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EARLY LIFE HISTORY OF THE SNOOK, *Centropomus undecimalis*, IN TAMPA BAY, FLORIDA

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ABSTRACT: Data accumulated during four sampling programs and incidental sampling are used to describe the distribution, growth, range of hatching dates, and diet of juvenile snook, *Centropomus undecimalis*, from Tampa Bay, Florida. A total of 1,655 juvenile snook ranging from 10 to 346 mm SL were collected (72% <70 mm SL). Small juveniles were common in small, quiet marshes, creeks, and lagoons, but their presence was not limited to areas with any single salinity range or vegetation type. Larger juveniles occupied similar habitats but were also found along more open bay and river shores. Length-frequency and otolith analyses were used to determine juvenile growth rates, which varied from 0.5 to 1.2 mm SL/day depending on the spawning date, size, and collection date. Growth data suggested that spawning took place from April until December, with peak spawning occurring in the summer (July to September). Juveniles <45 mm SL fed mainly on copepods and mysids; larger fish switched to a diet of palaemonid shrimp and cyprinodontid and poeciliid fishes.

The snook, *Centropomus undecimalis*, occurs from Pamlico Sound, North Carolina, to Rio de Janeiro, Brazil (Rivas 1986), and is a popular recreational and food fish along the inshore waters of south Florida (Seaman and Collins 1983). Adult (sexually mature) snook are found in rivers, estuaries, and on the outer shores of barrier islands, whereas immature fish are generally restricted to rivers and estuaries (Marshall 1958, Volpe 1959, Fore and Schmidt 1973, Gilmore *et al.* 1983). Fore and Schmidt (1973) examined 183 juveniles taken from tidal streams and dredged canals in the Ten Thousand Islands area. They found that snook ate fishes, shrimps, crabs, and zooplankton and estimated growth at 0.9 mm SL/day by using length-frequency analysis. Gilmore *et al.* (1983) examined 1167 juvenile and adult snook from bays and tributaries of the Indian River Lagoon. They found that young moved from shallow riverine habitat to deeper water or bays as they grew; they estimated growth at 1.0 mm SL/day by using length-frequency analysis and found that the fish were an average of 240 mm SL in March. Little information is available on the habitat, distribution, or diet of juvenile snook in Tampa Bay. Ours is the first study to determine juvenile snook age by counting daily otolith increments in order to verify early growth rates.

In the fall of 1981, we initiated a study in Tampa Bay, Florida, to examine

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the early life history of sciaenids. A large number of juvenile snook from our collections were retained for analysis. In addition to that study, four other studies contributed many juvenile snook to the database. In this paper, we summarize these data to describe the occurrence, relative abundance, habitat, age, growth, and feeding of juvenile snook in the Tampa Bay system.

MATERIALS AND METHODS

Juvenile snook were collected during four juvenile fish studies and several incidental collections made in Tampa Bay during 1981 through 1987 as follows: 1) a 1981-1983 larval and juvenile sciaenid study done at stations 1-19 (Fig. 1); 2) a 1984-1985 Coastal Management (CM) study (Grant No. CM-131) done at stations 5, 8, 20, and 21 concerning the food sources of juvenile snook and several other fishes; 3) a 1985-1987 CM study (Grant Nos. CM-131 and CM-157) done at station 9 A concerning the population dynamics of juvenile snook and red drum (*Sciaenops ocellatus*); 4) a 1986-1987 juvenile mullet (*Mugil cephalus*) study done at stations 5-9, 13-15, and 18-21; and 5) incidental samples taken at stations 5, 8, and 21 from 1986-1987 that targeted juvenile snook. Stations 1-4 and 7 were sampled aperiodically. All other stations were sampled at least monthly during one or more of the above studies. The primary gear used to collect juvenile fish were two bag seines (12.2 m × 1.2 m, 1.6 mm square mesh; and 30.5 m × 2.4 m, 6.4 mm square mesh). Occasionally, snook were captured in a monofilament gill net that had four alternating panels (each 15 m long) of 13 mm, 19 mm, 25 mm, and 38 mm stretch mesh.

Attempts to collect larval snook from Tampa Bay were unsuccessful. Although plankton collections were made at the surface and the bottom at stations 10, 11, 12, and 15 B during the sciaenid study, no identifiable snook larvae were present. Snook larvae used in this study came from a survey by Tolley *et al.* (1987) in Naples Bay (southwest Florida coast). These 11 larvae were used only in otolith analyses to help define early growth.

Habitats sampled ranged from fast- to slow-current grass flats, and from high-energy surf zones to quiet backwaters and rivers. Nursery habitats described in this report are mostly those of snook 10-70 mm SL because juveniles in this size range made up nearly three-quarters of all snook examined.

