

Relation of fish size with that of its otolith of Pama croaker, *Otolithoides pama* (Hamilton, 1822) from Narmada estuary, India

Dibakar Bhakta (✉ dibakar.bhakta@icar.gov.in)

Central Inland Fisheries Research Institute

Suhas Prakash Kamble

Vadodara Research Station of ICAR-CIFRI, GERI Campus

Wakamban Anand Meetei

Vadodara Research Station of ICAR-CIFRI, GERI Campus

Jayesh Kumar Solanki

Vadodara Research Station of ICAR-CIFRI, GERI Campus

Rajesh Kumar Sah

Vadodara Research Station of ICAR-CIFRI, GERI Campus

Sonia Solanki

Vadodara Research Station of ICAR-CIFRI, GERI Campus

Basanta K. Das

Central Inland Fisheries Research Institute

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Abstract

The relation of fish size with that of its otolith of pama croaker, *Otolithoides pama* (Hamilton, 1822) was established. Fish specimens were collected from the bagnet catch from Narmada estuary, India for a period of 8 months (November 2018 to June 2019). To understand the relationship between fish and otolith size, the sagittal otoliths were extricated, cleaned, measured, and photographed. The Otolith length (OL), Otolith breadth (OB), and Otolith weights (OW) were measured from each specimen to the nearest size of 0.01 mm and weight of 0.01 g. The observed length and weight of the fish were in the range of 85 to 288 mm (175.79 ± 33.13 mm) and 3.0 to 186.56 g (43.68 ± 27.67 g), respectively. The recorded otolith length, breadth, and weight were in the range of 2.65 to 12.54 mm (7.20 ± 1.77 mm), 2.01-10.48 mm (5.95 ± 1.33 mm), and 0.02 g to 0.75 g (0.23 ± 0.11 g), respectively. The data fitted well to the power model for the OL, OB, OW, and fish length and weight. High values of the coefficient of determination (R^2) were recorded between fish length and otolith length ($R^2 = 0.978$), fish length and otolith weight ($R^2 = 0.931$), fish length and otolith breadth ($R^2 = 0.985$), fish weight and otolith length ($R^2 = 0.942$), fish weight and otolith weight ($R^2 = 0.922$), and fish weight and otolith breadth ($R^2 = 0.962$). The study also depicted a high correlation of otolith dimensions with the size of the fish.

Introduction

Otolith, a crystallized structure located in the inner ear of fishes made up of Calcium carbonate is indirectly employed in studying the age and population structure of fishes, and to assess the relationships between fish and its environment (Lord et al. 2012; Zengin et al. 2015). These are important tools to study the life history traits of fishes, as they allow for studying the age and growth of fishes. Sagittal otoliths are mainly used for morphological studies in most of the bony fishes as these are the largest among the three pairs of otoliths (Harvey et al. 2000; Jawad & Al-Mamry 2012). Otolith morphometry is a widely used taxonomic feature in fish biology for intra- and inter-species comparisons (Campana 2004; Jawad et al. 2017; Basusta et al. 2020), as both the environmental changes and geographical separations develop certain variations in otolith structure (Torres et al. 2000; Vignon and Morat 2010; Sadighzadeh et al. 2014). Other than stock assessment studies, otoliths are also used to examine the feeding habits of fishes (Harvey et al. 2000). Further, to study the prey-predator relationships by stomach content analysis, the relationships between the fish size and otolith dimensions are important (Mehanna et al. 2016).

The morphology of otoliths is an important attribute that defines every fish species (Hossucu et al. 1999). The size and shape of otoliths differ from species to species; hence these hard structures are used in calculating the size of the fish species (Basusta et al. 2013; Zan et al. 2015). The otolith usually follows an allometric enhancement in dimensions with fish size (Chilton and Beamish 1982). Thus, the otolith length helps to estimate the length of fish species and vice versa (Sen et al. 2001; Yilmaz et al. 2014); such studies are frequently conducted in the fishery sciences (Battaglia 2015).

Due to the stable nature of otolith, and its species-specific features, otoliths act as a very useful tool in stomach contents analysis (Polito et al. 2011; Zan et al. 2015), since otoliths could remain undigested for a comparatively longer period in the stomach of carnivorous fishes (Bostanci 2009). Thus, the back-calculation of fish size from the otolith's measurements of prey species is common once the fish size and otolith dimension relationships are established (Zan et al. 2015). Such studies are also useful in the study of fish population dynamics.

Sciaenids are one of the major demersal fishery resources in the state of Gujarat with a production of around 47,510 t, constituting about 21.59% of the total demersal production during 2018–2019 (CMFRI 2019). Also, sciaenids contributed about 3.73% of the total marine production of India during the same period. The commercially important Sciaenid species occurring on the long Indian coast are *Otolithoides biauritus*, *O. pama*, *Protonibea diacanthus*, *Otolithes ruber*, *Otolithes cuvieri*, *Johnius glaucus*, *Johnius elongatus*, *Johnius carutta*, *Pennahia anea*, *Johnius borneensis* and *Johnius dussumieri* (Talwar 1995; Bhakta et al. 2020a & b). The important sciaenids species contributing significantly to the fish basket of the state of Gujarat are *Otolithes cuvieri*, *Otolithes ruber*, *Protonibea diacanthus*, *Nibea soldado*, *Otolithoides biauritus*, *Johnius glaucus*, *Johnius elongatus*, *Johnius macrorhynchus*, *J. belangeri*, *J. aneus*, *J. sina*, *Atrubucca nibe*, *O. pama*, etc. (Mohan, 1991). Among the sciaenids, *Otolithoides pama* forms an important commercial fishery in the Narmada and Hooghly-Matlah estuaries of India (Kumar et al. 2012; Bhakta et al. 2015 & 2019b).

