

RELATIONSHIPS BETWEEN FISH LENGTH, OTOLITH SIZE AND OTOLITH WEIGHT IN *SPERATA AOR* (BAGRIDAE) AND *LABEO BATA* (CYPRINIDAE) FROM THE GANGA RIVER, INDIA

Aafaq Nazir and M. Afzal Khan*

Section of Fishery Science and Aquaculture, Department of Zoology, Aligarh Muslim University, Aligarh 202 002, India

*Corresponding author. Email: khanmafzal@yahoo.com

Article history

Received: 4 October 2018;
accepted 15 May 2019

Keywords:

Long-whiskered catfish;
Bata; fish length; otolith
size

Abstract. The present study was conducted to investigate the relationships between fish length, otolith size and otolith weight. A total of 180 *Sperata aor* and 171 *Labeo bata* specimens were collected monthly during January 2016 to March 2017 from the River Ganga at the Narora site. Student's *t*-test showed no significant differences in the size of right and left otoliths in the selected fish species, therefore, a single linear regression based on the left otolith was carried out. Fish length was plotted against otolith weight, otolith length and otolith height. Moreover, otolith length was plotted against otolith weight and otolith height. The linear regression model was found to fit the data well for fish length to otolith size in both selected fish species. A strong relationship between otolith length and weight was found in both species ($r^2 > 0.8$). Furthermore, the study revealed that fish length is potentially related to otolith size and a strong relationship between fish length and otolith size exists in *S. aor* (mean $r^2 = 0.89$) as compared to *L. bata* (mean $r^2 = 0.70$). Such relationships should be determined for the fish species that are ecologically and socio-economically important in order to understand their trophic relationships, population dynamics and yield estimates.

INTRODUCTION

Otoliths are commonly used to estimate fish age and growth, which are useful for monitoring population dynamics, understanding trophic interactions as well as for carrying out stock assessments (Campana et al. 2000; Harvey et al. 2000; Viva et al. 2015; Khan, Nazir, and Banday 2018). Otolith size and morphology can be used as a taxonomic tool for species identification and delineation of fish stocks due to high levels of inter- and intraspecific variations (Campana et al. 2000; Stransky and MacLellan 2005; Aneesh-Kumar et al. 2017). It is reported that fossil otoliths are very useful for studying ancient teleost fish fauna (Nolf 1995; Annabi, Said, and Reichenbacher 2013).

Fish size and biomass can be back-calculated from fish length and otolith size relationships (Harvey et al. 2000; Waessle et al. 2003; Tarkan et al. 2007; Aneesh-Kumar et al. 2017). For most fish species, linear regression analyses have been used to delineate the relationship between fish length and otolith size (Battaglia et al. 2010, 2015). A number of studies have reported the relationship between fish length and otolith size in marine and freshwater fishes (Hunt 1992; Harvey et al. 2000; Waessle, Lasta, and Bavero 2003; Longenecker 2008; Zorica, Sinovcic, and Kec 2010; Potier et al. 2011; Skeljo and Ferri 2012; Battaglia et al. 2015; Humston et al. 2015; Viva et al. 2015; Aneesh-Kumar et al. 2017).

The long-whiskered catfish, *Sperata aor* (Hamilton 1822), a commercially important food fish, is distributed in India, Pakistan, Bangladesh, Nepal and upper Myanmar (Talwar and Jhingran 1991). In India, *S. aor* is usually caught for consumption from the wild since its culture practices have not been standardized to the commercial level (Khan, Nazir, and Khan 2016). The fishing practices in the Ganga basin are unorganized and no report is available on the trends in *S. aor* production from the selected River (Nazir and Khan 2019). Moreover, the decline in fish catches may be due to the overdependence of dense human population on the Ganga River for agricultural, developmental and religious activities (Nazir and Khan 2017; Khan and Nazir 2019). *S. aor* has been categorized as vulnerable in Indian rivers because of overfishing, noticeable change in its distribution patterns and anthropogenic threats (Lakra et al. 2010; Sarkar et al. 2012).

Bata, *Labeo bata* (Hamilton 1822), is a benthopelagic and potamodromous species distributed in Bangladesh, India and Pakistan (Rema Devi and Ali 2011). This fish species has a high market value and is considered to be a commercially important species for aquaculture (Rema Devi and Ali 2011). *L. bata* has been listed as lower risk near threatened (Molur and Walker 1998) and least concern by IUCN (Rema Devi and Ali 2011). Several threats, such as loss of habitat, overexploitation, water diversions, siltation and industrial discharges

are considered to be responsible for the decline in *L. bata* populations in natural environments (Molur and Walker 1998; Rema Devi and Ali 2011).