Data collected at each station included surface salinity (refractometer), surface water temperature and air temperature (mercury thermometer or temperature-compensated conductivity meter), bottom type, vegetation and cover types, and tidal stage. Subjective estimates were made of turbidity and the amount of shade produced by surround-

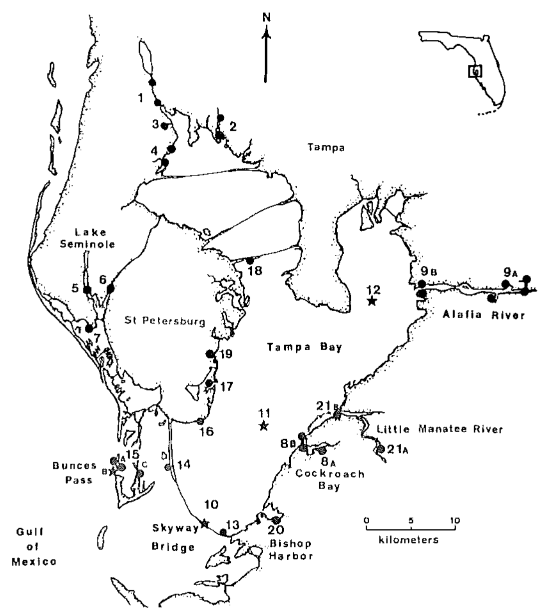

Figure 1. Map of Tampa Bay study area with numbered stations. Circles represent seine stations; stars represent plankton stations.

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ing vegetation. Because data from several studies were combined, data were used without statistical analysis to determine ranges and describe general conditions for stations.

Snook selected for otolith analysis were preserved in 95% ethanol; others were frozen or measured in the field and released. Larval snook were measured to the nearest 0.1 mm standard length (SL) using a dissecting microscope and ocular micrometer. Juvenile snook were measured to the nearest 0.1 mm SL using dial calipers. Juvenile snook fork lengths and total lengths obtained from other studies were converted to standard lengths using the equations of Fore and Schmidt (1973).

Diets of juvenile snook were described by noting the occurrence, volume, and numeric percentages of stomach contents. Prey were identified to the lowest practical taxon. Fullness was estimated subjectively on a scale of 0 (empty) to 5 (full). Volumes were measured by displacement or, for items <0.05 cm^3, by a squash technique (Hellawell and Abel 1971, Ross 1974). Only fish collected from the original juvenile fish survey (stations 9-19, 1981--1983) were used in dietary analyses. Specimens with empty stomachs were not used to compute occurrence, volume, or numeric percentages of dietary items. Comparisons of diets of the fish in different size classes were made using Schoener's (1968) index of proportional overlap based on percent volume.

Growth of young-of-the-year snook was determined by length-frequency analysis and by counting daily growth rings on sagittal otoliths. Length-frequency histograms were generated by dividing snook lengths into 5-mm length classes. Individual years and studies were examined in order to trace individual length-frequency modes for growth analysis although monthly length-frequency data were pooled from all years and studies for presentation in this report. An apparently long spawning period and variations in winter growth rates between early- and late-spawned cohorts resulted in a wide range of juvenile sizes during most months. To simplify age and growth analysis, juvenile snook were divided into two groups: summer recruits (spawned May-Aug) and fall recruits (spawned Sep-Dec). A random subsample of 87 summer-spawned fish and 31 fall-spawned fish <170 mm were used in otolith analysis. Estimating growth rates using length-frequency progressions was complicated by the long period of spawning and by the apparent seasonal and size-related movements into and out of sampling areas. Determining age by otolith analysis was complicated by variable growth rates caused by the long period of spawning and size-dependent seasonal growth. Neither length-frequency nor otolith analysis data alone gave a clear indication of growth rates, but by considering both sets of data, we were able to deduce new information on juvenile snook growth.

Determination of juvenile snook ages by otolith analysis was accomplished by counting the daily rings on sagittae removed from snook collected in Tampa Bay and from the eleven larvae collected in the Naples area. The number of otolith rings counted was assumed to be the actual age because Tucker and Warlen (1986) found that ring formation begins on the day of hatching. Otoliths from larvae were mounted whole on glass slides, and circuli were counted at 400-630 × magnification. Most otoliths from juveniles were mounted in Spurr's epoxy resin and sectioned to 0.125 mm using a low-speed Isomet saw. Sections were then cleared in glycerin for 1-4 weeks, mounted on glass slides, and examined at 100-630 ×. For small juveniles (10-20 mm), one of the two sagitta was also mounted whole on a microscope slide in thermoplastic cement and polished with 3-micrometer grit microtome paper to increase ring clarity. In some cases, it was necessary to polish sections from larger juveniles.

