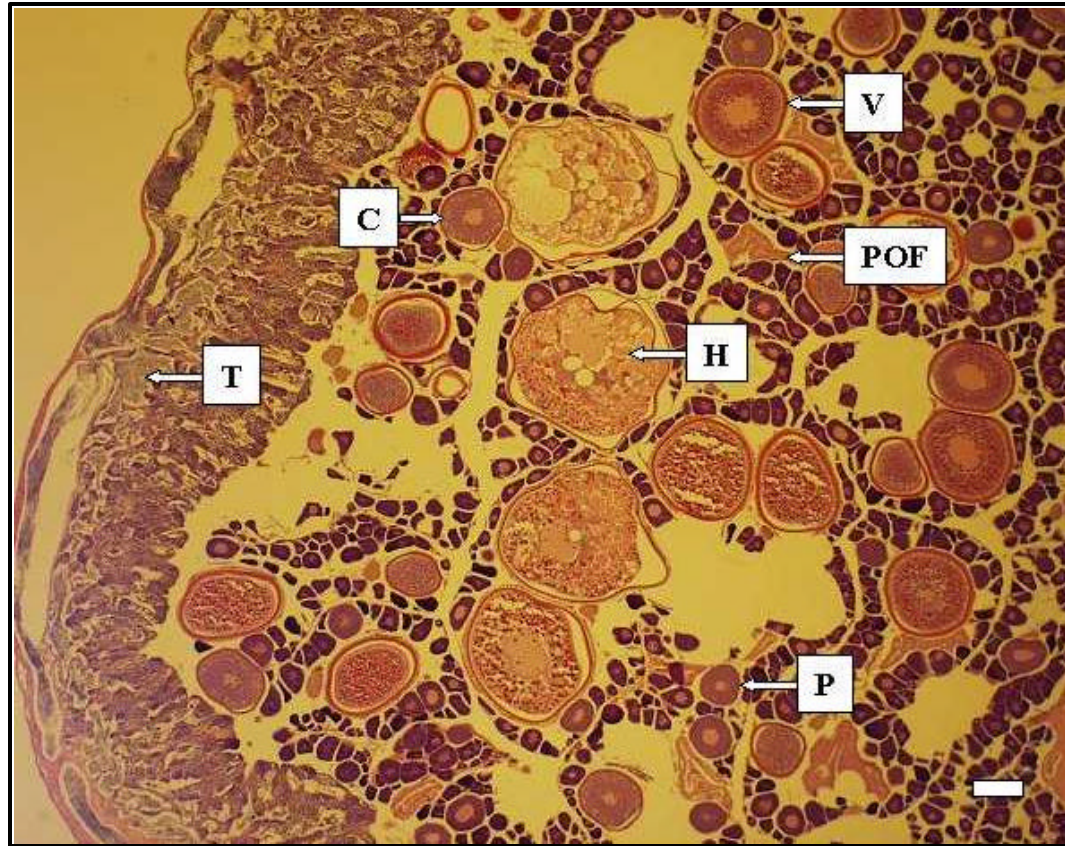


Figure 22. Histological features of *S. phoebe* gonad development. Partial cross section from a mature active individual. Major stages of gonad development are indicated by capital letters; cortical alveolar (C), hydrating oocyte (H), perinucleolar (P), post-ovulatory follicle (POF), tailed sperm (T). Scale bar is 0.250 mm.

