# Correlation of otolith to fish size of the invasive lionfish *Pterois volitans* near St. Kitts and Nevis, West Indies. An initial bio-survey and pilot study

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**Abstract**. In the first attempt to develop a local lionfish (*Pterois volitans*) population model for St. Kitts and Nevis, 105 specimens were harvested to inform and guide future management, disease events, environmental incidents, and planned targeted culling of this invasive species. Lionfish have a well-documented association with destruction of marine biodiversity and therefore these data were the logical first step toward a better understanding of lionfish on a regional level. Through the process of gathering this pilot study data, it was determined that the mass and length of lionfish otoliths was strongly correlated to the length and mass of the lionfish they came from. Otoliths are resistant to the processes of digestion in the cases of predation and consequently these conclusions will be useful for future marine food-web dynamics studies in the region.
**Key Words**: Caribbean, fisheries, marine conservation.

**Introduction**. Since its initial sighting off the coast of Florida in 1985 (Morris Jr. et al 2012), the invasion of the Pacific lionfish (*Pterois volitans*) has been one of the most rapid (Albins 2013) and important threats to biodiversity in the region's history (Sutherland et al 2017). Lionfish are ravenous carnivores, eating small reef fish and crustaceans at a rate approximately three times that of an equally sized native predator (Albins 2013), resulting in loss of local fish populations (Green et al 2012), destruction of marine biodiversity (Albins 2013; Malpica-Cruz et al 2021), and threatening local fisheries (Chagaris et al 2015). This invader's superior efficiency over that of native predators is likely accounted for by the early age of maturity, and fast growth rate (Bustos-Montes et al 2020). Lionfish can become sexually mature in less than one year, and spawn without adherence to seasonality, resulting in up to two million eggs produced per female per year (Morris Jr. & Whitfield 2009). Furthermore, lionfish thrive in an impressive and diverse water column ranging in depths of a few meters to over 300 meters (Morris Jr. et al 2012), and seem to be resistant to many native parasites and infections (Morris Jr. & Whitfield 2009). These facts make the eradication of lionfish virtually impossible, and management even more vital.

The first step in controlling any invasive species is to gain understanding of its population density and dynamics, so that its impact on local ecology and fishery economics can be determined, and population control methods can be informed (Switzer et al 2015). Attaining current population and distribution records is vital to understanding specific population thresholds, beneath which, lionfish damages might be mitigated (Green et al 2012).

There is limited evidence for the correlation between the predation of lionfish and slowed or reduced lionfish invasion of Caribbean waters (Hackerott et al 2013). Nonetheless, predator prey relationships are valuable to understanding lionfish impact on local marine ecology. In a theory previously described as "biotic resistance", a healthier native predator population may offer a superior defense to lionfish colonization and overpopulation (Levine et al 2004; Richardson & Pyšek 2007; Mumby et al 2011; Beaury et al 2020). Predators including some sharks (Handwerk 2012; Diller et al 2014), eels (Jud et al 2011), and groupers (Maljković et al 2008; Diller et al 2014) are known to eat lionfish based on evidence of postmortem stomach contents.

Unfortunately, prey fish are often difficult to study once consumed due to the obvious destructive processes of digestion. However, the sagittal otoliths of fish are relatively tolerant to digestion (Battaglia et al 2010). Fish have 3 sets of these structures which are vital to hearing and balance (Schulz-Mirbach et al 2019). They grow in size by the addition of minerals in annular ring formations and therefore record a life history for each fish (Belchier et al 2004; Hoffman & Harding 2018). These characteristics make otoliths one of the most utilized tissues for studying prey fish and understanding predator diets (especially the sagitta which is the largest of the three otoliths) (Granadeiro & Silva 2000; Kasapoglu & Duzgunes 2013; Zan et al 2015; Hanson & Stafford 2017). Like for many other oceanic fish (Battaglia et al 2010; Zan et al 2015), the size of lionfish can be estimated from otolith length and weight (Perera & Puerto 2016). Therefore, studies of potential predators of lionfish may elucidate vital information about lionfish as prey, along with their energy contribution to the predator's diet (Hernandez-Milian et al 2015). These data are the foundation of food-web dynamics research in marine ecology (Koen-Alonso & Yodzis 2005; Battaglia et al 2015).