Daily otolith ring formation has been validated in laboratory-reared larval snook by Tucker and Warlen (1986). We validated daily ring formation in juveniles by marking the otoliths of live juvenile fish with tetracycline. Fish were immersed for six hours in 10-15 mg/l tetracycline hydrochloride solution or injected intraperitoneally with 0.1-0.2 mg/gm body weight of 6 mg/ml tetracycline solution. The fish were then maintained for 14 days in the laboratory. Subsequent examination of those fish containing a visible fluorescent tetracycline mark revealed 14 rings between the mark and the edge of the otolith.

Spawning seasons for Tampa Bay snook were estimated from length-frequency data and from growth rates derived through otolith analysis.

Multiple regressions were generated using the Statistical Analysis System (SAS Institute Inc. 1982). Equations that best fit age and length data were determined by using the significance of the regression coefficients, the correlation coefficient (r^2), and the value of the y-intercept.

RESULTS

Juvenile Habitat

Seventy-two percent of the 1,655 juveniles analyzed from Tampa Bay were <70 mm (mode 32 mm; range 10 to 346 mm); therefore, our results are most applicable to smaller sized juvenile snook. Juveniles were most abundant in our seine hauls during the summer and fall (July and December). Surface salinities for collections containing snook ranged from 0‰ to 32‰; water temperatures ranged from 15.4° to 35.6° C.

It was difficult to label any single habitat as being the primary nursery for juvenile snook because relatively large numbers of juveniles occurred under a variety of conditions. Most juveniles (94%) were collected at 5 of the 23 stations that were located in areas characterized as being in relatively shallow, protected riverine or drainage areas with mud or sand/mud bottom: station 9 A (Alafia River, 34%), station 8 A (Cockroach Bay, 23%), station 5 (Lake Seminole outfall, 22%), station 21 A (Little Manatee River, 9%), and station 20 (Bishop Harbor, 6%) (Fig. 1). No submerged seagrasses were found at any of these five stations; however, various other types of vegetation were present. Floating mats of mixed *Panicum* sp., *Polygonum* sp., and *Paspalum* sp. were present at station 21 A. Prop roots and rhizomes of red and black mangroves (*Rhizophora mangle* and *Avicennia germinans*) were immersed during high tides at stations 8 A, 5, and 20, as were the stems of *Juncus roemarianus* at stations 5, 9 A, and 21 A and *Typha domingensis* and *Acrostichum* sp. at stations 5 and 21 A.

Another important element in the juvenile snook habitat may be shoreline vegetation. The shores of all of the 5 previously mentioned stations had various numbers of mangroves, palms (*Sabal palmetto*, *Serenoa* spp.), Brazilian peppers (*Schinus terebinthifolius*), and oaks (*Quercus* spp.). These trees afforded shaded areas for the fish and often provided physical cover in the form of branches that had fallen into the water or were partially submerged at high tide.

The five "primary" stations previously mentioned differed from one

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another with respect to tidal influence, basin profile, and surface area; these differences in turn affected the amount and rate of salinity and temperature changes. Four of the five stations were in tidally influenced dredged canals or drainage ditches and therefore experienced daily as well as seasonal changes in salinity. The fifth station (21 A) was in a small backwater slough in the middle reaches of a river beyond tidal influence and experienced mainly seasonal salinity fluctuations. Bottom slopes varied from very gradual (stations 8 A, 9 A, and 20) to abrupt, vertical drops of up to 1.0 m (stations 5 and 21 A). Surface area was especially limited in the drainage ditches at stations 8 A and 9 A during low tides. Bottom slopes, surface areas, and the resulting water volumes determined how quickly local salinity and temperature changes affected each station. For example, a drainage ditch at station 8 A had a narrow fresh- to salt-water transition zone and was also highly susceptible to daily summer temperature increases, while station 21 A had more surface area and a depth of about 1 m extending nearly to shore, making it a more stable environment.

High temperatures in shallow water during the summer did not appear to affect habitat utilization by juveniles, as was illustrated by a large collection of small juveniles (n = 113) taken at station 8 A during July 1986 in a water temperature of 35.6° C. Low water temperature, or possibly the periodic drop in temperature with cold front passage during the winter, apparently caused movement out of some of our sampling areas; few fish 100 to 200 mm were collected from November to January, even though we were able to capture those sizes in all other months. Juveniles collected during cold months were taken from deeper areas (stations 5 and 21 A) where temperatures were more stable than they were in shallower areas.