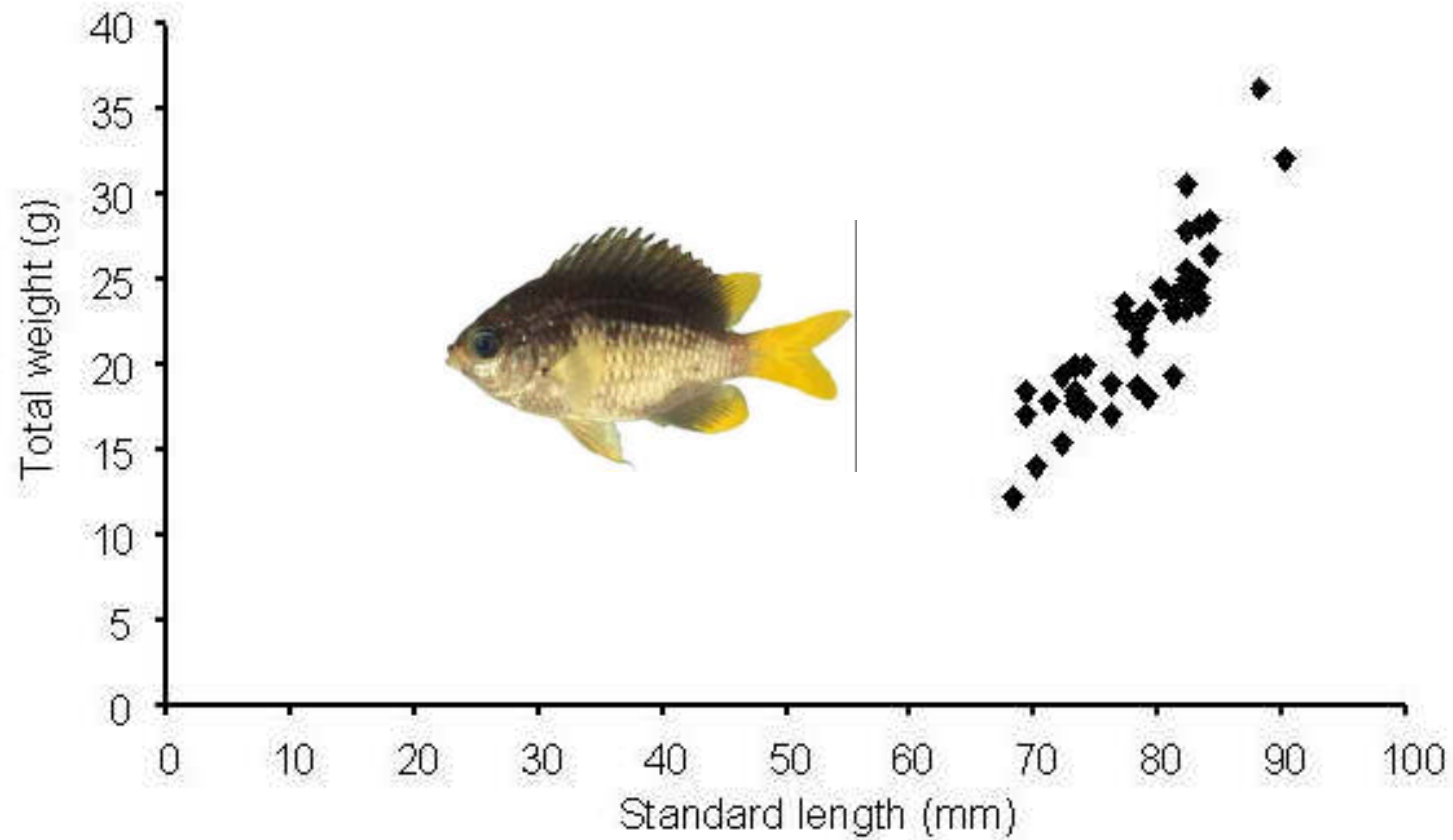


Figure 23. Standard length (mm) versus total weight (g) relationship for *C. enchrysurus* collected in the NEGOM (n=48). Relationship was generated using only fresh and frozen specimens of *C. enchrysurus*. No regression was generated as a result of the very limited length distribution available for analysis.