In general, fishes of the family Sciaenidae possess relatively large otoliths (Kumar et al. 2012; Bhakta et al. 2020a). There is very little information available on the otolith morphometry and fish length of *O. pama* inhabiting the estuarine waters of India and other associated water bodies (Bhakta et al. 2020a). The present study aimed to determine the correlation between the fish size and otolith dimensions of *O. pama* specimens collected from the Narmada estuary, Gujarat, located on the west coast of India.

Materials And Methods

During the sampling period of November 2018 to June 2019, a total of 196 sex undistinguished specimens of *O. Pama* were collected from the bag net catch of Narmada estuary, having a size range of 85.0-288.0 mm and weight range of 3.0-186.56 g. Efforts were made to collect the specimens fortnightly and compulsorily monthly, based on the availability of pama croaker from the bag net catches of the estuary (Fig. 1). Bag net is locally known as 'Golava' with a 10 mm cod-end mesh size, and length of 15–22 m, and is usually operated for 7–8 months (November to June) in the Bhadbhut-Mehagam fishing area of Narmada estuary (Bhakta et al. 2019d). Fish samples were brought to the laboratory in the icebox and preserved at -20 °C. The samples were thawed before further studies. The specimens were identified by using the standard taxonomical characters of the FAO species identification sheet (Fisher and Binanchi 1984), Mohan (1991) as well as Talwar (1995).

The total length (TL) and body weight (BW) of the specimen was measured to the nearest decimals of millimeter (0.1 mm) and gram (0.01 g), respectively before collection of the otolith. The largest otolith,

sagitta from each individual were collected with the help of the optic capsule using fine forceps which were then cleaned and stored dry in glass vials (Fig. 2). Maximum otolith length (OL) and breadth (OB) were measured using a digital calliper with a resolution of 0.01 mm and weight was measured by using an analytical balance with a resolution of 0.001g. For the present study, right otoliths were only segregated since no significant difference between left and right otoliths was noticed. While measuring the otolith, the longest length from the rostrum to the post rostrum and breadth from the dorsal to the ventral edge at right angles were taken (Smale et al. 1995).

To establish otolith length-weight relationships, the non-linear equation $W = aL^b$ (Le Cren 1951), was followed. The significance of the exponent (b) was tested with fisher't' test. The parameters compared with the total fish length (TL) and total fish weight (TW), were otolith length (OL), otolith weight (OW) and otolith breadth (OB). The morphometric relationships among compared characters were established using a power regression model, which best fit the data distribution (Myers 1990).

Results And Discussion

The length and weight of the fishes were in the range of 85 to 288 mm (175.79 ± 33.13 mm) and 3.0 to 186.56 g (43.68 ± 27.67 g), respectively. OL, OB and OW ranged from 2.65 to 12.54 mm (7.20 ± 1.77 mm), 2.01 to 10.48 mm (5.95 ± 1.33 mm) and 0.02 to 0.75 g (0.23 ± 0.11 g), respectively (Table 1). The length-weight relationships (LWRs) of the samples are provided in Fig. 3. The length and weight relationships of otoliths are provided in Fig. 4, which was showing a negative allometric growth pattern with a high value (0.898) of the coefficient of determination (R^2). A power model was followed to establish the relationships between fish sizes and otolith dimensions, and all six relationships exhibited negative allometry.

From the established power model, a high value of coefficient of determination (R^2) was found between TL and OL ($R^2 = 0.978$), TL and OW ($R^2 = 0.931$), TL and OB ($R^2 = 0.985$), TW and OL ($R^2 = 0.942$), TW and OW ($R^2 = 0.922$), and TW and OB ($R^2 = 0.962$) (Table 2 and Figs. 5a-f).

Only a few studies are available on the LWRs of 'Pama croaker' from India and other neighbouring countries (Nath et al. 2004; Hossain et al. 2015; Baitha et al. 2018; Bhakta et al. 2019b). In the present study 'b' value was found to be 3.038, pointing toward a positive allometric growth pattern. Nath et al. (2004) and Hossain et al. (2015) also found a similar kind of positive allometric growth of 'Pama croaker' from the Hooghly estuary, India, and Tetulia river, Bangladesh, respectively. In contrast to our study, negative allometric growth patterns also had been reported by Baitha et al. (2018) and Bhakta et al. (2018) of 'Pama croaker' from the Ganga River and Hooghly-Matlah estuary, respectively. A series of factors frame up such differences in 'b' values, mainly the area of collection, habitats, seasonal effects, degree of stomach fullness, maturity stages, sexes, overall health conditions, length of the studied specimens, etc. (Tesch 1971, Sarkar et al. 2017; Chakraborty et al. 2018; Vahneichong et al. 2018; Bhakta et al. 2019c).

We could not find any significant differences in terms of OL, OB, and OW between left and right otolith pairs ($p < 0.05$). Hence, right otoliths were used in comparison in the present study for convenience. In general, morphological features of otoliths of fishes are the most widely used tools for the identification of finfish species by comparing taxonomic characters, since otoliths are large, and their variability is inter-specific (Lord et al. 2012). Further, there are numerous advantages to studying the relationship between fish length and otolith size (eg. the age and size of the fish can be calculated).

The LWRs between otolith length and otolith weight indicates that the values of 'b' and 'R²' were at 1.835 and 0.898, respectively which showed a negative allometric growth pattern with a relatively high correlation. A similar kind of allometric growth pattern between otolith length-weight was also reported by Bhakta et al. (2020a) in *O. pama* from the Hooghly-Matlah estuarine systems, India.