Age and Growth

Summer recruits were defined as those fish spawned between May and August and are represented in the length-frequency summary (Fig. 2) by peaks that reflect length increases from about 30 mm in July to 100 mm in October. The number of summer recruits captured by seines decreased until November, and only a few individuals from this cohort were found during December and January. However, summer recruits with lengths of 100 to 310 mm (birth dates

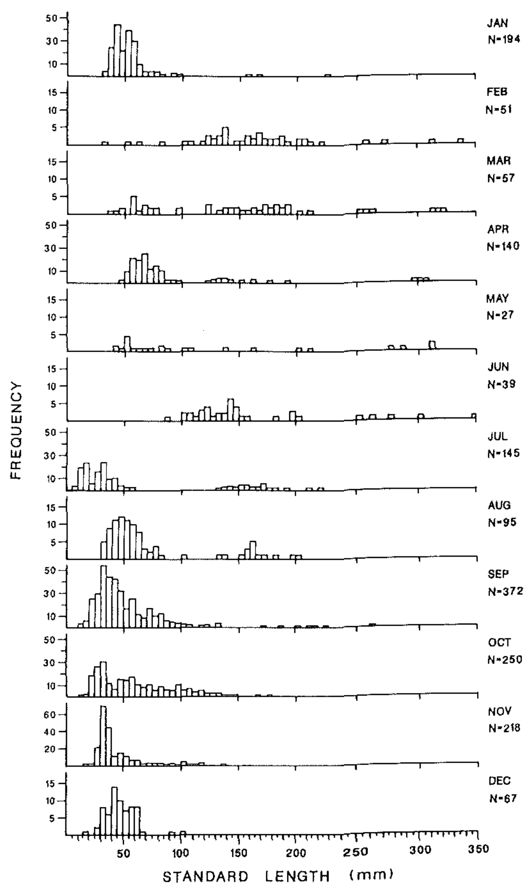

Figure 2. Pooled monthly length-frequency distributions of 1,655 juvenile *C. undecimalis* from Tampa Bay.

confirmed by otolith analysis) were found in February, March, and April collections. Length-frequency peaks of summer-spawned fish during 1986 reflected increased lengths from 30 mm in July to 110 mm in October to about 185 mm by February. Growth rates, determined by 1986 length data, were estimated at 0.9 mm/day during the late summer and early fall and 0.6 mm/day during the late fall and winter.

Fall recruits were defined as being those fish spawned between September and December and are represented in the length-frequency summary by peaks that reflected length increases from 30 mm in November to 50 mm in January (Fig. 2). Fall recruits were numerous in collections taken from September until January, when they had reached lengths from 30 to about 85 mm. Few individuals from this cohort were found in February; however, they were collected again from March (35 to 100 mm) until September (170 to 260 mm). Length-frequency peaks of fall-spawned fish in 1981 moved from about 25 mm in October to 40 mm in December. In 1987, peaks moved from 45 mm in January to 65 mm in April, and in 1986, peaks moved from 120 and 140 mm in June to 150 and 170 mm in July. Growth rates for these fish were estimated at 0.2 mm/day during the late fall and winter and 1.0 mm/day during the following summer.

The regression of otolith ages with lengths of summer-spawned juveniles resulted in a typical sigmoid growth curve (Fig. 3). Age-at-size and size-at-age were described by the following polynomial equations:

$$A = 2.903483L - 0.024782L^2 + 0.000096L^3, r^2 = 0.99, \quad (1)$$

and

$$L = 0.008610A^2 - 0.000025A^3, r^2 = 0.99, \quad (2)$$

where A is age of the fish in days and L is standard length in millimeters. These

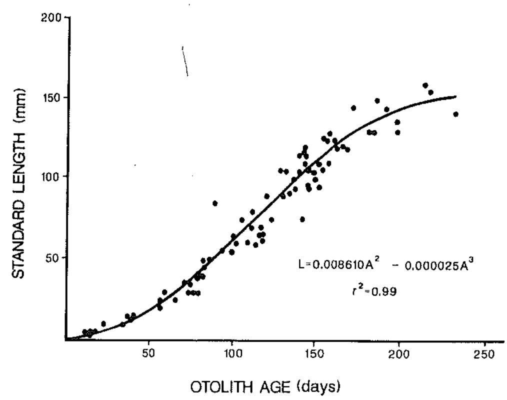

Figure 3. Growth rate of 87 larval and juvenile summer-spawned *C. undecimalis* <170 mm SL determined by counting daily rings on sagittal otoliths.