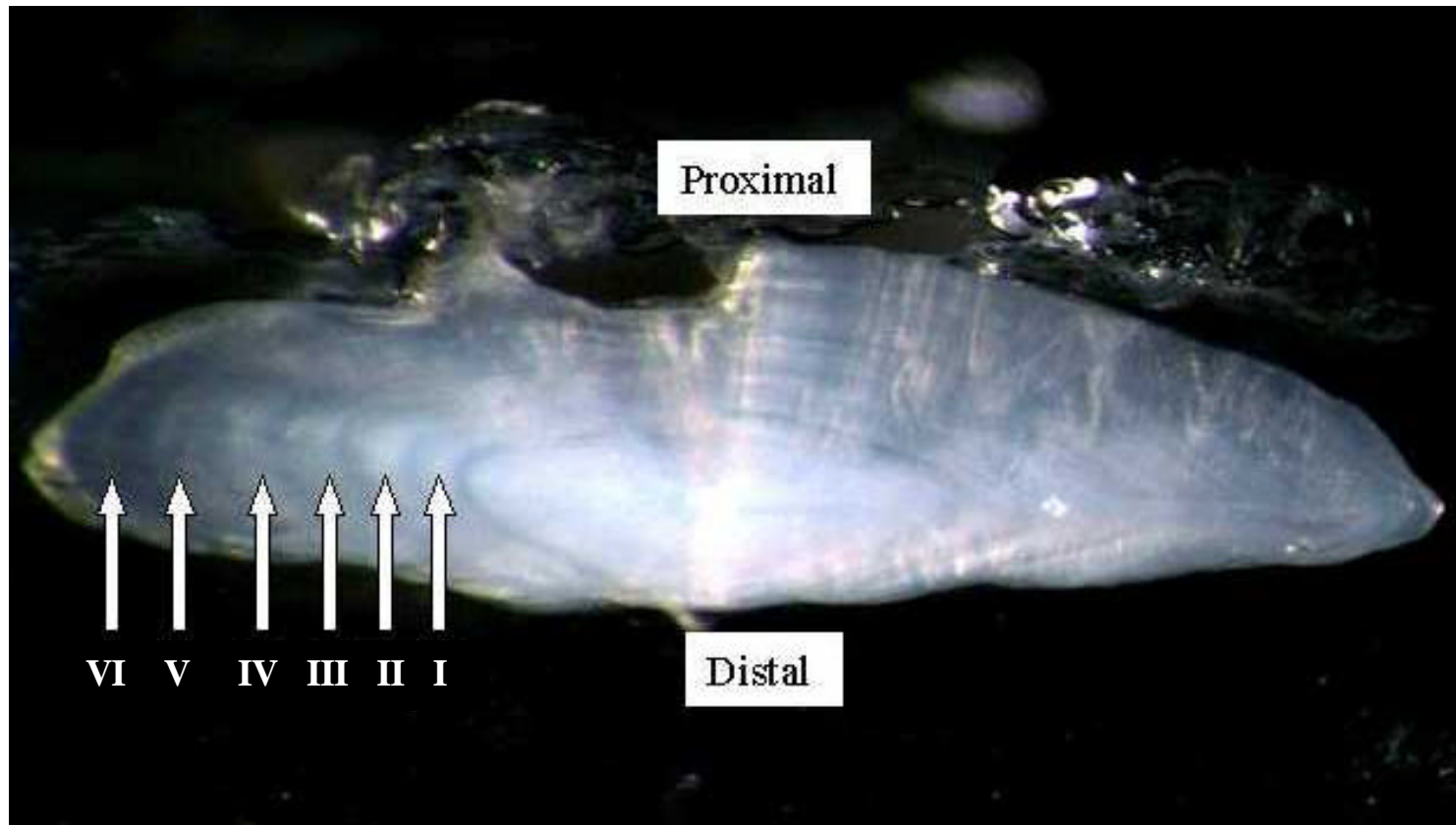


Figure 24. Digital image of sectioned sagittal otolith (shown distal side up) from an age-VI specimen of *C. enchrysurus* (SL = 78 mm) collected in the NEGOM. Arrows indicate ring structure representing annual growth rings, or annuli.

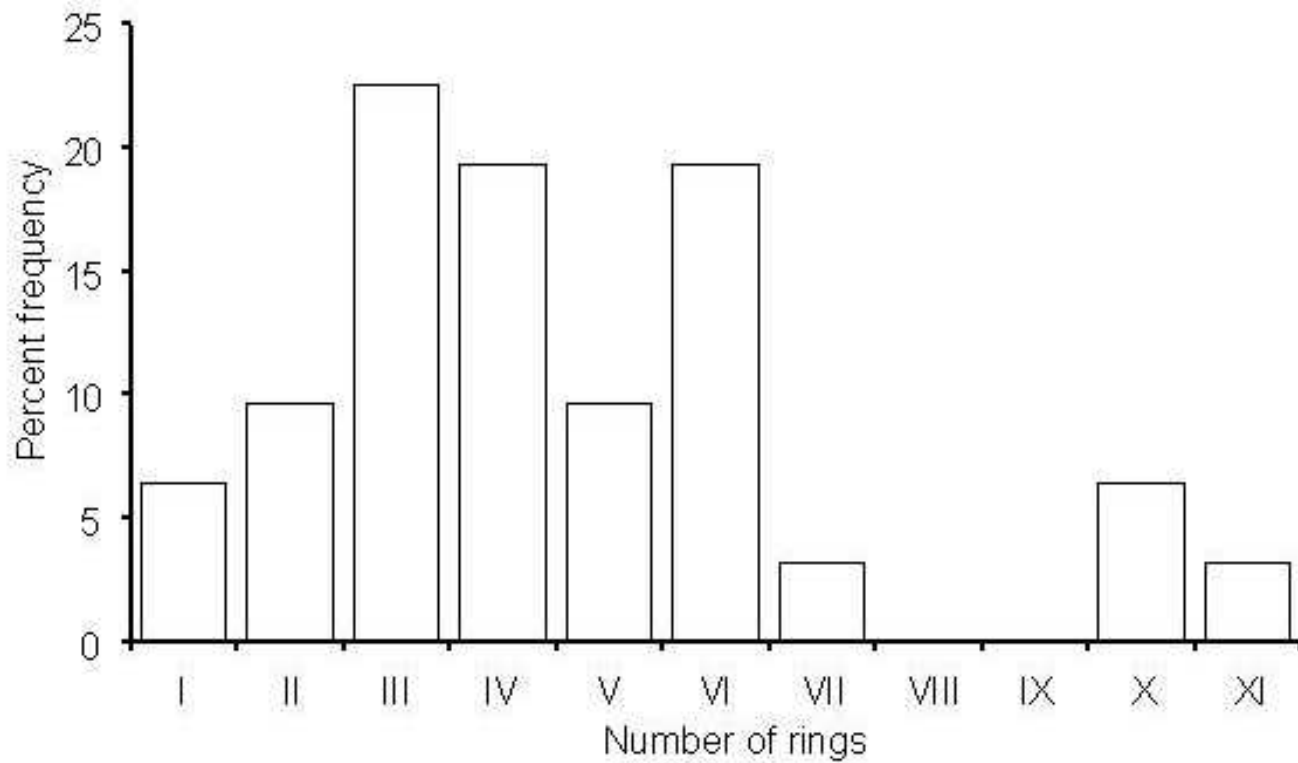


Figure 25. Histogram (percent frequency of individuals aged) of *C. enchrysurus* age-classes from NEGOM samples (n=31). Ages are based on number of opaque rings resolved in transverse sections (500  $\mu\text{m}$  thickness) of sagittal otoliths viewed beneath a dissecting microscope using reflected light.

