Preliminary Results from a Study of Reproduction in the Vermilion Snapper (Lutjanidae: *Rhomboplites aurorubens*) from the Eastern U. S. Gulf of Mexico, 1991-2001

L. ALAN COLLINS[1], WILLIAM T. WALLING, JR.[1],
JOHN H. BRUSHER[1], MARC G. REMY[2], JOSEPH J. MIKULAS[1],
GINNY M. CHANDLER[3], and DANIELLE M. LA FOND[3]

[1] *National Marine Fisheries Service*
3500 Delwood Beach Road
Panama City, Florida 32408 USA

[2] *Naval Oceanographic Office*
1002 Balch Boulevard
Stennis Space Center, Mississippi 39522 USA

[3] *Florida State University*
Department of Biological Sciences
Tallahassee, Florida 32306-1100 USA

ABSTRACT

Analysis of vermilion snapper (Lutjanidae: *Rhomboplites aurorubens*) spawning and fecundity from the U.S. Gulf of Mexico provided accurate length-specific estimates of fecundity (batch fecundity, frequency of spawning, and annual fecundity) for mature vermilion snapper in order to enhance stock assessment of this species. Fisheries-dependent sampling began off Panama City in northwest Florida (FL) in the northeastern Gulf of Mexico in 1991 and continues with greatly expanded sampling-coverage from off southwest FL to south Texas. Our main fisheries independent sampling began in 2000 and continues with day/night hook and line fishing as a necessity to determine length at first spawning, time of oocyte-hydration, spawning time, and location/depth/temperature of spawning. Maximum oocyte diameter, gonadosomatic index and histology indicate that vermilion snapper mainly spawn from April through September. We found at least 10 probable-spawning sites off west Florida in depths of 30 to 114 m. The smallest female with hydrated oocytes found thus far is 159 mm total length (TL). Most vermilion snapper spawned at approximately 2230 hours: most (90%) hydrated oocytes occurred from 1300 to 2230, with none occurring between 2230 and 0905. Most (91%) new postovulatory follicles occurred from 2230 to 0815, with none occurring between 0815 and 1320. Batch fecundity estimates for 1993 - 1994 ranged from 27,000 to 415,000 for 44 fish from 215 to 375 mm TL, for 2000 were 15,032 to 88,471 for 59 fish from 189 to 288 mm TL, and for 2001 were 7,385 to 377,226 for 20 fish from 159 to 510 mm TL. Average frequency of spawning for 2000 was 93 using the hydrated oocyte method. Average spawning periodicity for 2000 was 1.6 days. Annual fecundity estimates ranged from 1.4 to 8.2 million for 2000 (n = 59) and from 0.7 to 35 million including a few smaller and larger females for 2001 (n = 20), if the same spawning frequency estimate is used for both years.

KEY WORDS: Fecundity, snapper, spawning

RESUMEN

Nosotros estamos estudiando *Rhomboplites aurorubens* (Lutjanidae), el desove y la fecundidad en el Golfo de México de los Estados Unidos. Nuestro objetivo principal es proporcionar estimaciones longitud-específicas exactas de la fecundidad (fecundidad del tratamiento por lotes, frequencia de desove y fecundidad anual) para todas las talles de *R. aurorubens* del Golfo de México para avanzar la evaluacion de poblaciones de esta especie. El muestreo de pescas-dependiente comienzó de la costa de Panama City en Florida (FL) noroeste, en el noreste del Golfo de México en 1991 y continúa con la expansión del muestreo de el sudoeste de Florida al sur de Tejas. Nuestro muestreo principal de pescas independiente comienzó en 2000 y continúa para la pesca con gancho y sedal de día/noche para determinar largo a desove primero, tiempo de huevos hidración, tiempo de desove y posición/profundidad/temperatura de desove. El diámetro máximo del oocyte, el índice gonadosomatic y la histología indican que desove de *R. aurorubens* en el Golfo de México es de abril a septiembre. Encontramos al menos diez sitios probable para desove en la costa de Florida oeste en profundidades de 30 a 114 m. La hembra más pequeña con huevos hidratados encontrados hasta esta tiempo eran 159 mm largo total (TL). La mayoría de *R. aurorubens* desove a aproximadamente 2230 horas; la mayoría (90%) de los huevos hidratos occurrieron entre 1300 y 2230, con nadie ocurriendo entre 2230 y 0905. La mayoría (91%) de los folículos después de ovulación nuevos ocurrieron entre 2230 y 0815, con nadie occuriendo entre 0815 y 1320. Las estimaciones de la fecundidad del tratamiento por lotes para 1993-1994 extendido entre 27,000 y 415,000 para 44 peces de 215 a 375 mm TL; para 2000 fueron de 15,032 a 88,471 para 59 peces de 189 a 288 mm TL; y para 2001 fueron de 7,385 a 377,226 para peces de 159 a 510 mm TL. La frecuencia media de desove en 2000 fue 93 usando el metodo de los huevos hidratados. La desove periodicidad media de desove para 2000 fue 1.6 días. Las estimaciones anuales de fecundidad fluctuaron de 1.4 a 8.2 milliones para 2000 (n = 59) y de 0.7 a 35 milliones para algunas hembras mas pequenas y algunas hembras mas largas de 2001 (n = 20), si la misma frequencia de desove es usado en ambos anos.

