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Relationships between fish and otolith size of the Indian Ruff *Psenopsis cyanea* (Alcock 1980) collected from the south eastern Arabian Sea coast of India

K. V. Aneesh Kumar*, K. P. Deepa, Hashim Manjebrayakath, C. P. Rajool Shanis[1], N. Saravanane, V. N. Sanjeevan and M. Sudhakar

Centre for Marine Living Resources and Ecology (CMLRE), 6th Floor, C- Block, Kendriya Bhavan, P B No 5415, CZEZ P. O., Kochi 682037.

[1]National Bureau of Fish Genetic Resources (NBFGR),CMFRI Campus, Post Box No. 1603, Kochi, 682 018, Kerala.

*Correspondence e-mail: aneeshmenan12@gmail.com

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Original Article

Abstract

Length weight relationships and regressions between otolith size (length, width, size and aspect ratio) and fish length and weight of the bathy pelagic fish *Psenopsis cyanea* collected from Arabian Sea, west coast of India is provided. Statistical analysis indicate proportionately high females in the population compared to males. The length weight relationship for the fish showed an isometric growth pattern for male (b= 3.4574, $R^2>0.89$) and positively allometric growth pattern for female (b= 3.7782, $R^2>0.915$). Growth pattern among sexes was found to be statistically significant (ANCOVA). No significant difference was noticed between the size of left and right otoliths observed by t-test. The length weight relationship of the otolith of both male and female showed an isometric growth pattern ($R^2>0.97$). The data fitted well to the regression model for both otolith length (OL), otolith width (OW) and otolith weight (OWe) to standard length (SL) ($R^2>0.89$). The data indicated that aspect ratio is not well correlated with standard length (SL) ($R^2<0.45$). The study indicated that these relationships can be used as a helpful tool in predicting fish length and weight from the otoliths and in calculating the prey biomass. These relationships can be used to build the body size and prey biomass during feeding studies and palaeontology.

Keywords: *Psenopsis cyanea, length-weight relationship, otolith, Arabian Sea*

Introduction

Animal remains from the gut are frequently used to reconstruct faunal assemblages in dietary analysis, archaeology, geology, and palaeontology (Longenecker, 2008) but this technique is not effective in fishes since the bones and scales are difficult to identify, enumerate and there may be not much published information available on the relationship between the size of the bones or scales and the size of the fish (Longenecker, 2008). Scales and bones are not preferred for the age determination studies also due to the resorption of the minerals deposited by the fish body which is reported to be underestimating the age (Secor *et al*., 1995; Mendoza, 2006). During the feeding studies, the identification and quantification of the prey is a tedious task since those items, except the hard parts such as bones, scales and otolith, are in partially or fully digested condition. In particular, otoliths are quite resistant to the digestion and they are an important tool for prey classification in several dietary studies (Granadeiro and Silva, 2000; Pierce and Boyle, 1991; Pierce *et al*., 1991; Skelijo and Ferri, 2012).

By establishing a relationship between fish length and otolith size, it is possible to rebuild the fish body size and prey bio mass by applying a back-calculation (Echeverria, 1987; Gamboa, 1991;

Granadeiro and Silva, 2000; Harvey *et al.*, 2000; Waessle *et al.*, 2003; Tarkan *et al.*, 2007). For most species, the relationship between otolith length and fish length can be described by a simple linear regression (Gamboa, 1991; Battaglia *et al.*, 2010).

The Length-Weight Relationship (LWR) is a useful tool in fishery assessment, which helps in predicting weight of the fish from their length required in yield assessment (Garcia *et al.*, 1998) and in the calculation of the standing crop biomass (Martin-Smith, 1996).