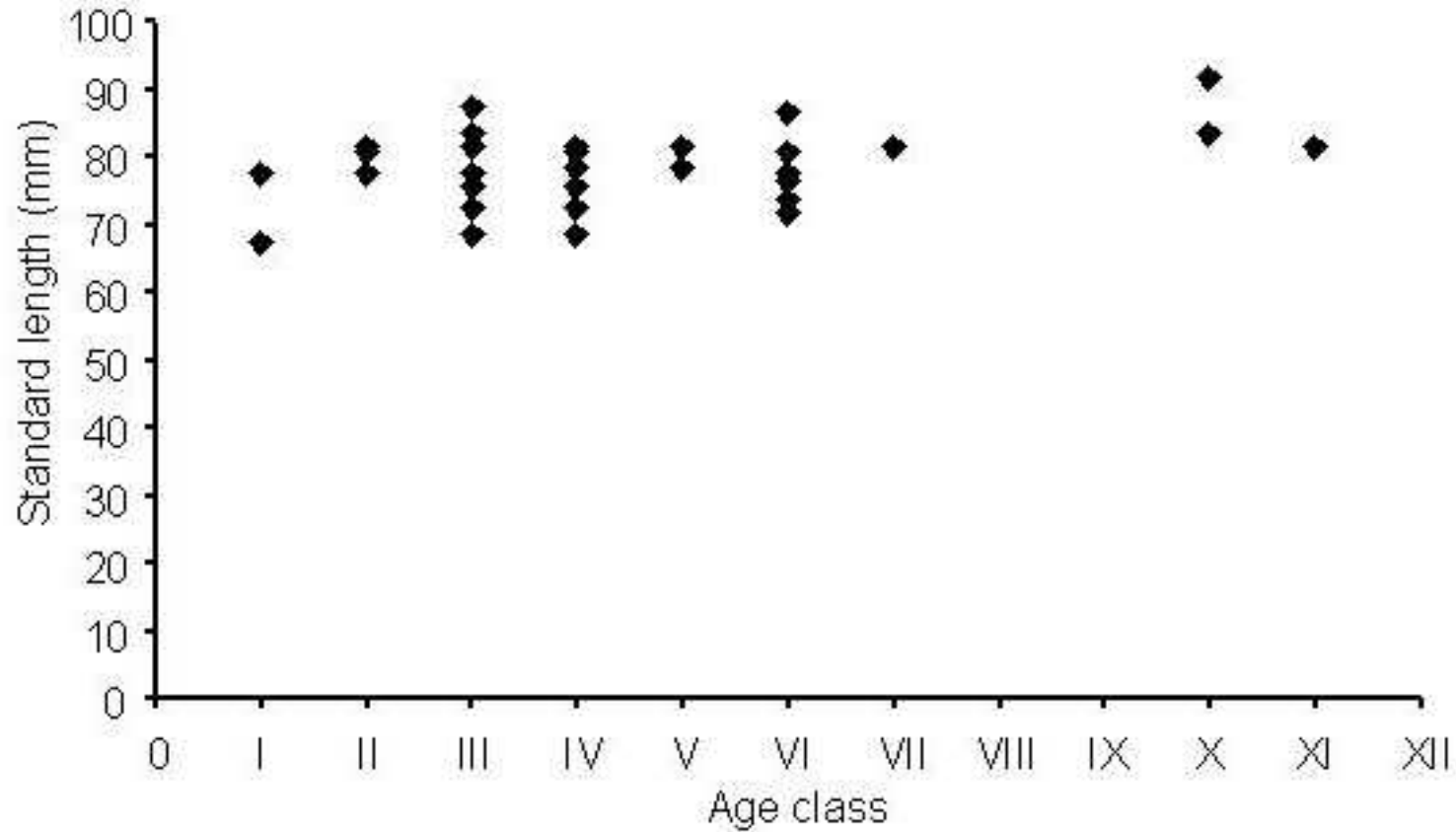


Figure 26. Distribution of SL (mm) versus age-class for *C. enchrysurus* collected in the NEGOM. Age-class was derived from number of opaque rings (= presumed annuli) observed on transverse sections (500µm thickness) of sagittal otoliths.



Rough Tongue Bass, *Pronotoqrammus martinicensis* (Serranidae), 103 mm SL



Red Barbier, *Hemanthias vivanus* (Serranidae), ? , 106 mm SL

Plate I. Adults of two small planktivorous anthiid species of the family Serranidae investigated in the present study. USGS true-color digital images of freshly captured specimens during NEGOM missions.





Tattler, *Serranus phoebe* (Serranidae), 134 mm SL



Yellowtail Reef-fish, *Chromis enchrysurus* (Pomacentridae), 85 mm SL

Plate II. A benthic microvore of the family Serranidae, and a planktivore of the family Pomacentridae, two species investigated in the present study. USGS true-color digital images of freshly captured adult specimens during NEGOM missions.