INTRODUCTION

The vermilion snapper (Lutjanidae: *Rhomboplites aurorubens*) is a relatively small fish that is important to both recreational and commercial fisheries in many areas along the U.S. southern Atlantic and Gulf of Mexico coasts. Compared to two other larger and more popular Gulf of Mexico species (the red snapper, *Lutjanus campechanus*, and gag, *Mycteroperca microlepis*), the vermilion snapper is usually considered a valuable alternative species due to its normal abundance, catchability, and taste.

The most recent stock assessment of vermilion snapper in the Gulf of Mexico suggests that the species is overfished (Porch and Cass-Calay 2001). A recent study by Hood and Johnson (1999) provided information on age, growth and reproduction including the first published batch fecundity estimates for this species from the Gulf

of Mexico, and they also found that it was probably overfished. A similar study was published on vermilion snapper from the U. S. coast off South Carolina by Cuellar et al. (1996) who made the first published estimates of spawning frequency (35 spawns per year) as well as the first batch fecundity estimates from this area.

Research on reproductive biology of reef fishes is important to assessing stocks, testing management tools, and evaluating habitat. Spawning potential ratios (SPRs) require age-specific fecundity estimates to determine if stocks are overfished. Reproduction studies also help to gauge the success of marine reserves as a management tool. Reef fishes are usually aggregate spawners and little is presently known about the structure and function of those aggregations. The identification of spawning sites also helps to delineate essential fish habitat.

Extensive sampling and study of both age/growth and reproduction from the northern Gulf of Mexico was requested by NMFS. We had previously studied red snapper reproduction and published our results on histology and fecundity estimates from the northeastern, northcentral and northwestern Gulf of Mexico (Collins et al. 1996, and Collins et al. 2001). Samples of snappers from the north-central and northwestern Gulf of Mexico were more difficult to obtain and required the assistance of Gulf samplers from the NMFS Beaufort, NC, Headboat Survey Program.

Our objectives for the reproduction study were threefold:

i) To acquire female vermilion snapper of all possible sizes to be used for estimating fecundity;
ii) To determine spawning period/time-of-day, in order to be able to ensure the best fecundity samples from batch fecundity and spawning frequency estimates, and
iii) To identify vermilion snapper spawning sites using histology and catch location data.

METHODS

Our methods were similar to those in Collins et al. (1999), except that fishery independent field sampling was more intensive during 2000 and 2001. During 2001 we specifically targeted larger (> 300 mm total length, TL) vermilion snapper off Panama City, although we sampled smaller fish that were also caught on our fishery independent trips. We also targeted larger fish from west of Panama City during 2000 and 2001. Large vermilion snapper gonads and otoliths were sampled mainly from recreational headboats out of northwest Florida (FL), Alabama (AL), Louisiana (LA), and Texas (TX). Headboats and charterboats from Panama City, FL, were also sampled. Fishery-independent samples came from NMFS scientific surveys off Panama City, FL, and from research cruises mainly in the eastern Gulf of Mexico.