In the present study, the size range of fish and otolith dimensions was found a little smaller than that of the study of *O. pama* from the Hooghly-Matlah estuary of India (Bhakta et al. 2020a). This might be due to the collection of fish samples from the smaller mesh size (bag net with 10 mm mesh size). Further, the established relationship between fish size and otolith dimensions varied due to the distribution range, respective stocks, and sexes (Sparre et al. 1989; Aneesh Kumar et al. 2017).

The present study established that otolith length and weight are significantly correlated ($p < 0.01$) to the fish size. It has been reported that along with an increase in the length of 'Pama croaker' in the Hooghly-Matlah estuary, the otolith length and weight also increase (Bhakta et al. 2020a) and similarly with age and length of the king soldier bream, *Argyrops spinifer*, in the Persian Gulf (Ghanbarzadeh et al. 2014). Some studies also reported that the otolith dimensions (length, width, and mass) have a high degree of reliance on the fish length and weight of 12 species of sciaenids inhabited along the north-west coast of India, which is like the present work (Kumar et al. 2012). Ye et al. (2014) reported that fish age is correlated with otolith shape and that the otolith weight has the potential to predict the age of a slow-growing fish Belanger's croaker, *Johnius belangerii* (Cuvier, 1830) from the coastal waters of China by the alternative and objective method.

Further, our study established somatic relationships with otolith measurements, and estimation indicated a strong correlation between them. A similar kind of relationship between otolith and somatic measurements was reported by several researchers (Harvey et al. 2000; Waessle et al. 2003; Monteiro et al. 2005; Jawad & Al- Mamry 2012; Kumar et al. 2012; Kumar et al. 2016; Borah et al. 2019). As per Munk (2012), a strong correlation between somatic measurements and otolith size suggests that somatic growth has a significant influence on otolith growth. In the present study, the relationship was established through the power regression model; and such a model is found to be the most suitable in certain fishes (Lleonart et al. 2000; Kumar et al. 2016). Through the power regression model, Kumar et al. (2016) reported a significant positive correlation between TL, and TW of fish along with OL, OW, and OB in four marine fishes from Indian waters.

Table 1
Range and mean of TL, TW, OL, OW, and OB of *O. pama* (combined sexes) collected from Narmada estuary, India

Parameters	Minimum	Maximum	Mean	SD
Total length (mm)	85.00	288.00	175.79	33.13
Total weight (g)	3.00	186.56	43.68	27.67
Otolith length (mm)	2.65	12.54	7.20	1.77
Otolith weight (g)	0.02	0.75	0.23	0.11
Otolith breadth (mm)	2.01	10.48	5.95	1.33

Table 2
Relationship between TL-TW, OL-OW, TL-OL, TL-OW, TL-OB, TW-OL, TW-OW and TW-OB of *O. pama* (combined sexes) with coefficients of determination (R^2)

Types of Relationship	Model used	R^2 value
TL-TW	Power	0.974*
OL-OW	Power	0.898*
TL-OL	Power	0.978*
TL-OW	Power	0.931*
TL-OB	Power	0.985*
TW-OL	Power	0.942*
TW-OW	Power	0.922*
TW-OB	Power	0.962*
(*Significant at $p < 0.01$).		

Conclusions

The established relationships between fish size and otolith dimensions of *O. pama* will be useful in the calculation of fish size from the otolith measurements. The present study is also in agreement that, the fish length and otolith measurements are very useful for establishing the role of otoliths in the identification of fish species. Otolith shape analysis serves as baseline information for the growth of *O. pama* as otolith size is increasing with the increase of fish size. Thus, otolith length, weight, and breadth can be used to estimate the fish length and weight of *O. pama* from the morphometric relationship analysis.

Declarations

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Ethics approval

“Not applicable” for that section.

Consent to participate

“Not applicable” for that section.

Consent for publication

All authors gave their consent for publication.

Availability of data and materials

“Not applicable” for that section.

Code availability

“Not applicable” for that section.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

References

1. Aneesh Kumar KV, Deepa KP, Hashim M, Vasu C, Sudhakar M (2017) Relationships between fish size and otolith size of four bathydemersal fish species from the southeastern Arabian Sea, India. *J Appl Ichthyol* 33(1):102–107
2. Baitha R, Karna SK, Ray A (2018) Length–weight and length–length relationships of eight fish species from river Ganga, India. *J Appl Ichthyol* 34(4):1052–1054. doi.org/10.1111/jai.13698

