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COASTAL ORIGIN OF COMMON SNOOK, *CENTROPOMUS UNDECIMALIS*, IN FLORIDA BAY

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ABSTRACT We used the elemental signatures of otoliths to investigate the coastal origin of common snook (*Centropomus undecimalis*) in Florida Bay, Florida and evaluate current management boundaries. We examined juvenile otoliths from Florida's Atlantic and Gulf of Mexico (Gulf) populations and determined that there were significant differences in several elemental ratios (Mn/Ca, Cu/Ca, Sr/Ca, Ba/Ca). In addition, a discriminant function analysis (DFA) indicated a significant separation between the juveniles from each coast and otoliths were never misclassified by coast, indicating a distinct difference in their otolith chemistry. Using only juvenile otoliths to derive a calibration function, a separate DFA indicated that the adults from Florida Bay likely originated from both coasts of Florida in roughly equal proportions. Although these preliminary results contradict tagging studies, they concur with genetic studies suggesting that both east and west coast populations contribute to the common snook found in Florida Bay.

INTRODUCTION

The effective management of marine species requires some knowledge of the source of recruits to the population. Despite the importance of such information, discerning the origin of individuals can often be quite difficult, as many marine species have larvae or juveniles that can widely disperse, thereby creating demographically open populations (Roughgarden et al. 1988). Conventional techniques such as genetics and mark-recapture have often proven inadequate in identifying recruitment source either due to low resolution (e.g., < 1% exchange renders populations genetically homogeneous; Kimura and Maruyama 1971) or logistical problems (e.g., tagging and recapturing larvae/juvenile that can disperse vast distances and suffer high mortality; Thorrold et al. 2002). In this paper we examine the issue of the coastal origins of common snook, *Centropomus undecimalis*, an economically and ecologically important species, using otolith chemistry.

Common snook are long-lived (21 years), late-maturing (4–5 years) protandric hermaphrodites that are distributed along the coasts of Florida's Atlantic Ocean (Atlantic) and Gulf of Mexico (Gulf) (Taylor et al. 1998, 2000). This gamefish supports valuable sport fisheries throughout its range and contributes substantially to Florida's economy (Tucker et al. 1985). Adult common snook support popular fisheries in the Florida Keys and adjoining Everglades National Park (Figure 1, Tilmant et al. 1989), but the source of recruits to this area remains unknown. Several studies have reported collecting common snook in Florida Bay (Tabb and Manning 1961, Tabb et al. 1962, Roessler 1970). However, none recorded the sizes of the individuals and it is likely that these records are of adults because of the high salinities of the waters in which they were collected. No eggs, larvae, or juvenile common snook were found in several other studies in Florida Bay (Rutherford et al. 1986, Collins and Finucaine 1987, Powell et al. 1989, Ley et al. 1999), suggesting that the major source of recruitment to the adult stock in this region originates elsewhere.

Tringali and Bert (1996) examined the genetic stock structure of common snook throughout its range and found that Atlantic and Gulf populations were reproductively isolated. Their data showed that adult common snook from the western portion of Florida Bay exhibit transitional properties of both populations and suggested that adult common snook in that area were recruited from both coasts of Florida. Tagging studies, however, have indicated that the Atlantic population is the most likely source of common snook in Florida Bay (Peters 1993, Bruger and Whittington, unpublished data).

Water masses vary in their chemical composition in both time and space. During otolith growth, elements from seawater can substitute for calcium in the otolith matrix (Campana 1999). Thus, otoliths have the potential to act as natural tags. Otolith trace element signatures have been useful in delineating stocks (Campana et al. 1994, Patterson et al. 1999, 2004), distinguishing juvenile nursery areas (Gillanders and Kingsford 2000, Forrester and Swearer 2002), and examining natal homing and self-recruitment (Swearer et al. 1999, Thorrold et al. 2001).