The overarching goal of collecting lionfish specimens in this study was to create the first ever population survey of lionfish near the islands of St. Kitts and Nevis. However, the focus of this manuscript is on a subset of data aiming to better understand the correlation between lionfish otolith size (length and weight), and fish size (length and weight). Although data associated with otoliths of fish have been utilized in the study of many other marine species (Kasapoglu & Duzgunes 2013; Giménez et al 2016), to the authors' knowledge, data specific to lionfish otoliths of this nature has been documented in only one other population near the Alacranes reef in the southern Gulf of Mexico (Perera & Puerto 2016), and has never been substantiated elsewhere in Caribbean or Atlantic waters.

**Material and Method**. Data was collected from 105 lionfish, over an 8-month timeframe (between November 2019 and July 2021), across 5 geographic locations of the Caribbean waters southwest of St. Kitts and Nevis (Figure 1).


Figure 1. Map of dive site (Google Earth®).

Specimens were collected by SCUBA diving and pole-spearing, as is predominantly done for research and harvest of lionfish due to their almost invulnerability to conventional hook-and-line fishing (Morris Jr. & Whitfield 2009). Upon arriving to the surface, harvested fish were immersed into an ice/saltwater slurry in accordance with guidelines for use of fish in research and AVMA recommendations (AVMA 2020). For each specimen, total length, weight, sex, and reproductive staging was recorded. A metric ruler was utilized to measure the total length from tip of the snout to the longest point of the caudal fin, with a precision of 1 mm. Weight was determined by first blotting excess water from each fish with a paper towel prior to measuring on a scale (model Kern EW820-2NM©). Gonad staging was assessed where possible based on maturity as described in the Lionfish Dissection Guide (Green et al 2012). The gastrointestinal content and fecal samples for bacterial culture were collected, multiple organs were immediately fixed in formalin (for histologic study), and sagittal otoliths were retrieved, weighed, and measured for length. Weight of otolith was attained via a VWR® scale model #123-P. Otolith lengths were documented with an Olympus® dissection microscope and CellSens® imaging software. Where both sagittal otoliths could be successfully dissected free (n=68), the mean of the two was used in both weight and length otolith measurements. Data was collected and stored in an MS Excel database, with descriptive statistic performed in MS Excel and SAS 9.4. Further statistical comparisons were performed to assess the relationship between variables, using parametric or non-parametric tests, depending on the nature of the data. This research was approved by the Ross University School of Veterinary Medicine (RUSVM) Institutional Animal Care and Use Committee (IACUC # 19.11.32).

**Results**. Descriptive statistics were performed on fish and otolith variables, for the whole population and by fish sex. All four variables proved to be normally distributed after statistical assessment using the Shapiro-Wilk test and a graphical evaluation. Descriptive statistics are provided in Table 1.

Table 1

Descriptive statistics for lionfish (*Pterois volitans*)

| *Variable* | *n* | *Mean* | *Standard deviation* | *Minimum* | *Maximum* |
|---|---|---|---|---|---|
| Otolith length (μm) | 105 | 5523.3 | 838.47 | 3206.9 | 7501.3 |
| Otolith weight (ug) | 105 | 10.4 | 3.89 | 3.5 | 24 |
| Fish total length (cm) | 118 | 27.5 | 4.58 | 17 | 37.4 |
| Fish mass (g) | 118 | 312.4 | 160.27 | 57 | 752 |

Initial correlations were performed to evaluate the relationship between otolith length and weight. This correlation proved to be strong (correlation coefficient 0.81) and statistically significant ($p<0.0001$). Fish mass and length were also obviously highly correlated (correlation coefficient 0.9; $p<0.0001$) (Figure 2).

