

USE OF RIVERS BY COMMON SNOOK *CENTROPOMUS UNDECIMALIS* IN SOUTHWEST FLORIDA: A FIRST STEP IN ADDRESSING THE OVERWINTERING PARADIGM

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ABSTRACT: *Common snook Centropomus undecimalis in Florida are thought to move from open estuarine and coastal marine habitats into rivers during colder months to overwinter; however, this paradigm has never been formally tested. Seasonal electrofishing surveys (2004–2006) were conducted to determine the distribution, abundance, and size of common snook in the three major rivers leading to the Charlotte Harbor estuary, Florida. Common snook abundance in the tidal freshwater portions of all three rivers was high in spring and summer, and then doubled in fall. In the open estuary, haul seine data (1997–2007) were used to examine seasonal trends; common snook abundance was significantly lower during winter. No specific size group alone appeared to be involved in these seasonal changes, as length frequencies did not differ between seasons. Although these results provide evidence that a portion of the population moves between the rivers and the open estuary, the reasons for these movements require further study. The strong presence of common snook in the rivers during summer and their peak abundance in fall as opposed to winter, were unexpected and suggest that there may be interactions between their use of freshwater and marine environments that are more complex than previously considered.*

Key Words: Fish, electrofishing, Peace River, Myakka River, Caloosahatchee River, Charlotte Harbor estuary

EURYHALINE fishes able to survive low salinities of the upper estuary are thought to benefit from reduced competition, lower predation pressure, and an abundant food supply (Day et al., 1989). Consequently, tidal rivers are important to the life histories of many marine fishes (e.g., Weinstein, 1979; Ross and Epperly, 1985; Peterson and Ross, 1991). Although freshwater and oligohaline portions of tidal rivers are widely recognized as habitat for juveniles of marine species, few studies have considered the importance of these areas for adults of marine species, particularly for those that do not use rivers as spawning habitat. One nonanadromous species that uses tidal rivers as adults is the common snook *Centropomus undecimalis* (Bloch) (50% maturity at 330 mm SL; Peters et al., 1998) a popular gamefish that supports a large recreational fishery throughout much of coastal south and central Florida.

Most anglers, outdoor writers, and biologists have long subscribed to the paradigm that common snook move from open estuarine shorelines into rivers, creeks, and canals during colder months, presumably to overwinter where temperatures are thought to be warmer (Volpe, 1959). Research into the life history of this species has uncovered biological information that gives credence to the possibility that this species has seasonal patterns of movement. Common snook spawn during late spring and summer (April–September) and require high salinity (≥ 28 psu) to buoy their fertilized eggs (Chapman et al., 1978), which explains their prevalence in the passes and high-salinity waters of the open estuary during summer (Marshall, 1958; Fore and Schmidt, 1973; Taylor et al., 2000). Common snook terminate feeding and lose equilibrium at water temperatures of 12–18°C, and die at lower temperatures (Shafland and Foote, 1983; Howells and Sonski, 1990), which may explain their movements into rivers during winter if these areas offer warmer or more thermally stable waters.

A more complete understanding of common snook and their seasonal habitat use is now needed as rivers face increasing anthropogenic pressure from urban development, mining, and water withdrawals. In early reports, the principal habitat of adult common snook was defined as brackish waters of estuaries and marine waters of inlets, barrier islands, and beaches (Marshall, 1958), and most sampling efforts have focused in these areas (Taylor et al., 2000; Kupchus and Tremain, 2001; Blewett et al., 2006). Currently, little information exists on the use of rivers by common snook (Champeau, 1990); consequently, there are no scientific studies that either definitively support or refute the widely accepted paradigm that common snook use rivers to overwinter. Baseline information is still needed on the seasonal use of common snook in both riverine and estuarine habitats. This study is the first to report seasonal abundances and sizes of common snook from both tidal rivers and open estuarine shorelines in southern Florida.

MATERIALS AND METHODS—Study Area—Charlotte Harbor is a 700-km² subtropical estuary located on the southwest coast of Florida (Hammett, 1990; FIG. 1). The Peace, Myakka, and Caloosahatchee rivers provide about 13.25×10^6 m³ of fresh water to the estuary each day.

The Peace River is 182 river-kilometers (rkm; distance along the river's centerline) long, descends 30 m at an average gradient of 0.2 m km⁻¹, drains a 5,959-km² watershed, and has an average annual discharge of 32.7 m³ s⁻¹ (Estevez et al., 1981). Strip mines, agriculture, and urban development within the Peace River basin have altered the hydrology and degraded water quality (PBS&J Inc., 2007) but the river remains unimpounded and its banks are relatively unaltered. A total of 26 rkm of the upper-tidal Peace River were sampled for this study, 13 rkm in the main stem and 13 rkm in two large oxbows (Hunter and Deep creeks) (FIG. 1). Within the sampling area, the width of the main river stem ranged from 114 m at the upstream boundary to 324 m at the downstream boundary. The shorelines were dominated by emergent marsh grasses and mangroves in the lower section, and then transitioned to oaks and palms approximately 9 rkm upstream.

The Myakka River is 87 rkm long, descends at an average of 0.39 m km⁻¹, drains a 1,399-km² watershed, and has an average annual discharge of 7.1 m³ s⁻¹ (Bass and Cox, 1985). Pasture and agriculture lands occur within the Myakka River basin; however, the upper half of the river is within the boundaries of a large state park (150 km²), and a large portion of the river is designated as a "Wild and Scenic River" by the State of Florida. Two shallow weirs exist on the river and are

