

OVERWINTERING POPULATION DYNAMICS OF *CENTROPOMUS UNDECIMALIS* IN ST. LUCIE RIVER

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Abstract

Sixty-one common snook caught in the Indian River Lagoon by the Florida Fish and Wildlife Conservation Commission (FWC) were measured, sexed, implanted with a Vemco acoustic transmitter, and released so their movement could be tracked. Snook were clustered based on movement between river systems during spawning and non-spawning seasons, resulting in four clusters: Resident, Spawning Transient, Overwintering Transient, and Traveler. Sex and length of individuals were compared between clusters using ANOVA to determine if these characteristics influenced movement strategy. Resident and Traveler snook had the most even sex ratio compared to other movement strategies. The majority of snook were categorized as Travelers but Spawning Transient snook had the highest mean length. It couldn't be concluded that St. Lucie estuary serves as a significant overwintering habitat particularly for large, female snook, possibly due to small sample size.

Introduction

Fish move about their environment in response to a variety of ecological and physiological demands and environmental conditions. Many mobile organisms move with changing environmental conditions to stay within optimal salinity or follow the flow of similar salinity concentrations to allow their osmoregulatory processes to adjust before returning to their original location (Heupel and Simpfendorfer, 2008). *Myliobatis californica*, bat rays have been observed feeding in warmer, shallower waters then moving to cooler waters to lower energetic demands and decrease gastric evacuation rate during digestion (Mattern, Cech, and Hopkins, 2000). Water temperature has been identified as a key regulator in the spawning runs of Atlantic salmon (*Salmo salar* L.; Byrne et al. 2004) and migration of European eels (*Anguilla anguilla*; White and Knights, 1997) once it reaches a certain threshold. Snook, like many other organisms, rely on environmental cues to coordinate spawning and other types of movement (Young et al., 2016).

Centropomus undecimalis (common snook, hereafter, snook) is a catadromous gamefish that contributes millions of dollars to Florida's economy through recreational angler expenses (Fedler, 2009). Snook have been identified as a species of special concern due to the stock depletion in the late 1970's (Bruger and Haddad, 1986) and Florida now enforces strict

regulations on their harvest including specified open and closed seasons (Muller et al., 2015). Snook are protandric hermaphrodites, so they all mature initially as males and most transition to females as they age. Male snook reach sexual maturity at 169 to 222 mm in total length (TL) and under a year old while most transition to female between 246 and 876 mm TL at about 1 - 7 years of age, although some remain male throughout their life (Taylor et al. 2000).

Snook typically spawn between April 15th and October 15th in inlets along the coast (Taylor et al. 1998) in temperatures >22°C and salinities >27‰ (Peters, Matheson, and Taylor, 1998). Snook form spawning aggregations where they broadcast spawn, freely releasing their gametes into the water column in inlets (Taylor et al., 1998). Aggregations serve several purposes including ensuring availability of other spawners, larval distribution, and resource availability (Boucek et al. 2017). These aggregations are vulnerable to overexploitation from fishing due to their predictability of timing and high density of fish (Johannes, 1978).

Although snook are known to travel to river mouths and inlets prior to spawning to take part in aggregations, some overwinter in a different estuarine system from where they spawn. For example, in these data there were snook taking part in spawning aggregations in the Loxahatchee River in Jupiter, FL (Figure 1A) that overwintered in the St. Lucie River (Figure 1B) in Port St. Lucie, FL. Habitats serve different purposes in the life history of common snook possibly making them more important to a specific size or sex of snook. Snook are known to travel to several spawning sites outside of their home range and take part in multiple aggregations (Young et al., 2014). The Big Old Fat Female Fish (BOFFFF) hypothesis suggests that large females contribute proportionately larger than smaller females to spawning aggregations and larval recruitment by producing more and larger offspring (Hixon et al., 2014). Young et al. (2016) noted high site fidelity of snook to specific spawning sites. Snook were recorded in multiple spawning aggregations through the spawning season but were seen four times as often in their primary spawning sites. High site fidelity creates critical spawning habitats for returning and growing snook. In line with the BOFFFF hypothesis, these larger returning snook will contribute more to the population within those specific sites than other individuals.