## Appendix I – FMRI Metadata File Documenting the Current Investigation and Project Report

### *Identification Information*

**Citation:****Citation Information:**

**Originator:** FWC-FMRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute)

**Title:** FA\_FB\_Seabasses

**Description:****Abstract:**

Three serranid species (*Pronotogrammus martinicensis*, *Hemanthias vivanus*, and *Serranus phoebe*) and one damselfish (*Chromis enchrysurus*) were collected during cruises to outer-continental shelf reefs of the northeastern Gulf of Mexico. Age was estimated for all serranid species using whole otoliths, and *C. enchrysurus* ages were determined from transverse sections of sagittal otoliths. Ring structure observed on otoliths was validated as having an annual periodicity for *P. martinicensis* using marginal increment analysis, while ring structure on remaining species was assumed to correspond to age (years). *Pronotogrammus martinicensis*, *H. vivanus*, *S. phoebe*, and *C. enchrysurus* exhibited maximum age classes of age-IX, age-VIII, age-V, and age-XI, respectively. Spatial variations in size-at-age were observed in *P. martinicensis* populations. Individuals inhabiting reefs in the Madison Swanson region exhibited the fastest growth rates, while the slowest growing *P. martinicensis* were collected from the Alabama Alps. *Pronotogrammus martinicensis* and *H. vivanus* are both protogynous hermaphrodites. Evidence of active spawning was observed in the months from February through July and March and May for *P. martinicensis* and *H. vivanus*, respectively. *Serranus phoebe* was observed to be a simultaneous hermaphroditic capable of spawning year-round. Batch fecundity estimates for *P. martinicensis* ranged from 149-394 oocytes per fish.

Size selectivity was evident in our primary sampling method, hook and line. Smaller size-classes of all species examined were under-represented in our samples, hindering accurate growth modeling. Due to the protogynous nature of *P. martinicensis* and *H. vivanus*, hook and line sampling also tended to select for males. Future descriptions of the reproductive biology of both protogynous species would be more complete using less selective sampling methods.

The data presented here contribute to a better assessment of the fish community of the northeastern Gulf of Mexico. Little information on age and reproduction was previously available for the serranid and pomacentrid species examined here, but these species are important links between both

planktonic or benthic food resources and the economically-valuable groupers, snappers, and amberjacks. If a catastrophic event occurred in these offshore, continental-shelf habitats then the loss of these forage species could be immediately detrimental to regional fish production via the food chain, particularly with regard to resident commercial and recreational fish species. A return to a stable or dynamically stable community would require at least a decade, possibly longer if the abiotic structure of the community was significantly altered.

**Purpose:**

Project: To develop information on age, growth, maturity schedules, spawning seasonality, size- and age-specific maturity and fecundity of roughtongue bass, red barbier, and tattler in northeastern Gulf of Mexico outer-continental shelf reefs.

Database: To provide a queriable, structured repository for project data.

**Supplemental Information:**

This study was supported by the U.S. Geological Survey, Outer Continental Shelf Ecosystem Studies Program, through a cooperative agreement with the Florida Marine Research Institute (Award #01ERAG0017).

As of July 1, 2004, the Florida Marine Research Institute (FMRI) will be known as the Fish and Wildlife Research Institute (FWRI). The institute name will not be changed in historical data sets or references to work completed by the Florida Marine Research Institute. The institute name will be changed in references to ongoing research, new research, and contact information.

**Time Period of Content :**

**Time Period Information:**

**Range of Dates/Times:**

**Beginning Date :** 4/1/2001

**Beginning Time :** 08:00:00

**Ending Date :** 8/1/2004

**Ending Time :** 17:00:00

**Currentness Reference :** Project Dates

**Status :**

**Progress:** Complete

**Maintenance and Update Frequency:** As needed

**Spatial Domain:**

**Description of Geographic Extent :**

Several sites in the northeastern Gulf of Mexico. Active collections offshore of the Florida panhandle; some archived material from offshore of Alabama. Some SCUBA-diver or ROV collections from offshore of the Florida Keys and North Carolina.

**Keywords :****Theme :****Theme Keyword Thesaurus :** FWRITheme**Theme Keyword:** age**Theme Keyword:** biology**Theme Keyword:** growth**Theme Keyword:** otolith**Theme Keyword:** reef fish (grouper, grunts, snappers, porgies, butterfly fish, barracuda, parrotfish, damsels, blennies, angels, 'aquarium fish')**Theme Keyword:** reproduction**Taxonomy :****Access Constraints :** All data must be verified by Principle Investigator or Group Database Analyst prior to release.**Use Constraints :** All data must be credited to FWC-Florida Wildlife Research Institute and the USGS Outer Continental Shelf Ecosystem Studies Program.**Point of Contact :****Contact Information:****Contact Person Primary :****Contact Person:** Richard McBride**Contact Organization:** FWC-FMRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute)**Contact Position:** Fisheries Biologist**Contact Address:****Address Type :** mailing and physical address**Address:**Fish and Wildlife Research Institute 100 Eighth Avenue  
Southeast**City:** Saint Petersburg**State or Province :** FL**Postal Code :** 33701**Country :** USA**Contact Voice Telephone :** (727) 896-8626**Contact Electronic Mail Address:** richard.mcbride@fwc.state.fl.us**Data Set Credit:** Paul E. Thurman, Richard S. McBride, G. Dennis, K. Sulak**Native Data Set Environment :** Microsoft Access 2000***Data Quality Information*****Logical Consistency Report:** Data in Access database are proofed for agreement with hard copy field data sheets. No further efforts have been made to verify the logical consistency of these data.**Completeness Report :** Some project activities which effect the completeness of the data set continue; therefore, the data set is not complete.**Lineage:**