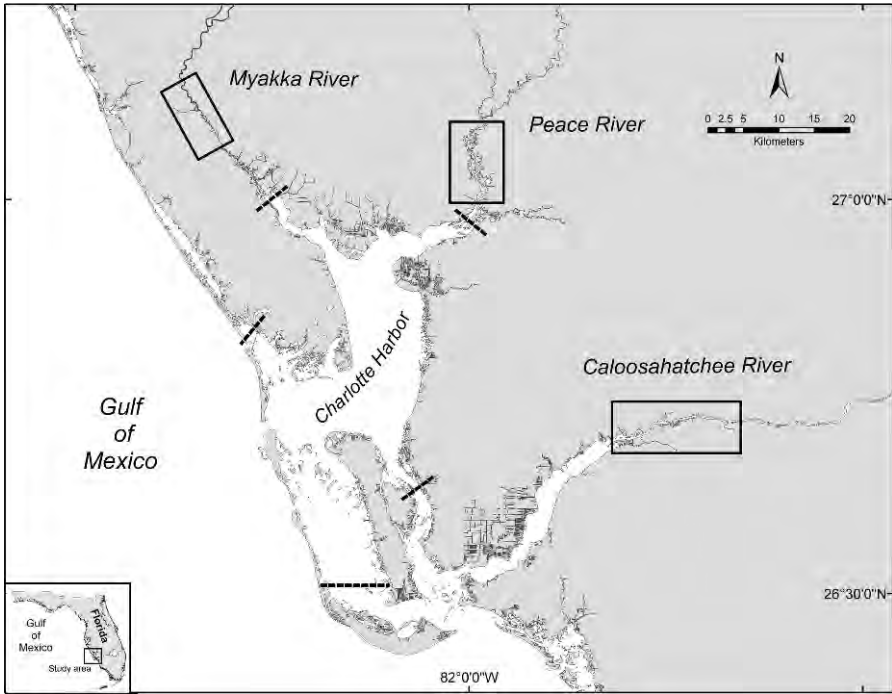


FIG. 1. Map of the Peace, Myakka, and Caloosahatchee rivers, and the Charlotte Harbor estuary. The boxes indicate the electrofishing study area within the rivers and the dotted lines denote the boundaries for Fisheries-Independent Monitoring program haul-seine sampling universe.

passable to fish except during very dry conditions. A total of 14 rkm of the upper-tidal Myakka River were sampled for this study (FIG. 1). Within the sampling area, the width of the river ranged from 14 m (upstream) to 77 m (downstream). The shorelines were dominated by emergent marsh grasses and mangroves in the lower section, and then transitioned to oaks and palms approximately 8 rkm upstream.

The Caloosahatchee River is now best described as a cross-state canal because of extensive anthropogenic alteration (Bass and Cox, 1985). Conversion to a canal began in the 1800s with the construction of a connection between its headwaters and Lake Okeechobee. In the following years, the Caloosahatchee River was gradually channelized and three water-control structures with navigational locks were installed between Lake Okeechobee and the estuary. The river is 121 rkm long, descends at an average gradient of 0.04 m km^{-1} , drains approximately $3,569 \text{ km}^2$ and has an average annual discharge of $40.8 \text{ m}^3 \text{ s}^{-1}$ (Hammet, 1990). A total of 25 rkm of the Caloosahatchee River was sampled for this study (19 rkm upper-tidal and 6 rkm nontidal, separated by the Franklin Lock) (FIG. 1). Sampling occurred along shorelines in the main stem (channel) and in relict meanders (meanders that remained after channelization). Within the sampling area, the width of the main river stem ranged from 114 m (upstream) to 500 m (downstream). The shorelines were dominated by mangroves, exotic plants, seawalls, steep unvegetated banks, and docks in the lower section of the study area and by unvegetated banks with scattered docks, hardwood trees (e.g., oak and cypress), and emergent vegetation in the upper portion.

Common snook sampling—Common snook were sampled seasonally (calendar seasons; fall [21 September–20 December], winter [21 December–20 March], spring [21 March–20 June], summer

TABLE 1. Sampling effort for electrofishing in three southwest Florida rivers (fall 2004 – summer 2006).

River	Number of Samples (fixed/random)								Total
	2004		2005				2006		
	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	
Peace	4/6	4/6	4/6	4/6	4/8	4/8	*0/4	4/8	28/52
Myakka	2/4	2/4	2/4	2/4	2/8	2/8	2/8	2/8	16/48
Caloosahatchee	-	-	*3/8	4/8	4/8	4/8	4/8	4/8	23/48
Total	6/10	6/10	9/18	10/18	10/24	10/24	6/20	10/24	67/148

*not all samples were completed

[21 June–20 September]) in the Peace and Myakka rivers from November 2004 to August 2006 and in the Caloosahatchee River from May 2005 to August 2006 (Table 1). Fish were collected with an electrofishing boat, with pulsating direct current. Electrical output was regulated by a Smith-Root model 9.0 electrofisher, which used the aluminum boat hull as the cathode and a pair of bow-mounted-boom electrode arrays as anodes. The electrofisher was set at 120 pulse s^{-1} , 480–680V, and 6–12 amps for the majority of samples (> 90%), which were collected in freshwater (conductivity ca. 200–800 $\mu S\ cm^{-1}$). Electrofishing transects were conducted into the current along the shoreline, except at several sites in the Caloosahatchee River, where bridges and large docks were sampled. Two research staff at the bow of the boat and one at the stern captured stunned common snook and largemouth bass (*Micropterus salmoides* [Lacepède]) with dip nets. Common snook were measured to the nearest mm total length (TL) and released alive.

A standardized fixed and stratified-random seasonal sampling protocol was followed for all electrofishing collections. For the purpose of site selection each of the three rivers was divided into logistical zones (each approximately 6 km long); fixed and stratified-random sites were distributed among the zones to ensure adequate sampling coverage. Since we had no prior knowledge of the distribution of common snook in the rivers, the selection of fixed sites involved the use of local angler knowledge to help ensure that adequate numbers of common snook would be collected for the study. Transects at fixed sites were sampled for 10 min (approx. 300m); time periods were measured by the electrofisher as the length of time that the electricity was actually applied to the water. Random sites were selected by randomly choosing points spaced ca. 0.1 km apart along the centerline of the river within each logistical zone. Depth was used as a strata in the random sampling; at each randomly selected point, one 5-min transect (approx. 150m) was completed at a depth of >0.9 m, then a second 5-min transect was completed at a depth of >1.7 m within 0.75 km of the original random point. A total of 215 samples (67 fixed, 148 stratified-random) were collected from the three rivers, in depths of 1.0–4.0 m. Natural shorelines were sampled exclusively in the Peace and Myakka rivers. Natural and dredged shorelines, and areas around man-made structures (e.g., bridges, docks), were sampled in the Caloosahatchee River. All sampling was completed between 0800 and 1800 Eastern Standard Time. Water depth was recorded at the beginning, middle, and end of each 10-min transect and at the beginning and end of each 5-min transect.