The Indian ruff *P. cyanea* (Alcock, 1980) belonging to the family Centrolophidae is a non-commercial bentho-pelagic fish usually found at depths between 250-300 m in shoals. This species showed a discontinuous distribution in the east and west coasts of India, off Socotra and the mouth of the Gulf of Aden (Fischer and Bianchi, 1984). This is not a commercially important species and fishery for the species is not yet fully established. In India, they are caught in deep sea trawlers especially off Quilon, Kerala in 250-300 m depth zone, and are most abundant during November-April (Abdussamad and Achayya, 1999). *P. cyanea* was found to be one of the most dominant species in the deep-sea trawling operations of FORV *Sagar Sampada* from the west coast of India and was found abundant at lat. 11° to 12" N and vertically at 201-300 and 301-400 m depth zones and females are dominated irrespective of seasons or depth (Venu and Kurup, 2002).

No information available on the otolith and fish size relationships of this species in spite of their significant role in the food web and one of the dominant fish species caught during the bottom trawling operations beyond 200 m depth in Indian EEZ. The main objective of this paper is to provide information about the length weight relationship of the fish and the relationship between otolith size (length, width and aspect ratio) and fish size of this species in Indian EEZ.

Material and methods

A total of 212 *P. cyanea* specimens (sizes range: 7.5 to 16.5 cm Total Length and 5.48 to 64.73 gram Total weight) collected from the south eastern Arabian Sea were used for the study. Sampling was carried out in the 2 deep-sea fisheries expeditions onbaord FORV *Sagar Sampada* (cruise no: 317, 322) during 2013-14. Two sampling stations (9° 57′ 40″-76° 00′ 44″ and 11° 57′ 317″-74° 26′ 081″) were covered at a depth of 200 m off west coast of India. The samples were identified at species level using standard identification keys (Haedrich, 1984) and preserved in 5% formaldehyde for further analysis.

High Speed Demersal Trawl II and 45.6 m Expo-model Demersal Trawl were used for fishing. All the biometric characteristics were measured to the nearest 0.1 mm using digimatic vernier calliper with a rated accuracy of ±0.01 mm. The length weight relationships were calculated by the least square regression (Le Cren, 1951; Zar, 1984). The relationship between the length and weight is expressed by the regression equation $W=aL^b$. The parameters a and b were calculated by least square regression. *t*-test was used to understand if the slope of regression line differs significantly from the isometric value 3 (Pauly, 1993). The analysis of covariance (ANCOVA) on the regression equations and comparisons of slopes were carried out according to Snedecor and Cochran (1967).

The sagittal otoliths were removed through a cut in the cranium. The otoliths were cleaned, dried and stored in glass vials. Measurements of the otoliths were taken using a digital vernier calliper. The longest length of the otolith between rostrum and post rostrum and width from the dorsal to ventral edge at right angles to the length through the focus of the otolith were taken (Smale *et al.*, 1995). Individual otolith weight (in milligram) was determined using an electronic balance (Metler Toledo, ML 503). The relationship between the otolith size (length, width, weight, aspect ratio) and fish size (standard length, total weight) were determined using least square regression between various measurements. These relationships were tested with both left and right otoliths and between sexes; ANCOVA is used to check the difference between the regressions (Fowler and Cohen, 1992). The regression coefficients were compared and when significant differences ($p<0.05$) were not found, the H_0 hypothesis (b right = b left) was accepted.

Results

Length weight relationship of P. cyanea

The length of the male and female ranged from 8.4-15.9 cm (mean 11.84±1.98) and 7.5-16.5 cm (mean 11.75±1.99), respectively. The female predominates in the sample and sex ratio was 1:0.55. Statistical analysis indicates that the female in the population were significantly high compared to male (*Chi-square test*). The length weight relationship of the male, female and sexes combined are presented in the Table 1 and Fig.1 respectively. The b values obtained for both male, female and sexes combined were 3.46, 3.78 and 3.72, respectively. The b value obtained for male are statistically not significant from the isometric value 3 (*t-test, $P<0.05$*) and for female showed positive allometric growth (*$P>0.02$*). The sex linked changes in the length weight relationship were examined statistically using ANCOVA test showing that significant difference in the growth between sexes. When the length weight relationship of both the sexes combined, b value obtained was very close to the b value of the female, which can be due to the predominance of female in the samples analysed. The relationship between various morphometric measurements of the fish is shown in Table 2. The exponential

Table 1. Length, weight and length-weight regression summaries for *P. cyanea* male, female and sexes combined

