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SHORT COMMUNICATION

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Relationships between fish and otolith size of nine deep-sea fishes from the Andaman and Nicobar waters, North Indian Ocean

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Summary

The study presents for the first time the otolith morphology of nine deep-sea fishes (*Polymixia fusca* Kotthaus, 1970, *Neoepinnula orientalis* (Gilchrist & von Bonde 1924), *Chlorophthalmus nigromarginatus* (Kamohara, 1953), *Cubiceps baxteri* (McCulloch, 1923), *Bembrops caudimacula* (Steindachner, 1876), *Neoscopelus microchir* (Matsubara, 1943), *Ostracoberyx dorygenis* Fowler, 1934, *Synagrops japonicus* (Döderlein, 1883), and *Bathyclupea hoskynii* Alcock 1891). Numerical relationships derived from the relation between size of the otolith and the fish can be used as predictors to estimate the prey size and to understand the trophic relations and food web dynamics of these less studied deep-sea organisms. The study was based on sampling carried out onboard FORV *Sagar Sampada* (Cruise No 349) during March-April 2016, along the continental margin of the Andaman and Nicobar islands in the Bay of Bengal using high speed demersal trawl. Length–weight relationships (LWR) and the regression between otolith size (width, weight, area and perimeter) and fish length (TL) of nine deep-sea fishes were considered. LWR showed negative allometric otolith growth in five species; four species showed positive allometric growth. Otolith size to fish size (TL) relation is explained by a simple linear regression considering otolith width (OW), otolith weight (OWe), otolith area (OA) and otolith perimeter (OP). Stronger r^2 values (>.76) indicate robustness, except for *Cubiceps baxteri* (r^2 = .65), and give better estimates for the TL of the fish.

1 | INTRODUCTION

Accurate identification of prey species and size is a necessity in food and feeding studies, and forms the basic data to study the trophic structure and food web dynamics of marine ecosystems (Ayllon, Davaine, Beall, & Garcia-Vazquez, 2006; Morat et al., 2008). Otoliths are a powerful taxonomic feature for fish species identification due to their high interspecific variability in morphology (Battaglia, Malara, Romeo, & Andaloro, 2010; Campana, 2004; Smale, Watson, & Hecht, 1995; Tuset, Lombarte, & Assis, 2008). Otoliths are used extensively for aging fishes (e.g., Campana, 2001; Taniuchi et al., 2004; Vieira, Figueiredo, Figueiredo, & Menezes, 2013) and to understand their trophic interactions (Campana, Chouinard, Hanson, Freâchet, & Brattey, 2000; Sadighzadeh et al., 2014; Saetersdal, 1953; Templemann & Squires, 1956). However, very few attempts have been made on the aging of commercially important fishes using otolith morphology in Indian waters (David & Pancharatna, 2003; Prema et al., 2012; Seshappa, 1999).

Precise identification of prey species is extremely difficult in feeding studies from partially or completely digested food, which is often classified as either unidentified or identified at family or genus level (Akhilesh et al., 2013; Venu & Kurup, 2002). Hard body parts such as bones and scales gives unrealistic estimates on the prey type and size (Longenecker, 2008). Due to their large size, sagittal otoliths are preferred (Nolf, 1985; Platt & Popper, 1981) and with a high intra-specific morphological variation over lapillus and asteriscus (Chilton

& Beamish, 1982; Jenkins & Davis, 1990; Longenecker, 2008; Vieira et al., 2013). Numerical expressions derived from simple linear regressions on morphometric measurements of otoliths are used to back-calculate the prey biomass (Battaglia, Malara, Ammendolia, Romeo, & Andaloro, 2015; Battaglia et al., 2010; Gamboa, 1991; Tarkan, Gaygusuz, Gaygusuz, & Acipinar, 2007).