After the expected high correlations between both otolith measurements and both fish measurements were effectively demonstrated, the relationship between otolith length and fish mass was evaluated. The result indicated a strong statistically significant correlation of 0.74, n=105, $p<0.0001$ (Figure 1). With further investigations, this correlation stratified by sex, and it was discovered that the pattern persists with correlation coefficients of 0.77 (n=56, $p<0.0001$) and 0.79 (n=46, $p<0.0001$) for females and males, respectively. When comparing otolith mass between lionfish sex, no statistically significant differences were found ($p>0.05$).

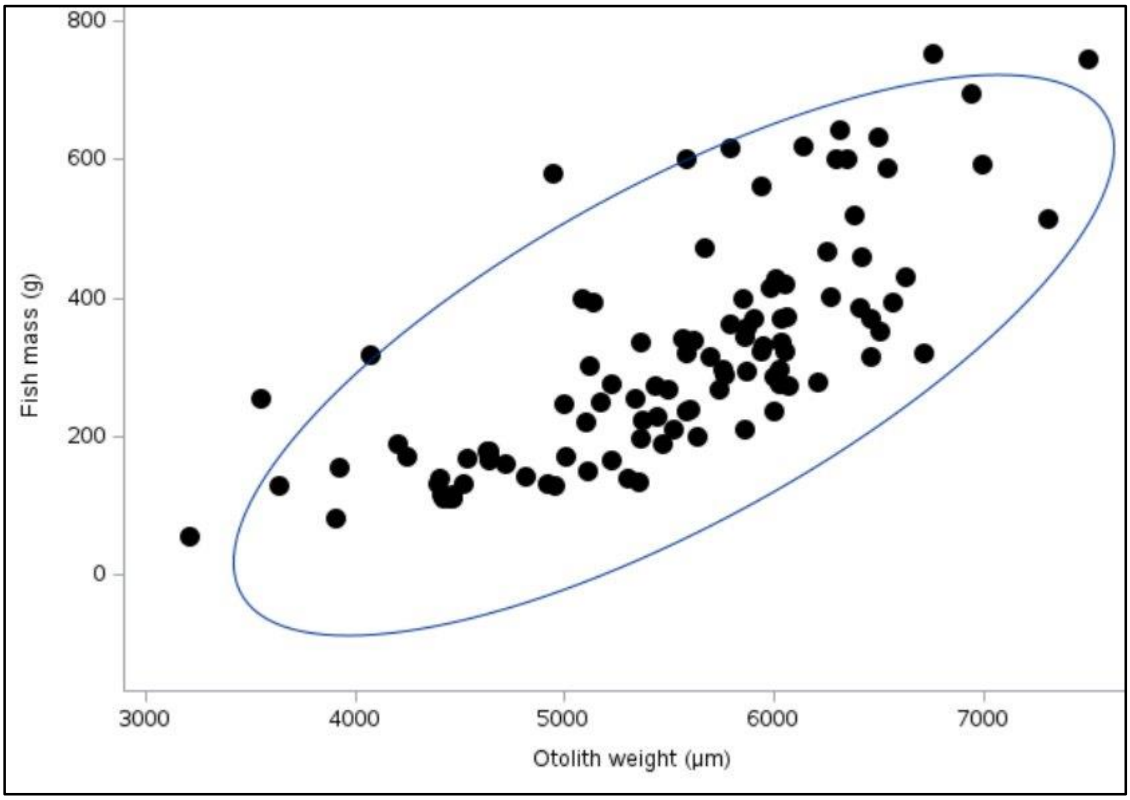


Figure 2. Scatterplot depicting the correlation between lionfish (*Pterois volitans*) mass (g) and otolith length (µm).

**Discussion**. Region-specific data gathered in this project is the first logical step in developing a current local lionfish population model, and for assessment of future management plans, disease events, environmental incidents, and planning targeted culling (Morris Jr. & Whitfield 2009; Johnson & Swenarton 2016; Dahl et al 2019; Fogg et al 2019). Furthermore, this is the first time lionfish population has been studied around the St. Kitts and Nevis region and is only the second set of data to document the association between lionfish size and otolith size. This data is similar to that of a study of lionfish in the southern Gulf of Mexico (Perera & Puerto 2016).