equations were good predictors of growth in summer-spawned fish, even for the smaller sizes. Based on equation 1, our smallest juveniles (7.7 and 8.0 mm) would be expected to be an average of 21 to 22 days old, whereas the actual increment counts were 18 and 19 rings, respectively. Average calculated ages of 10 mm, 30 mm, and 40 mm juveniles were 27, 67, and 83 days old, respectively. For larger sizes, the equations predicted that juveniles 50, 100, 150, and 170 mm would average 95, 138, 202, and 250 days old, respectively. These ages compare favorably with length-frequency peaks of 50 mm in August (~3 mos.), 100 mm in October (~4.5 mos.), 150 mm in December (~6.5 mos.), and 170 mm in February (~8.5 mos.) derived from length-frequency data. Equation 2 predicts that four-month-old, summer-spawned juveniles would average 83 mm and eight-month-old, summer-spawned juveniles would average 150 mm; these growth rates are about the same as those estimated by using length-frequency data, but are a little slower than those rates estimated by age-at-size calculations (equation 1). Therefore, after considering both otolith and length-frequency growth data, we conclude that summer-spawned snook average 80-85 mm after four

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months of growth and 150-170 mm after eight months.

In addition to the randomly selected summer-spawned juveniles, we made increment counts on three specimens 289 to 300 mm from a January collection. Their daily increments were difficult to count, but we estimated their ages to be roughly 230 days old (spawned in May). These fish probably represented some of the fastest-growing juveniles (about 1.2 mm/day) from the Tampa Bay area. The size of these fish after almost eight months of growth was much larger than the "typical" summer-spawned fish.

The regression analysis of otolith ages with lengths of fall-spawned juveniles were poor predictors of our observed sizes and ages because few fall-spawned juveniles (n = 31) were available for otolith analysis. The equations for these data (Fig. 4) were:

$$A = 2.400L - 0.006L^2, r^2 = 0.98, \quad (3)$$

and

$$L = 0.580A, r^2 = 0.96. \quad (4)$$

Equation 3 was valid only up to lengths of about 100 mm because we had too few fish >100 mm to show the increased spring growth, although it tends to support the length-frequency interpretation that fish that are 45 mm in January are about three months old. The length-at-age equation, equation 4, was linear and therefore reflected neither the slow winter growth we found in counts of actual otoliths nor the increased spring growth. Taking into consideration growth data derived from otolith and length-frequency analyses, we conclude that fall-spawned snook are an average of 50 to 65 mm after four months of growth and 80 to 90 mm after six months. Growth rates of fall-spawned fish appear to increase in the spring; however, our data did not allow us to estimate the size-at-age for these older fish.

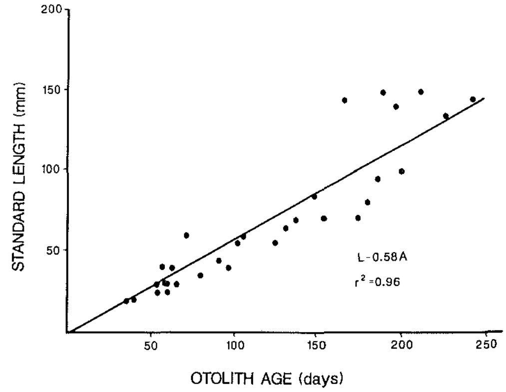

Figure 4. Growth rate of 31 fall-spawned juvenile *C. undecimalis* <160 mm SL determined by counting daily rings on sagittal otoliths.

As the above results show, early growth of Tampa Bay snook varied considerably with size at capture and month of capture. We estimated that the growth rate from hatching until recruitment to our sampling sites was 0.3 mm/day (20 to 27 days old). Summer-spawned fish grew about 0.9 mm/day during the summer and fall, but their growth slowed to about 0.6 mm/day during the winter months. Fall-spawned juveniles grew an estimated 0.5 mm/day during the winter, but then their growth increased to about 1.0 mm/day during the summer. Our highest growth rates (1.2 mm/day) were estimated for fish spawned in spring. It was difficult to determine an average growth rate from our data, but our best estimate is that snook grow at an average rate of 0.6-0.7 mm/day during their first eight months of life.

The otoliths we examined to determine the range of sizes present during March annulus formation suggested that growth slows considerably during the winter and that this slowing is greater in the smaller sizes. This slow growth concentrated the daily growth rings that form the first annulus. Our summer-spawned snook were 120 to 300 mm and 7 to 10 months old at the time of annulus formation. Fall-spawned fish were much smaller. They were only 30 to 100 mm

Table 1. Volume (cm × 10^3) of all food items identified from Tampa Bay *C. undecimalis* stomachs.