Sex	n	Length (cm)		Weight (g)		Length-weight regression		Parameters of relationships		
		Min	Max	Min	Max	a	b	S.E. (a)	S.E. (b)	R2
Male	76	8.4	15.9	5.65	52.14	0.0000002	3.4574	1.60154	0.05093	0.915
Female	136	7.5	16.5	5.48	64.73	0.0000003	3.7782	0.86087	0.03053	0.890
Combined	212	7.5	16.5	5.48	64.73	0.0000004	3.7273	0.76107	0.02588	0.900

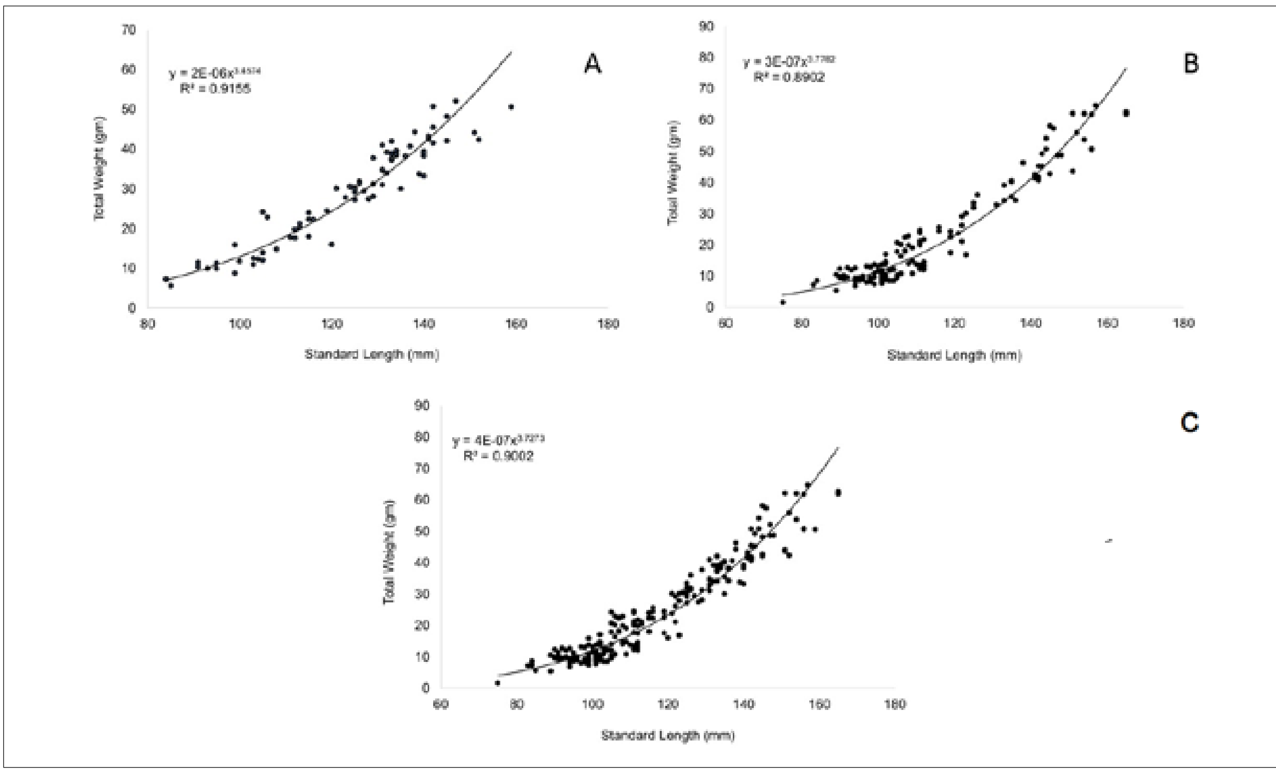

Fig. 1. Length-weight relationship of *P. cyanea* (A: male, B: female, C: sexes combined)

formulae worked out for the length weight relationship of the species is expressed as follows:

Male : $W = 0.0000002L^{3.4574}$

Female : $W = 0.0000003L^{3.7782}$

Both sexes pooled : $W = 0.0000004\,L^{3.7273}$

Length weight relationship between fish size and otolith size

The difference in the morphometric measurements of both left and right otoliths are found to be statistically not significant (*t-test, $P<0.05$*). Hence the right otolith selected for the morphometric analysis.

