# Where Have They Been Hiding? Spatial Distributions and Ontogenetic Movements of Goliath Grouper (*Epinephelus itajara*) in the State of Florida

# Dónde han Estado Escondiendo? Distribuciones Espaciales y Movimientos Ontogenéticos de Mero Guasa (*Epinephelus itajara*) en el Estado de Florida

# Où Ont-ils été Cachés ? Les Distributions Spatiales et les Mouvements Ontogénétique de Mérou (*Epinephelus itajara*) dans L'état de Floride

ORIAN TZADIK*, DAVID JONES, ERNST PEEBLES, and CHRISTOPHER STALLINGS
*University of South Florida, College of Marine Science, 140 7th Avenue South, St. Petersburg, Florida 33701 USA. *otza.dik@mail.usf.edu.*

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## EXTENDED ABSTRACT

### Introduction

Essential nursery habitats (ENH) are characterized as those which have the greatest contribution to the adult spawning-population (Beck et al. 2001). Such habitats are critical towards the recovery of depleted stocks as they contribute disproportionally to the fitness of the population (Dahlgren et al. 2006). Indeed, the recovering status of the Goliath Grouper (*Epinephelus itajara*) in the state of Florida may have resulted from the protection of the mangrove habitat within the ten thousand island region, thought to be the most productive nursery of Goliath Groupers in the world (Koenig et al. 2007). In the current study, we set out to identify and classify the ENHs of Goliath Groupers in southern Florida via non-lethal methods. Using fin rays as an alternative to otoliths for microchemical analyses, we were able to employ a method with no effects on the growth or survival of the sampled individuals (Zymonas and McMahon 2006). Considering the implications towards the recovery of depleted stocks, we set out to test the limits of spatial characterizations of nursery habitats via the microchemical analyses of fin rays. The data presented in the current study should be used as a baseline for future studies that can trace individuals back to their exact nurseries of origin.

### Methods

We captured juveniles in known nursery locations throughout southern Florida via both hook-and-line and trapping methods. In addition, we captured adult samples via hook-and-line methods. Two soft-dorsal fin-rays were excised as close to the base of the fin as possible. In juvenile fin rays, the outer-most annuli of cross-sections of fin rays were analyzed in an inductively coupled plasma mass spectrometer via laser ablation. For adults, we analyzed the annuli corresponding to the year 2006, representing a time when the majority of samples were thought to occupy their juvenile habitats. The concentrations of twenty five elements were quantified and used for further analysis. In addition to fin rays, water samples were collected at sites with high abundances of juvenile Goliath Groupers. These samples were analyzed to assess the spatial distributions of elemental fingerprints within the watershed.

Statistical analyses for this study primarily consisted of non-parametric, distance-based multivariate techniques from the fathom toolbox for matlab (Jones 2014). We used canonical analyses of principal coordinates (CAP) to model the group separation of known nursery locations based on chemical fingerprints in the fin rays of juvenile Goliath Groupers. For the adult and water samples, we used a similarity profile analysis that had been modified to use values of dissimilarity to model the significantly distinct groupings based on the chemical compositions of the samples. Last, the adult samples were visualized using a random forest technique based on the disprof groups.

### Results

When juveniles were categorized on small spatial scales, 11 unique areas were identified. Five areas were not included in further analyses because they had less than 3 individuals in the sample set. When divided into 6 groups, the data from the juvenile fin-rays were classified correctly 66.67% of the time with the output model created by the CAP (Trace Stat = 3.29, m = 12, $p = 0.001$), compared to 17.83% when classified by random chance ($p = 0.001$). Divisions occurred at very small spatial scales, in some cases less than 200 m, and were largely driven by Co, V and Ba. When grouped on larger spatial scales 3 areas were identified. These 3 groupings consisted of two sites within the ten thousand islands and a third site from the lower Florida Keys. The classification success rate for the output model produced by the CAP was 100% (Trace Stat = 1.71, m = 14, $p = 0.001$). Thus, the CAP classified individuals more accurately than a model generated by chance (Classification Rate = 44.83%, $p = 0.001$). Groupings at these spatial scales were tight with very little overlap. The primary drivers of these classifications were Co and Sn. The disprof of water samples separated each sample by the location from which it came. The results suggest that significant differences exist between the chemical compositions of water at each of

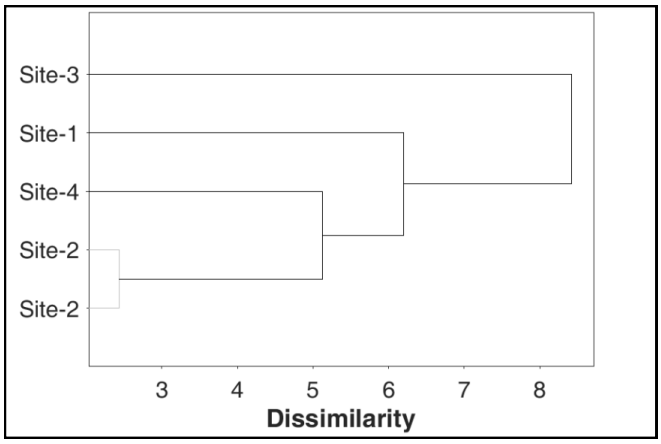


**Figure 1.** A cluster plot of the disprof analysis based on an unweighted pair group method with arithmetic mean and a Euclidean distance matrix. Solid lines represent significant groupings (α = 0.05).

the study sites sampled (Figure 1). The disprof of adult samples identified four unique groups. The random forest used to visualize these groups classified samples correctly 91% of the time as compared to a 51% classification rate by random chance ($p = 0.001$).

**Discussion**

Individuals within the population of Goliath Groupers in the state of Florida can be accurately classified into their nursery habitats via the microchemical analysis of their fin rays. The implementation of a long-term monitoring project in the region would lead to the successful classification of adults into their nurseries of origin. The data generated in the current study should be used as the first baseline from which to classify adult fish. The water samples used in this study represent a snapshot in time. In order to compare the chemical constituents of the water to those in the fin rays, a much longer time series would be needed. However, the significant delineation of water samples at each sample site suggests that the groupings of juvenile Goliath Groupers are driven by the chemical properties of the ambient water.

The elements that were the most influential in driving the groupings in both fish and water samples may be representative of the natural environment, or may be heavily influenced by anthropogenic sources. These sources are not mutually exclusive and most likely operate in concert. The elements that drive the distributions differ between spatial scales and thus may differ with respect to source as well. Studies that will analyze the ENH of Goliath Groupers in Florida in the future should use the classifications from the current study to trace adult fish back to their exact nurseries of origin. The chemical properties of fin rays can be used to trace individuals to specific locations on small or large spatial scales. Using this technique, researchers can evaluate the contributions of individuals to the spawning stock in the region.

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