For seasonal evaluations of common snook size and abundance from the Charlotte Harbor estuary, data from the Fish and Wildlife Research Institute's Fisheries-Independent Monitoring program from January 1997 through December 2007 were used. Common snook were collected monthly with a 183-m center-bag haul seine (38-mm stretched mesh) from the Charlotte Harbor estuary. Monthly seine samples were grouped in the same calendar seasons as the electrofishing samples. A standardized random sampling protocol was followed for all collections, and a total of 2,244 samples (17 per month) were collected throughout the entire estuary along shorelines in depths of 2.5 m or less (see Casey et al. [2007] for more detailed descriptions of the survey design, deployment techniques, and sample processing). Length measurements of common snook from the

open estuary were recorded as standard length; conversions to total length were made following Taylor and co-workers (2000). At all sampling sites (electrofishing and seining), surface and bottom temperature and salinity were recorded with a water quality datasonde.

Data analysis—Nonparametric tests were used to analyze the data because sample sizes were relatively small and the data did not meet the parametric assumption of normality. To evaluate the differing sampling strategies in the rivers (fixed vs. random sites), abundances (fish min^{-1} electrofishing time) of common snook collected from fixed and random sites were compared using the Mann-Whitney U-test. Comparisons of temperature and depth between fixed and random sites were also made using the Mann-Whitney U-test (salinity was not tested because all electrofishing was done in <3 ppt; 95% of the samples in <1 ppt). Because of the differences in gear (electrofishing vs. seines) used to sample the rivers and open estuary, we tested for seasonal changes in abundance and length frequencies in these two habitats separately. Length frequencies of common snook were compared by season (six pairwise comparisons) using the Kolmogorov-Smirnov (KS) test, adjusting p-values to avoid an inflated overall level of significance (p values \times number of pairwise comparisons) (Sokal and Rohlf 1981). Abundances of common snook were pooled by season (in the case of the river habitat, all rivers were combined) and compared using Kruskal-Wallis One-Way Analysis of Variance. Pairwise comparisons were made using Dunn's Method (Zar, 1984).

RESULTS—We collected a total of 1,144 common snook ranging 100–1,085 mm TL from the three rivers. Common snook were widespread throughout the sampled portions of the rivers, as indicated by similar catch rates within each season at fixed and random sites (FIG. 2). During fall, spring, and summer the abundances of common snook were not significantly different between fixed and random sites (p values > 0.1); however, during winter they were significantly greater at fixed sites ($p = 0.01$). Depth was significantly greater at fixed sites during each season (p values < 0.02), except for spring ($p = 0.24$). Temperature did not differ within any season between fixed and random sites (p values > 0.18 ; Table 2).

Abundance of common snook was consistently highest in the Peace River, followed by the Myakka and Caloosahatchee rivers, respectively (FIG. 3). During both years of the study common snook in all three rivers showed a similar seasonal abundance trend: typically higher abundances in fall and winter than in spring and summer. The only notable variation from the trend was observed during fall 2005 in the Myakka River, where abundances were considerably lower than the previous fall. The Caloosahatchee River, the only river with a lock and dam within the study area, had similar seasonal abundance trends both upstream and downstream of the structure, so samples upstream of the lock were pooled with those below. Examining all rivers and all years combined, common snook were approximately twice as abundant during fall as in spring and summer (p values < 0.05 ; FIG. 4). Abundance in winter was consistently lower than fall and higher than spring and summer but these differences were not significant (p values > 0.05). The size distribution of common snook in the rivers did not change among seasons (six pairwise comparisons; p values > 0.30 ; FIG. 5).

In the open estuary, we collected 7,761 common snook ranging 143–1,140 mm TL. The abundance of common snook was typically high in summer and

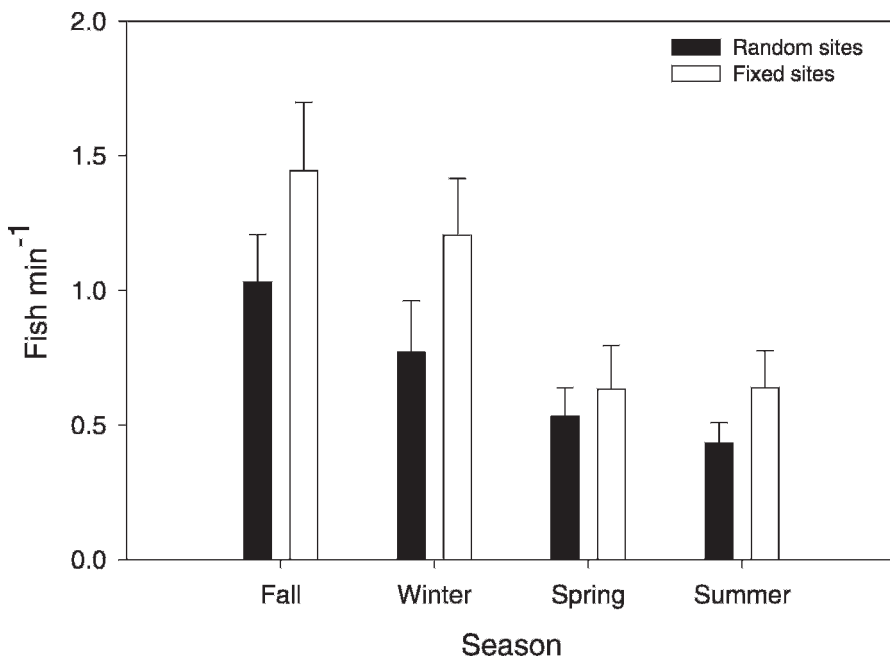


FIG. 2. Abundance of common snook (\pm standard error) *Centropomus undecimalis* collected at both fixed and random sites in the Peace, Myakka, and Caloosahatchee rivers by season (fall 2004–summer 2006).

low in winter (years 1998-99, 2002-04, and 2007; FIG. 6a); however, several years showed a different pattern of high abundances during spring (1997 and 2001), fall (2005 and 2006), or winter (2000) (FIG. 6b). For all years combined, winter abundance was significantly lower than spring, summer, and fall (p values < 0.001; all other pairwise seasonal comparisons were not significant; FIG. 7). The size distributions of common snook in the open estuary did not differ among seasons (six pairwise comparisons; p values > 0.12; FIG. 8).

Average seasonal temperatures from the river and the open estuary were very similar and ranged from a winter low of 18.0°C to a summer high of 31.3°C. In the open estuary, the average seasonal salinity ranged from 15.2 to

TABLE 2. Mean (standard error) water temperature and depths by season at electrofishing sites in the Peace, Myakka, and Caloosahatchee rivers.