The objective of this study was to further investigate the coastal origin of common snook in Florida Bay as considerable research effort has yet to provide a clear understanding of the source of adult common snook in the Florida Bay assemblage. In addition, we wanted to evaluate the current fisheries management boundaries of com-

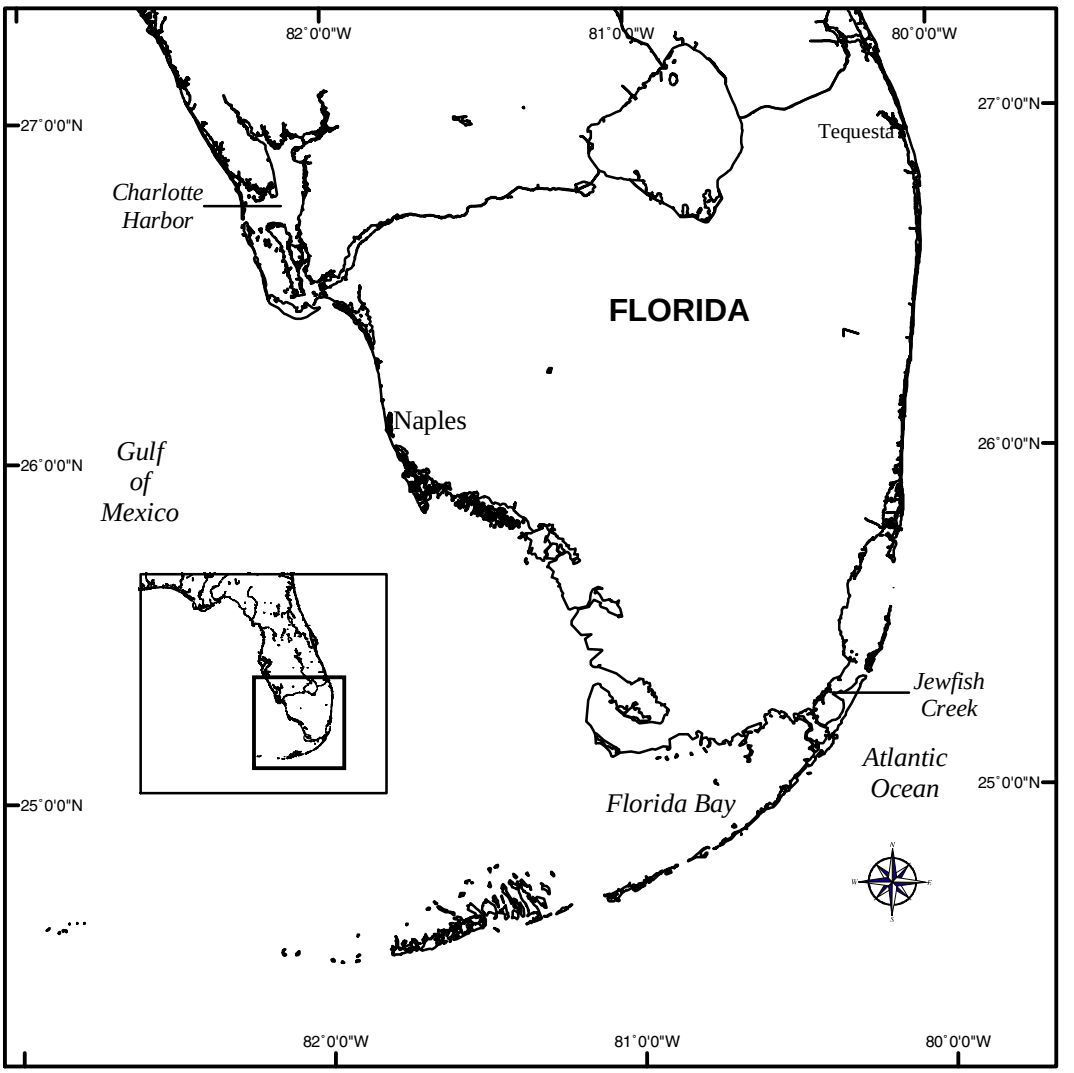

Figure 1. Map of Florida depicting the three sampling locations: Charlotte Harbor (CH), Tequesta (TQ), and Florida Bay (FB).

mon snook in Florida Bay based on our findings. We chose to take a new approach to the issue of common snook origin and examined the chemistry of juvenile common snook otoliths from both Atlantic and Gulf populations, as well as the otolith cores from adult common snook in Florida Bay. Because otolith chemistry primarily reflects the chemistry of the water in which the fish resides (Bath et al. 2000), the elemental composition of the cores of adult common snook otoliths should bear the signatures of their natal estuary. The results of this type of investigation may identify not only the coastal origin of the recruits to Florida Bay, but also may be used to quantify the relative contributions of Atlantic and Gulf stem populations if mixing of these populations occurs.

