Life Through the Eyes of a Hogfish: Investigating Movement of *Lachnolaimus maximus* Using Eye-lens Stable Isotopes

La Vida a traves de los Ojos de un Boquinete: Investigacion del Movimiento de *Lachnolaimus maximus* Utilizando Isotopos Estables dentro de Lentes del Ojo

La Vie à Travers les Yeux d'un Labre: Étude des Mouvements du *Lachnolaimus maximus* à Travers L'utilization D'isotopes Stables de Lentilles Oculaires

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EXTENDED ABSTRACT

Ontogenetic migrations of fishes can lead to depth-specific size distributions across habitats occupied during different life stages. For example, Hogfish in the eastern Gulf of Mexico (eGOM) use seagrass beds as juveniles and reefs as adults. In the eGOM, Hogfish residing on deep, offshore reefs (> 30 m depth) are significantly larger than those on shallow, nearshore reefs (< 30 m depth), even within the same age class (Collins and McBride 2011). Since Hogfish are targeted primarily by spearfishers, harvest activity is limited to depths within recreational diving limits (~30 m), and could result in a deepwater refuge for offshore fish (Collins and McBride 2011, Tupper and Rudd 2002). Thus, it is unknown whether the observed depth-specific size distribution is the result of ontogenetic migrations, intense spearfishing with a deepwater refuge, or both.

Hypothesized ontogenetic movement is often based on observed differences in size and abundance across depth and habitat. Ontogenetic migration has been inferred for Hogfish and other reef fishes solely based on observed size distributions, without evidence from movement studies (Lindeman 2000, Tupper and Rudd 2002). However, Hogfish form harems and exhibit high site-fidelity (Colin 1982), which would suggest little to no movement once fish have settled into a harem, contrary to the theory of gradual offshore migration. Knowledge on Hogfish movement patterns is needed to disentangle the relative influences of life history and fishing intensity on these depth-specific size distributions, and can also help to identify effective juvenile habitat (i.e., areas of origin) for the eGOM Hogfish population.

Various techniques are used to study fish movement, including physical tags, dyes, and stable isotopes. Stable isotope ecology often involves measuring the relative values from muscle, liver, and other fish tissues. However, these tissues have relatively rapid turnover, and the tissue is replaced by new cells within days, weeks, or months, thus precluding lifetime-scale assessments. Recently, $\delta^{13}C$ and $\delta^{15}N$ values have been sampled from the laminae (layers) of fish eye lenses, which can serve as chronological recorders of isotopic values at a lifetime-scale (Wallace et al. 2014). Here, we examine Hogfish movement using stable isotope analysis on eye lenses sampled across size, age, and depth gradients. Since background $\delta^{13}C$ and $\delta^{15}N$ change predictably East-West and North-South in the eGOM (Radabaugh and Peebles 2014), we can estimate the fish's previous locations using measured values from laminae and recreate their movements.

Samples were collected from hogfish donated by recreational spearfishers. Information on depth, distance from shore, and fork length (FL, to 0.1 cm) for each fish was recorded. Eyes were removed from the fish by severing the sclera, or connective tissue, releasing the entire eye. Eye lenses were processed according to the methods described by Wallace et al. (2014). Briefly, this involved creating an incision in the cornea, removing the lens, and peeling the laminae (layers) from the lens with fine-tip forceps under a dissection scope. Material from each lamina was stored separately for later analysis. Lens diameter was measured (to 0.1 mm) between each layer. Each layer was dried at 70°C for 18 hours. Dried samples were analyzed for $\delta^{13}C$ in duplicate using a ThermoFinnigan Delta+XL isotope ratio mass spectrometer.

The Hogfish analyzed so far ranged from 28.6 cm to 62.1 cm FL and were captured at depths between 10-60 m. Three phases were evident in the eye lenses analyzed. The core exhibited low $\delta^{13}C$ values, which could be indicative of their planktonic, larval phase in the oligotrophic eGOM. The $\delta^{13}C$ values then peaked, perhaps indicating the time of larval settlement to inshore habitats. This was followed by a subsequent decrease in $\delta^{13}C$ values which may be a result of gradual, offshore movement back into the oligotrophic eGOM. We also tested a low-resolution method on one fish to save processing time by grouping several laminae together. The fish analyzed with the low-resolution method (30.7 cm specimen in Figure 1) had a notably different pattern in $\delta^{13}C$ values during its early life stages (i.e., those < 1.5 mm lamina midpoint). It is unclear whether the difference was due to variation in larval origin and subsequent pathways, or methodology. Further processing may resolve this issue. Furthermore, we are working to couple these data with temporal information to explain how movements translate to specific life history stages.