Information about the relationship between fish length and otolith size in the selected fish species is lacking; moreover, there is a paucity of published reports on such types of relationships for most of the freshwater fish species from India. Therefore, the present study was conducted to examine the relationship between fish length, otolith size and otolith weight in *S. aor* and *L. bata* collected from the River Ganga.

MATERIALS AND METHODS

A total of 180 *S. aor* and 171 *L. bata* samples were collected from January 2016 to March 2017 from the River Ganga at the Narora site (28°11' N, 78°23' E). The taxonomic identification of samples was carried out following Talwar and Jhingran (1991). Fish samples were placed on ice, transported to the laboratory, measured for total length (nearest 0.1 cm), and frozen for subsequent analyses. Otoliths (lapilli in *S. aor* and asterisci in *L. bata*) were removed and cleaned with water, kept at room temperature to dry and then placed into marked envelopes (Khan, Nazir, and Khan 2016). The otoliths of both fish species were photographed with a Nikon® SMZ745T Stereozoom microscope and the morphometric measurements of the otoliths (length and height) were taken using ImageJ software (ImageJ 1.51j8, National Institute of Health, USA) (Figure 1). Otolith weight of each individual (in milligrams) was

determined using an electronic balance (SI-234 Denver Instruments, Germany) with an accuracy of 0.1 mg.

Linear regression analysis was performed to determine the relationship between otolith weight and otolith length in both species. Also, the linear regression analysis was conducted to relate fish length (FL) to otolith weight (OW), otolith length (OL) and otolith height (OH). For each fish sample, these equations were first calculated for both left and right otoliths and the *t*-test was used to compare regression coefficients; when significant differences ($p < 0.05$) were not found, the null hypothesis ($b_{\text{right}} = b_{\text{left}}$) was accepted. Hence, the left otolith was selected for further linear regression analysis. Thus, a single linear regression was described for each variable (OW, OL and OH) and species (Battaglia et al. 2015).

RESULTS

The information about sample size, minimum and maximum values of fish length, otolith length, weight and height of both species are presented in Table 1. A strong relationship between otolith length and otolith weight ($r^2 > 0.8$) was found in both species (Figures 2–3). The relationships between fish length and otolith size (length and height) are shown in Figures 4–11. In *S. aor*, otolith weight was found to be best correlated with fish length ($r^2 = 0.96$) and nearly the same correlation was discovered between otolith length and otolith height ($r^2 = 0.95$). In the case of *L. bata*, the highest correlation was found to exist between otolith length