Equations for estimating the prey sizes are restricted mostly to certain geographical areas (Al-Mamry, Jawad, Al-Busaidi, Al-Habsi, & Al-Rasbi, 2010; Longenecker, 2008; Morat et al., 2008) and access to the reference materials for a region such as the Indian EEZ, well known for their vast fishery resources especially deep-sea fishes, remain unavailable (Kumar, Deepa, Hashim, Vasu, & Sudhakar, 2016; Santos, Clarkei, & Pierce, 2001). No studies has been carried out thus far on the otolith morphology and morphometric relationship between fish and otolith weight and dimensions (width, area and perimeter), from Andaman and Nicobar waters, in the eastern part of the North Indian Ocean. Objectives of the present study were to develop numerical expressions that provide reliable estimates on the prey species and otolith sizes, which are necessary input for trophic modelling and to study the food web dynamics.

2 | MATERIALS AND METHODS

A total of nine species belonging to nine families (Polymixiidae, Gempylidae, Percophidae, Chlorophthalmidae, Bathyclupeidae, Nomeidae, Myctophidae, Acropomatidae and Ostacroberycidae) were studied where no prior information was available on otolith and fish size relationships. The species are: *Polymixia fusca* Kotthaus, 1970; *Neoepinnula orientalis* (Gilchrist & von Bonde 1924), *Chlorophthalmus nigromarginatus* (Kamohara, 1953); *Cubiceps baxteri* (McCulloch, 1923); *Bembrops caudimacula* (Steindachner, 1876); *Neoscopelus microchir* (Matsubara, 1943); *Ostracoberyx dorygenis* Fowler, 1934; *Synagrops japonicus* (Döderlein, 1883); and *Bathyclupea hoskynii* Alcock 1891. The aforementioned were the major deep-sea fish species captured during exploratory trawling operations onboard FORV *Sagar Sampada* beyond 200 m in Andaman and Nicobar waters (Hashim, 2012). Information on the deep-sea fishery resources in Andaman waters are poorly known, in comparison to the Arabian Sea waters (Hashim, 2012). A majority of the studies were carried out with regard to the resource assessment, taxonomy and biology of dominant fish species (Jayaprakash et al., 2006; Kumar, Thomy, Deepa, Hashim, & Sudhakar, 2016; Sreedhar, Sudhakar, & Meenakumari, 2013).

Samples were collected as a part of deep-sea fishery expeditions onboard FORV *Sagar Sampada* (Cruise No. 349), during March–April 2016, in the Andaman and Nicobar waters of the eastern Bay of Bengal. Bottom trawling was in ten locations, based on the suitability of the ground, at depth ranges of 300–650 m using High Speed Demersal Trawl II (HSDT II [crustacean version]). The morphometric measurements of the fishes (total length, total weight) were taken onboard and samples were identified up to species level, based on standard identification keys (Alcock, 1898, 1899; FAO, 1984), and samples were taken to the shore laboratory for further analyses. Sagittal otoliths were removed by making an incision in the head, for preservation of the otoliths in glass vials after proper cleaning and drying. Proper labelling was provided, giving information on cruise number, station ID, date of collection and position of the otolith (right/left).

Nine deep-sea fishes belonging to five Orders and nine Families were selected for the study. A total of 224 right otoliths were used for the analysis. We selected otoliths from the right side for the study since both of the otoliths are considered to be mirror images of each other, as confirmed by various authors (Battaglia et al., 2010; Longenecker, 2008). The otoliths were photographed with a stereo zoom trinocular microscope (Leica model No. S8APO Camera, Leica DFP-425), with the sulcus acusticus oriented towards the observer. Morphometric measurements of the otoliths (width, weight, area, and perimeter) were taken using the image analysing software ImageJ from the photographs (Figure 1). Individual otolith weight (OWe; in grams) was determined using an electronic balance (Metler Toledo, ML 503) with an accuracy of 0.001 g. Relationships between the otolith weight and dimensions and fish size (total length, TL) were determined using the linear regression model (Le Cren, 1951; Zar, 1984).