Table 2. The relationship between various morphometric measurements and the regression summaries of *P. cyanea*

Relationship between		Regression values		Parameters of relationships		
		a	b	SE (a)	SE (b)	R2
Head length and Standard length of fish	Male	2.1207	1.1104	0.92533	0.00769	0.801
	Female	3.2615	0.9912	0.88179	0.00739	0.845
	Combined	2.9265	1.0218	0.88179	0.00739	0.839
Head width - Standard length of fish	Male	5.9704	0.7147	0.12966	0.01078	0.769
	Female	6.2576	0.6521	0.12059	0.01010	0.713
	Combined	6.1528	0.6761	0.12059	0.01010	0.741
Head length of fish - Total weight	Male	0.1285	3.9377	0.02960	0.00098	0.771
	Female	0.1228	3.9324	0.02666	0.00090	0.872
	Combined	0.1186	3.9739	0.2666	0.00090	0.854

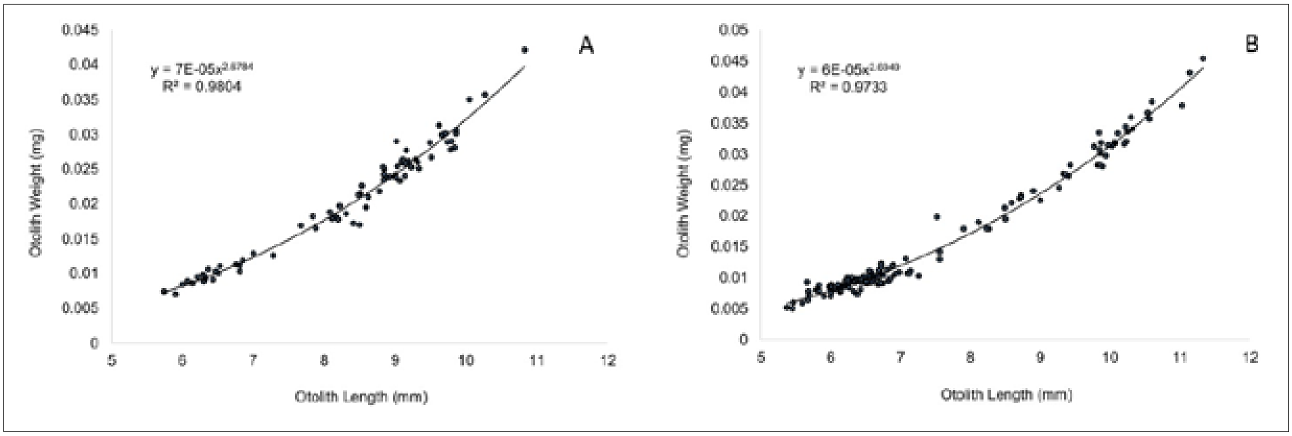

Fig. 2- The length weight relationship of otolith of *P. cyanea* (A: male, B: female)

The length weight relationship of otolith of both sexes showed negatively allometric value (*t-test, P>0.05*) (Fig. 2). The relationship between otolith lengths, weight, width, aspect ratio against various morphometric measurements of the fish is presented in the Table 3.

High values of coefficient of correlation (R^2) were obtained and the morphometric measurements are fitted excellently to the regression model for otolith length, weight, width except aspect ratio. The Aspect showed very low R^2 value (0.33 and 0.46 for male and female, respectively) against the fish size (Fig. 3). The exponential formula derived for the various size variables of otolith and fish showed significant correlations is expressed as

Relationship between Standard Length and Otolith length

$SL= 21.543\ OL^{0.8228}$ ($R^2 = 0.898$) (Male)
$SL = 23.647\ OL^{0.7848}$ ($R^2 = 0.897$) (Female)
$SL = 23.509\ OL^{0.7854}$ ($R^2 = 0.90$) (Sexes combined)