For each fish sampled in the field, fork length (FL) and TL were first measured to the nearest mm, and total wet weight was usually recorded to the nearest 0.01 kg. Gonads were then removed, placed dry in plastic bags and kept on ice until

processed. A sagittal otolith was also removed from each fish. Samplers from remote areas shipped otoliths and gonads on ice to our lab in Panama City by overnight mail.

In the laboratory, gonad samples on ice were processed as soon as possible. Excess tissue was removed and a small sample of each gonad (ovaries and testes) was examined at 250x to determine preliminary sex and stage of gonad maturation (1-immature/resting; 2-early developing; 3-late developing; 4-ready to spawn or spawning; 5-recently spawned or spawned-out; (West 1990)). The diameter of the largest oocyte (maximum oocyte diameter, MAXOD) found in the small sample was also recorded for each female. We previously ran a two-way analysis of variance that showed that hydrated oocytes were homogeneously distributed in hydrated ovaries. If no oocytes were visible under a microscope and the gonad was not round in cross-section, then the sex was male; male Stages 1-3 were judged from gonad thickness and Stage 4 males had milt when cut. All gonads were then weighed to the nearest 0.1 g before selected samples were placed in 10% buffered formaldehyde solution (formalin, mixed according to Hunter, 1985) inside a sealed plastic bag.

A gonadosomatic index (GSI = 100 X gonad weight/ total weight - gonad weight), the MAXOD, and preliminary gonad stages were used to generally delineate the spawning season, as well as to compare to the final staging from histology. Only female GSIs will be reported in this paper. After at least two weeks in formalin, tissue samples were used for standard histological slides (Fitzhugh et al. 1993) which were then examined at our laboratory in order to record the final sex, gonad-maturation stage, presence of postovulatory follicles (POFs), presence of atresia and quality of preservation. Histological-stages for females were determined by the most-advanced stage of oocyte development found in each fish: 1-primary growth; 2-cortical alveolar; 3-vitellogenic; 4- migratory nucleus; 5- hydrated; 6-at least 50% atretic. Histological-stages for males were: 1-inactive; 2-active, with many secondary spermatocytes; 3-developing, with some spermatids in ducts; 4-ripe, with large pools of spermatozoa in ducts.

Batch fecundity and spawning frequency were estimated using the hydrated oocyte method of Hunter et al. (1985) and Hunter and Macewicz (1985), respectively. Only histological Stage 5 females were used for batch fecundity estimates. We used the length of the smallest hydrated female as a benchmark for selecting fish included in the spawning frequency estimate: only histological Stage 5 females were counted as spawning. Reference to stages from here on refer to histological stage. Batch fecundity was regressed on TL using linear and non-linear models to identify which model best explained the variation in batch fecundity. The spawning frequency estimate was the estimated number of spawns per year by each female and was calculated as: duration of spawning season in days/100% of females/percent of females hydrated.

Possible spawning sites were identified as those locations where at least one female with hydrated oocytes or new POFs was found. Locating these sites required catch-coordinates from fishers.

RESULTS

We sampled a total of 3,234 vermilion snapper (159 - 587 mm TL) between Key West, FL, and Port Aransas, TX, from February 1991 through September 2001. The majority of gonad samples (98.8%) came from the west coast of Florida (Figure 1). Most samples (94.2%) were collected during 1991 - 1994 (60.2%) and 2000-2001 (33.9%). Although commercial and recreational catches were sampled in all years, most samples came from these fisheries during 1991 - 1994. Almost all fishery independent sampling occurred during 2000 and 2001.

Randomly sampled fish were 58.5% female. Sex ratio varied widely at different sampling locations. On one fishery independent sampling trip during August 2001, the first 15 fish caught were males. Typically, however, catches were at least slightly dominated by females.

The spawning season for vermilion snapper from FL to TX in this study was April through September or October, according to GSI (Figure 2, with low GSIs for November and December not shown), MAXOD and histological gonad-stages. Ovaries with hydrated oocytes were usually found from mid-April through mid-September. Results are shown graphically from 2000 and 2001 only, since data from earlier years were very similar to those and we were able to collect more important catch data with gonads from the last two sampling years. Nearly all nighttime sampling was done during 2000 - 2001 along with extensive daytime sampling, both as part of our fishery independent sampling. Data on time of catch was valuable since GSI, MAXOD and histological stage could change appreciably during the few hours before and after spawning. Samples taken right before spawning occurred were the best indicator of gonad-maturation, spawning and fecundity.