The authors acknowledge that attaining age measurements from each specimen in this study would have been ideal, as otolith annuli have been used successfully to determine age in other studies (Fogg et al 2019). Unfortunately, our attempts to measure age via otolith annuli was not productive. This is not the first time otolith annulus visualization has been reported as challenging with limited success. It is well documented that otoliths from tropical fish contain annuli which may be indistinguishable or difficult to read compared to those living in temperate regions. This is likely due to the lack of seasonality associated with minimal variation in water temperatures and therefore consistent growth of both the animal and its otoliths year-round (Hart & Pitcher 1983; Caldow & Wellington 2003; Marriott & Mapstone 2006; Green et al 2009; Fogg et al 2019). Age estimates attained from otoliths are typically accepted when multiple readers attain a minimum standard of variation, but this still does not assure that the ages attained are precise and accurate (Hanson & Stafford 2017). Furthermore, even when a measurement of age is gathered fruitfully, lack of within-reader agreement can result in many erroneous datapoints. For example, in one study, the measurements of 689 otoliths (58% of total samples) had to be eliminated (Giménez et al 2016), and only there was only 51% agreement between otolith readers in another (Blakeway et al 2022).

Overall, data in this study supports previous works indicating a strong correlation between otolith and fish size (Perera & Puerto 2016). Our data provides a baseline population database and provides insight to future research of predators of lionfish near St. Kitts and Nevis. This is especially important as a valuable complement to human spearfishing because predator fish will naturally select smaller or wounded lionfish that are more easily captured, whereas human culling efforts focus heavily on larger, healthy specimens for harvest and consumption (De León et al 2013).

**Conclusions**. This study provides the first regional parameters for red lionfish near the islands of St. Kitts and Nevis and describes a direct correlation between fish size and otolith dimensions. This information will assist in future stock assessments, food-web dynamics research and management decision-making processes. Direct correlation of otolith size to fish size allows for interpretation of predator diet from stomach content study (Zan et al 2015). Continued recordkeeping of local lionfish population and distribution will be necessary to determine the accuracy of healthy ecology thresholds over time, as well as relative measures of culling and predation successes.

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**Conflict of Interest**. The authors declare that there is no conflict of interest.

**References**

Albins M. A., 2013 Effects of invasive Pacific red lionfish *Pterois volitans* versus a native predator on Bahamian coral-reef fish communities. Biological Invasions 15:29-43.

Battaglia P., Malara D., Ammendolia G., Romeo T., Andaloro F., 2015 Relationships between otolith size and fish length in some mesopelagic teleosts (Myctophidae, Paralepididae, Phosichthyidae and Stomiidae). Journal of Fish Biology 87(3):774-782.

Battaglia P., Malara D., Romeo T., Andaloro F., 2010 Relationships between otolith size and fish size in some mesopelagic and bathypelagic species from the Mediterranean Sea (Strait of Messina, Italy). Scientia Marina 74(3):605-612.

Beaury E. M., Finn J. T., Corbin J. D., Barr V., Bradley B. A., 2020 Biotic resistance to invasion is ubiquitous across ecosystems of the United States. Ecology Letters 23(3):476-482.

Belchier M., Clemmesen C., Cortes D., Doan T., Folkvord A., Garcia A., Geffen A., Høie H., Johannessen A., Moksness E., 2004 Recruitment studies: manual on precision and accuracy of tools. ICES, ICES Techniques in Marine Environmental Sciences, 35 p.

Blakeway R. D., Fogg A. Q., Johnston M. A., Rooker J. R., Jones G. A., 2022 Key life history attributes and removal efforts of invasive lionfish (*Pterois volitans*) in the Flower Garden Banks National Marine Sanctuary, Northwestern Gulf of Mexico. Frontiers in Marine Science 9:65.