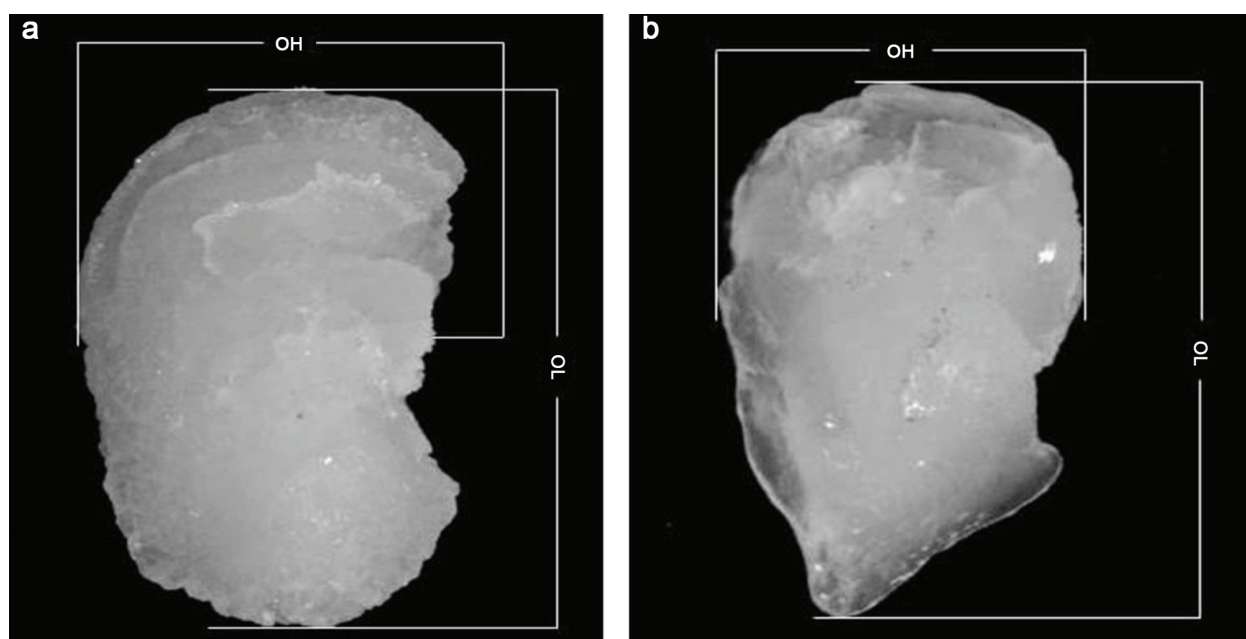


Figure 1. Otolith measurements (OL, otolith length; OH, otolith height) of lapilli in *Sperata aor* (A) and asterisci in *Labeo bata* (B) collected from the River Ganga.

and otolith weight ($r^2 = 0.94$), the correlation determined between fish length and otolith weight being also strong ($r^2 = 0.87$). Overall, a strong correlation between fish length and otolith size and otolith weight was found in *S. aor* (mean $r^2 = 0.91$) as compared to that of *L. bata* (mean $r^2 = 0.79$).

DISCUSSION

Otolith morphology and morphometric relationships are valuable tools in species and stock identification, and can be used in feeding ecology to estimate fish size and biomass (Granadeiro and Silva 2000; Mehanna et

Table 1. Information about sample size (N), fish length (cm), otolith weight (mg), otolith length (mm) and otolith height (mm) of *Sperata aor* and *Labeo bata* collected from the River Ganga.

Species	N	Fish length (cm) Min–Max	Otolith weight (mg) Min–Max	Otolith length (mm) Min–Max	Otolith height (mm) Min–Max
<i>Sperata aor</i>	180	16.5–81.4	4.1–62.3	2.5–7.1	1.6–4.5
<i>Labeo bata</i>	171	14–31.2	1.6–5	2–3.1	1.1–2.1

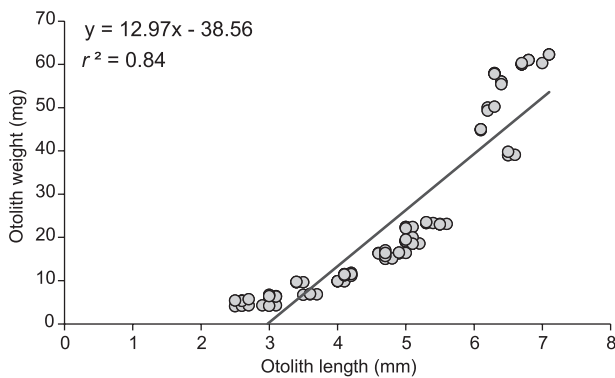


Figure 2. Relationship between otolith length and otolith weight in *Sperata aor*.

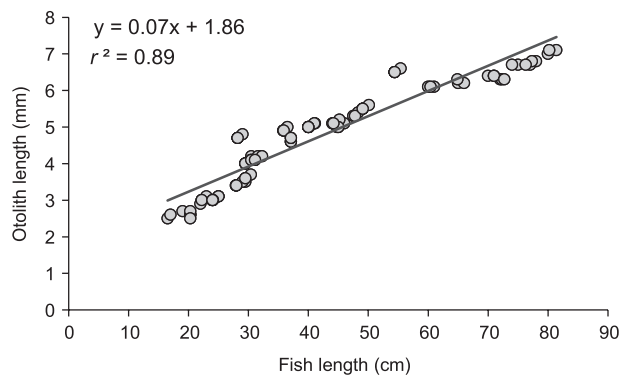


Figure 5. Relationship between fish length and otolith length in *Sperata aor*.

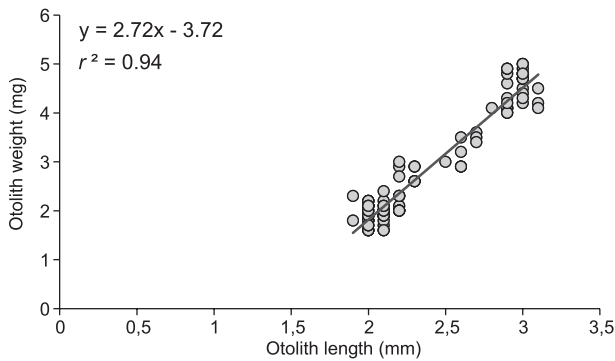


Figure 3. Relationship between otolith length and otolith weight in *Labeo bata*.