3. Basusta A, Bal H, Aslan E (2013) Otolith biometry-total length relationships in the population of Hazar Bleak, *Alburnus heckeli* (Battalgil, 1943) inhabiting Lake Hazar, Elazig, Turkey. Pak J Zool 45(1):1180–1182
4. Başusta A, Çetinkaya B, Başusta N (2020) The relationships between fish size and otolith dimensions in the common sole (*Solea solea* (Linnaeus, 1758)) captured in the Northeastern Mediterranean. J Appl Ichthyol 36(6):888–892
5. 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). J Fish Biol 87:774–782. doi.org/10.1111/jfb.12744
6. Bhakta D, Das SK, Das BK, Nagesh TS, Behera S (2019a) Food and feeding habits of *Otolithoides pama* (Hamilton, 1822) occurring from Hooghly-Matlah estuary of West Bengal, India. Reg Stud Mar Sci 32:100860. https://doi.org/10.1016/j.rsma.2019.100860
7. Bhakta D, Das SK, Das BK, Nagesh TS, Behera S, Das SCS (2019b) Length-weight relationship and condition factor of *Otolithoides pama* (Hamilton, 1822) from Hooghly-Matlah estuarine system of West Bengal, India. Indian J Fish 66(4):51–59
8. Bhakta D, Das SK, Das BK, Behera S, Nagesh TS (2020a) Relationship between otolith morphometry and fish size of *Otolithoides pama* (Hamilton, 1822) from Hooghly-Matlah estuary, India. Indian J Geo Mar Sci 49(10):1636–1642
9. Bhakta D, Das SK, Das BK, Nagesh TS, Samanta R (2020b) Growth, mortality and exploitation status of *Otolithoides pama* (Hamilton, 1822) from Hooghly-Matlah estuary of West Bengal, India. Reg Stud Mar Sci 39:101451. https://doi.org/10.1016/j.rsma.2020.101451
10. Bhakta D, Das SK, Manna RK, Roshith CM, Sudhesan D (2015) Fishery of *Otolithoides pama* (Hamilton, 1822) in Narmada estuary. J Inland Fish Soc India 47(2):78–80
11. Bhakta D, Meetei WA, Solanki JK, Manna RK, Das SK, Das BK (2019d) Assessment of bag net fishery of Narmada estuary, Gujarat: A case Study. J Inland Fish Soc India 51(2):179–183
12. Bhakta D, Meetei WA, Vaishak G, Kamble SP, Solanki JK, Das SK (2019c) Season-wise length-weight relationship and relative condition factor of *Tenulosa ilisha* (Hamilton, 1822) at Narmada estuary, Gujarat, India. Indian J Geo Mar Sci 48(05):635–638
13. Borah S, Vaisakh G, Jaiswar AK, Bhattacharjya BK, Sahoo AK, Deshmukhe G, Das BK (2019) Association pattern between dimensions of fish and otolith to expedite morphometric variations of three geographically isolated stocks of *Tenulosa ilisha* (Hamilton, 1822) from diverse ecosystems. Indian J Fish 66(3):48–52
14. Bostanci D (2009) Otolith biometry-body length relationships in four fish species (chub, pikeperch, crucian carp, and common carp). J Freshwa Ecol 24(4):619–624
15. Campana SE (2004) Photographic atlas of fish otoliths of the Northwest Atlantic Ocean Canadian special publication of fisheries and aquatic sciences No. 133. NRC Research Press
16. Chakraborty R, Das SK, Bhakta D (2018) Length-weight relation, relative condition and GSI of *Channa punctata* (Bloch, 1793) in wetlands of Nadia district, West Bengal. J Aquacul Trop 33(1–2):11–18

17. Chilton DE, Beamish RJ (1982) Age determination methods for fishes studied by the groundfish program at the Pacific Biological Station. Department of Fisheries and Oceans. Edinburgh, UK, Ottawa, Canada, pp 97–130
18. CMFRI (2019) Annual Report 2018-19. Central Marine Fisheries Research Institute, Kochi. 320 p
19. Fischer W, Bianchi G(1984) FAO Species Identification Sheet for Fishery Purposes Western Indian Ocean Fishing Area 51. Vols 1–5. Rome, Italy
20. Ghanbarzadeh M, Soofiani NM, Keivany Y, Taghavi-Motlagh SA (2014) Use of otolith length and weight in age estimations of the king soldier bream, *Argyrops spinifer*, in the Persian Gulf. Iran J Ichthyol 1(1):1–6. doi.org/10.22034/iji.v1i1.1
21. Harvey JT, Loughlin TR, Perez MA, Oxman DS(2000) Relationship between fish size and otolith length for 63 species of fishes from the Eastern North Pacific Ocean. NOAA Technical Report NMFS, 150, 1–36 p
22. Hossain MY, Sayed SRM, Rahman MM, Ali MM, Hossen MA, Elgorban AM, Ahmed ZF, Ohtomi J (2015) Length-weight relationships of nine fish species from the Tetulia River, southern Bangladesh. J Appl Ichthyol 31:967–969
23. Hossucu B, Kaya M, Taşkavak E (1999) An investigation of growth parameters and otolith-total length relationship of *Solea solea* (L., 1758) (Pisces: Soleidae) in İzmir Bay. Isr J Zool 45(2):277–287
24. Jawad LA, Al-Mamry JM (2012) Relationship between fish length and otolith dimensions in the carangid fish (*Carangoides coeruleopinnatus* Rüppell, 1830) collected from the Sea of Oman. J Fish Sci 6(3):203–208
25. Jawad LA, Park JM, Kwak SN, Ligas A (2017) Study of the relationship between fish size and otolith size in four demersal species from the south-eastern Yellow Sea. Cah Biol Mar 58(1):9–15
26. Kumar KA, Deepa KP, Manjebayakath H, Shanis CR, Saravanane N, Sanjeevan VN, Sudhakar M (2016) Relationships between fish and otolith size of the Indian Ruff *Psenopsis cyanea* (Alcock 1980) collected from the south eastern Arabian Sea coast of India. J Mar Biol Assoc India 58(2):1–6
27. Kumar P, Chakraborty SK, Jaiswar AK (2012) Comparative otolith morphology of sciaenids occurring along the north-west coast of India. Indian J Fish 59(4):19–27
28. LeCren ED (1951) The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). J Anim Ecol 20(2):201–219
29. Lleonart J, Salat J, Torres GJ (2000) Removing allometric effects of body size in morphological analysis. J Theor Biol 205:85–93
30. Lord C, Morat F, Lecomte-Finiger R, Keith P (2012) Otolith shape analysis for three *Sicyopterus* (Teleostei: Gobioidae: Sicydiinae) species from New Caledonia and Vanuatu. Environ Biol Fishes 93(2):209–222
31. Mehanna SF, Jawad LA, Ahmed YA, Abu El-Regal MA, Dawood D (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. J Appl Ichthyol 32(2):356–358