At least ten probable-spawning sites were identified from many fully hydrated oocytes in vermilion snapper caught at known fishing locations (Figure 1). Most of these sites were within 40 miles offshore of Panama City in 30 to 60 m where our intensive fishery-independent sampling occurred in 2000 and 2001 (Figure 1). Our 1996 at-sea sampling on commercial boats identified a probable spawning location at a depth of 85 m southwest of Panama City (Figure 1). Headboat dockside-sampling in 2001 found two Stage 5 females caught at a site 60 m deep located 80 miles northwest of St. Petersburg, and commercial fish house sampling in Key West also found a "running-ripe" female (our Stage 5 with fully hydrated oocytes) for which a fishermen provided a catch-location west of the Dry Tortugas (Figure 1). A 2001 at-sea sampling trip on a commercial boat found several fully hydrated females west of Ft. Myers in 114 m at a "spring" (Figure 1). Headboat samplers from just west of Panama City, FL, to AL, LA and TX also found a few large female vermilion snapper that were early hydrated and close to spawning, but apparently the catches were made before spawning was about to occur because oocyte hydration was never full in those fish (most headboat trips occur during daytime hours and many vermilion snapper are caught during the morning hours).

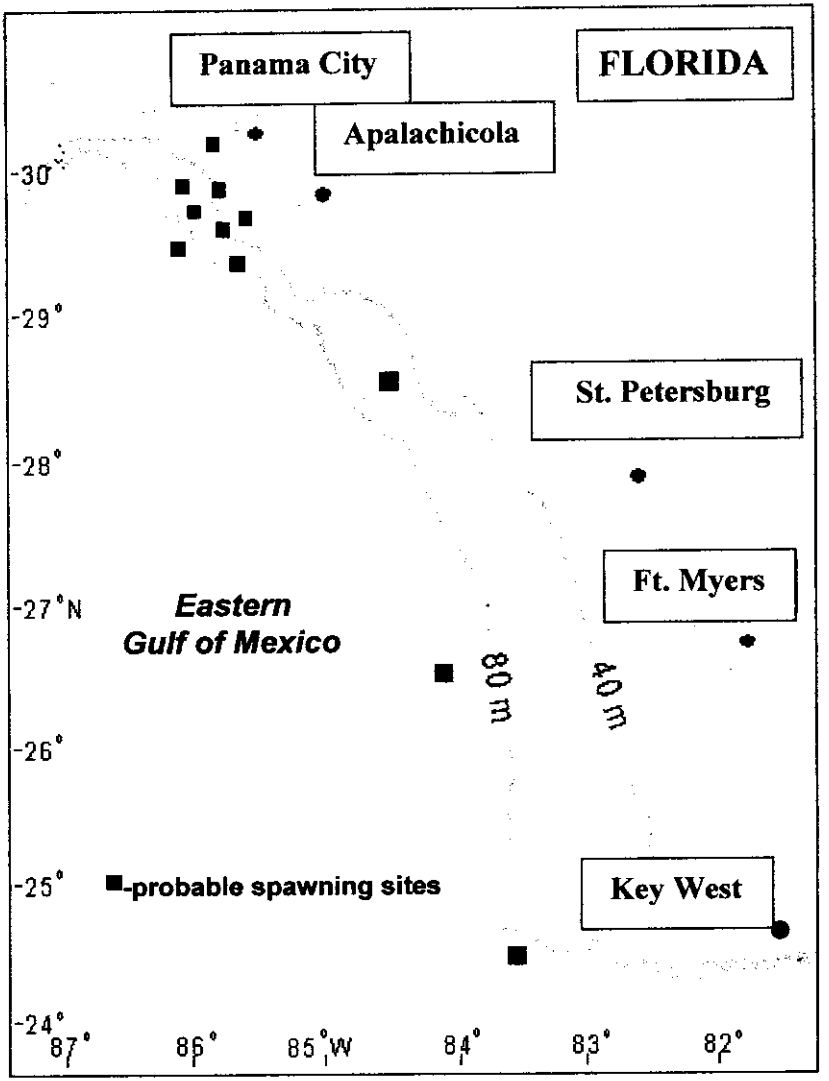

Figure 1. Vermilion snapper sampling area with probable spawning sites.