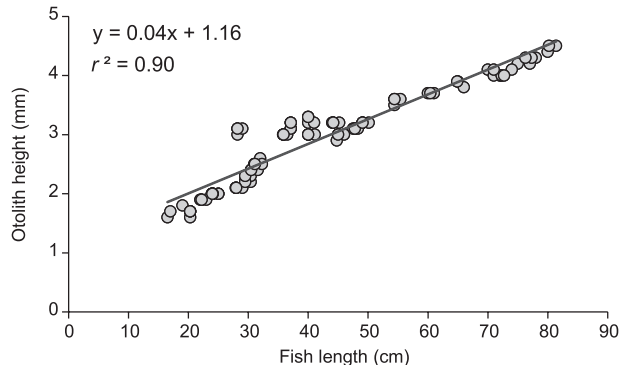


Figure 6. Relationship between fish length and otolith height in *Sperata aor*.

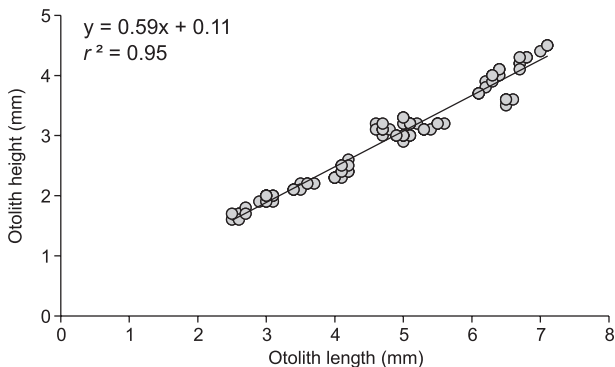


Figure 4. Relationship between otolith length and otolith height in *Sperata aor*.

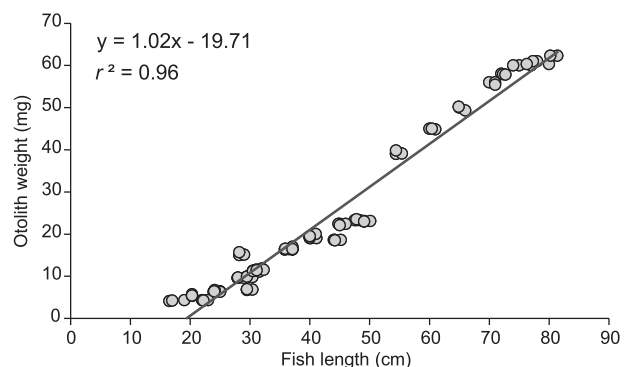


Figure 7. Relationship between fish length and otolith weight in *Sperata aor*.

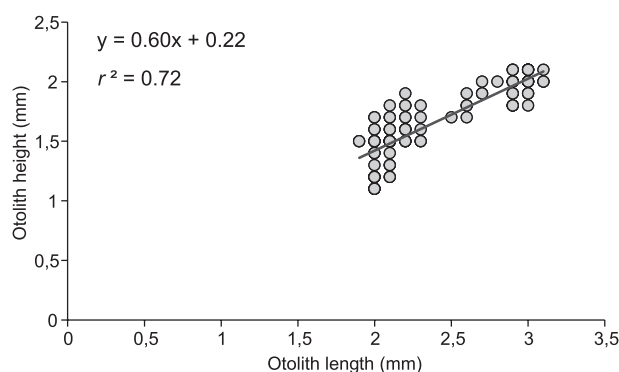


Figure 8. Relationship between otolith length and otolith height in *Labeo bata*.

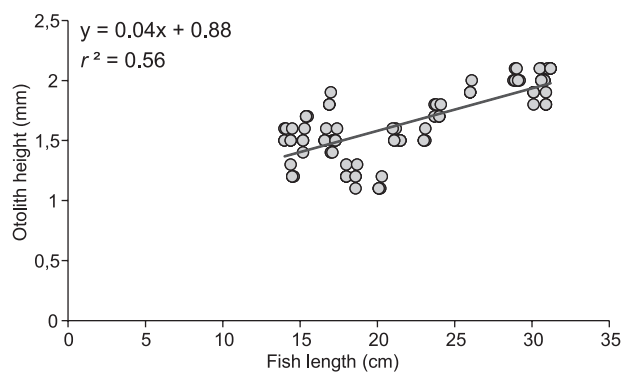


Figure 10. Relationship between fish length and otolith height in *Labeo bata*.