METHODS

Sample collection

Young-of-the-year common snook (n = 20 per location; 93–250 mm SL) were collected by seine and hook and line during March–July 1999 in the vicinity of Tequesta and Charlotte Harbor on the Atlantic and Gulf coasts of Florida; these 2 locations represented Atlantic coast and Gulf coast common snook populations (Figure 1). The common snook were frozen whole until all the samples from these 2 locations were collected. Adult common snook (n = 20; 306–615 mm SL) from northeastern Florida Bay were captured during September–December 1999 (Figure 1). The otoliths were removed in the field, rinsed, and stored dry. Due to the limited number of adults available, it was not possible to match adults and juveniles by year class.

TABLE 1

Mean elemental ratios (± SE) in the otoliths of common snook, *Centropomus undecimalis*, from each of the 3 sampling locations (n = 20). Ratios are given in µmol/mol Ca.

Elemental Ratio	Florida Bay	Tequesta	Charlotte Harbor
Mg/Ca	125.70 ± 4.73	122.74 ± 5.08	130.92 ± 5.12
Mn/Ca	4.54 ± 0.41	2.88 ± 0.20	4.94 ± 0.30
Cu/Ca	0.26 ± 0.022	0.16 ± 0.0078	0.19 ± 0.013
Zn/Ca	0.72 ± 0.099	0.56 ± 0.060	0.52 ± 0.034
Sr/Ca	2249 ± 115	3094 ± 30	3865 ± 66
Ba/Ca	2.18 ± 0.29	1.40 ± 0.41	2.65 ± 0.3

Sample preparation and analysis

Sample preparation and analysis procedures are similar to those described in Patterson et al. (2004). Juvenile otoliths were polished evenly on all sides with 220-grit size lapping paper until the remaining core section weighed about 10 mg. Adult otoliths from Florida Bay were first sectioned with a Buehler Isomet low-speed saw and were then polished using the method described above. The weights of the otolith sections used in the analysis did not differ (ANOVA, $F_{2,57} = 2.37$, $P > 0.05$). To remove surface contamination, all the sections were then acid washed in 1% ultrapure HNO3 for 15 seconds and triple-rinsed in Milli-Q water. They were then dried in a class 100 laminar flow hood for 24 h and weighed to the nearest 10 µg. The otoliths were then placed in 0.5 ml of 70% ultrapure HNO_3 and dissolved for analysis. The final volume was brought up to 5 ml with Milli-Q water. Blanks were prepared in the same manner to calculate limits of detection (LOD) and for blank corrections.

Elemental concentrations of the otoliths were determined using a Perkin-Elmer Elan 5000 inductively coupled plasma mass spectrometer (ICP-MS). Preliminary tests indicated that 7 elements (^{26}Mg, ^{55}Mn, ^{43}Ca, ^{63}Cu, ^{66}Zn, ^{86}Sr, and ^{138}Ba) were detectable and suitable for ICP-MS analysis. Sample order was blocked so that one otolith from each location was sampled in turn, with the order within each block randomized. Internal standards for each element were used and referenced against ^{45}Sc, ^{72}Ge, ^{89}Y, and ^{159}Tb. Instrument drift was monitored by analyzing a calibration verification solution every 20 samples; acceptable recovery was ±10% of the expected value. Precision was typically < 5% relative standard deviation (RSD) for Ca and Sr and < 10% for trace elements. The LOD for each element was calculated from the prepared blanks as 3 plus the mean blank value with the following results (in µg g^{-1}): ^{43}Ca 126, ^{86}Sr 0.43, ^{138}Ba 0.04, ^{26}Mg 0.29, ^{55}Mn 0.08, and ^{66}Zn 0.04, ^{63}Cu 0.03. Observed values were well above the LOD.