Bustos-Montes D., Wolff M., Sanjuan-Muñoz A., Acero A. P., 2020 Growth parameters of the invasive lionfish (*Pterois volitans*) in the Colombian Caribbean. Regional Studies in Marine Science 38:101362.

Caldow C., Wellington G. M., 2003 Patterns of annual increment formation in otoliths of pomacentrids in the tropical western Atlantic: implications for population age-structure examination. Marine Ecology Progress Series 265:185-195.

Chagaris D., Binion S., Bodanoff A., Dahl K., Granneman J., Harris H., Mohan J., Rudd M., Swenarton M., Ahrens R., 2015 Modeling lionfish management strategies on the West Florida Shelf: workshop summary and results. UF IFAS, Workshop Summary and Results, 31 p.

Dahl K. A., Edwards M. A., Patterson III W. F., 2019 Density-dependent condition and growth of invasive lionfish in the northern Gulf of Mexico. Marine Ecology Progress Series 623:145-159.

De León R., Vane K., Bertuol P., Chamberland V. C., Simal F., Imms E., Vermeij M. J., 2013 Effectiveness of lionfish removal efforts in the southern Caribbean. Endangered Species Research 22(2):175-182.

Diller J. L., Frazer T. K., Jacoby C. A., 2014 Coping with the lionfish invasion: Evidence that naïve, native predators can learn to help. Journal of Experimental Marine Biology and Ecology 455:45-49.

Fogg A. Q., Evans J. T., Peterson M. S., Brown-Peterson N., Hoffmayer E. R., Ingram G. W. Jr., 2019 Comparison of age and growth parameters of invasive red lionfish (*Pterois volitans*) across the northern Gulf of Mexico. Fishery Bulletin 117(3):1-15.
Giménez J., Manjabacas A., Tuset V. M., Lombarte A., 2016 Relationships between otolith and fish size from Mediterranean and north-eastern Atlantic species to be used in predator–prey studies. Journal of Fish Biology 89(4):2195-2202.
Granadeiro J. P., Silva M. A., 2000 The use of otoliths and vertebrae in the identification and size-estimation of fish in predator-prey studies. Cybium 24(4):383-393.
Green B. S., Mapstone B. D., Carlos G., Begg G. A., 2009 Tropical fish otoliths: information for assessment, management and ecology. Springer Science & Business Media, 313 p.
Green S. J., Akins J. L., Maljković A., Côté I. M., 2012 Invasive lionfish drive Atlantic coral reef fish declines. PLoS ONE 7(3):e32596.
Hackerott S., Valdivia A., Green S. J., Côté I. M., Cox C. E., Akins L., Layman C. A., Precht W. F., Bruno J. F., 2013 Native predators do not influence invasion success of Pacific lionfish on Caribbean reefs. PLoS ONE 8(7):e68259.
Hanson S. D., Stafford C. P., 2017 Modeling otolith weight using fish age and length: applications to age determination. Transactions of the American Fisheries Society 146(4):778-790.
Hart P., Pitcher T. J., 1983 Fisheries ecology. Springer Science & Business Media, 414 p.
Hernandez-Milian G., Berrow S., Santos M. B., Reid D., Rogan E., 2015 Insights into the trophic ecology of bottlenose dolphins (*Tursiops truncatus*) in Irish waters. Aquatic Mammals 41(2):226-239.
Hoffman K. J., Harding J. M., 2018 Ontogeny of otolith formation in two demersal estuarine reef fishes. Journal of North Carolina Academy of Science 134(3-4):1-9.
Johnson E. G., Swenarton M. K., 2016 Age, growth and population structure of invasive lionfish (*Pterois volitans*/*miles*) in northeast Florida using a length-based, age-structured population model. PeerJ 4:e2730.
Jud Z. R., Layman C. A., Lee J. A., Arrington D. A., 2011 Recent invasion of a Florida (USA) estuarine system by lionfish *Pterois volitans*/*P. miles*. Aquatic Biology 13(1):21-26.
Kasapoglu N., Duzgunes E., 2013 The relationship between somatic growth and otolith dimensions of Mediterranean horse mackerel (*Trachurus mediterraneus*) from the Black Sea. Journal of Applied Ichthyology 29(1):230-233.
Koen-Alonso M., Yodzis P., 2005 Multispecies modelling of some components of the marine community of northern and central Patagonia, Argentina. Canadian Journal of Fisheries and Aquatic Sciences 62(7):1490-1512.
Levine J. M., Adler P. B., Yelenik S. G., 2004 A meta-analysis of biotic resistance to exotic plant invasions. Ecology letters 7(10):975-989.
Maljković A., Van Leeuwen T. E., Cove S. N., 2008 Predation on the invasive red lionfish, *Pterois volitans* (Pisces: Scorpaenidae), by native groupers in the Bahamas. Coral Reefs 27:501.
Malpica-Cruz L., Fulton S., Quintana A., Zepeda-Domínguez J. A., Quiroga-García B., Tamayo L., Canto Noh J. A., Côté I. M., 2021 Trying to collapse a population for conservation: commercial trade of a marine invasive species by artisanal fishers. Reviews in Fish Biology and Fisheries 31(3):667-683.
Marriott R. J., Mapstone B. D., 2006 Geographic influences on and the accuracy and precision of age estimates for the red bass, *Lutjanus bohar* (Forsskal 1775): a large tropical reef fish. Fisheries Research 80(2-3):322-328.
Morris J. A. Jr., Akins L., Buddo D., Green S., Lozano R., 2012 Invasive lionfish: a guide to control and management. Gulf and Caribbean Fisheries Institute, 113 p.
Morris Jr. J. A., Whitfield P. E., 2009 Biology, ecology, control and management of the invasive Indo-Pacific lionfish: an updated integrated assessment. NOAA Technical Memorandum NOS NCCOS 99, 57 p.
Mumby P. J., Harborne A. R., Brumbaugh D. R., 2011 Grouper as a natural biocontrol of invasive lionfish. PLoS ONE 6(6):e21510.