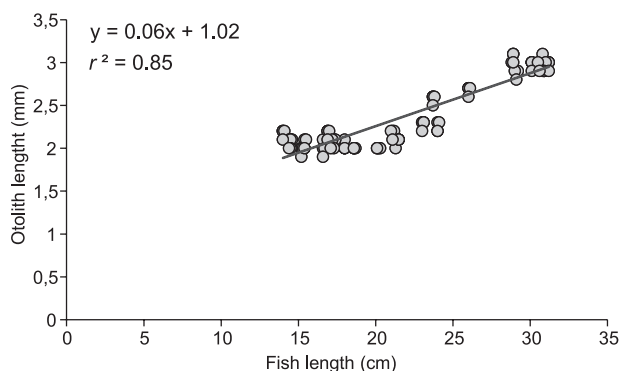


Figure 9. Relationship between fish length and otolith length in *Labeo bata*.

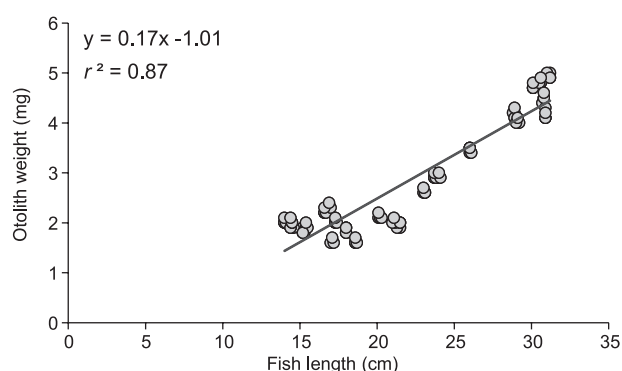


Figure 11. Relationship between fish length and otolith weight in *Labeo bata*.

al. 2016). There are no published reports available on the relationship between fish length and otolith size and length-weight relationship of otoliths from the target habitat or elsewhere for both fish species. Several researchers have reported that the relationships between fish length and otolith size can be used to back-calculate fish length from otolith size (Harvey et al. 2000; Zan et al. 2015; Aneesh-Kumar et al. 2017).

A strong relationship between fish length and otolith size suggests that somatic growth has a major effect on otolith growth (Munk 2012); there are published reports about similar relationships revealed between somatic and otolith growth (Aneesh-Kumar et al. 2017; Yilmaz et al. 2019). In the present study, linear regressions between fish length and otolith size showed a higher coefficient of determination ($r^2 > 0.8$) except between fish length and otolith height for *L. bata*. There are a number of factors that influence fish length and otolith size relationships such as differences in fish species, habitat condition, food availability and other environmental factors (Aydin et al. 2004); therefore further studies into the effect of these variables are highly warranted.

The present study has revealed that the fish length is potentially related to otolith size and a strong relationship exists between fish length and otolith size in both target fish species. Therefore, it is highly important that the relationship between fish length and otolith size, and oto-

lith length-weight relationship be estimated for a large number of fish species inhabiting the Gangetic river system in order to understand the trophic relationships between the fishes and their population dynamics.

ACKNOWLEDGEMENTS

The authors are thankful to the Chairman, Department of Zoology, Aligarh Muslim University, Aligarh, India for providing necessary facilities for the study. The first author greatly acknowledges the financial support in the form of a Project Fellowship provided by the Science and Engineering Research Board, Department of Science and Technology, New Delhi.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

FUNDING

This research work was supported by the Science and Engineering Research Board, Department of Science and Technology, New Delhi (SR/SO/AS-40/2012).