32. Mohan RSL (1991) A review of the sciaenid fishery resources of the Indian Ocean. *J Mar Biol Assoc India* 33(12):134–145
33. Monteiro LR, Di Benedetto APM, Guillermo LH, Rivera LA (2005) Allometric changes and shape differentiation of sagittal otoliths in sciaenid fishes. *Fish Res* 74(1–3):288–299. doi.org/10.1016/j.fishres.2005.03.002
34. Munk KM (2012) Somatic-otolith size correlations for 18 marine fish species and their importance to age determination. *Alaska Dep Fish Game Region Info Rep* 5J:12–13
35. Myers RH (1990) *Classical and modern regression application*, 2nd edn. Duxbury Press, CA
36. Nath D, Misra RN, Karmakar HC(2004) *The Hooghly estuarine system Ecological flux, fishery resources and production potential*. ICAR-CIFRI, Barrackpore, Bulletin No. 130, p. 47
37. Polito MJ, Trivelpiece WZ, Karnovsky NJ, Ng E, Patterson WP, Emslie SD (2011) Integrating stomach content and stable isotope analyses to quantify the diets of pygoscelid penguins. *PLoS ONE* 6(10):e26642. <https://doi.org/10.1371/journal.pone.0026642>
38. Sadighzadeh Z, Valinassab T, Vosugi G, Motallebi AA, Fatemi MR, Lombarte A, Tuset VM (2014) Use of otolith shape for stock identification of John's snapper, *Lutjanus johnii* (Pisces: Lutjanidae), from the Persian Gulf and the Oman Sea. *Fish Res* 155:59–63
39. Sarkar S, Das SK, Bhakta D (2017) Length weight relationship and relative condition factor of Indian shad, *Tenualosa ilisha* from Hooghly estuary system, West Bengal. *J Inland Fish Soc India* 49(1):22–26
40. Sen D, Aydin R, Calta M (2001) Relationships between fish length and otolith length in the population of *Capoeta capoetaumbla* (Heckel, 1843) inhabiting Hazar Lake, Elazig, Turkey. *Fish Aquat Life* 9(2):267–272
41. Smale MJ (1995) Otolith atlas of southern African marine fishes. *Ichtyol Monogr* 1:1–253
42. Sparre P, Ursin E, Venema S(1989) *Introduction to tropical fish stock assessment. Part 1. Manual*. FAO Fish. Tech. paper (306). Revision, 2. Rome, FAO. 1998: 407 p
43. Talwar PK(1995) *Fauna of India and the adjacent countries, Pisces Perciformes: Sciaenidae*. Zoological Survey of India, Calcutta-700 020, 144 p
44. Tesch W(1971) Age and growth. In: *Methods for Assessment of fish production in fresh waters*, 2nd edn. W.E. Ricker, (Ed.) International Biological Programme, Oxford and Edinburgh. 97–130 p
45. Torres GJ, Lombarte A, Morales-Nin B (2000) Sagittal otolith size and shape variability to identify geographical intraspecific differences in three species of the genus *Merluccius*. *J Mar Biol Assoc UK* 80:333–342
46. Vahneichong E, Das SK, Mondal A, Bhakta D (2018) Length-weight relationship, condition factor and gonado-somatic index of *Labeo calbasu* (Hamilton, 1822). *J Fish* 6(3):645–649. DOI: 10.17017/jfish.v6i3.2018.269
47. Vignon M, Morat F (2010) Environmental and genetic determinant of otolith shape revealed by a non-indigenous tropical fish. *Mar Ecol Prog Ser* 411:231–241

48. Waessle JA, Lasta CA, Favero M (2003) Otolith morphology and body size relationships for juvenile Sciaenidae in the Rio de la Plata estuary (35–36 °S). *Sci Mar* 67(2):233–240. doi.org/10.3989/scimar.2003.67n2233
49. Ye ZJ, Zhang C, Panhwar SK, Li ZG, Wan R (2014) Ageing Belanger's croaker, *Johnius belangerii* (Cuvier, 1830), based on otolith shape analysis. *J Appl Ichthyol* 31(1):27–31. doi: 10.1111/jai.12451
50. Yilmaz S, Yazicioglu O, Saygin S, Polat N (eds) (2014) Relationships of Otolith Dimensions with Body Length of European Perch, *Perca fluviatilis* L., 1758 From Lake Ladik, Turkey. *Pak J Zool* 46(5):1231–1238
51. Zan XX, Zhang C, Xu BD, Zhang CL (2015) Relationships between fish size and otolith measurements for 33 fish species caught by bottom trawl in Haizhou Bay, China. *J Appl Ichthyol* 31(3):544–548
52. Zengin M, Saygin S, Polat NAZMI (2015) Otolith shape analyses and dimensions of the anchovy *Engraulis encrasicolus* L. in the Black and Marmara Seas. *Sains Malays* 44(5):657–662