Relationship between Standard Length and Otolith Weight

$SL = 398.35\ OW^{0.298}2$($R^2 = 0.85$) (Male)

Table 3. The relationship between otolith lengths, weight, width, aspect ratio against various morphometric measurements and regression summaries of *P. cyanea*

Relationship between		Regression values		Parameters of relationships		
		a	b	S.E. (a)	S.E. (b)	R^2
Otolith length – Otolith weight	Male	0.00007	2.6784	0.45559	2.20805	0.980
	Female	0.00006	2.6949	0.04245	2.09475	0.973
	Combined	0.00006	2.7091	0.04102	2.02559	0.977
Otolith length - Otolith width	Male	0.7541	0.8354	0.12159	0.02854	0.951
	Female	0.7474	0.837	0.11298	0.02674	0.971
	Combined	0.743	0.8409	0.11285	0.02672	0.968
Otolith length – Standard length of fish	Male	21.543	0.8228	0.35748	0.00287	0.898
	Female	23.647	0.7848	0.231953	0.001998	0.897
	Combined	23.509	0.7854	0.1934	0.00162	0.901
Otolith weight - Standard length of fish	Male	398.87	0.2982	0.002768	0.000022	0.849
	Female	382.02	0.283	0.001588	0.0000136	0.885
	Combined	378.35	0.2822	0.00137	0.000011	0.877
Otolith weight - Total weight of fish	Male	1773.3	1.0666	0.000491	0.0000164	0.851
	Female	1796.7	1.0632	0.000441	0.0000149	0.830
	Combined	1736.4	1.0574	0.00044	0.000015	0.845
Otolith width - Standard length of fish	Male	30.058	0.9472	0.101469	0.000841	0.876
	Female	32.212	0.912	0.96223	0.000807	0.897
	Combined	32.19	0.9083	0.96223	0.000807	0.894
Aspect ratio - Standard length of fish	Male	3.4997	1.9841	0.025182	0.002112	0.330
	Female	2.1001	2.7259	0.26773	0.002229	0.459
	Combined	2.3943	2.5404	0.025182	0.002112	0.426

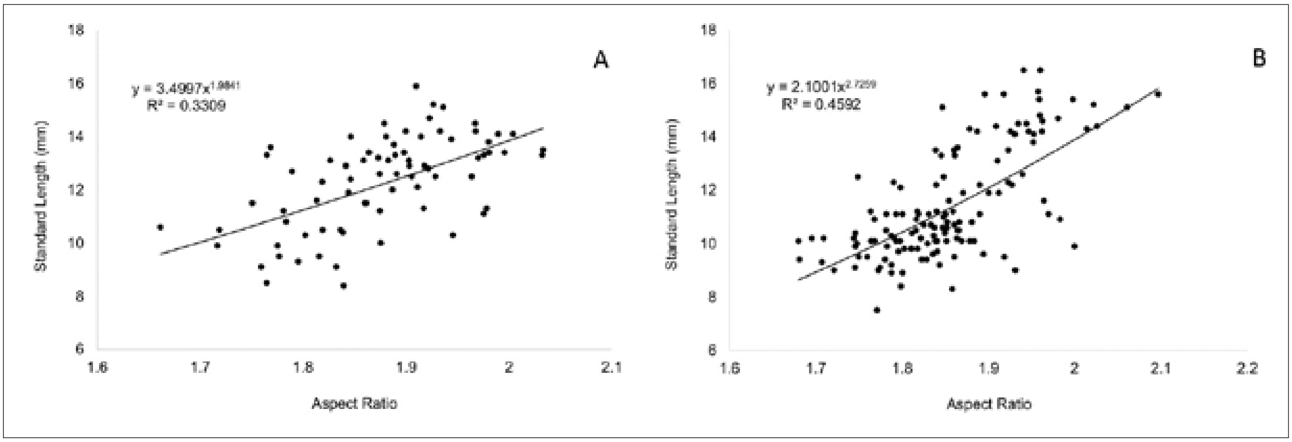

Fig. 3. Relationship between aspect ratio and standard length of *P. cyanea* (A: male, B: female)