Perera A. A., Puerto L. Q., 2016 Relations between fish length to weight, and otolith length and weight, of the lionfish *Pterois volitans* in the Parque Nacional Arrecife Alacranes, southern Gulf of Mexico. Revista de Biología Marina y Oceanografía 51(2):469-474.
Richardson D. M., Pyšek P., 2007 Elton, C.S. 1958: The ecology of invasions by animals and plants. London: Methuen. Progress in Physical Geography 31(6):659-666.
Schulz-Mirbach T., Ladich F., Plath M., Heß M., 2019 Enigmatic ear stones: what we know about the functional role and evolution of fish otoliths. Biological Reviews 94(2):457-482.
Sutherland W. J., Barnard P., Broad S., Clout M., Connor B., Côté I. M., Dicks L. V., Doran H., Entwistle A. C., Fleishman E., 2017 A 2017 horizon scan of emerging issues for global conservation and biological diversity. Trends in Ecology & Evolution 32(1):31-40.
Switzer T. S., Tremain D. M., Keenan S. F., Stafford C. J., Parks S. L., McMichael Jr. R. H., 2015 Temporal and spatial dynamics of the lionfish invasion in the eastern Gulf of Mexico: perspectives from a broadscale trawl survey. Marine and Coastal Fisheries 7(1):1-8.
Zan X. X., Zhang C., Xu B. D., Zhang C. L., 2015 Relationships between fish size and otolith measurements for 33 fish species caught by bottom trawl in Haizhou Bay, China. Journal of Applied Ichthyology 31(3):544-548.
*** AVMA (American Veterinary Medical Association), 2020 AVMA guidelines for the euthanasia of animals. 2020 Edition. Available at: https://www.avma.org/sites/default/files/2020-02/Guidelines-on-Euthanasia-2020.pdf.
*** Handwerk B., 2012 Shark's lionfish lunch. National Geographic. Available at: http://news. nationalgeographic. com/news/2011/03/pictures/110404-sharkslionfish-alien-fish-invasive-species-science/.
*** https://earth.google.com/web/

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