The smallest females that we sampled (153 and 159 mm TL) were Stage 4 (with migratory nuclei) and Stage 5 (hydrated), respectively. We found very few non-spawning fish during April through September. A scarcity of extremely low GSIs during the spawning season also suggests that gonad maturation and spawning occur in small fish (Figure 2).

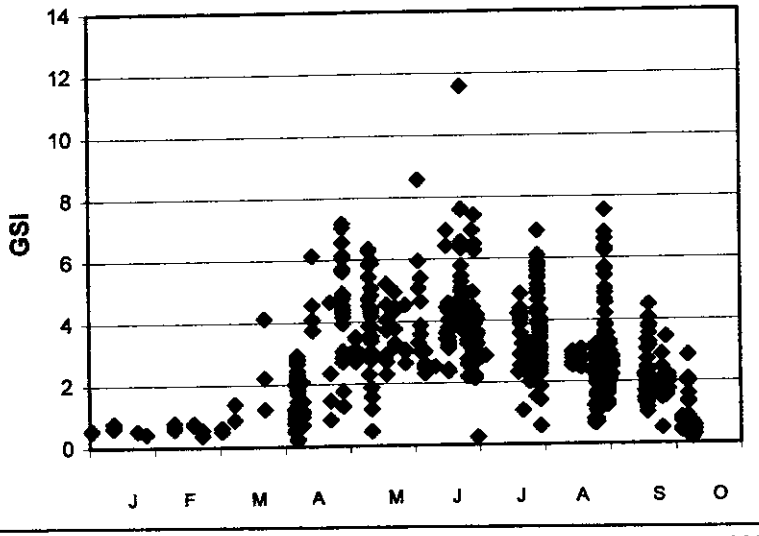

Figure 2. Gonadosomatic Index of all female vermillion snapper during 2000 - 2001 (N = 572).

Spawning occurred at approximately 2230 hours according to ovarian histology during our intensive fishery independent sampling off Panama City in 2000 and 2001 (Figure 3). In both years, early hydration occurred as early as 0905, but late hydration did not begin until about 1300 or 1330 hours. During 2000, 25% of females were early-hydrated from 0905 to 1300 and all late hydrated ovaries occurred from 1300 to 2300; no females were early or late hydrated between 2300 and 0905. At the time that fully hydrated oocytes disappeared in the sampled females, some new POFs appeared to mark the time of spawning given above. A decrease in gonad weight and MAXOD was also noted for similar-sized spawning females between 2200 and 2300. During 2001, fully hydrated oocytes appeared from 1330 to 2240 and new POFs appeared from 2200 to 0130; two "running ripe" females that spewed large eggs on the deck of the headboat during sampling and contained both fully hydrated oocytes and new POFs (when viewed back at the laboratory) were collected at 2200 and 2210.

Batch fecundity was estimated as 7,385 to 407,570 from all females (n = 123) that contained intact ovaries with fully hydrated oocytes and no new POFs (Figure 4). Total length proved to be an effective predictor, with this model explaining almost 67% of the variation in batch fecundity (Figure 4). Dates of catch on these fish ranged from late April to early September during the four different years. Total length ranged from 159 to 510 mm TL. Depth and time of catch was 30 to 114 m and 1300 to 2240 hours, respectively (n = 79).