Figures

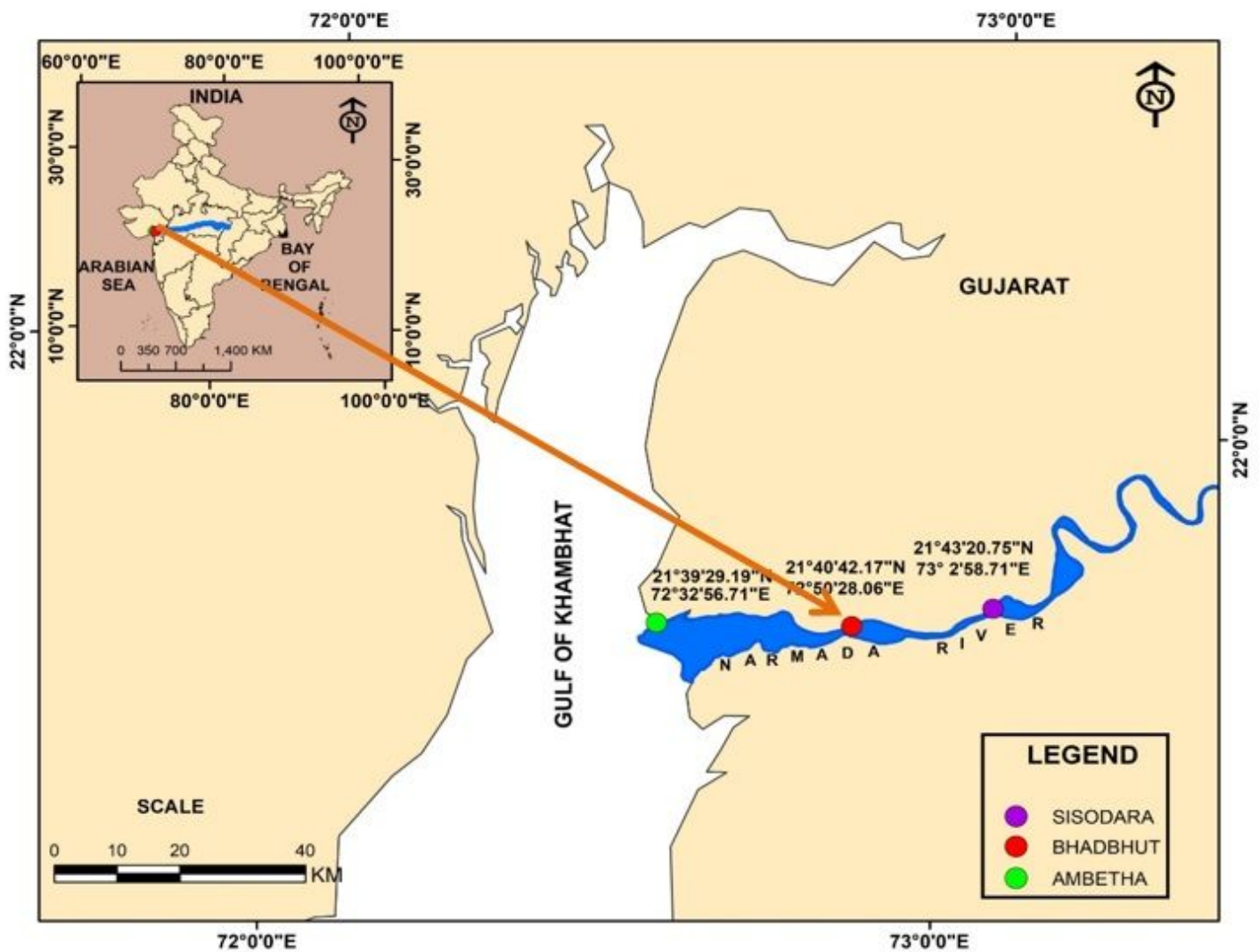


Figure 1

Map showing the collection site (Bhadbhut) of *O. pama* from the Narmada estuary

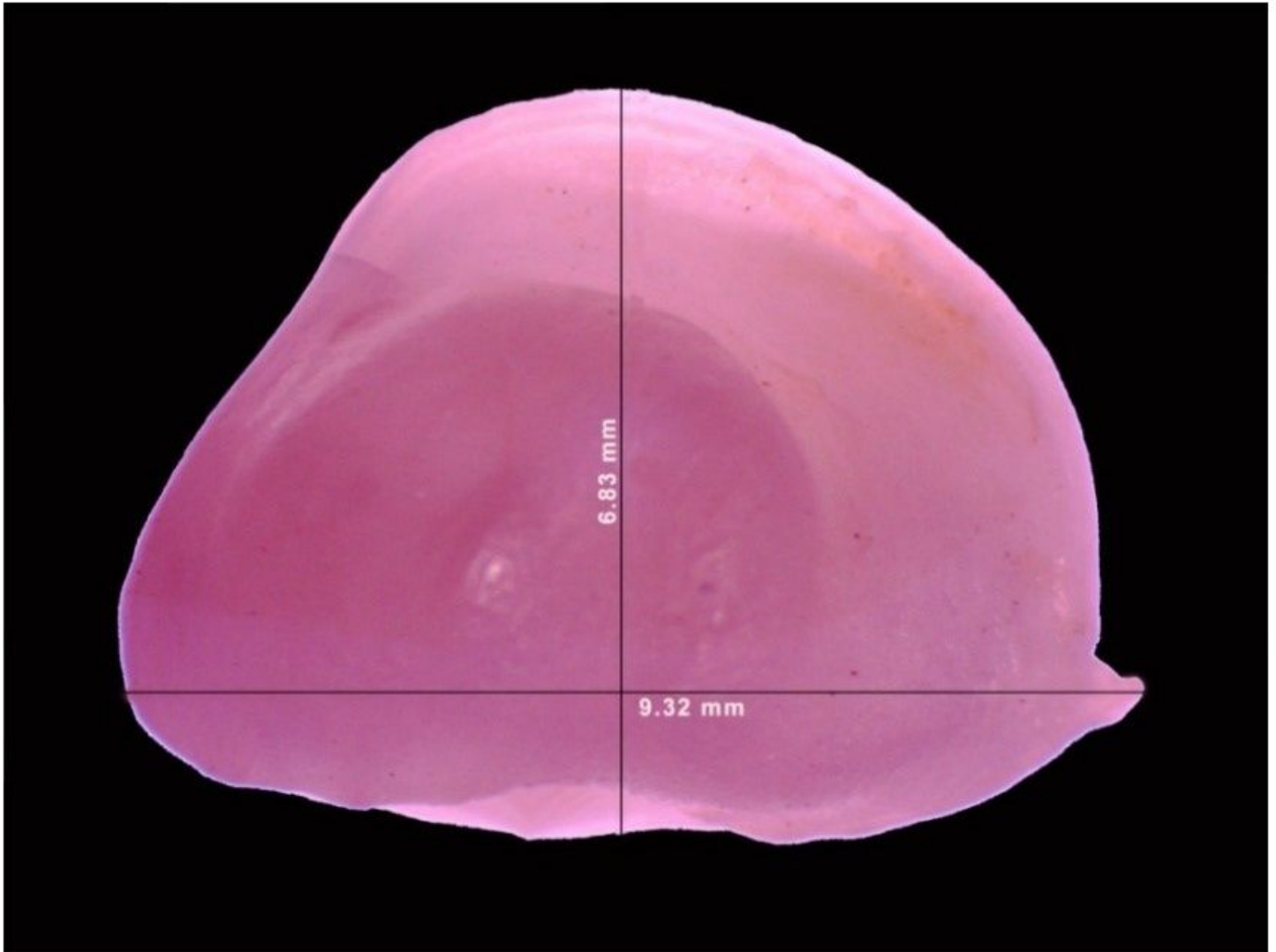


