DOI: 10.2478/cjf-2023-0003

CODEN RIBAEG ISSN 1330-061X (print)
1848-0586 (online)

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TAXONOMIC AND OTOLITH SHAPE PARAMETERS OF NINE SYMPATRIC CATFISHES COMMERCIALLY HARVESTED IN PAKISTAN

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ARTICLE INFO

Received: 2 November 2022
Accepted: 20 January 2023

Keywords:
Fish taxonomy
Lapillus otoliths
Species segregation
Catfishes
Ariidae
Multivariate approach

ABSTRACT

Accurate reorganization of harvested species is essential for appropriate fisheries monitoring but often unnoticed. In this study, an attempt was made to provide an accurate species description based on fish taxonomy and otolith shape parameters of nine sea catfishes living in Pakistan. The lapillus, the largest otolith of catfishes, includes the position of the umbo, the structure of the anterior mesial projection (amp), the incisura linea basalis (ilb) and sulcus lapilli marks (slm) in nine ariid catfishes were evaluated. Discriminant function analysis was performed using twenty-two morphometric parameters showed significant variations between the length of the maxillary barbel, adipose length and preorbital length, which were highlighted as basic discriminating characters. Species without barbells, such as *Batrachocephalus mino* and *Osteogeneiosus militaris*, were found to be distant. The taxonomic characters of the genera *Netuma* and *Plicofollis* overlapped due to a short adipose fin length. Nevertheless, species *Arius arius*, *Sciades sona* and *Nemapterxy caelatus* differed in a moderate adipose fin length. The preorbital length of *Netuma bilineata* has a short and rounded snout, while *N. thalassina* has a long and pointed snout, which is a distinguishing characteristic of both species. The coincident use of fish taxonomy and otolith shape parameters is an effective tool for catfish identification could be helpful in appropriate fisheries sampling programs and management in Pakistan whenever implemented.

How to Cite

Farooq, N., Panhwar, S. K. (2023): Taxonomic and otolith shape parameters of nine sympatric cat-fishes commercially harvested in Pakistan. Croatian Journal of Fisheries, 81, 23-32. DOI: 10.2478/cjf-2023-0003.

INTRODUCTION

Members of the family Ariidae can be differentiated using the supraoccipital process, bony shield, median groove, preorbital protuberance on the head and teeth patches present on the roof of the mouth (Kailola, 1999; Fischer and Bianchi, 1994). An attempt was made to identify this group of fishes through phylogenetic studies (Acero et al., 2007; Marceniuk and Menezes, 2007; Marceniuk et al., 2012). Considering taxonomy as a solid and sound fish identification tool has been adopted by several authors from different geographical regions (Al-Hassan et al., 1988; Singh et al., 2003; Dan et al., 2005a, b; Kumar et al., 2015). However, a confirmed species number is not yet known and the presence of the exact number of sea catfishes is still ambiguous. Moreover, coincident use of biometry and otolith of fishes is common practice to identify them appropriately (Harvey et al., 2000; Longenecker, 2008; Battaglia et al., 2010; Škeljo and Ferri, 2012; Yilmaz et al., 2015; Freire et al., 2017; Kashani and Panhwar, 2022). About 150 species of the family Ariidae were reorganized (Nelson, 2016), and later this number was increased to 155, with five new species documented between 2011 and 2020 (Froese and Pauly, 2022). Fischer and Bianchi (1984) recorded 24 species within three genera from the western Indian Ocean. However, Bianchi (1985) recorded 14 species in three genera from Pakistan, which have been nominally updated (Psomadakis et al., 2015).

In a recent study (Farooq et al., 2016, 2017), only nine species were recorded, including threadfin catfish *Arius arius*, giant catfish *Netuma thalassina*, bronze catfish *N. bilineata*, engraved catfish *Nemapteryx caelata*, black tip catfish *Plicofollis dussumieri*, thin spine catfish Π. λαψαρδι, sona catfish *Sciades sona*, beardless sea catfish *Batrachocephalus mino* and soldier catfish *Osteogeneiosus militaris*. These species migrate mainly in coastal waters but few enter the Indus River Estuary and are confined to freshwater channels.

In addition to phenotypic characters, otolith shape and morphology are central to fish taxonomy and systematics (Qamar et al., 2019; Kashani and Panhwar, 2022). In typical bony fishes, the sagitta is usually the largest otolith but in the case of catfishes, the lapillus is the largest pair and is widely used for growth studies and species differentiation (Campana, 2004; Qamar et al., 2019). The otolith biometric relationships are essential for reconstruction in the paleoichthyology of bony fishes and provide a better understanding of the predator-prey relationship and prey composition (Reichenbacher et al., 2007; Yilmaz et al., 2015; Kashani and Panhwar, 2022). We hope that this study will mitigate taxonomic ambiguities among species of close resemblance, facilitate species status and provide predictive relationships between otolith dimensions.