The morphometric measurements were converted into logarithmic values (log10) to identify and exclude the possible outliers in the data (Froese, Tsiklirans, & Stergiou, 2011). Regression parameters a and b were estimated by least square regression method (Froese, 2006; Froese, Thorson, & Reyes, 2014; Le Cren, 1951; Zar, 1984). The b value for each species was evaluated using a t test at 0.05 significance level to ascertain whether the value was significantly different from the isometric value (Morey et al., 2003; Pauly, 1993).

3 | RESULTS

We used 224 otoliths (right) collected from 9 deep-sea fishes in Andaman and Nicobar waters, India. The highest number of specimens analysed were *P. fusca* (43), followed by *N. orientalis*

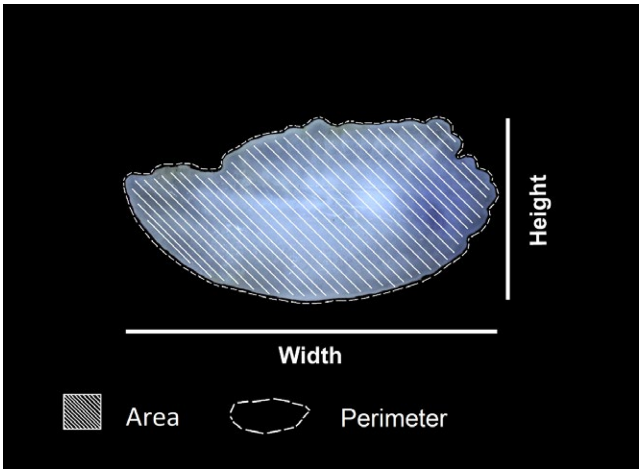

FIGURE 1 Morphological measurements used for the study

TABLE 1 Relationship between otolith width (OW), weight (OWe) and for the size ranges (total length, TL) of nine deep-sea fish species captured in Andaman and Nicobar waters during 2016 using a bottom trawl. Min–Max = minimum and maximum values observed; *n* = sample size; "*a*" and "*b*" = regression parameters; *SE* = standard error; r^2 = correlation coefficient; CL = confidence limits

		TL (cm)	OW (mm)	OWe (g)	Regression parameters for Otolith Width-Otolith Weights		SE of the regression parameters			95% CL	
	n	Min–max	Min–max	Min–max	*a*	*b*	*SE* (*a*)	*SE* (*b*)	r^2	*a*	*b*
Bembrops caudimacula (Steindachner, 1876)	20	15.5–24	4.59–6.39	0.012–0.04	0.0001	3.38	0.29	0.37	.82	0–0.0002	2.60–4.17
Chlorophthalmus nigromarginatus (Kamohara, 1953)	28	17.2–22	5.59–7.74	0.009–0.025	0.0001	2.51	0.25	0.31	.73	0–0.0005	1.88–3.14
Neoscopelus microchir (Matsubara, 1943)	20	15.5–22	6.12–8.33	0.024–0.054	0.0003	2.5	0.17	0.2	.9	0.0001–0.0006	2.08–2.92
Ostracoberyx dorygenis Fowler, 1934	17	9.07–11.8	3.89–5.43	0.008–0.033	0	4.1	0.24	0.35	.89	0–0.0001	3.36–4.85
Synagrops japonicus (Döderlein, 1883)	16	9.1–10.2	4.36–5.17	0.007–0.013	0.0001	3.35	0.27	0.41	.83	0–0.0002	2.42–4.22
Cubiceps baxteri (McCulloch, 1923)	27	12.7–20	5.56–7.21	0.008–0.018	0.0004	1.84	0.27	0.34	.48	0.0001–0.0013	1.15–2.54
Neoepinnula orientalis (Gilchrist & von Bonde 1924)	38	16.4–27.6	5.27–7.65	0.004–0.11	0.0001	2.41	0.18	0.22	.78	0–0.0002	1.97–2.86
Polymixia fusca (Kotthaus, 1970)	43	8.4–22.4	5.3–10.63	0.017–0.177	0.0001	3.22	0.1	0.11	.96	0.0001–0.4049	3.00–3.43
Bathyclupea hoskynii (Alcock, 1891)	15	12.7–16.7	5.24–7.01	0.024–0.043	0.0008	2.03	0.14	0.17	.91	0.0004–0.0016	1.66–2.41