Statistical analysis

Elemental data were standardized to Ca and expressed as molar concentrations. The assumption of homogeneity of variances in elemental data was tested using a Cochran's C-test and data were subsequently ln (x+1) transformed. Differences between otoliths from the 2 coastal calibration sites were tested using both univariate (analysis of variance; ANOVA) and multivariate (multivariate analysis of variance; MANOVA) techniques. For MANOVAs, Pillai's trace was used as the test statistic as it is robust, especially when variance-covariance matrices are not similar (Quinn and Keough 2002).

ANOVAs were performed for each elemental ratio. A Box's M-test was used to determine the equality of variance-covariance matrices and a quadratic discriminant function analysis (DFA) and jackknife cross-validation procedure were used to evaluate how accurately otoliths could be assigned to coast. Finally, otoliths from adult common snook collected from Florida Bay were applied as the test data set to a DFA using otoliths from Tequesta and Charlotte Harbor as the calibration data set to determine to which coastal group the adults were assigned. We acknowledge that this method (DFA) creates a best case scenario and have considered this in our interpretation.

RESULTS

Three of the 6 elemental ratios of otoliths from the 2 coastal locations differed significantly (Table 1; ANOVA; Mn/Ca: $F_{1,38} = 39.67$, $P < 0.05$; Sr/Ca: $F_{1,38} = 126.41$, $P < 0.05$; Ba/Ca: $F_{1,38} = 114.37$, $P < 0.05$) and MANOVA indicated a significant difference in the multi-element signatures of the juvenile otoliths ($F_{12,106} = 18.17$, $P < 0.0001$). In addition, a DFA depicted a clear separation between the coastal groups and otoliths were classified to coast with 100% accuracy by a cross-validation procedure (Figure 2). A DFA using the juvenile otoliths as a training data set and the adult cores as the test data set indicated

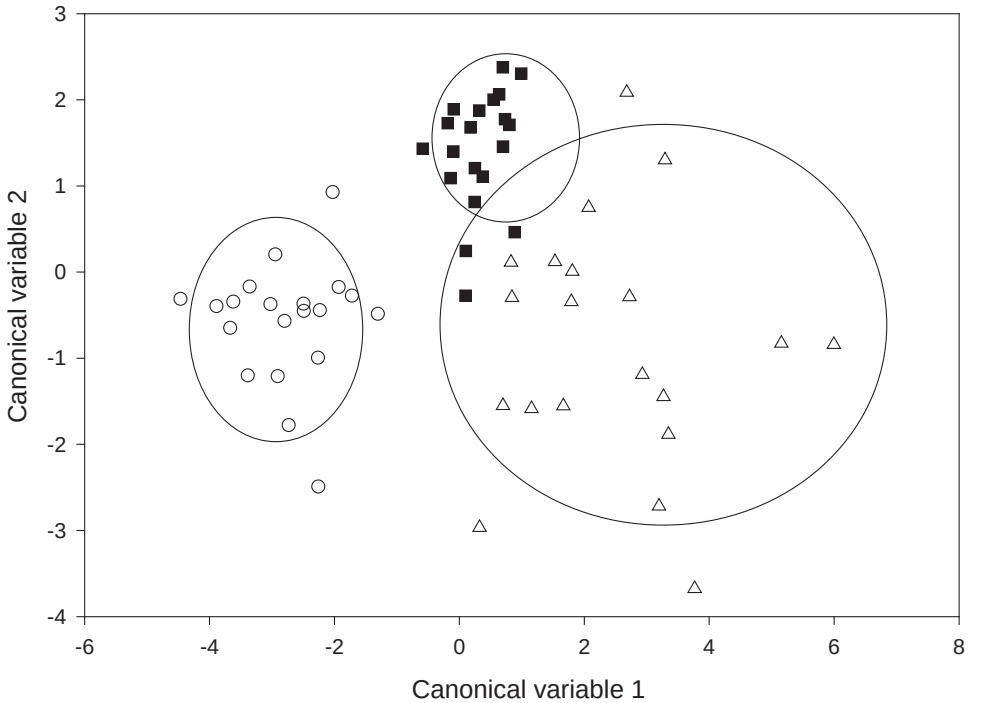

Figure 2. Canonical plot scores and 95% confidence ellipses from the discriminant analysis of multi-element signatures (Mg/Ca, Mn/Ca, Zn/Ca, Cu/Ca, Sr/Ca, and Ba/Ca) of common snook (*Centropomus undecimalis*) otoliths from Charlotte Harbor (circles), Tequesta (black squares), and Florida Bay (triangles).