MATERIALS AND METHODS

A total of 832 specimens of *Arius arius* (76), *Betrachocephalus mino* (18), *Netuma bilineata* (373), *N. thalassina* (8), *Nemapteryx caelatus* (27), *Osteogeneiosus militeris* (41), *Plicofollis dussumieri* (265), *P. liyardi* (18) and *Scides sona* (6) were collected from commercial catches landed at Karachi fish harbor and fishery surveys conducted in the Indus River Estuary (IRE) from December 2014 to September 2017 (Fig. 1).

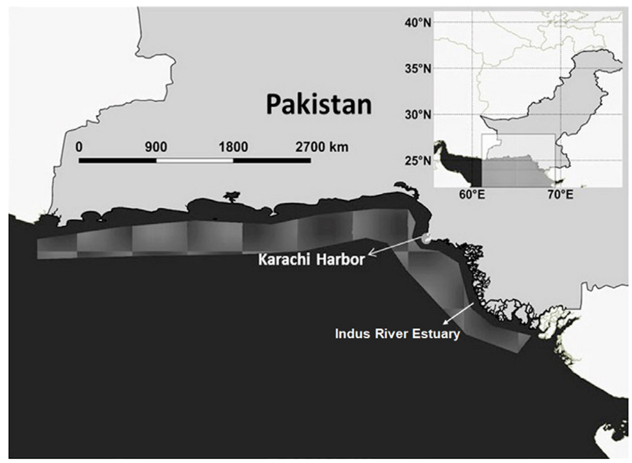

Fig 1. Shaded area indicating commercial fishing grounds along the Pakistan coast under the provincial fishing jurisdiction (35 nautical miles), fishery sampling (Karachi Fish Harbor) and fishery surveys (Indus River Estuary)

For further analysis, specimens were transported into fisheries laboratory at the Centre for Excellence in Marine Biology (CEMB). Each species was identified using the FAO field guide and fish taxonomic keys (see Fischer and Bianchi, 1985; Kailola, 1999; Psomadakis et al., 2015; Froese and Pauly, 2022; WoRMS, 2022). Lapillus otoliths from each species were removed from the utricular chambers of the otic region, cleaned with tap water, dried, labeled and kept in small plastic vials. No significant differences were found in the measurements of the left and right otoliths. Therefore, the right otolith was considered in all morphometric measurements, such as otolith length (OL), otolith height (OH), otolith width (OW) with an accuracy of 0.1 mm using a vernier caliper, and otolith mass (OM) with an accuracy of 0.0001 g using an electronic balance model AR2140 Ohaus, Diamond MCT-500. A detailed morphometric description of lapillus otolith of each species was given (Fig. 2, 3).

A log-converted simple linear regression model (y= bx + a) was applied to the morphometric data of each species (Griffiths, 1995). The data of twenty-two morphometric measurements (FL, HL, EyeDia, PreOr, PosOr, Gir, DFL, PcFL, PiFL, AFL, CFL, CFD, AFR, CFR, CPdl, CPDd, PreDFL, PrePcFL, PrePelv, PreAnal, Adps, LMB) of nine ariid species were used to perform discriminant function analysis (DFA). A scatter plot was established on SPSS ver. 16.0

by conducting DFA with an optional selection of matrices such as within-group correlations, covariance matrix and Fisher's function coefficients. It is worth noting that some measurements were constant in all ariid species, such as the number of dorsal and pectoral fin rays, etc., and therefore were not included in the statistical analysis.

RESULTS

Morphometric data from 832 specimens of nine species were used to perform linear regression. Descriptive statistics of fish sizes and weights against otolith measurements (otolith length (OL), thickness (OT), height (OH) and mass (OM)) are presented in Table 1. From the coefficient of determination (R^2 = 0.7~0.9), it can be seen that there is strong linearity between parameters (X~Y).

The computed means and standard errors of total length and weight of fish, otolith length, height, thickness and mass are also summarized. The values of the slopes "b" of TL/OL (in the case of *A. arius* and *O. militaris*) and TL/OT (otolith thickness) in the case of *A. arius* and *N. caelatus* were less than 1.00 (Table 2).

The data from twenty-two morphometric and meristic parameters were used to establish a canonical discriminant analysis (Table 3).