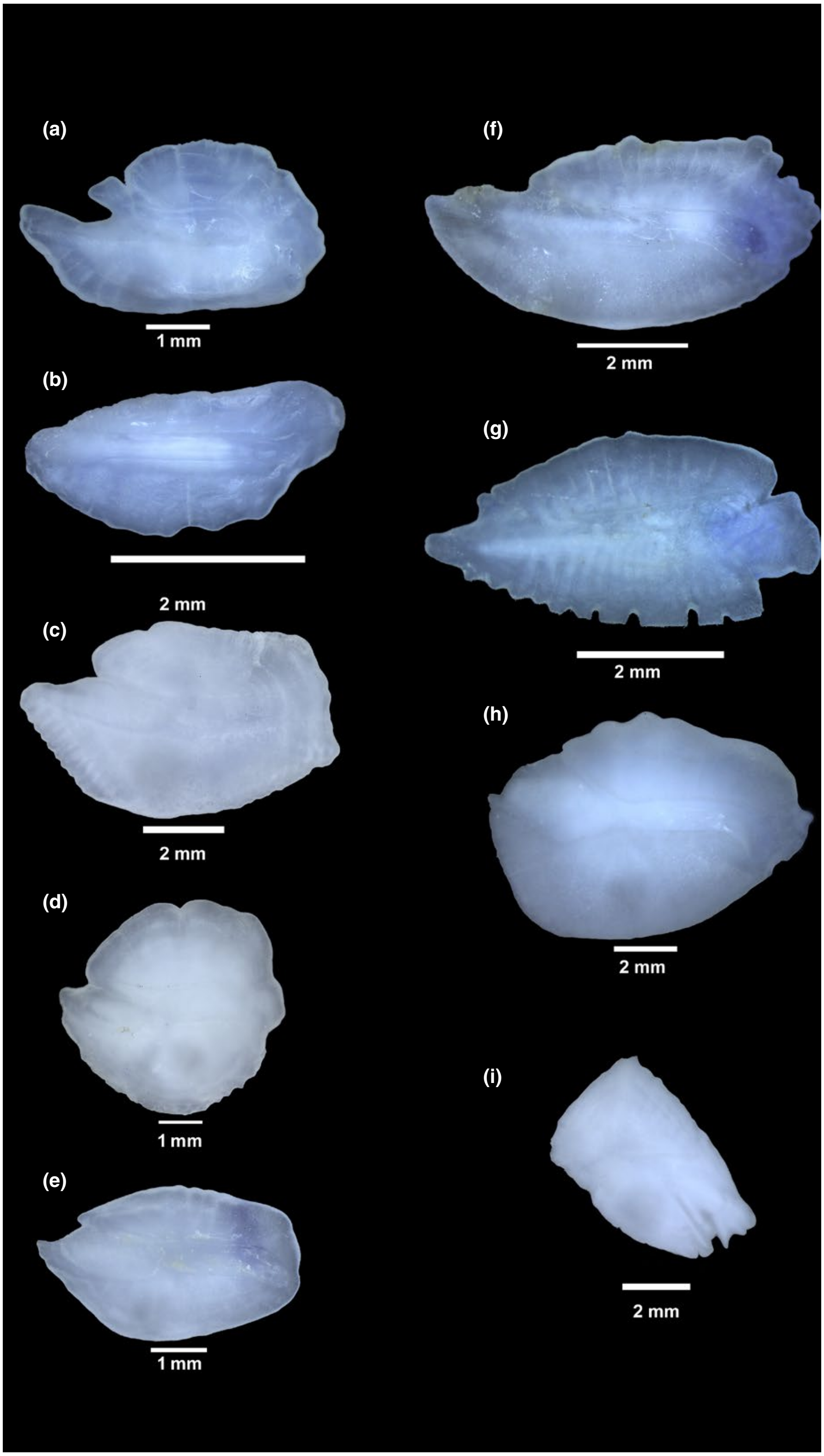

FIGURE 2 (a) *Bembrops caudimacula* (TL = 24 cm), right otolith (OW = 6.39 mm, OWe = 0.04 g); (b) *Chlorophthalmus nigromarginatus* (TL = 22 cm), right otolith (OW = 7.74 mm, OWe = 0.03 g); (c) *Neoscopelus microchir* (TL = 22 cm), right otolith (OW = 8.33 mm, OWe = 0.05); (d) *Ostracoberyx dorygenis* (TL = 11.8), right otolith (OW = 5.43 mm, OWe =0.03 g); (e) *Synagrops japonicus* (TL = 10.2 cm), right otolith (OW = 5.17 mm, OWe = 0.13); (f) *Cubiceps baxteri* (TL = 20 cm), right otolith (OW = 7.21 mm, OWe = 0.18 g); (g) *Neoepinnula orientalis* (TL = 27.6), right otolith (OW = 7.65 mm, OWe = 0.11 g); (h) *Polymixia fusca* (TL = 22.4 cm), right otolith (OW = 10.63 mm, OWe = 0.18 g) (i) *Bathyclupea hoskynii* (TL = 16.7 cm), right otolith (OW = 7.01 mm, OWe = 0.04 g)

(38), *C. nigromarginatus* (28), *C. baxteri* (27), *B. caudimacula* (20), *N. microchir* (20), *O. dorygenis* (17), *S. japonicus* (16), and *B. hoskynii* (15). Table 1 provides the details regarding sample size, minimum and maximum values of length and weight, otolith width, weight for all nine species and the regression parameters, explaining the inter-relationships.

3.1 | Otolith morphology

The representative otoliths of all nine fishes are shown in Figure 2, which shows their morphological features and anatomy. The morphological description and nomenclature used in this paper were derived from Smale et al. (1995) and Tuset et al. (2008).

TABLE 2 Relationship of various morphometric measurements of otolith of the fishes collected from Andaman and Nicobar waters during 2016. Coefficient of determination (r^2), slope and intercept values (*a* and *b*), 95% confidence limits and parameters of relationships (*SE* [*a*] and *SE* [*b*] are given). OW = otolith width; Owe = otolith weight; OA = otolith area; OP = otolith perimeter; TL = total length of the fish