**Methodology:****Methodology Type :** Field**Methodology Description:**

Three species of Serranidae were targeted for life history characterization. Small Hook and line (Sabiki) sampling was the primary gear for sampling these planktivorous/benthic feeding fishes in depths of 60-80 m. Sampling was largely from surface ships, on extended (multi-day) cruises at different times of the year. Extensive bottom trawling collections produced some small juveniles, and extensive trapping was completed but this failed to produce the fishes we were targeting (small seabasses). Some ROV suction sampling (w/ rotenone) was attempted, which produced limited numbers of valuable small stages. Finally some SCUBA dives were made to collect fish in the Florida Keys, some of which were used for a M.S. Thesis physiological experiment at USF. Fish were worked up directly on the cruises, or they were frozen or fixed in 10% formalin. Dissection included removal of both sagittae, Lengths (SL, FL, and TL in mm) and weight (to the nearest 10th of a gram in the lab) were recorded. Gonads were removed and the sex determined then weighed to the nearest 100th of a gram (in the lab). A sample from fixed gonads were removed and stored in 70% ETOH until an histology slide could be prepared. Otoliths were stored until they could be aged. Ages were estimated from sectioned material or surface reads.

***Entity and Attribute Information*****Detailed Description:****Entity Type :****Entity Type Label:** *P. martinicensis***Entity Type Definition:** Contains information concerning the life history of roughtongue bass, *Pronotoqrammus martinicensis*.**Attribute:****Attribute Label:** Age**Attribute Definition:** Number of completely formed rings observed on whole sagittal otoliths.**Attribute:****Attribute Label:** Atresia**Attribute Definition:** Whether any signs of atresia are present (1) or not (0) in the gonad**Attribute:****Attribute Label:** EOW**Attribute Definition:** Weight of the whole right otolith in grams.

**Attribute:****Attribute Label:** FL**Attribute Definition:** Fork length in millimeters.**Attribute:****Attribute Label:** GonW**Attribute Definition:** Total weight of the gonad.**Attribute:****Attribute Label:** LOW**Attribute Definition:** Total weight of the whole left otolith.**Attribute:****Attribute Label:** Margin**Attribute Definition:** Describes whether an annuli is locate on the edge (1) or not (0) of the sagittal otolith.**Attribute:****Attribute Label:** Oocytes**Attribute Definition:** Describes whether any signs of oocytes are visible (1) or not (0) in transitional and male gonads.**Attribute:****Attribute Label:** POF**Attribute Definition:** Describes whether post-ovulatory follicles are visible in the gonad (1) or not (0).**Attribute:****Attribute Label:** Sample**Attribute Definition:** Describes the number used to identify a particular fish.**Attribute:****Attribute Label:** Sex**Attribute Definition:** Describes the sex of a fish as male (m), female (f), or transitional (t).**Attribute:****Attribute Label:** SL**Attribute Definition:** Describes the standard length of a particular fish.**Attribute:****Attribute Label:** Species**Attribute Definition:** Describes the species of fish as *P.martinicensis*.**Attribute:****Attribute Label:** Stage**Attribute Definition:** Describes the most-advanced stage of development observed in female gonads.**Attribute:**

**Attribute Label:** Station

**Attribute Definition:** Describes the USGS station where the fish was collected from.

**Attribute:**

**Attribute Label:** TW

**Attribute Definition:** Describes the total weight of a particular P. Martincensis.

**Detailed Description:**

**Entity Type :**

**Entity Type Label:** P.martincensis-fecundity

**Attribute:**

**Attribute Label:** .

**Attribute:**

**Attribute Label:** Count1

**Attribute Definition:** Number of oocytes counted in the left lobe of the gonad.

**Attribute:**

**Attribute Label:** Count2

**Attribute Definition:** Number of oocytes counted in the whole left gonad.

**Attribute:**

**Attribute Label:** Count3

**Attribute Definition:** Number of oocytes counted in the whole left gonad.

**Attribute:**

**Attribute Label:** GW-total

**Attribute Definition:** Whole gonad weight in grams.

**Attribute:**

**Attribute Label:** Lobe-avg

**Attribute Definition:** Average of count1, count2, and count3 which represents the average number of oocytes in the whole left gonad.