that 45% and 55% of the adult cores from Florida Bay were classified as Atlantic and Gulf coasts, respectively.

DISCUSSION

The geochemical signatures in the otoliths of juvenile common snook collected from the Gulf and Atlantic coasts of Florida were distinct. This difference in otolith chemistry presumably mainly reflects the differences in water chemistry for each coast, as well as the distinct terrestrial inputs for each estuary (Bath et al. 2000). It was not possible to match the juveniles and adults by year class. Although temporal variation of otolith chemistry within a location has been demonstrated in previous studies (Patterson et al. 1999, Gillanders 2002), it seems likely that overall differences in large water masses such as the Atlantic and Gulf would be temporally persistent to some degree. Indeed, elemental signatures of Gulf red drum (*Sciaenops ocellatus*) from several different years (1982, 1985 and 1998) were quite distinct from those of Atlantic red drum (1998 and 1999), suggesting the consistent separation of these water masses and the otolith signatures produced by them (Patterson et al. 2004).

We were not expecting to match the adults to estuary of origin as this would require that all potential source estuaries be characterized, a task clearly beyond the scope of this study. Instead, the results presented here are limited to identifying the coastal origin of common snook in Florida Bay and suggest that both the Atlantic and Gulf coastal areas contributed in nearly equal proportions to the adult common snook we examined. Extrapolating beyond our data set to make predictions about the relative contribution of each coastal population to the entire Florida Bay assemblage is not prudent at this time given the limited spatial coverage in our calibration data set. However, this preliminary finding does support the idea that both populations contribute to the Florida Bay common snook assemblage.

These geochemical results concur with those obtained from a genetic study that demonstrated common snook in western Florida Bay exhibited transitional properties of both Atlantic and Gulf coast stocks, and thus both stocks likely contributed to the Florida Bay assemblage (Tringali and Bert 1996). However, the required type of genetic markers (i.e., microsatellites) and likelihood-based statistical methods for assigning individuals to genetically subdivided stocks (e.g., Wasser and Strobeck 1998) postdated their study, so relative contributions of Atlantic and Gulf populations could not be estimated.

In contrast, the geochemical and genetic results do not readily agree with the available tagging data demonstrating that tagged common snook from east coast, but not west

coast locations have moved into Florida Bay. Of the 19,410 common snook tagged on the east coast during 1984–1997, 2 were recaptured inside Florida Bay (Bruger and Whittington, unpublished data). In contrast, of the 8,655 common snook tagged on the west coast during 1976–1986, none were reported as recaptured in Florida Bay (Bruger and Whittington, unpublished data). However, the recapture ratios for each coast were not significantly different. These tagging studies were, therefore, inconclusive regarding the origin of common snook in Florida Bay.

Our results derived from the geochemical signatures of common snook otoliths suggest that both Atlantic and Gulf coast populations in Florida contribute to the common snook assemblage found in Florida Bay. The east-west common stock boundary for management of common snook in Florida occurs at Jewfish Creek in the Upper Keys. This boundary places common snook from Florida Bay and the Florida Keys into the Gulf stock. Common snook occurring north of this line are assigned to the Atlantic stock. The evidence reviewed here suggests the position of this boundary may need to be reevaluated or that the Florida Bay/Keys assemblage may need to be considered separately for management purposes. Future efforts should encompass multiple methods (i.e., genetics, otolith chemistry) and a more detailed spatial analysis of fish from both source areas (east and west coasts) and within Florida Bay to account for the likelihood that both coasts are a source of common snook to parts of Florida Bay.

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