Species	Relationship between	Length–weight regression		Parameters of relationships			95% CL	
		a	*b*	*SE* (*a*)	*SE* (*b*)	r^2	*a*	*b*
Bembrops caudimacula (Steindachner, 1876)	OW X TL	2.669	1.186	0.08	0.10	.89	0.265–0.588	0.974–1.398
	OWe X TL	54.5	0.244	0.04	0.03	.84	44.299–67.112	0.189–0.099
	OA X TL	4.786	0.587	0.05	0.05	.9	3.697–6.197	0.486–0.687
	OP X TL	1.459	0.97	0.13	0.11	.83	0.785–2.712	0.746–1.194
Chlorophthalmus nigromarginatus (Kamohara, 1953)	OW X TL	5.2687	0.7074 7074	0.08	0.10	.75	3.571–7.773	0.498–0.918
	OWe X TL	47.83	0.2154	0.07	0.04	.64	34.025–67.235	0.133–0.297
	OA X TL	0.155	0.416	0.07	0.06	.76	4.580–9.113	0.287–0.545
	OP X TL	0.844	0.987	0.14	0.11	.74	1.241–1.169	0.511–0.997
Ostracoberyx dorygenis Fowler, 1934	OW X TL	3.2248	0.7871	0.07	0.01	.78	2.2824–4.5551	0.566–1.008
	OWe X TL	23.845	0.1982	0.34	0.02	.86	20.2582–28.0543	0.157–0.239
	OA X TL	4.117	0.361	0.25	0.02	.95	3.644–4.652	0.316–0.406
	OP X TL	1.196	0.814	0.07	0.06	.93	0.846–1.897	0.688–0.941
Bathyclupea hoskynii (Alcock, 1891)	OW X TL	2.6357	0.9544	0.06	0.08 0.0752	.93	1.9523–3.5583	0.792–1.117
	OWe X TL	69.0717	0.4429	0.07	0.0406	.9	51.239–93.089	0.355–0.531
	OA X TL	3.41	0.492	0.06	0.0457	.9	2.521–4.612	0.393– 0.591
	OP X TL	1.467	0.779	0.15	0.1177	.77	0.682–3.157	0.525–1.033
Neoscopelus microchir (Matsubara, 1943)	OW X TL	3.1696	0.889	0.0854	0.0998	.82	2.092–4.801	0.678–1.099
	OWe X TL	57.24	0.343	0.0505	0.0348	.85	44.7713–73.1644	0.270–0.416
	OA X TL	3.74	0.498	0.0616	0.0445	.88	2.773–5.045	0.404–0.592
	OP X TL	1.038	0.962	0.1284	0.0992	.85	0.556–1.937	0.753–1.172
Neoepinnula orientalis (Gilchrist & von Bonde 1924)	OW X TL	2.1213	1.2589	0.0789	0.099	.9	1.4474–3.1081	1.050–1.467
	OWe X TL	155.4891	0.4091	0.1331	0.0628	.7	81.6582–296.006	0.277–0.544
	OA X TL	3.657	0.683	0.045	0.0402	.95	2.935–4.556	0.598–0.769
	OP X TL	7.432	0.025	0.0464	0.0025	.86	5.924–9.324	0.020–0.030
Polymixia fusca (Kotthaus, 1970)	OW X TL	1.4876	1.1616	0.0672	0.0745	.86	1.0879–2.0338	1.011–1.312
	OWe X TL	41.8215	0.3436	0.6304	0.0253	.83	36.2911–48.1726	0.292–0.395
	OA X TL	2.024	0.601	0.0534	0.035	.88	1.578–2.595	0.530–0.672
	OP X TL	0.265	1.333	0.1084	0.0804	.87	0.160–0.439	1.171–1.496
Synagrops japonicus (Döderlein, 1883)	OW X TL	2.5177	0.85	0.0878	0.1294	.75	1.6308–3.8806	0.572–1.129
	OWe X TL	20.3517	0.1624	0.03735	0.0185	.85	16.9239–24.4737	0.123–0.202
	OA X TL	3.875	0.397	0.03274	0.0334	.91	3.297–4.555	0.325–0.468
	OP X TL	1.697	0.686	0.08004	0.0734	.86	1.143–2.519	0.529–0.844
Cubiceps baxteri (McCulloch, 1923)	OW X TL	4.928	1.3904	0.2243	0.2847	.5	2.3405–3.5867	0.804–1.976
	OA X TL	1.476	0.891	0.1497	0.1307	.65	0.726–3.002	0.621–1.160
	OP X TL	0.226	1.529	0.2833	0.2362	.63	0.059–0.218	1.043–2.016

The otolith of *P. fusca* was observed to be the largest (OW, 10.63 ± 1.33 mm; OWe, 0.177 ± 0.039 mg), and *O. dorygenis* was the smallest (3.89 ± 0.41 mm; OWe, 0.022 ± 0.007) among the nine species studied. Five species, namely, *C. nigromarginatus*, *B. hoskynii*, *N. microchir*, *N. orientalis* and *C. baxteri* showed negative allometry in otolith length–weight relationships (*b* value ranges from 1.84 to 2.5) (*t* test, $p < .05$). Isometric (*B. caudmacula* and *S. japonicus*) and positive allometry in LWR was observed in two fishes (*O. dorygenis* and *P. fusca*, respectively) (*t* test, $p < .05$). OW showed highest correlation with the OWe in *P. fusca* ($r^2 = .96$) and lowest correlation in *C. baxteri* ($r^2 = .48$).