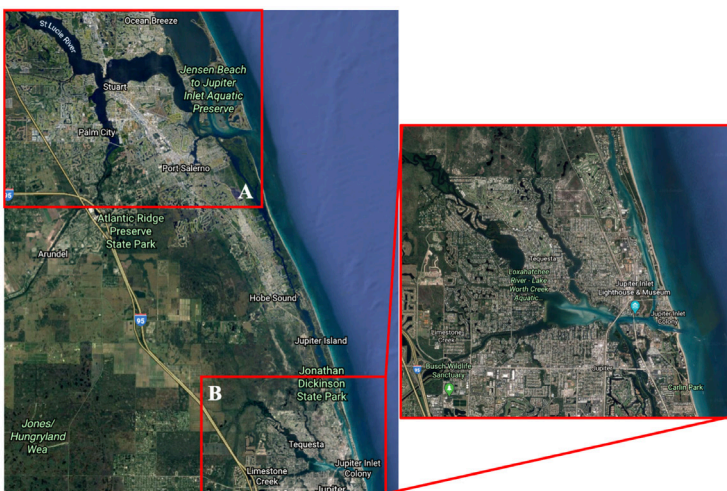


Figure 1. (A) Port St. Lucie River located in East Florida. (B) Loxahatchee River located in Southeast Florida.

The St. Lucie River, located on Florida's east coast, is a brackish estuary that flows into the Indian River Lagoon. It has been hypothesized that this estuary is an important overwintering habitat for common snook, used during non-spawning seasons for foraging and development (Jud, 2014). This study focused on testing this hypothesis.

Effective regulations rely on identifying important snook habitats as well as the seasonal timing of their use. This study aims to identify the habitat use of St. Lucie River by large, female snook to inform proper regulations that will allow protection of the snook population.

Methods

Two hundred eighty-one snook were tagged by Florida Fish and Wildlife Conservation Commission (FWC) in St. Lucie (STL) and passively monitored using an array of acoustic receivers (Vemco). Snook were caught by FWC and implanted with a transmitter that emits a unique ID code every 60-180 seconds. Once a fish with a transmitter swims past an acoustic receiver, the receiver records the ID code, date, and time of a specific fish.

Adult snook were collected by FWC researchers using a rod and reel, a seine, and a cast net (Young et al., 2016). They were measured for total length (TL; 602-1020 mm), sexed (33 Female, 17 Male, 11 Unknown) by examining the vent area (Lowerre-Barbieri et al., 2003), implanted with a transmitter (V16; 4-year tag life; Vemco), and released. Implantation was conducted by placing the fish ventral side up with the head and gills submerged in water and the surgical procedure was performed. Following implantation, fish were sutured and held in an aerated tank for observation post surgery for 30 minutes to ensure recovery before release (Young

et al., 2016). The data used for this study were provided by the Florida Fish and Wildlife Commission's Florida Wildlife Research Institute, Tequesta Florida. Tagging and data collection was carried out by FWC personnel from 2008-2015 as part of a larger FWC study. FAU personnel were not involved in the collection of the data or the handling of animals, only involved in the further analysis of the previously collected FWC data with the purpose of expanding our understanding of snook movement patterns.