Season	Temperature (°C)		Depth (m)	
	Random	Fixed	Random	Fixed
Fall	22.3 (0.3)	22.3 (0.3)	2.0 (0.2)	2.5 (0.2)
Winter	19.0 (0.4)	19.4 (0.6)	1.9 (0.2)	2.4 (0.2)
Spring	26.3 (0.3)	26.4 (0.7)	2.2 (0.2)	2.6 (0.3)
Summer	29.6 (0.2)	29.1 (0.2)	1.9 (0.1)	2.5 (0.2)

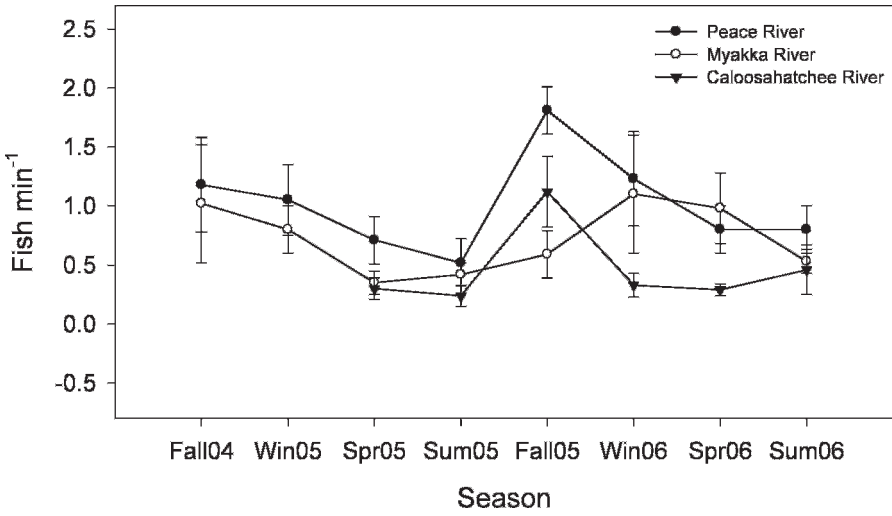


FIG. 3. Abundance of common snook (\pm standard error) *Centropomus undecimalis* collected in each season (fall 2004–summer 2006) for each river. Each season and year sampled is represented along the x-axis; the letters represent the season and the numbers represent the year.

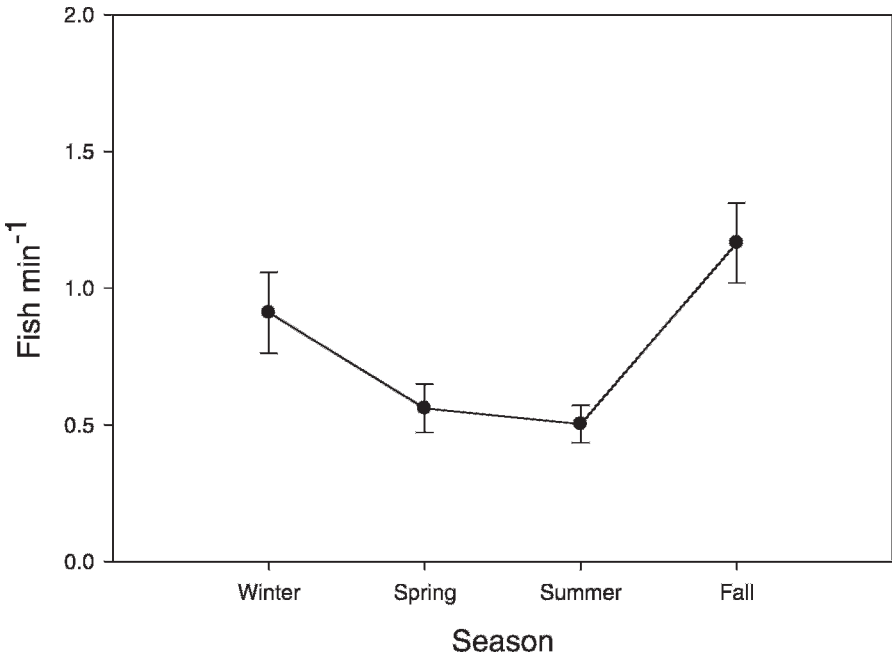


FIG. 4. Abundance of common snook (\pm standard error) *Centropomus undecimalis* collected in the Peace, Myakka, and Caloosahatchee rivers by season for all years combined (fall 2004–summer 2006).