Figure 2

Otolith morphology of *O. pama* from the Narmada estuary

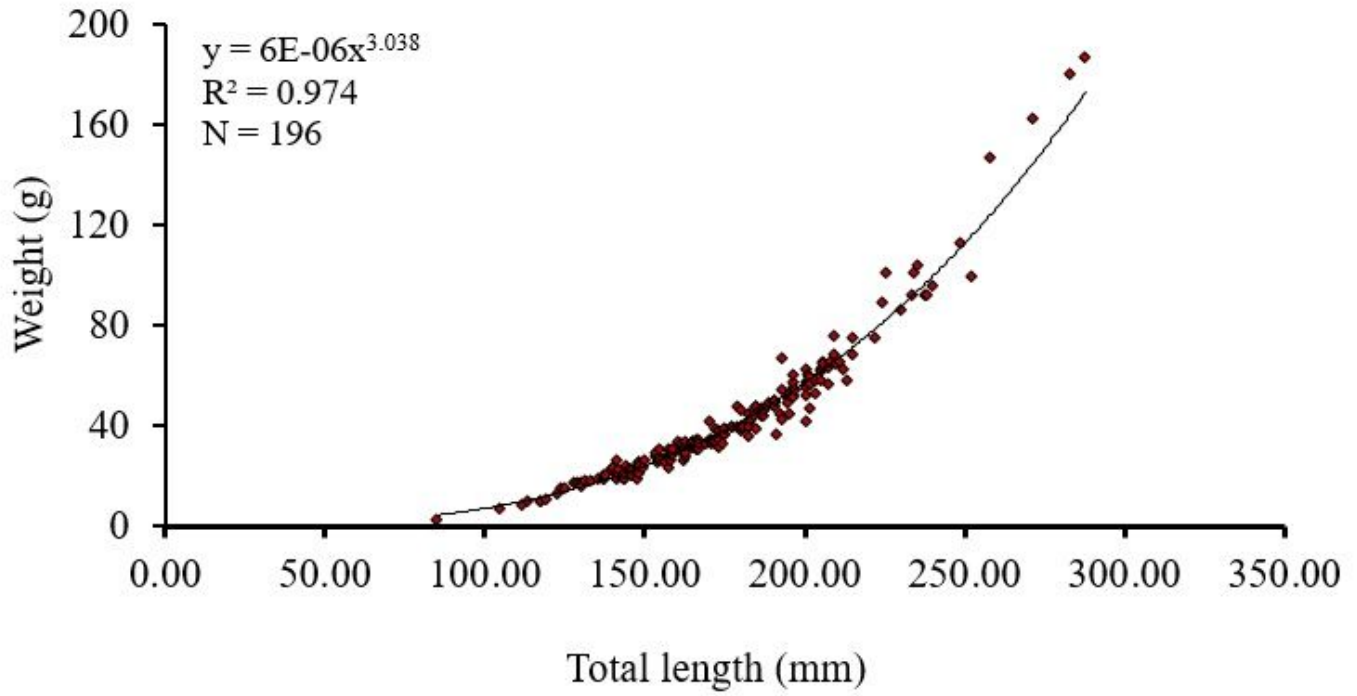


Figure 3

Length-weight relationship of *O. pama* (sex combined)