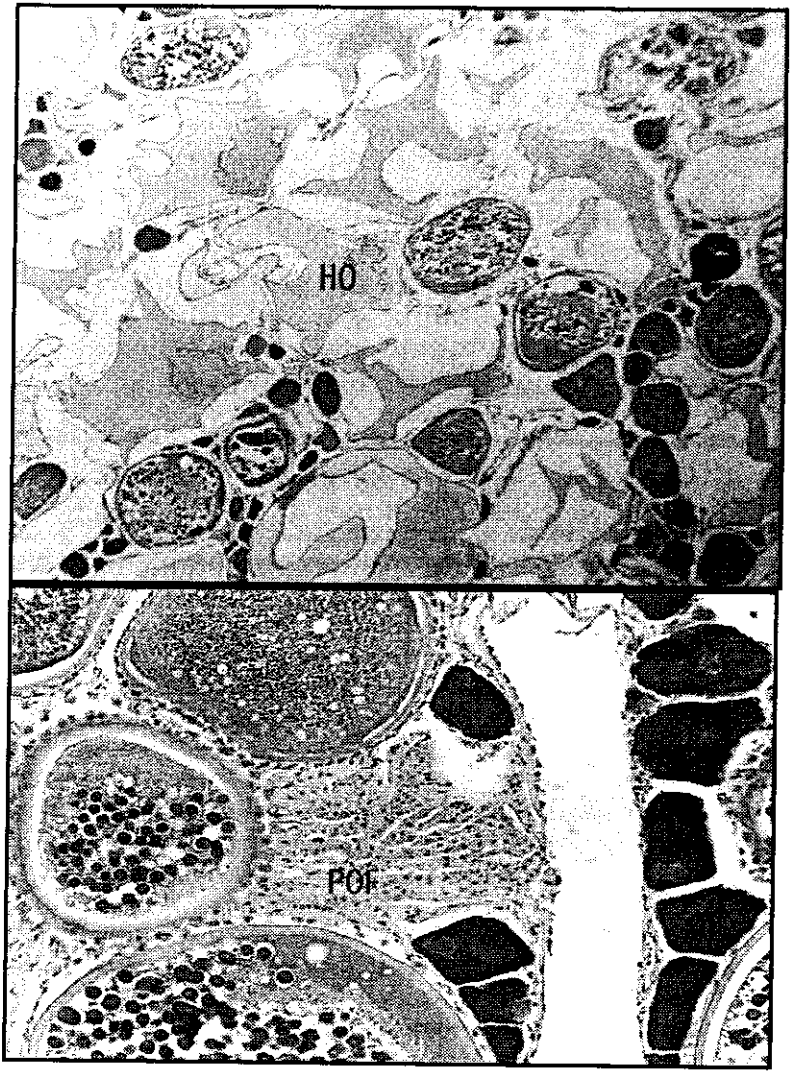

Figure 3. Photomicrographs of histological sections of typical vermillion snapper ovaries collected on June 27, 2000, from one location 10 miles south of Panama City, Florida. The top photo is from a 245 mm total length (TL) female collected between 19:340 and 21:00 hours: shown are fully hydrated oocytes (HO) indicating that the fish was ready to spawn. The bottom photo is from a 244 mm TL female collected between 23:15 and 23:45 hours: shown is a relatively new postovulatory follicle (POF) indicating that the fish just spawned.

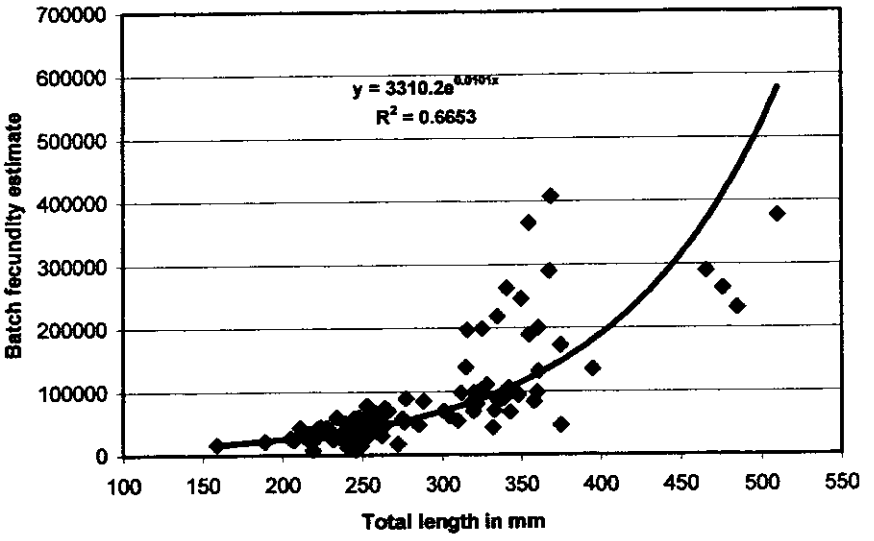

Figure 4. 1993 - 1994 and 2000 - 2001 vermilion snapper batch fecundity regressed on total length (N = 123)