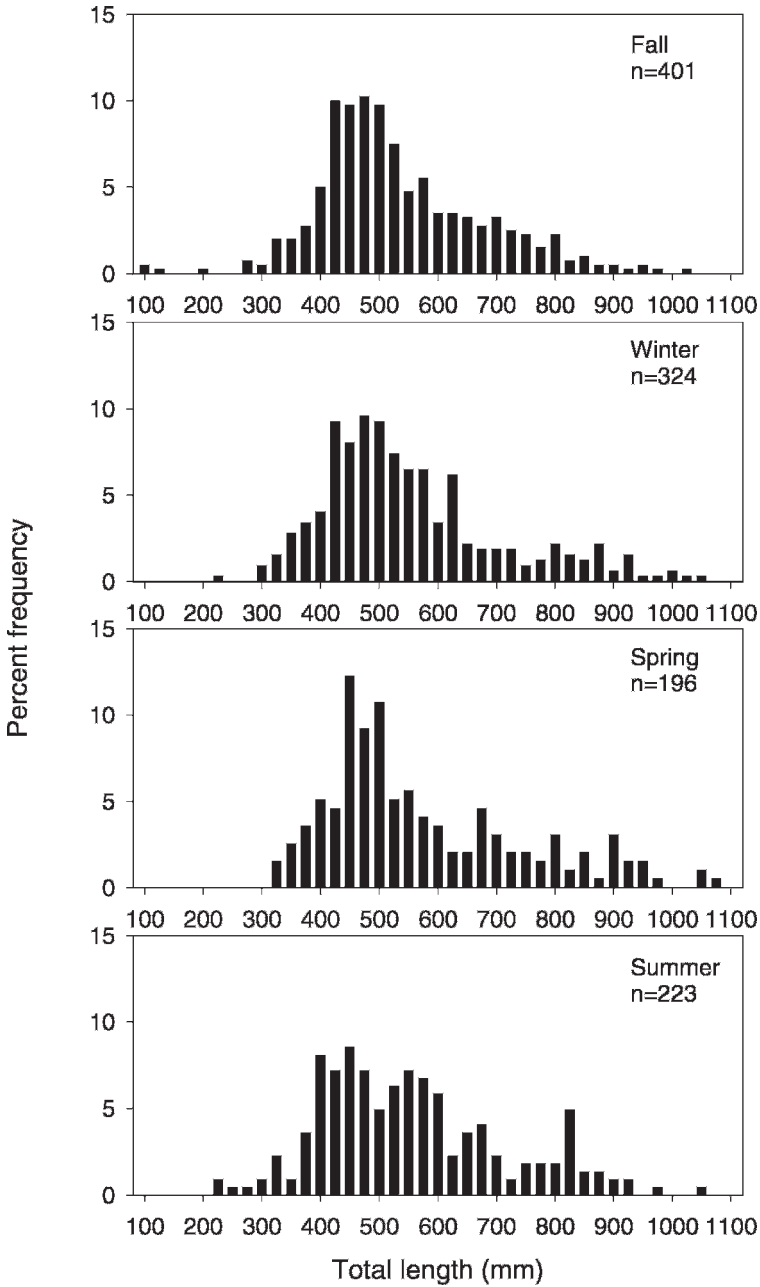


FIG. 5. Length-frequency distribution of common snook *Centropomus undecimalis* collected in the Peace, Myakka, and Caloosahatchee rivers by season (fall 2004–summer 2006).

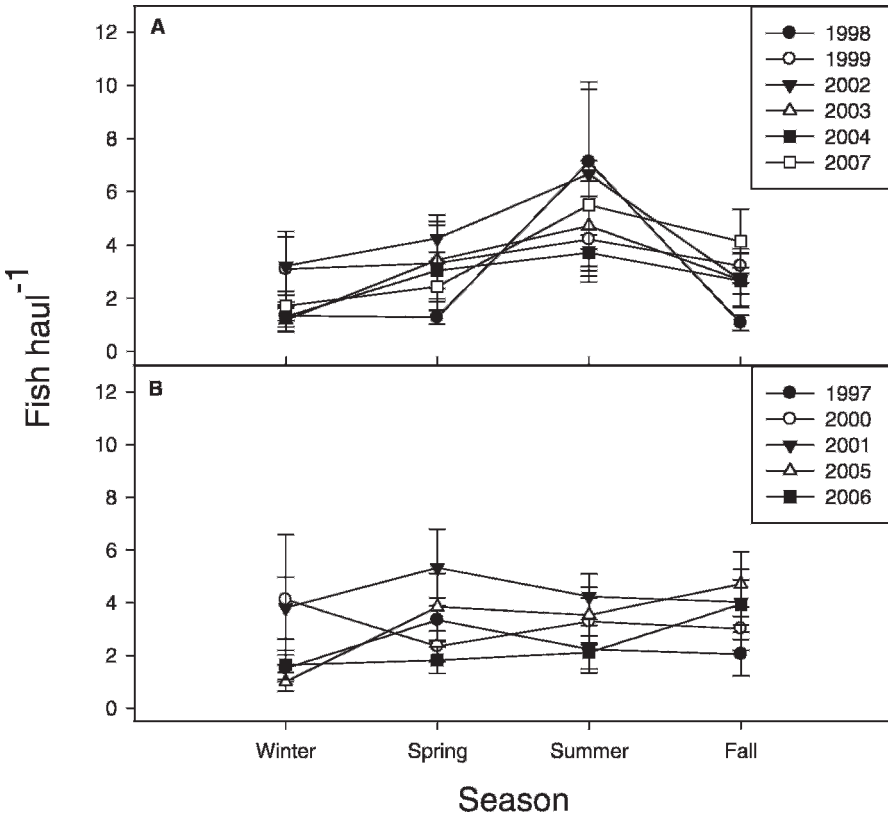


FIG. 6. Abundance of common snook (\pm standard error) *Centropomus undecimalis* collected in the Charlotte Harbor estuary by season and by year (January 1997–December 2007). A) Years with a high abundance of common snook during summer and low abundance during winter. B) Years with the highest abundance of common snook occurring during either winter, spring, or fall.

36.7 ppt, and in the river from 0.1 to 1.0 ppt. Seines in the open estuary typically sampled shallower water (average seasonal depth 1.0 to 1.4 m) than samples taken by electrofishing in the rivers (average seasonal depth 2.1 to 2.6 m) (FIG. 9).

DISCUSSION—Adult common snook in Florida have been known to occur principally in brackish areas of the estuary within close proximity to mangroves, and in marine waters of inlets and along barrier island shorelines (Marshall, 1958). They have also been known to occupy oligohaline and freshwater river environments; however, these habitats have not been viewed as a major component of their life history. This is most likely due to a lack of sampling in these areas. This study documented relatively high abundance of common snook in three rivers of southwest Florida during all seasons. For example, electrofishing catch rates were greater for common snook than for large freshwater predators such as largemouth bass occupying similar systems

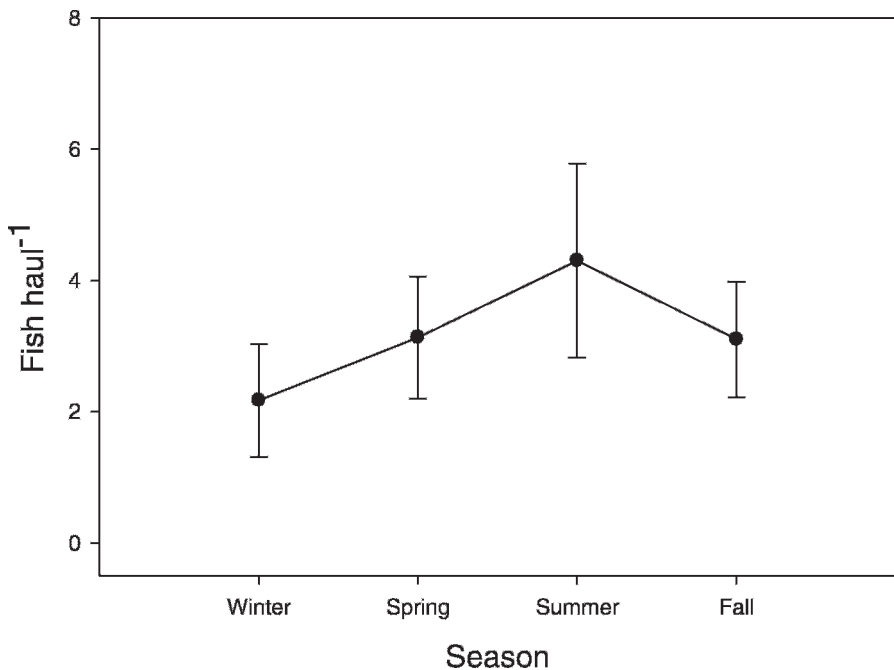


FIG. 7. Abundance of common snook (\pm standard error) *Centropomus undecimalis* collected in the Charlotte Harbor estuary by season for all years combined (January 1997–December 2007).