**Attribute:**

**Attribute Label:** Lobe-wt

**Attribute Definition:** Total weight of the whole left gonad.

**Attribute:**

**Attribute Label:** Sample

**Attribute Definition:** Sample number which is used to identify a single fish.

**Attribute:**

**Attribute Label:** Species

**Attribute Definition:** Species which corresponds to the Sample number.

**Detailed Description:**

**Entity Type :**

**Entity Type Label:** H.vivanus

**Attribute:**

**Attribute Label:** 4 Dorsal

**Attribute Definition:** Describes the length of the 4th dorsal filament in mm.

**Attribute:**

**Attribute Label:** Age

**Attribute Definition:** Number of completely formed rings observed on whole sagittal otoliths.

**Attribute:**

**Attribute Label:** Atresia

**Attribute Definition:** Describes whether any signs of atresia were evident in the gonad (1) or not (0).

**Attribute:**

**Attribute Label:** GonW

**Attribute Definition:** Describes the weight of the whole gonad in grams.

**Attribute:**

**Attribute Label:** LOW

**Attribute Definition:** Describes the weight of the left whole sagittal otolith in grams.

**Attribute:**

**Attribute Label:** Margin

**Attribute Definition:** Describes whether an annulus is located on the margin of the sagittal otolith (1) or not (0).

**Attribute:**

**Attribute Label:** Oocytes

**Attribute Definition:** Describes whether oocytes remain(1) or not (0) in transitional and male gonads.

**Attribute:**

**Attribute Label:** POFs

**Attribute Definition:** Describes whether post-ovulatory follicles remain (1) or not (0) in female gonads.

**Attribute:**

**Attribute Label:** ROW

**Attribute Definition:** Describes the weight in grams of the whole right sagittal otolith.

**Attribute:**

**Attribute Label:** Sample

**Attribute Definition:** Describes the sample number used to identify a particular fish

**Attribute:**

**Attribute Label:** Sex

**Attribute Definition:** Describes the sex of the fish as either male (m), female (f), or transitional T).

**Attribute:**



**Attribute Label:** SL

**Attribute Definition:** Describes the standard length of the fish in millimeters.

**Attribute:**

**Attribute Label:** Species

**Attribute Definition:** describes the species which was collected. Species are *P.martinicensis*, *H.vivanus*, *S. Phoebe*, and *C.enchrysurus*

**Attribute:**

**Attribute Label:** Stage

**Attribute Definition:** Describes the most advanced stage of stage of oocyte development

**Attribute:**

**Attribute Label:** Station

**Attribute Definition:** Describes the cruise and station (USGS-Outer-continental shelf program) number during which the individual was collected.