Receiver data was downloaded by FWC every six months with our snook data ranging from 2008-2015. Snook were excluded from analysis if they had less than two seasons of spawning and non-spawning data or if they were tagged late in the season. Due to the exclusions, 61 snook (33F, 17M, 11U) ranging from 602-1020 mm in TL were used for this study. The proportion of days in St. Lucie was averaged over overall days of detections for non-spawning and spawning seasons to remove temporal bias. We used hierarchical clustering in R Studio (Version 1.2.1335) (agnes package) utilizing a Euclidean dissimilarity matrix and Ward's linkage to cluster. Linkage methods were tested using the agglomerative coefficient, with Ward's linkage being closest to 1, indicating the strongest linkage. Hierarchical clustering iteratively groups the two most similar data points until all data are merged, creating a dendrogram (Figure 2). The height of clustering represents the "distance" between those clusters, so it is a measure of similarity. The linkage method determines how the distance is calculated. Ward's linkage bases the clustering on reducing the sum of squared distances of each datapoint from the average data in a cluster.

Results

Elbow and silhouette plots were used to determine that four clusters best fit the data which matched hypothesized potential behavior patterns. Using hierarchical clustering, the 61 snook were clustered into

four categories: Resident, Traveler, Spawning Transient, and Overwintering Transient. Resident snook were observed in St Lucie estuary (STL) through the spawning and non-spawning seasons. Travelers did not have specific patterns to their movement and seemed to move in and out of STL freely. Spawning Transients overwintered in STL and spawned in other systems and Overwintering Transients spawned in STL and overwintered in another system.

Once the clusters were identified, we examined the mean number of days in STL for spawning season (SP) and non-spawning season (NSP). Residents averaged >87.5% days in STL during NSP and 100% days during SP. Travelers averaged <26.6% days in STL during NSP and <33.3% days during SP. Spawning Transient averaged >54.1% days in STL during NSP and <2.1% days during SP. Finally, Overwintering Transient averaged <46.4% days in STL during NSP and >50% days during SP. The majority of snook tagged in STL were classified as travelers (n = 31), while fourteen were resident, seven were overwintering transient, and nine were spawning transient (Figure 2).

Total length of resident snook had the largest range in total length (602-999 mm) but lowest average (799 mm). Travelers ranged in total length from 734 mm to 1005 mm and had the highest average of 869 mm. Overwintering Transient ranged from 753 mm to 1020 mm with an average of 848 mm and Spawning Transient had the smallest range of 763 mm to 922 mm and averaged at 858 mm (Figure 3). An ANOVA indicated no significant difference in length between clusters (p = 0.0729).

Resident (6F, 4M, 4U) and Traveler (16F, 10M, 5U) snook had more even sex ratios compared to both Overwintering Transient (5F, 2M, 0U) and Spawning Transient (6F, 1M, 2U) (Figure 4).

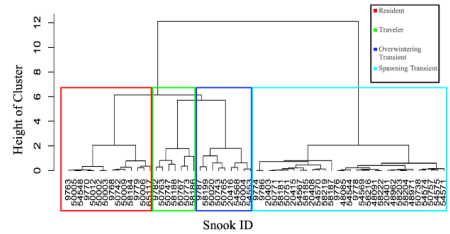


Figure 2. Hierarchical clustering based on movement in and out of St. Lucie estuary.

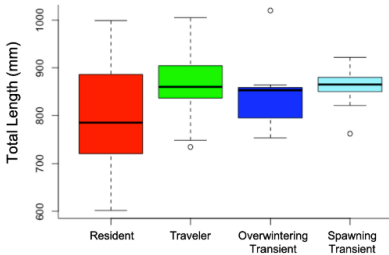


Figure 3. Total length of snook by movement cluster.

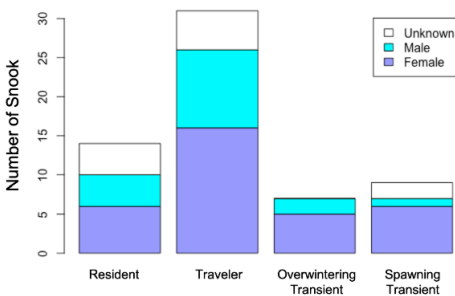


Figure 4. Stacked bar plot showing four clusters and sex ratio.