SL = 382.02 OW $^{0.283}$ (R^2 = 0.89) (Female)
SL = 378.35 OW $^{0.2822}$ (R^2 = 0.88) (Sexes combined)

Relationship between Standard Length and Otolith Width

SL = 30.058OWi $^{0.9472}$(R^2 = 0.88) (Male)
SL = 32.212 OWi $^{0.912}$ (R^2 = 0.90) (Female)
SL = 32.19 OWi $^{0.9083}$ (R^2 = 0.90) (Sexes combined)

Relationship between Total Weight and Otolith Weight

TW = 17733 OW $^{1.0666}$ (R^2 = 0.85)
TW = 1796.7 OW $^{1.0632}$ (R^2 = 0.83)
TW = 1736.4 OW $^{1.0574}$ (R^2 = 0.85)

(SL = Standard Length, TW = Total Weight, OL=Otolith Length, OW= Otolith Weight, OWi = Otolith Width)

Discussion

Variations in the length weight relationships for male and female fishes were observed. The males showing isometric growth pattern and female exhibit a positively allometric growth pattern. Venu and Kurup (2002) indicated a positively allometric for male and isometric for female populations at a depth zone of 201-300 m. The authors reported that in shallow depth, fish showing an isometric growth pattern compared to deeper waters (201-400 m). Khan *et al.* (1996) reported that females are little heavier than that of male. The b value observed for females are in conformity with the previous research (b=3.76) (Khan *et al.*, 1996). Further studies with large sample set are highly essential for the accurate assessment of the length weight relationship of this species.

Present study estimated the somatic relationship with otolith length, width, weight and aspect ratio (Shape factor) which is expected to give more accurate extrapolations. Study indicated strong correlation between otolith and somatic measurements. Many researchers reported similar relationships between otolith and somatic measurements (Jawad *et al.*, 2011; Metin and Ilkyaz, 2008). The strong correlation between the otolith size and somatic size suggests that somatic growth have significant influence on the otolith accretion as reported by Munk (2012). Aspect ratio was found to be not suitable for extrapolating fish length and weight for *P. cyanea*. The aspect ratio is one of the factor which describes the shape of the otolith; the more elongated the otolith, the larger the aspect ratio (Zorica *et al.*, 2010).

There is no significant difference between the right and left otolith indicated that these are mirror images of each other (Hunt, 1979). Previous studies by Harvey *et al.* (2000) and Waessle *et al.* (2003) confirmed the similarity of right and left otolith in *Lutjanus bengalensis*. Linear relationship between otolith length and fish length depend upon the growth rate of the fish (Mugiya and Tanaka, 1992) and these relationship became curvilinear in some larval or juvenile fishes (West and Larkin, 1987). The relationship reported to be changed at intervals relative to fish size (Frost and Lowry, 1981) and ontogenetic changes in the life history (Hare and Cowen, 1995). There is a chance of getting errors in the extrapolation due to these errors. Majority of the studies conducted previously focussed on the relationship with one otolith size (Harvey *et al.*, 2000; Waessle *et al.*, 2003; Battaglia *et al.*, 2010). The extrapolation of the fish length would give false estimate when the rostrum of the otolith is broken or lost which can be solved by considering the otolith width for the calculation. Calculation may be fitted well only in the size range of the fish discussed in the paper. Since *P. cyanea* being a dominant species in deeper waters beyond 100 m range and prey of many deep sea carnivorous fishes, the estimation of specific equations would be very much useful to calculate the size and mass of preys during the food and feeding studies. This work expected to give a better understanding in the trophic relationship in the Arabian Sea food web by the reconstruction of the prey biomass using the otolith size. Under estimation of otolith size may also happen due to the exposure of otolith to chemical and mechanical abrasion in the digestive tract (Granadeiro and Silva, 2000). The strongly correlated relationship of standard length and total weight of the fish between otolith length, width and weight was investigated and the study concluded that these equations can be used to estimate the fish size and prey biomass for trophic dynamics studies.

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