	SIZE CLASS (mm SL)								
	8-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	>120
Number examined	2	86	146	83	22	15	28	13	39
Number with food	1	81	137	72	19	12	24	10	30
ITEM									
COPEPODA									
Acartia tonsa	—	193.5	423.0	—	—	—	—	—	—
Acartia sp./copepodites	—	—	15.9	—	—	—	—	—	—
Pseudodiaptomus coronatus	—	3.3	3.1	—	—	—	—	—	—
Calanoid remains	—	10.0	66.2	—	—	—	—	—	—
AMPHIPODA									
Amphipod remains	—	1.8	—	—	—	—	10.0	—	—
ISOPODA									
Aegathoa	—	—	—	—	—	—	—	—	20.0
MYSIDACEA									
Mysidopsis almyra	—	293.3	358.4	170.5	10.5	—	—	—	—
Taphromysis sp.	—	3.0	44.0	—	—	—	—	—	—
Mysid remains	1.8	9.1	35.4	13.0	10.0	—	2.0	—	—
DECAPODA									
Hippolyte zostericola	—	—	—	—	—	—	—	—	30.0
Palaemonetes pugio	—	—	34.0	—	—	—	—	—	1400.0
Palaemonidae	—	—	—	68.0	—	3250.0	1430.0	52.0	—
Decapod larvae/zoea	—	—	0.9	—	—	—	—	—	—
Shrimp remains	—	9.0	147.7	529.6	191.0	135.0	100.0	620.0	1264.0
Crab remains	—	—	—	—	1.8	—	—	12.0	770.0
Crustacean remains	—	3.0	0.1	47.6	—	—	—	—	—
OSTEICHTHYES									
Adinia xenica	—	—	—	—	—	—	1200.0	900.0	3100.6
Anchoa mitchilli	—	—	18.0	—	—	—	—	—	—
Anchoa sp.	—	—	—	—	—	—	18.0	—	—
Atherinidae	—	—	—	—	—	—	1500.0	—	3400.0
Brevoortia sp.	—	—	—	—	—	—	—	—	3000.0
Cyprinodon variegatus	—	—	—	—	250.0	—	600.0	—	1600.0
Cyprinodontidae	—	—	—	—	—	800.0	—	—	—
Fundulus similis	—	—	—	—	—	—	—	—	2000.0
Fundulus sp.	—	—	—	50.0	—	—	—	—	—
Gamusia affinis	—	—	—	5.0	150.0	—	100.0	—	—
Gobiidae larvae	—	3.0	—	—	—	—	—	—	—
Lucania parva	—	—	—	2010.0	—	—	—	—	—
Menidia beryllina	—	—	—	—	—	—	—	—	2300.0
Poecilia latipinna	—	—	20.0	350.0	—	—	—	1100.0	2000.0
Fish larvae	—	0.5	0.9	0.9	—	—	—	—	—
Fish scales[a]	—	—	—	—	—	—	1	1	—
Fish remains	—	21.0	200.0	835.6	1179.8	940.0	5359.5	3380.0	17270.0
MISCELLANEOUS									
Polychaete setae	—	—	—	0.1	—	—	—	—	—
Polychaete remains	—	—	—	—	—	—	—	—	22.0
Plant remains	—	—	—	—	—	—	—	—	23.0
Unidentified remains	—	0.9	4.7	—	—	7.5	0.9	—	—

[a] Indicates occurrence instead of volume

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and 4 to 6 months old when the annulus formed during their first winter.

Spawning and Recruitment

Snook in Tampa Bay have a protracted spawning period. Recruitment of small (<30 mm) juveniles to our sampling sites occurred from July to December, and juveniles <50 mm were collected during every month except June (Fig. 2). Length-frequency data suggest that snook spawn from April through December with peak spawning occurring during summer. Evidence that spawning occurs in April is provided by the capture in July of juveniles 55 mm (Fig. 2). Evidence that spawning occurs as late in the year as early December is provided by the specimens 15 mm collected in December and a specimen 20 mm from late January. Spawning activity was greatest during the summer months (July to September), as indicated by the large number of small juveniles taken from September to November in those studies that conducted periodic sampling over the entire year.

Diet

The majority of the juvenile snook stomachs we examined contained food. Of the 434 snook (11-346 mm) examined, 89% of the stomachs contained food. Although only one of the two fish <15 mm had food in its gut, the percentage of stomachs with food from other size classes ranged from 94.4% in 15-30 mm juveniles to 76.9% in 105-120 mm juveniles. Mean fullness values for fish whose stomachs contained food ranged from 3.3 to 4.4 for size classes >15 mm. Because our samples were collected between 0900 and 1500 hrs., these index values indicate daytime feeding; however, no diel collections were made to determine feeding periodicity.