A spawning frequency of 93 was estimated from females collected during 2000 and 2001 off Panama City between the day of first and last occurrence of Stage 5 ovaries in each year. We examined a total of 426 histological slides during these two spawning periods (n = 228 (with fish all < 300 mm TL) for 2000 and n = 198 (with 152 fish < 300 mm TL and 46 fish > 299 mm TL) for 2001). The percentage of females with fully hydrated oocytes between the hours of 1300 (or 1330) and 2230 was used as the best indicator of the percentage of females spawning per day in both years.

Only fishery-independent catches off Panama City were used for 2000 and 2001 spawning frequency estimates. During 2000, hydrated females were found between mid-April and mid-September (=150 days); we sampled 127 females between 1300 and 2230 hours and 63.8% of them were hydrated, giving an average spawning periodicity of 1.6 days (between spawns for each female) and a spawning frequency estimate of 150 (=length of the spawning season in days)/1.6 = 93. During 2001 for fish <300 mm TL, hydrated females were found between early May and late August (=107 days); we sampled 75 females between 1330 and 1700 (and unfortunately only one more female by 2230) and 32.0% of them were hydrated, giving an average spawning periodicity of 3.1 days and a spawning frequency of 107/3.1=35. During 2001 for fish >299 mm TL, hydrated females were found between mid-June and late August (=70 days); we sampled 16 females between 1330 and 2230 and 62.5% of them were hydrated, giving an average spawning periodicity of 1.6 days and a spawning frequency of 70/1.6=44. However, the latter two estimates for 2001 suffered from the fact that we were not able to sufficiently sample the late afternoon

and early evening hours for small fish, or find large fish until June or get good sampling trips in during September; therefore, we believe that it is better to use the same 150 day spawning period for all sizes of female vermilion snapper during 2000 and 2001.

Annual fecundity estimates ranged from 1.4 to 8.2 million for 2000 (n = 59) and from 0.7 to 35 million for some smaller and some larger females for 2001 (n = 20), if the same spawning frequency estimate is used for both years.

DISCUSSION

Our results on sex ratio, spawning months, spawning-time-of-day, and batch fecundity for smaller fish generally agree with recently published estimates for vermilion snapper, but Cuellar et al. 1996 estimated spawning frequency off South Carolina as 35. Our estimate of 93 was larger than theirs possibly due to differences in: areas sampled (Gulf of Mexico versus Atlantic Ocean), our longer sampling period (at least two years versus 13 months for Cuellar et al. 1996), time of sampling (day and night versus daytime), and slightly different methods of estimating spawning frequency. We chose the simplest spawning frequency estimation method using hydrated oocytes because it was too difficult for us to properly preserve gonads at sea in order to ensure that new POFs could always be separated from old POFs in histological slides. Also, ours is not the first seemingly high estimate of spawning frequency for a snapper: Davis and West (1993) found that *Lutjanus vittus* spawn 22 times per month for seven months each year in Australian waters.

Vermilion snapper in the Gulf of Mexico certainly warrant further study. The large vermilion snapper (n = 22 females) caught during June 2001 by a commercial boat off Fort Myers, FL, (Figure 1) were especially interesting. The four largest specimens (466, 476, 485, and 510 mm TL) used in estimating batch fecundity (Figure 4) were collected at this site, which was a 114 m deep "freshwater-spring" (personal communication, Capt. Eric Schmidt and Lisa Hallock, June - August 2001). These fish's reproductive parameters should probably be considered separately from fish in other areas because only the largest females were spawning at this site. All of the smallest females (313 - 424 mm TL; n = 8) from this site had Stage 2 ovaries which were most unusual in our samples from off Panama City: we found very few non-spawning vermilion snapper of any size during the spawning season. All other larger "spring" females (470 - 555 mm TL; n = 14) were Stage 4 and 5. Vermilion snapper from this site may essentially be unfished, or possibly the effects of the "spring" environment are directly or indirectly responsible for this occurrence of large non-spawning females.

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