**Attribute:**

**Attribute Label:** TW

**Attribute Definition:** Describes the total weight of the sample in grams.

**Detailed Description:**

**Entity Type :**

**Entity Type Label:** S.phoebe

**Attribute:**

**Attribute Label:** Age

**Attribute Definition:** Describes the number of rings observed on whole sagittal otoliths.

**Attribute:**

**Attribute Label:** Atresia

**Attribute Definition:** Describes whether any signs of atresia are visible in gonad sections (1) or not (0).

**Attribute:**

**Attribute Label:** GonW

**Attribute Definition:** Describes the weight of the whole gonad in grams.

**Attribute:**

**Attribute Label:** LOW

**Attribute Definition:** Describes the weight of the left sagittal otolith.

**Attribute:**

**Attribute Label:** Margin

**Attribute Definition:** Describes whether an annuli is on the edge of the otolith (1) or not (0).

**Attribute:**

**Attribute Label:** POFs

**Attribute Definition:** Describes whether post-ovulatory follicles are visible in the gonad sections.

**Attribute:**

**Attribute Label:** ROW

**Attribute Definition:** Describes the weight of the whole right otolith.

**Attribute:**

**Attribute Label:** Sample

**Attribute Definition:** Describes the sample number used to identify a particular sample.

**Attribute:**

**Attribute Label:** SL

**Attribute Definition:** Describes the standard length in millimeters of the sample.

**Attribute:**

**Attribute Label:** Species

**Attribute Definition:** Describes the species as *Serranus phoebe*.

**Attribute:**

**Attribute Label:** Station

**Attribute Definition:** Describes the USGS cruise where the sample was collected from.

**Attribute:**

**Attribute Label:** StgFem

**Attribute Definition:** Describes the most advanced oocyte stage observed in the female portion of the gonad.

**Attribute:**

**Attribute Label:** StgMale

**Attribute Definition:** Describes the stage of development of the male portion of the gonad.

**Attribute:**

**Attribute Label:** TW

**Attribute Definition:** Describes the total weight of the sample in grams.

**Detailed Description:**

**Entity Type :**

**Entity Type Label:** C.enchrysurus

**Attribute:**

**Attribute Label:** Age

**Attribute Definition:** Describes the number of rings observed on sectioned sagittal otoliths.

**Attribute:**

**Attribute Label:** Sample

**Attribute Definition:** Describes the sample number used to identify an individual sample.

**Attribute:**

**Attribute Label:** Sex

**Attribute Definition:** Describes the sex of the sample as male (m) or female (f).

**Attribute:**

**Attribute Label:** SL

**Attribute Definition:** Describes the standard length of the sample in millimeters.

**Attribute:**

**Attribute Label:** Species

**Attribute Definition:** Describes the species as *Chromis enchrysurus*.

**Attribute:**

**Attribute Label:** Station

**Attribute Definition:** Describes the USGS station where the sample was collected from.

**Attribute:**

**Attribute Label:** TW

**Attribute Definition:** Describes the total weight of the sample in grams.

## Chronological List of NEGOM OCS Studies Publications From the USGS Coastal Ecology & Conservation Research Group

- Weaver, D. C., K. J. Sulak, W. Smith-Vaniz, and S. W. Ross. 1999. Community structure and trophic relationships of demersal reef fishes of the Mississippi-Alabama outer continental shelf. Pp. 286-292, In: Proceedings Seventeenth Gulf of Mexico Information Transfer Meeting, Kenner, LA, December 1997, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA, OCS Study MMS 99-0042 (M. McKay and J. Nides, eds.).
- Gardner, J. V., K. J. Sulak, P. Dartnell, L. Hellequin, B. Calder, and L. A. Mayer. 2000. The bathymetry and acoustic backscatter of the Pinnacles area, northern Gulf of Mexico. U.S. Geological Survey Open-File Report 2000-350, 35 pp.
- Weaver, D. C., and K. J. Sulak. 2000. Trophic subsidies in the twilight zone: Food web structure of deep reef fishes along the Mississippi-Alabama outer continental shelf. Pp. 203-208, In: Proceedings: Eighteenth Gulf of Mexico Information Transfer Meeting, Kenner, LA, December 1998, U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA, OCS Study MMS 2000-030 (M. McKay and J. Nides, eds.).
- Gardner, J. V., P. Dartnell, K. J. Sulak, B. Calder, and L. Hellequin. 2001a. Physiography and late Quaternary-Holocene Processes of northeastern Gulf of Mexico outer continental shelf off Mississippi and Alabama. *Gulf of Mexico Science* 2001(2):132-157.
- Gardner, J. V., L. A. Mayer, J. E. Hughes Clarke, P. Dartnell, and K. J. Sulak. 2001b. The bathymetry and acoustic backscatter of the mid shelf and upper slope off Panama City, Florida, northeastern Gulf of Mexico. Cruise Report, RV *Moana Wave*, Cruise M1-01-GM, September 3, through October 12, 2001. U.S. Geological Survey Open-File Report 2001-448, 60 pp.
- Gardner, J. V., P. Dartnell, and K. J. Sulak. 2002a. Multibeam mapping of the West Florida Shelf, Gulf of Mexico. U.S. Geological Survey Open-File Report OF02-5, CD-ROM; online at: <http://geopubs.wr.usgs.gov/openfile/of02-5>.
- Gardner, J. V., P. Dartnell, and K. J. Sulak. 2002b. Multibeam mapping of the Pinnacles Region, Gulf of Mexico. U.S. Geological Survey Open-File Report OF02-6, CD-ROM; online at: <http://geopubs.wr.usgs.gov/openfile/OF02-6>.
- Weaver, D. C. G. D. Dennis III, and K. J. Sulak. 2002. Community structure and trophic ecology of demersal fishes on the Pinnacles Reef tract. U.S. Department of the Interior, U.S. Geological Survey Biological Sciences Report USGS BSR 2001-0008; Minerals Management Service, OCS Study MMS-2002-034.
- Gardner, J. V., J. E. Hughes Clark, L. A. Mayer, and P. Dartnell. 2003. Bathymetry and acoustic backscatter of the mid and outer continental shelf, head of DeSoto Canyon, Northeastern Gulf of Mexico – Data, images, and GIS. USGS Open-File Report )F03-007, CD-ROM; online at: <http://geopubs.wr.usgs.gov/openfile/OF03-007>.

- Lyczkowski-Shultz, J., D. S. Hanisko, G. D. Dennis, III, and K. J. Sulak. 2004. Characterization of ichthyoplankton within the U.S. Geological Survey's Northeastern Gulf of Mexico Study Area. Based on analysis of Southeast Area Monitoring and Assessment Program (SEAMAP) sampling surveys, 1982-1999. USGS Scientific Investigation Report (SIR) 2004-5059 (USGS CEC NEGOM Program Investigation Report No. 2004-02, April 2004) available in CD-ROM format and online in Adobe® .pdf and .html formats at: <http://cars.er.usgs.gov/coastaleco/>
- Thurman, P, R. McBride, G. D. Dennis, III, and K. J. Sulak. 2004. Age and reproduction in three reef-dwelling serranid fishes of the Northeastern Gulf of Mexico Outer Continental Shelf: *Pronotogrammus martinicensis*, *Hemanthias vivanus* & *Serranus phoebe* (with preliminary observations on the Pomacentrid fish, *Chromis enchrysurus*. USGS Outer Continental Shelf Ecosystem Studies Program Report, USGS Scientific Investigation Report (SIR) 2004-5162 (USGS CEC NEGOM Program Investigation Report No. 2004-03, May 2004), available in CD-ROM format and online in Adobe® .pdf and .html formats at: <http://cars.eer.usgs.gov/>

**Other Publications Resulting in Part  
From NEGOM OCS Research Undertaken by the  
USGS Coastal Ecology & Conservation Research Group**

- Quattrini, A. M., S. W. Ross, K. J. Sulak, A. M. Necaie, T. L. Casazza, and G. D. Dennis. 2004. Marine fishes new to continental United States waters, North Carolina, and the Gulf of Mexico. *Southeastern Naturalist* 3(1):155-172.



*CEC Research Group Emblem Design: Jana M. Miller, Visual Graphics Specialist*

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U.S. Geological Survey  
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