Analysis of chronological isotope data from Hogfish of varying size and age can be used to identify connectivity between juvenile and adult habitats. Since Hogfish diet is consistent throughout their lives (Randall and Warmke 1967), changes in $\delta^{13}C$ can be attributed to depth-related movement rather than ontogenetic diet shifts (Radabaugh and Peebles 2014). Stable isotope analysis of eye lens nuclei that are developed at hatching can reveal information about early life stages, and perhaps identify areas of origin. If muscle tissue isotope values differ by region, these can be used as a baseline

to identify areas previously occupied and help interpret isotope patterns. Comparing eye lens isotope values with the muscle tissue isotope values (baseline), we will attempt to assess which juvenile habitats (i.e., those serving as nurseries) contribute to success of older Hogfish, and the relative importance of different regions to the adult population. The results from this study could be used to enhance knowledge on the habitat use, migration patterns, and population dynamics of Hogfish. Further understanding of fish movement patterns can help define nurseries and essential fish habitats, and clarify connectivity between juvenile and adult habitats.

KEY WORDS: Fish migration, isoscape, reef fish, Hogfish, *Lachnolaimus maximus*

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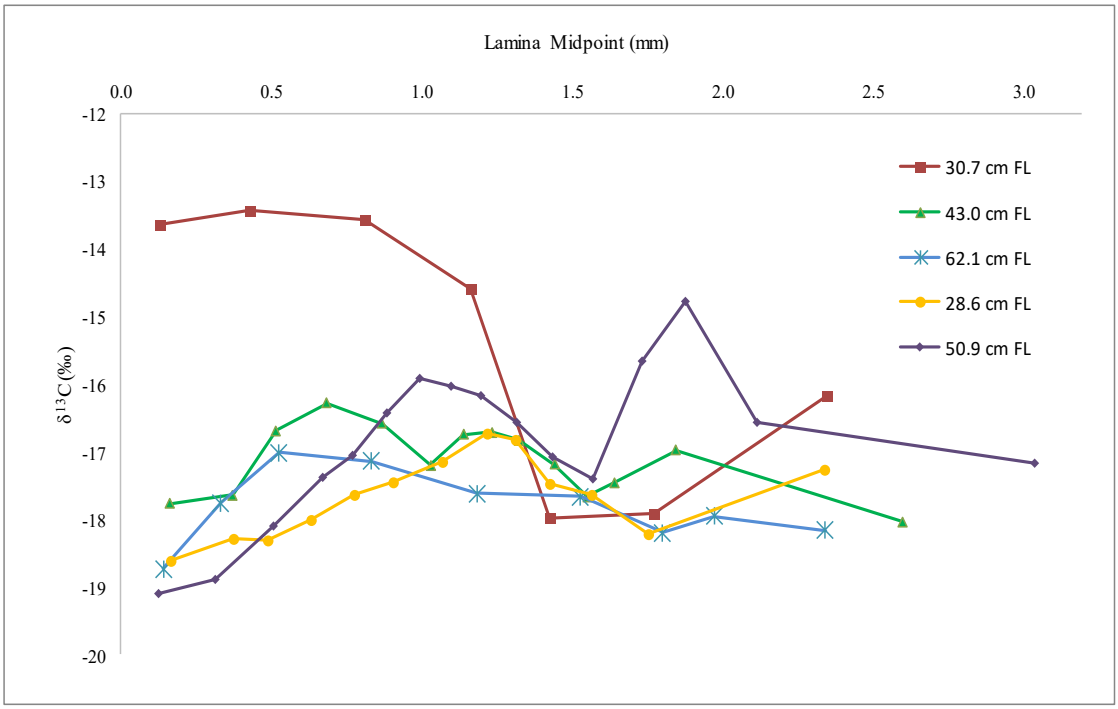

Figure 1. Carbon isotope values plotted against lamina midpoint (mm), or distance from the core of the eye lens. Legend displays FL (cm) for each specimen from which the eye lens data were collected.