Discussion

If St. Lucie estuary serves as an overwintering habitat, more snook would be expected to spend time in St. Lucie during non-spawning season, i.e., spawning transient and resident movement types. In addition, if St. Lucie was a preferred overwintering habitat compared to available areas in Indian River Lagoon, large females should be present in higher numbers as they highly contribute to the spawning population and are able to outcompete other snook for that preferred habitat due to their larger size.

The large number of travelers through St Lucie estuary indicate that some snook could be either foraging or taking part in spawning aggregations, then moving on to other rivers. Many of the tagged snook could also be taking part in multiple aggregations, as much as 51% is seen in Young et al. (2016). Although there is a large range in length, Residents were smaller in average compared to the other three clusters. It could be due to higher risk of predation for smaller individuals once they travel through deeper waters for spawning or foraging. Travelers had the highest average total length; their larger size likely decreases risk of predation and increases their resilience to variable environmental conditions that they are more likely to encounter when traveling. Differences in size have been shown to influence movement strategy in fish (Trotter et al., 2012).

In previous studies, when examining snook spawning, residents were classified as snook that remained in the river and migrants were snook that migrated out of the river to spawning aggregations (Trotter et al., 2012). Based on that study, we would expect our transients and travelers to be larger and therefore female. Migrants in Trotter et al. (2012) were significantly larger than residents. Even though our results were insignificant, the trends are similar, and suggest that larger fish are more likely to move. We did not see a specific size or sex predictability of a category of movement. Movement could also be based on personality rather than size and sex, which will require future research to examine this parameter. We were not able to make a definitive conclusion that snook were moving because they were bigger and able to travel with less predation risk or they were growing larger due to traveling offering better foraging opportunities. To address this question, snook would need to be recaptured and measured throughout their life, which is a difficult feat for highly mobile fish in the wild. Size and sex as well as other factors could possibly affect movement or predict future movement, but these conclusions were confined by our sample size.

We recognized behavioral contingents, but due to a small sample size, no definitive conclusion could be met. With only seven overwintering transients and nine spawning transients, our hypothesis could not be supported. A more representative sample size would provide complete information on movement behavior contingents, wider range in sex and size distribution,

and general snook population movement overall. This study provides us with important information as we observed behavioral contingents, but a larger sample size is necessary to provide the entire picture.

Potential bias in sampling methods may have skewed the results because telemetry data were initially collected for a different study. All sampled snook were at a size where they were assumed to be sexually mature. Tagged fish were sampled mainly from spawning aggregations and larger, female fish were specifically targeted. As a result of the methodology, the fish in this telemetry data may have preferentially sampled one movement contingent and the results would not be representative of the population's movement contingent distribution overall. The overall sex ratio (33F, 17M, 11U) as well as those for the contingents were heavily female-biased and do not reflect recorded population sex ratios (1.8M:1F) for snook in this region (Taylor et al., 2000). Even though the sex ratios were not representative, large, female snook are included in the movement data and were of the most interest in this study.

The BOFFFFF hypothesis posits that larger females contribute proportionately more to the spawning population due to the larger body size and increased internal resources to contribute to spawning (Hixon et al., 2014). Managers concerned with preserving breeding populations would protect habitats that these fish highly utilize. In this study though, female snook were fairly evenly distributed between the behavioral contingents, indicating that large females are not all prioritizing one movement strategy. While St. Lucie is an important estuary for snook, providing a mosaic of habitats, our results suggest that large females are not seeking out this area as a primary overwintering habitat. Large female snook could not be protected in one habitat since they do not all congregate in the same place during the sensitive overwintering season. Therefore, it would not be possible under these conditions to protect the majority of the breeding female snook population in one place. Closed seasons and areas during overwintering (which are currently enacted), while not necessarily protecting the majority of large females, would likely protect enough large females to increase population resilience to disturbance events and recreational fishing.

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