REFERENCES

- Annabi, A., K. Said, and B. Reichenbacher. 2013. 'Inter-population differences in otolith morphology are genetically encoded in the killifish *Aphanius fasciatus* (Cyprinodontiformes).' *Scientia Marina* 77 (2): 269–279. doi:10.3989/scimar.03763.02A
- Aneesh-Kumar, K. V., K. P. Deepa, M. Hashim, C. Vasu, and M. Sudhakar. 2017. 'Relationships between fish size and otolith size of four bathydemersal fish species from the south eastern Arabian Sea, India.' *Journal of Applied Ichthyology* 33 (1): 102–107. doi:10.1111/jai.13250
- Aydin, R., M. Calta, D. Sen, and M. Z. Coban. 2004. 'Relationships between fish lengths and otolith length in the population of *Chondrostoma regium* (Heckel, 1843) inhabiting Keban Dam lake.' *Pakistan Journal of Biological Sciences* 7 (9): 1550–1553.
- Battaglia, P., D. Malara, G. Ammendolia, T. Romeo, and F. Andaloro. 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. doi:10.1111/jfb.12744
- Battaglia, P., D. Malara, T. Romeo, and F. Andaloro. 2010. 'Relationship 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. doi:10.3989/scimar.2010.74n3605
- Campana, S. E., G. A. Chouinard, J. M. Hanson, A. Frechet, and J. Bratney. 2000. 'Otolith elemental fingerprints as biological tracers of fish stocks.' *Fisheries Research* 46: 343–357. doi:10.1016/S0165-7836(00)00158-2
- Granadeiro, J. P., and M. A. Silva. 2000. 'The use of otoliths and vertebrae in the identification and size-estimation of fish in predator prey studies.' *Cybium* 24: 383–393.
- Harvey, J. T., T. R. Loughlin, M. A. Perez, and D. S. Oxman. 2000. 'Relationship between fish size and otolith length for 63 species of fishes from the eastern North Pacific Ocean.' *NOAA Technical Report NMFS* 150: 35. <http://aquaticcommons.org/id/eprint/2511>
- Humston, R., M. Moore, C. Wass, D. Dennis, and S. Doss. 2015. 'Correlations between body length and otolith size in smallmouth bass *Micropterus dolomieu* Lacépède, 1802 with implications for retrospective growth analyses.' *Journal of Applied Ichthyology* 31 (5): 883–887. doi:10.1111/jai.12801
- Hunt, J. J. 1992. 'Morphological characteristics of otoliths for selected fish in the Northwestern Atlantic.' *Journal of Northwest Atlantic Fishery Science* 13: 63–75.
- Khan, M. A., A. Nazir, and U. Z. Bandy. 2018. 'Utility of otolith weight to estimate age of *Labeo bata* (Actinopterygii: Cypriniformes: Cyprinidae) inhabiting the Ganga River.' *Acta Ichthyologica et Piscatoria* 48 (3): 257–260. doi:10.3750/AIEP/02342
- Khan, M. A., A. Nazir, and S. Khan. 2016. 'Assessment of Growth Zones on Whole and Thin-sectioned Otoliths in *Sperata aor* (Bagridae) Inhabiting the River Ganga, India.' *Journal of Ichthyology* 56 (2): 242–246. doi:10.1134/S0032945216020041
- Khan, M. A., and A. Nazir. 2019. 'Stock delineation of the long-whiskered catfish, *Sperata aor* (Hamilton 1822), from River Ganga by using morphometrics.' *Marine and Freshwater Research* 70 (1): 107–113. doi:org/10.1071/MF17306
- Lakra, W. S., U. K. Sarkar, A. Gopalakrishnan, and A. Kathirvelpandian. 2010. *Threatened freshwater fishes of India*. Lucknow, India: National Bureau of Fish Genetic Resources.
- Longenecker, K. 2008. 'Relationships between otolith size and body size for Hawaiian reef fishes.' *Pacific Science* 62 (4): 533–539. doi:10.2984/1534-6188-(2008)62[533:RBOSAB]2.0.CO;2
- Mehanna, S. F., L. A. Jawad, Y. A. Ahmed, M. A. Abu El-Regal, and D. Dawood. 2016. 'Relationships between fish size and otolith measurements for *Chlorurus sordidus* (Forsskål, 1775) and *Hipposcarus harid* (Forsskål, 1775) from the Red Sea coast of Egypt.' *Journal of Applied Ichthyology* 32 (2): 356–358. doi:10.1111/jai.12995
- Molur, S., and S. Walker. 1998. *Report of the workshop conservation assessment and management plan for freshwater fishes of India*. Zoo Outreach Organisation, Conservation Breeding Specialist Group (CBSG), Coimbatore.
- Munk, M. K. 2012. 'Somatic-Otolith Size Correlations for 18 Marine Fish Species and Their Importance to Age Determination.' *Regional Information Report* No. 5J12–13. Alaska Department of Fish and Game.
- Nazir, A., and M. A. Khan. 2017. 'Stock discrimination of *Sperata aor* from river Ganga using microsatellite markers: implications for conservation and management.' *Aquatic Living Resources* 30: 1–9. doi:10.1051/alr/2017033
- Nazir, A., and M. A. Khan. 2019. 'Spatial and temporal variation in otolith chemistry and its relationship with water chemistry: Stock discrimination of *Sperata aor*.' *Ecology of Freshwater Fish* 00: 1–13. doi:10.1111/eff.12471
- Nolf, D. 1995. 'Studies on fossil otoliths – the state of the art.' In *Recent Developments in Fish Otolith Research*, edited by Secor, D. H., J. M. Dean, and S. E. Campana, 513–544. Columbia: University of South Carolina Press.
- Potier, M., F. Menard, H. D. Benivary, and R. Sabatie. 2011. 'Length and weight estimates from diagnostic hard part structures of fish, crustacean and cephalopods forage species in the western India Ocean.' *Environmental Biology of Fishes* 92 (3): 413–423. doi:10.1007/s10641-011-9848-5