TABLE 3 Equations derived for estimating fish size from otolith size (TL = total length; OW = otolith width; OWe = otolith weight; OA = otolith area; OP = otolith perimeter; r^2 = coefficient of determination

Species	Exponential formula	r^2
Bembrops caudimacula (Steindachner, 1876)	TL = 4.786 $OA^{0.59}$	.90
	TL = 2.669 $OW^{1.19}$	.89
Chlorophthalmus nigromarginatus (Kamohara, 1953)	TL = 0.155 $OA^{0.42}$	.76
	TL = 5.269 $OW^{0.71}$	.75
	TL = 0.844 $OP^{0.99}$	.74
Ostracoberyx dorygenis Fowler, 1934	TL = 4.117 $OA^{0.36}$	.95
	TL = 1.196 $OP^{0.81}$	.93
Bathyclupea hoskynii (Alcock, 1891)	TL = 2.636 $OW^{0.95}$	.93
	TL = 69.071 $OWe^{0.44}$	.90
	TL = 3.410 $OA^{0.49}$	.90
Neoscopelus microchir (Matsubara, 1943)	TL = 3.740 $OA^{0.50}$	.88
	TL = 57.24 $OWe^{0.34}$	.85
	TL = 1.038 $OP^{0.96}$	.85
Neoepinnula orientalis (Gilchrist & von Bonde, 1924)	TL = 3.657 $OA^{0.68}$	.95
	TL = 2.121 $OW^{1.26}$	.90
Polymixia fusca (Kotthaus, 1970)	TL = 2.024 $OA^{0.60}$	.88
	TL = 0.265 $OP^{1.33}$	.87
	TL = 1.488 $OW^{1.61}$	.86
Synagrops japonicus (Döderlein, 1883)	TL = 3.875 $OA^{0.397}$	.91
	TL = 1.697 $OP^{0.69}$	.86
	TL = 20.351 $OWe^{0.16}$	.85
Cubiceps baxteri (McCulloch, 1923)	TL = 1.476 $OA^{0.89}$	.65
	TL = 0.226 $OP^{1.53}$	.63

All other fishes showed reasonably good correlation between the OW and OWe (r^2 ranges from .73 to .91) (Table 1).

The relationship between fish size and otolith size (weight, width, area and perimeter) are shown in Table 2. High coefficient of determination (r^2 > .9) reported for five fishes indicates its utility for estimating TL of the fishes from the otolith size. Two species showed r^2 values of more than .8, followed by two species that showed greater than .7. Lowest r^2 values were reported in *C. baxteri* (.5 to .65). Highest and lowest r^2 values were reported for the relationship between OA-TL (*O. doygenis*) and OW-TL (*C. baxteri*) (.95 and .50, respectively). OA gave the best estimations for total length for seven species (r^2 ranges from .95 to .88), except for *B. hoskynii*. OW gave better estimates for *B. hoskynii* (r^2 = .93) compared to OA (r^2 = .90). A very low coefficient of determination was observed in *C. baxteri* with all otolith size variables (.50–.65). OP gave second highest r^2 values for the estimation of TL for six species after OW (*O. dorygenis*, *N. microchir*, *N. oreinetalis*, *P. fusca*, *S. japonicus* and *C. baxteri*), and the coefficient of determination ranged from .93 to .63. OW gave third highest estimation for TL for four species (*B. caudimacula*, *C. nigromarginatus*, *N. oreientalis* and *P. fusca*); the r^2 ranges were from .75 to .90, followed by OWe (*B. hoskynii*, *N. microchir* and *S. japonicus*) (r^2 ranges from .70 to .90). The exponential formula derived for estimating fish size from the otolith size is given in Table 3.

4 | DISCUSSION

The morphology and morphometric relationships of otoliths are useful tools in species, stock and population discrimination and can be utilised to estimate fish size and biomass in food and feeding studies (Campana, 2005; Campana & Thorrold, 2001; Granadeiro & Silva, 2000; Hussy, Coad, Farrell, Clausen, & Clarke, 2012). Studies on these aspects of fishes from Indian waters are very limited (Kumar, Deepa, et al., 2016). The resources in Andaman waters are the least explored with regard to such studies on deep sea fishery; the major sources of information on deepsea fishes from the Andaman and nearby areas are restricted to scientific exploratory surveys (Khan et al., 1996; Nair & Reghu, 1990).