(Champeau, 1990; Havens et al., 2005). Seasonal abundance trends of common snook were evident during the two-year study of the rivers, and abundance nearly doubled from summer to fall. In the open estuary during 11 consecutive years of sampling, common snook seasonal abundance was typically lowest in winter. Changes in seasonal abundance between the two habitats provide evidence that a portion of the population moves between the rivers and open estuary. However, there does not appear to be any specific size group that is involved in these seasonal changes because no differences were detected in seasonal length frequencies in either the river or open estuary. Additional research using acoustic telemetry to document the movement patterns of individual fish would greatly augment the results of this study.

Although seasonal patterns of common snook abundance were apparent, the causal factors driving these patterns remain uncertain. Scientists and anglers have hypothesized that cold intolerance has been the primary reason for common snook leaving coastal and estuarine waters in the fall to seek presumed warmer waters in the rivers. A study that uses an array of temperature loggers in the rivers and estuary is needed to fully evaluate the relative temperature differences between these areas. Nevertheless, this study documents some evidence of small-scale shifts in the distribution of common snook that may occur within rivers or within an open estuary during cold periods. For example, common snook were found to be widespread throughout

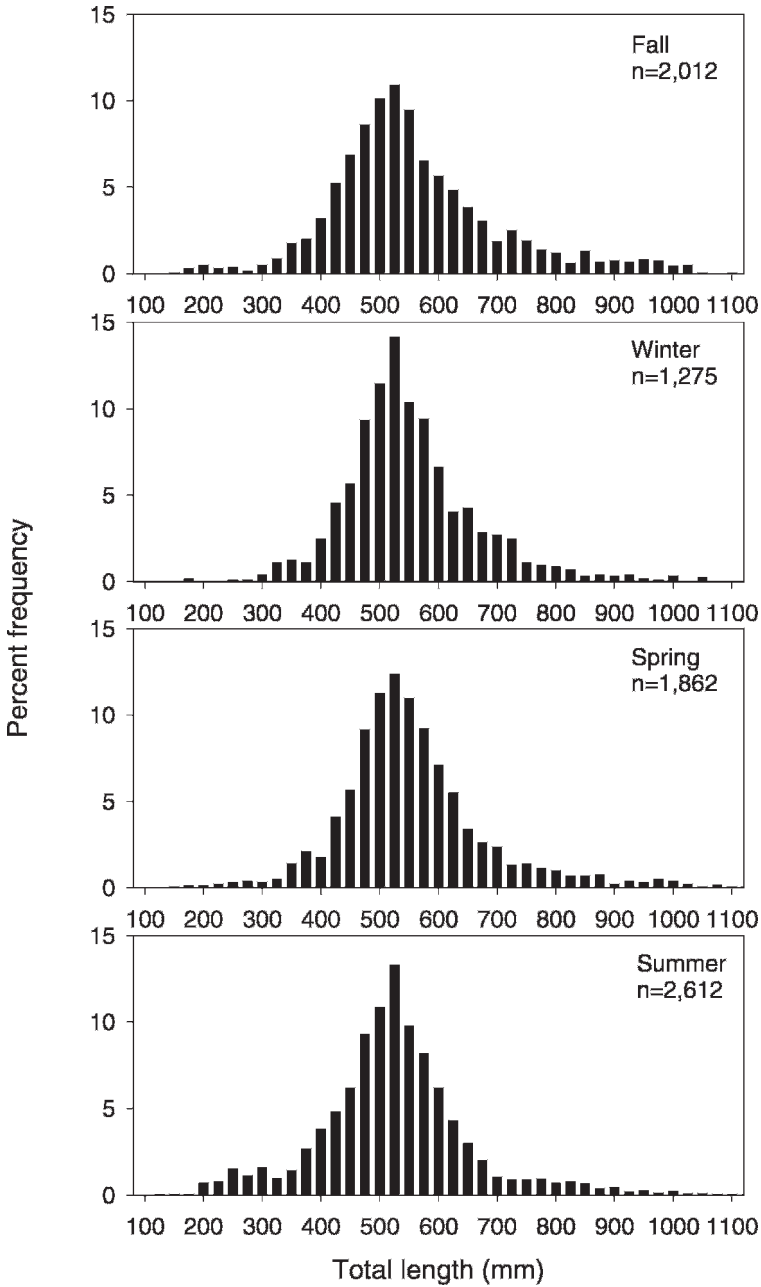


FIG. 8. Length-frequency distribution of common snook *Centropomus undecimalis* collected in the Charlotte Harbor estuary by season (January 1997–December 2007).