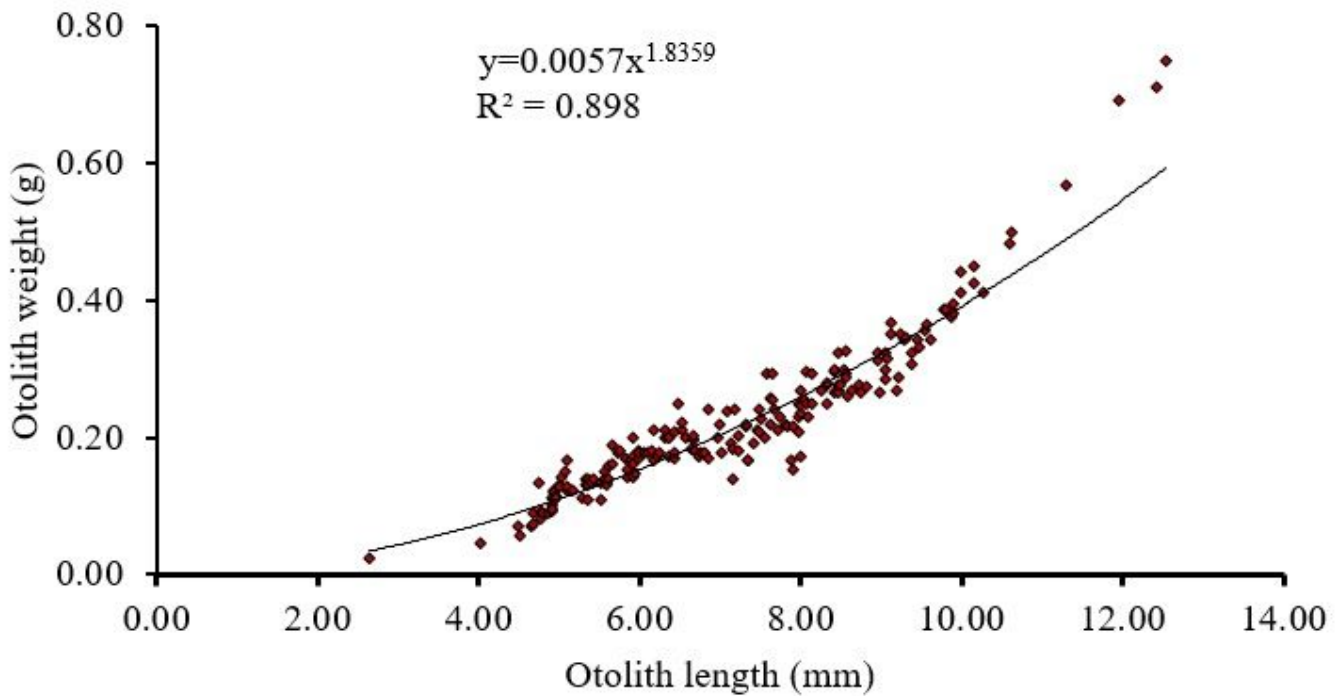


Figure 4

Relationship between otolith length and otolith weight of *O. pama* (sex combined)

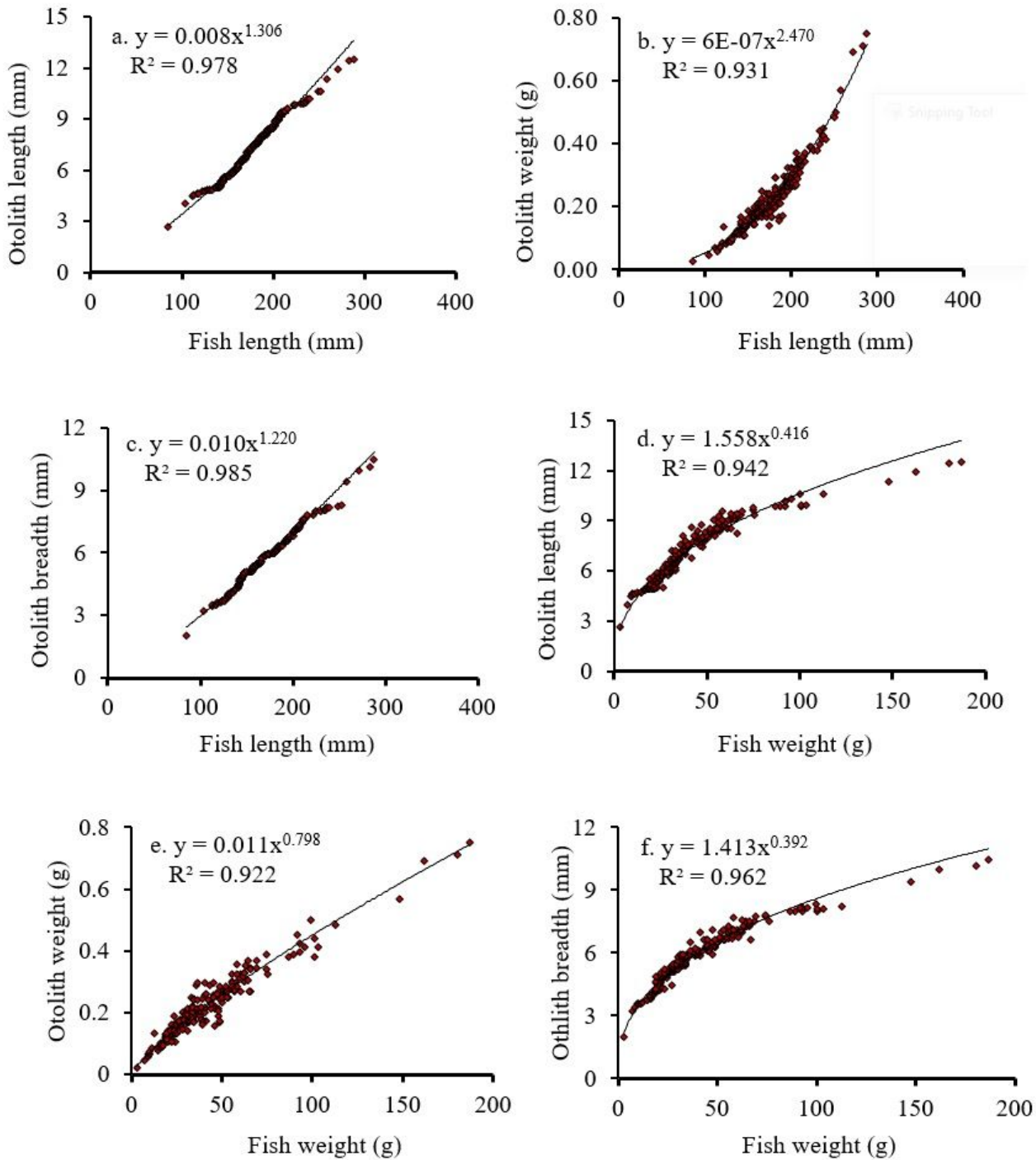


Figure 5

Relationship between (sex combined): a) fish length and otolith length; b) fish length and otolith weight; c) fish length and otolith breadth; d) fish weight and otolith length; e) fish weight and otolith breadth, and f) fish weight and otolith breadth of *O. pama* from Narmada estuary, India