A majority of the studies use otolith width, height and weight as variables for estimating fish size (Battaglia et al., 2010, 2015). However, the present study puts forward the equations based on otolith area and perimeter apart from the conventional variables explaining width, height and weights (Lombarte, 1992; Smith, 1992; Torres, Lombarte, & Morales-Nin, 2000).

Otolith LWRs indicate negative allometry (*b* values ranged from 1.84 to 2.51) in five species and positive allometry in four species (*b* values from 3.22 to 4.1). The otolith weight continues to increase over time, even after the cessation of growth in the otolith width and height, and shows a nonlinear relationship (Munk & Smikrud, 2002). There are no previous estimations available for LWR estimates of otoliths from the same region or elsewhere, except for *B. caudimacula*. The otolith growth pattern of *B. caudimacula* is found to be different from the fish collected in the Arabian Sea (*b* = 2.58, r^2 = .71) (Kumar, Deepa, et al., 2016). The *b* value (*b* = 1.19, r^2 = .89) reported for the relationship between OW and TL of this species is in contrast to the previous estimates (*b* = 0.38, r^2 = .74) (Kumar, Deepa, et al., 2016). Andaman and Nicobar waters are oceanographically different from the Arabian Sea (Jensen, 2001; Madhupratap et al., 2001, 2003; Prasannakumar et al., 2000, 2002). These extremely different environmental conditions, productivity patterns and prey preferences as well as the abundance of the organisms in the region could be possible reasons for this variability (Haedrich & Barnes, 1997; Madhupratap et al., 2001, 2003; Nair, Madhupratap, Gopalakrishnan, Haridas, & Gauns, 1999).

Otoliths that show negatively allometric growth have an ovate, and oblong- to rhomboidal shape; positively allometric otoliths have shapes that vary from pentagonal, hexagonal and discoid morphology. It was observed that otoliths showing positive allometric growth are more-or-less spherical, and that negatively allometric otoliths have a lanceolated- to-oval shape. Otolith diameter is found to be more related to age, compared to linear growth, after the somatic growth halts (Nedreaas, 1990). Thus, the relationship representing positive allometric growth might underestimate the prey size since the otolith increases in thickness (due to mineral deposition) (Fletcher, 1991) with somatic growth of the fish, rather than longitudinal growth after maturity (Nedreaas, 1990; Nishimura & Yamada, 1988; Williams & Bedford, 1974). Here, equations using otolith weight would be more appropriate for the prediction of the prey size (Al-Mamry et al., 2010; Metin & Ilkyaz, 2008; Munk & Smikrud, 2002). The otolith weight is found to be the most suitable for predicting age of fishes, as suggested by various authors (Brander, 1974; Ghanbarzadeh, Soofiani, Keivany, & Taghavi-Motlagh, 2014). All of these aspects have to be considered when using the regression equations for predicting the prey size from the otolith size.

It is advisable to use these equations within the size ranges applied in this study for precise estimations (Battaglia et al., 2010). There are limitations in predicting the prey size of even the same species using the regression equations, mainly due to the different geographical areas, stocks, populations, and/or sexes (Campana & Casselman, 1993; Reichenbacher, Kamrani, Esmaeili, & Teimori, 2009), ontogenic changes in the life history (Hare & Cowen, 1995), as well as also due to the chemical and mechanical aberrations in the digestive tract (Granadeiro & Silva, 2000; Jobling & Breiby, 1986) that underestimate the size of the prey. However, the specific equations derived from the present study can be useful for studies explaining food and feeding, population dynamics, yield estimates and paleontological studies of data-deficit deep-sea fishery resources of Andaman and Nicobar waters in the Bay of Bengal. Such numerical relations to predict fish size from the otolith size need to be determined for more species, to supplement the studies and understand the trophic relationship between the fishes from Andaman and Nicobar waters, quite renowned for their rich deep-sea fish diversity.

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