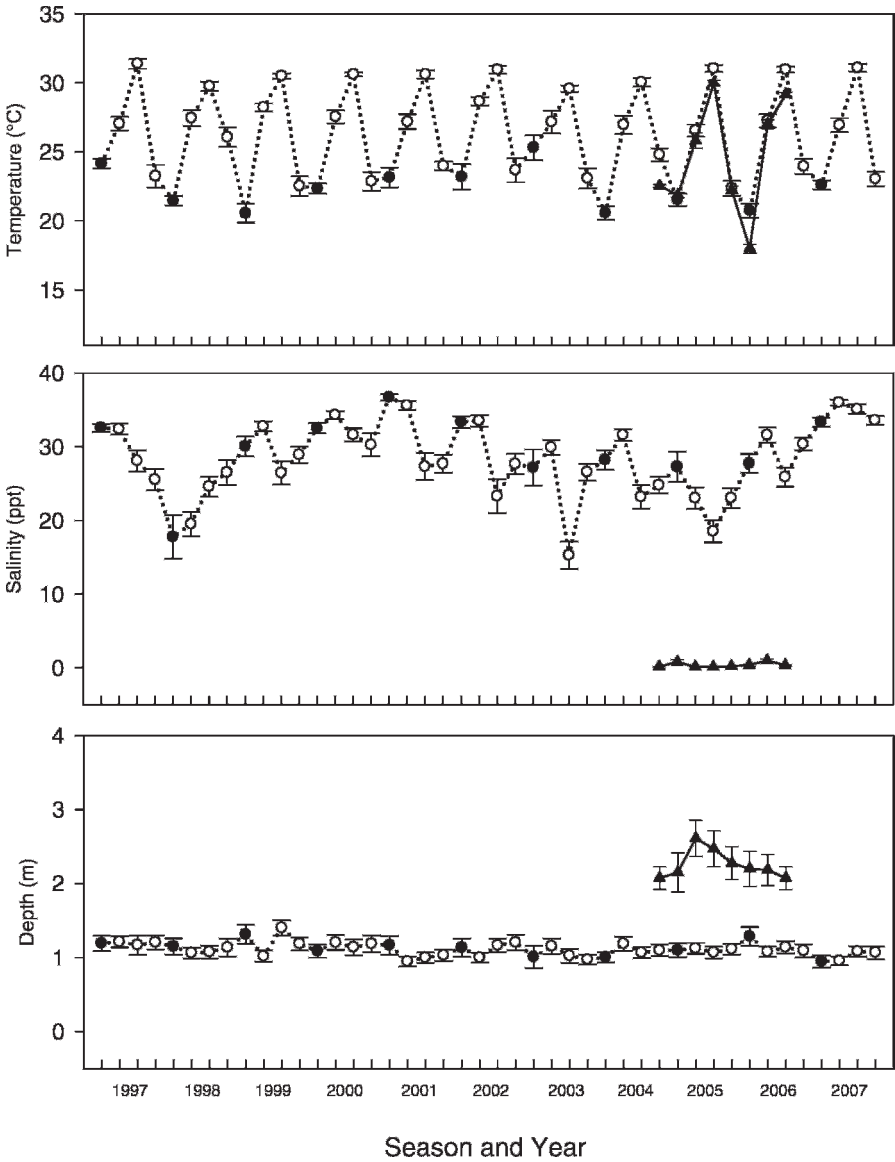


FIG. 9. Mean seasonal temperature, salinity, and depth (\pm standard error) by season and year at sampling sites where common snook *Centropomus undecimalis* were collected. The triangles represent data from electrofishing in rivers (fall 2004–summer 2006) and the circles represent data from haul seines in the open estuary (winter 1997–fall 2007); black circles represent winter and provide a reference to identify the seasons.

the rivers during fall, spring, and summer, but were more abundant at deeper, fixed sites during winter. Also, electrofishing (random design) during a companion study in the Peace River showed that common snook abundance, a day after a cold front, was much higher in a man-made backwater canal (2.5 fish min^{-1} ; water temperature=16.7°C) than at adjacent sites on the main stem (< 0.5 fish min^{-1} ; water temperature=15.1°C) (unpubl. data; Blewett, 2005). These results indicate that during a cold front common snook may move to sites that are slightly warmer or have more stable temperatures, if such sites are available nearby. These small movements out of the sampling area could partly explain the slight decrease in common snook abundance from fall to winter in the rivers. Considering that many common snook are still collected in the open estuary during winter suggests that nearby warm water sites are available there also. Many of these potential sites are too deep to be sampled with a haul seine (e.g., canals, marinas) or are inaccessible to the haul seine boat (e.g., backwater creeks and ponds). The significant decrease in abundance during winter in the open estuary may be attributed to a combination of both small-scale movements to warmer sites within the estuary and large-scale movements into rivers.

Many factors such as feeding, predation risk, competition, and reproduction are known to influence cyclic seasonal movements of estuarine fishes (Roundtree and Able, 2007), and these factors must be considered in addition to temperature when developing a conceptual model of habitat use for common snook. In the case of common snook, an obvious factor influencing large-scale, seasonal movements is reproductive success. Common snook require high salinity for successful reproduction; thus those inhabiting rivers must move into the lower estuary and passes during summer to successfully spawn (Taylor et al., 1998). After the completion of the spawning season, movement of common snook to the rivers in fall could simply be the return of a portion of the population that has an affinity for rivers. Although it has been assumed by biologists and fisheries managers that all adult common snook (> 330 mm SL) spawn during summer, we documented a large number of adult fish in the freshwater and oligohaline portions of the rivers during their protracted spawning season (April–September). These findings suggest at least three possibilities about adult common snook and their use of rivers during their protracted spawning season: 1) individuals might leave the river at different intervals to spawn and then quickly return to the river; 2) some individuals are semiresidents in the river — staying one or more years within the river without moving to more saline waters to spawn; 3) some individuals are residents in the river and spend their entire lives in the riverine environment, possibly never leaving to spawn. Multiple-year residency in rivers has been suggested for barramundi (*Lates calcarifer*; Davis, 1986; Pender and Griffin, 1996; Milton and Chenery, 2005), a species occurring in tropical Australia and the Indo-West Pacific with a life history similar to that of common snook (Davis, 1982; Moore, 1982).

In summary, this study shows that common snook can be abundant in southwest Florida tidal rivers and in the open estuary year-round and that

seasonal patterns of abundance were present in both of these habitats. The use of freshwater and marine environments by common snook appears more complex than was previously considered. Unexpected findings were the relatively large numbers of common snook still remaining in the open estuary during winter, and those still present in the rivers during summer. Although the significant increase in common snook abundance in the rivers during fall is consistent with the overwintering paradigm, the high abundances did not continue through winter as expected. Further research regarding their habitat use is needed to build an accurate conceptual model that incorporates a suite of factors that influence their seasonal and annual movements.