Snook showed evidence of ontogenetic changes in diet at sizes of about 45 mm (Table 1, Fig. 5). Juveniles <45 mm obtained most of their prey volume from mysids (predominantly *Mysidopsis almyra*) and copepods (principally *Acartia tonsa*). Juveniles >45 mm consumed some mysids but obtained most of their prey volume from fish (cyprinodontids and

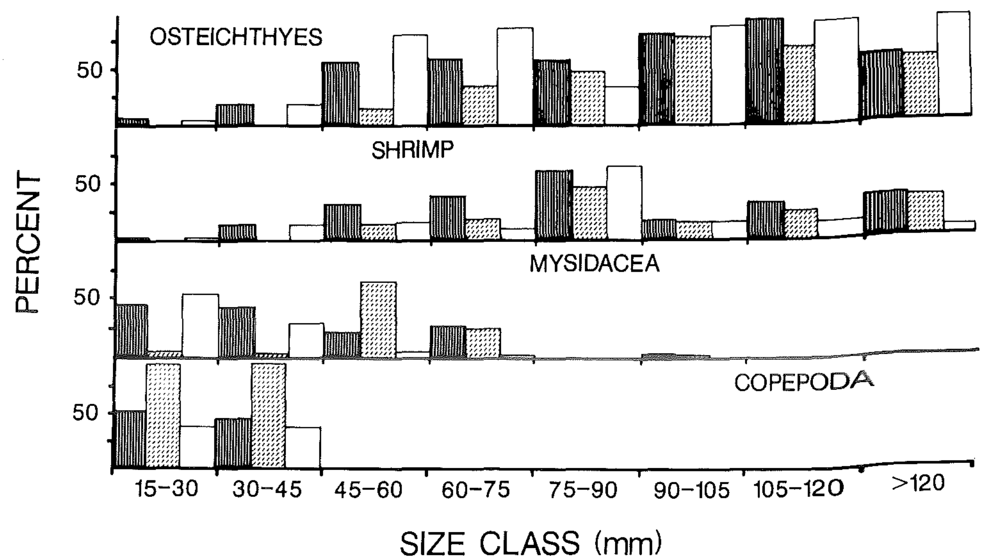

Figure 5. Percentages of volume (shaded), number (stippled), and occurrence (open) of major prey groups for each 15-mm-SL size class of *C. undecimalis* collected in Tampa Bay.

Table 2. Dietary overlap based on volume percentage of prey items for 15-mm size classes of *C. undecimalis*. Number of fish with food in their stomachs is shown in parentheses. (Values approaching 1 indicate similarity of diet, and values approaching 0 indicate no similarity.)

Size Class (mm SL)		30-45 (137)	45-60 (72)	60-75 (19)	75-90 (12)	90-105 (24)	105-120 (10)	>120 (30)
15-30	(81)	.76	.08	.07	.06	.06	.06	.06
30-45	(137)		.35	.27	.31	.31	.30	.24
45-60	(72)			.92	.49	.94	.91	.87
60-75	(19)				.45	.95	.99	.95
75-90	(12)					.49	.45	.41
90-105	(24)						.96	.92
105-120	(10)							.96

poeciliids) and shrimp (palaemonids). This transition was further indicated by the low dietary overlap (<35%) between smaller (<45 mm) and larger size classes (Table 2).

DISCUSSION

Juvenile Distribution

Juvenile snook from Tampa Bay were found in habitats similar to the brackish tidal stream and dredged canal habitats described by Springer and Woodburn (1960) and Fore and Schmidt (1973) and also the "freshwater" habitat described by Gilmore *et al.* (1983). The flooded marsh habitats described by Harrington and Harrington (1961) and Gilmore *et al.* (1983) are uncommon in Tampa Bay.

Movement of snook between habitats has been attributed to size and temperature changes. Gilmore *et al.* (1983) noted that juveniles left stream bank habitats and migrated to deeper water or into salt marshes after reaching 40 to 60 mm and that larger juveniles (mean length 240 mm) were collected in the bay over seagrass beds during March. The number of snook declined sharply in our samples at lengths >70 mm, although these larger juveniles were more abundant in some months than in others. Snook 70 to 135 mm were collected at regular stations during September and October and to a lesser extent during November. This cohort was rare in collections from December and January, but they were present in collections from February and March, suggesting movement out of and back into our sampling habitat. We believe movement out of the area took place rather than net avoidance because from February until August we were able to capture juveniles of this size and larger. Temperature decreases may have affected Tampa Bay snook movements in winter because water temperatures at some of our stations fell below that at which snook reportedly stop feeding (Shafland and Foote 1983).

In Tampa Bay, large juveniles (135 to 210 mm) were mainly taken during February and March at stations with riverine habitat. Gilmore *et al.* (1983) also collected juveniles in March; however, their fish were collected over seagrass beds and were much larger than our fish (mean length 240 mm), which suggests that they observed a different cohort of fish.