- Ramakrishniah, M. 1992. 'Studies on the breeding and feeding biology of *Mystus aor* (Hamilton) of Nagarjunasagar Reservoir.' *Proceedings of the National Academy of Sciences India Section B Biological Sciences* 62: 357–364.
- Rema Devi, K. R., and A. Ali. 2011. *Labeo bata*. The IUCN Red List of Threatened Species 2011: e.T166595A6243968
<https://www.iucnredlist.org/species/166595/6243968>
- Sarkar, U. K., A. K. Pathak, R. K. Sinha, K. Sivakumar, A. K. Pandian, A. Panday, V. K. Dubey, and W. S. Lakra. 2012. 'Freshwater fish biodiversity in the River Ganga (India): changing pattern, threats, and conservation perspectives.' *Reviews in Fish Biology and Fisheries* 22 (1): 251–272. doi:10.1007/s11160-011-9218-6
- Skeljo, F., and J. Ferri. 2012. 'The use of otolith shape and morphometry for identification and size-estimation of five wrasse species in predator-prey studies.' *Journal of Applied Ichthyology* 28 (4): 524–530. doi:10.1111/j.1439-0426.2011.01925.x
- Stransky, C., and E. S. MacLellan. 2005. 'Species separation and zoogeography of redbfish and rockfish (genus *Sebastes*) by otolith shape analysis.' *Canadian Journal of Fisheries and Aquatic Sciences* 62 (10): 2265–2276. doi:10.1139/f05-143
- Talwar, P. K., and A. G. Jhingran. 1991. *Inland Fishes of India and Adjacent Countries*. New Delhi: Oxford and IBH Publishing Co.
- Tarkan, S. A., G. C. Gaygusuz, O. Gaygusuz, and H. Acipinar. 2007. 'Use of bone and otolith measures for size-estimation of fish in predator-prey studies.' *Folia Zoologica* 56 (3): 328–336.
- Viva, C., P. Sartor, D. Bertolini, S. De Ranieri, and A. Ligas. 2015. 'Relationship of otolith length to fish total length in six demersal species from the NW Mediterranean Sea.' *Journal of Applied Ichthyology* 31 (3): 973–974. doi:10.1111/jai.12838
- Waessle, J. A., C. A. Lasta, and M. Bavero. 2003. 'Otolith morphology and body size relationships for juvenile Sciaenidae in the Rio de la Plata estuary (35–36°S).' *Scientia Marina* 67 (2): 233–240. doi:10.3989/scimar.2003.67n2233
- Yilmaz, S., O. Emiroglu, S. Aksu, S. Baskurt, and N. Polat. 2019. 'Relationships between otolith dimensions and body growth of North African Catfish *Clarias gariepinus* (Burchell, 1822) from the upper basin of the Sakarya River, Turkey.' *Croatian Journal of Fisheries* 77 (1): 57–62. doi:10.2478/cjf-2019-0006
- Zan, X. X., C. Zhang, B. D. Xu, C. L. Zhang. 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): 1–5. doi:10.1111/jai.12751
- Zorica, B., G. Sinovcic, and V. C. Kec. 2010. 'Preliminary data on the study of otolith morphology of five pelagic fish species from the Adriatic Sea (Croatia).' *Acta Adriatica* 51 (1): 89–96.