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LITERATURE CITED

- BASS, D. G. AND D. T. COX. 1985. River habitat and fishery resources of Florida. in W. SEAMAN, JR. (ed.), Florida aquatic habitat and fishery resources. pp. 121–187. Florida Chapter of American Fisheries Society, Eustis.
- BLEWETT, D. A., R. A. HENSLEY, AND P. W. STEVENS. 2006. Feeding habits of common snook, *Centropomus undecimalis*, in Charlotte Harbor, Florida. Gulf and Car. Res. 18:1–13.
- . 2005. Florida Fish and Wildlife Conservation Commission, Port Charlotte, FL, Unpublished Data.
- CASEY, J. P., G. R. POULAKIS, AND P. W. STEVENS. 2007. Habitat use by juvenile gag, *Mycteroperca microlepis* (Pisces: serranidae), in subtropical Charlotte Harbor, Florida (USA). Gulf and Car. Res. 19:1–9.
- CHAMPEAU, T. R. 1990. Ichthyological evaluation of the Peace River, Florida. Fla. Scien. 53:302–311.
- CHAPMAN, P., G. HOREL, W. FISH, K. JONES, AND J. SPICOLA. 1978. Artificial culture of snook, Rookery Bay, 1977. Job No. 2. Induced spawning and fry culture. Annual Report on Sportfish Introductions, Florida Game and Fresh Water Fish Commission.
- DAVIS, T. L. O. 1982. Maturity and sexuality in barramundi, *Lates calcarifer* (Bloch), in the Northern Territory and South-eastern Gulf of Carpentaria. Aust. J. Mar. Fresh. Res. 33:529–545.
- . 1986. Migration patterns in barramundi, *Lates calcarifer*, in van Diemen Gulf, Australia, with estimates of fishing mortality in specific areas. Fish. Res. 4:243–258.
- DAY, J. W., C. A. S. HALL, W. M. KEMP, AND A. YANEZ-ARANCIBIA. 1989. Estuarine Ecology. (John Wiley and Sons: New York).
- ESTEVEZ, E. D., J. MILLER, AND J. MORRIS. 1981. Charlotte Harbor estuarine ecosystem complex and the Peace River. Vols 1 and 2. Mote Marine Laboratory for Southwest Florida Regional Planning Council. Fort Myers, Florida.
- FORE, P. L. AND T. W. SCHMIDT. 1973. Biology of juvenile and adult snook, *Centropomus undecimalis*, in the Ten Thousand Islands, Florida, Chap. 16. In Ecosystems analysis of the Big Cypress Swamp and Estuaries. U.S. Environmental Protection Agency, Region IV, Athens, Georgia, 18 p.

- HAMMETT, K. M. 1990. Land use, water use, streamflow characteristics, and water-quality characteristics of the Charlotte Harbor inflow area, Florida. U.S. Geological Survey Water-Supply Paper 2359-A.
- HAVENS, K. E., D. FOX, S. GORNAK, AND C. HANLON. 2005. Aquatic vegetation and largemouth bass population responses to water-level variations in Lake Okeechobee, Florida (USA). *Hydrobiologia* 539:225–237.
- HOWELLS, R. G. AND A. J. SONSKI. 1990. Lower temperature tolerance of snook, *Centropomus undecimalis*. *Northeast Gulf Sci.* 2:155–158.
- KUPUSCHUS, S. AND D. TREMAIN. 2001. Associations between fish assemblages and environmental factors in nearshore habitats of a subtropical estuary. *J. Fish Bio.* 58:1383–1403.
- MARSHALL, A. R. 1958. A survey of the snook fishery of Florida, with studies of the biology of the principal species, *Centropomus undecimalis* (Bloch). Florida State Board of Conservation Marine Laboratory, Miami, FL, USA. Technical Series No. 22.
- MILTON, D. A. AND S. R. CHENERY. 2005. Movement patterns of barramundi *Lates calcarifer*, inferred from $^{87}\text{Sr}/^{86}\text{Sr}$ and Sr/Ca ratios in otoliths, indicate non-participation in spawning. *Mar. Ecol. Prog. Ser.* 301:279–291.
- MOORE, R. 1982. Spawning and early life history of barramundi, *Lates calcarifer* (Bloch), in Papua New Guinea. *Aust. J. Mar. Fresh. Res.* 33:647–661.
- PENDER, P. J. AND R. K. GRIFFIN. 1996. Habitat history of barramundi *Lates calcarifer* in a north Australian river system based on barium and strontium levels in scales. *Trans. Am. Fish. Soc.* 125:679–689.
- PETERS, K. M., R. E. MATHESON, JR., AND R. G. TAYLOR. 1998. Reproduction and early life history of the common snook, *Centropomus undecimalis* (Bloch), in Florida. *Bull. Mar. Sci.* 62:509–529.
- PETERSON, M. S. AND S. T. ROSS. 1991. Dynamics of littoral fishes and decapods along a coastal river-estuarine gradient. *Est. Coast. Shelf Sci.* 33:467–483.
- PBS&J INC. 2007. Peace River Cumulative Impact Study. Report prepared for the Department of Environmental Protection Bureau of Mine Reclamation and the Southwest Florida Water Management District. <http://www.swfwmd.state.fl.us/waterman/peaceriver/>
- ROSS, S. T. AND S. P. EPPERLY. 1985. Utilization of shallow estuarine nursery areas by fishes in Pamlico Sound and adjacent tributaries. In A. YANEZ-ARANCIBIA (ed.), *Fish community ecology in estuaries and coastal lagoons: Towards an ecosystem integration*. pp. 207–232. DR (R) UNAM Press Mexico, ISBN 968-837-618-3.
- ROUNDTREE, R. A. AND K. W. ABLE. 2007. Spatial and temporal habitat use patterns for salt marsh nekton: implications for ecological functions. *Aquat. Ecol.* 41:25–45.
- SHAFLAND, P. L. AND K. J. FOOTE. 1983. A lower lethal temperature for fingerling snook, *Centropomus undecimalis*. *Northeast Gulf Sci.* 6:175–177.
- SOKAL, R. R. AND F. J. ROHLF. 1981. *Biometry. The Principles and Practices of Statistics in Biological Research*. 2nd Edn. (W.H. Freeman: New York.)
- TAYLOR, R. G., H. J. GRIER, AND J. A. WHITTINGTON. 1998. Spawning rhythms of common snook in Florida. *J. Fish Biol.* 53:502–520.
- , J. A. WHITTINGTON, H. J. GRIER, AND R. E. CRABTREE. 2000. Age, growth, maturation, and protandric sex reversal in common snook, *Centropomus undecimalis*, from the east and west coasts of South Florida. *Fish. Bull.* 98:612–624.
- VOLPE, A. V. 1959. Aspects of the biology of the common snook, *Centropomus undecimalis* (Bloch) of southwest Florida. Florida State Board of Conservation Marine Laboratory, Miami, FL, USA. Technical Series No. 31.
- WEINSTEIN, M. P. 1979. Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear River, North Carolina. *Fish. Bull.* 77:339–357.
- ZAR, J. H. 1984. *Biostatistical analysis*. 2nd Edn. (Prentice Hall, Inc.: Englewood Cliffs).

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