Age and Growth

The early growth rates of Tampa Bay snook in this study were compared with growth rates from other studies. Our estimated growth rates for juvenile snook (0.6 to 0.7 mm/day) are lower than literature values. Fore and Schmidt (1973) estimated growth of 12 to 177 mm SL

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snook (not including larval growth) from the Ten Thousand Islands area to be about 0.9 mm/day. Gilmore *et al.* (1983) suggested even faster growth (about 1.0 mm/day, including larval growth), but that figure may be revised with new data from the Indian River Lagoon (Gilmore, Harbor Branch Oceanographic Institute, *pers. comm.*). Our highest growth estimate was 1.2 mm/day for spring-spawned fish whereas that of Gilmore *et al.* (1983) was 1.1 mm/day, but growth estimates of fish from natural areas are not as high as those reported for fish cultured in the laboratory (1.4 mm/day) by Chapman (1982).

We compared the sizes of our fish at the time of the first annulus formation with sizes at first annulus formation from other juvenile and adult studies. Volpe (1959) and Bruger (Fla. Marine Research Institute, *pers. comm.*) determined that annulus formation occurs in March. Our March young-of-the-year ranged in size from about 35 to 300 mm and were an average of about 150 mm; those of Gilmore *et al.* (1983) were an average of 240 mm. However, Gilmore (Harbor Branch Oceanographic Institute, *pers. comm.*) suggested that new data on Indian River snook will give information concerning a 120 to 200 mm cohort that was absent from the Gilmore *et al.* (1983) data and may modify growth data for that area. The back-calculated sizes at age I reported by Volpe (1959, 141 mm) and Bruger (Fla. Marine Research Institute, *pers. comm.*, 129 mm) are close to our estimate of 150 mm and fall within our range of lengths of juvenile snook captured during March. The back-calculated length at age I reported by Thue *et al.* (1982, 326 mm) appears to be too high when compared to the above studies and the snook lengths we found during March, unless Everglades snook are growing much faster than snook in other parts of Florida.

Spawning and Recruitment

Adult snook studies generally indicate a range of April or May until December as the spawning period for snook, with peak spawning occurring between May and August (Marshall, 1958; Chavez, 1963; Fore and Schmidt, 1973; Ager *et al.*, 1976; Bruger, Fla. Marine Research Institute, *pers. comm.*). Juvenile recruitment studies tend to support these spawning periods (Fore and Schmidt 1973, present study), although Gilmore *et al.* (1983) found specimens <30 mm in every month except April and May and concluded that spawning occurred year-round in the Indian River area. Our studies showed that small, fall-spawned fish captured in winter may be growing more slowly than larger, summer-spawned young-of-the-year, and therefore may not have been spawned as late in the winter as length-frequency data indicate.

Dietary Habits

We found an apparent feeding transition period for snook at about 45 mm. Snook of this length were consuming fewer copepods and more fish and shrimp. Harrington and Harrington (1961) and Fore and Schmidt (1973) found a transition in snook diets involving similar food items, but this transition took place at a smaller size (15 to 25 mm).

Juvenile snook 25 to 120 mm primarily consume fish, palaemonid shrimp, and microcrustaceans (Harrington and Harrington 1961; Fore and Schmidt 1973; Gilmore *et al.* 1983, present study). Our snook stomach content analyses yielded ten fish species, all of which are commonly collected with snook. Gilmore *et al.* (1983) found that snook consumed the most abundant small fish in the habitat. In freshwater, Gilmore *et al.* (1983) found that *Gambusia affinis* was the most abundant fish in snook stomachs and in the study area, whereas at their seagrass bed station, *Anchoa mitchilli* and *Lagodon rhomboides* were the most abundant fish in snook stomachs and in the study area. Fore and Schmidt (1973) identified fishes (mainly poeciliids, cyprinodontids, and atherinids) as making up 81% of the volume and occurring in 78% of the stomachs examined.

The type of shrimp eaten by snook depends on the size of the snook and the area where the snook were feeding. Fore and Schmidt (1973) reported that palaemonid shrimp were common in the stomachs of their small juveniles (26-100 mm), whereas larger penaeid shrimp formed the major shrimp prey in the diets of their large juveniles (100-200 mm). Juveniles examined by Linton and Richards (1965) fed predominantly (88% frequency of occurrence) on *Palaemonetes* sp. Austin and Austin (1971) and Gilmore *et al.* (1983) found penaeid shrimp in the snook stomachs they examined. Palaemonid shrimp were important in the diet of Tampa Bay snook <45 mm, but no fish stomachs contained penaeid shrimp.

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