The estimated F-ratio value for the length of the maxillary barbel, adipose length and preorbital length was comparatively higher, highlighting basic discriminating factors. The first three functions of the discriminant function represent 48, 32 and 11 percent variability among axes. Moreover, the DFA estimate reveals that percent of share variance (48%) of function I is higher than that of II & III (32% and 11%, respectively). The canonical correlation of function I is also higher (.911) than (.874 and .730) (Fig. 4).

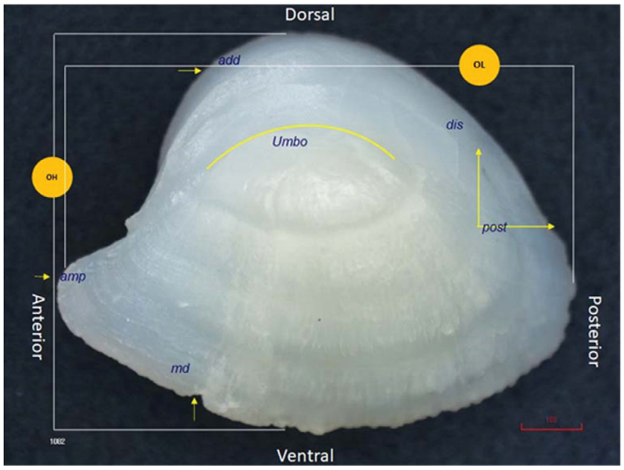

Fig 2. A dorsal view of otolith (lapilli) of *Plicofollis dussumieri*, anterodistal ditch (add), anterior mesial projection (amp), mesial dent (md), distal (dis), posterior (post), otolith length (ol), otolith height (oh)

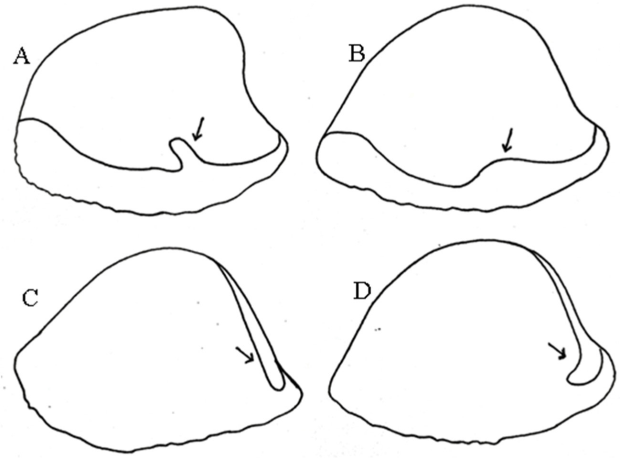

Fig 3. Drawing of incisura linea basalis on ventral view of lapillus otolith of *Scides sona* (A) (arrow indicates deep incisura), *Plicofollis dussumieri* (B) (shallow) and position of sulculus lapilli in *Plicofollis dussumieri* (C) (tubular curve) and *Plicofollis layardi* (D) (tubularly straight)

Table 1. Summary of the estimated total length, total body weight, means and standard errors for each species (abbreviations: TL=total length, BW= body weight, OL=otolith length, OH= otolith height, OT= otolith thickness, OM= otolith mass and N= specimens)

Species	Fish TL (cm)	Fish BW (gm)	OL (cm)	OH (cm)	OT (cm)	OM (gm)
Netuma bilineata (n = 373)	32.97±0.49	419.77±41.74	0.90±0.01	0.71±0.01	0.37±0.01	0.28±0.01
Plicofollis dussumieri (n = 265)	32.29±0.55	456.04±27.32	0.93±0.01	0.71±0.01	0.39±0.01	0.31±0.01
Netuma thalassina (8)	44.46±8.16	1536.63±1238.43	1.12±0.12	0.86±0.08	0.45±0.05	0.59±0.24
Plicofollis liyardi (n = 18)	28.54±1.80	253.87±51.52	0.91±0.03	0.70±0.02	0.36±0.02	0.25±0.03
Arius arius (n = 76)	24.92±0.33	161.73±8.70	0.93±0.01	0.69±0.01	0.40±0.01	0.29±0.01
Nemapteryx caelatus (n = 27)	29.07±0.65	281.70±27.19	1.05±0.02	0.80±0.02	0.47±0.01	0.42±0.02
Sciades sona (6)	28.53±0.94	255.00±21.99	1.07±0.02	0.84±0.01	0.49±0.01	0.45±0.02
Osteogeneiosus militarus (n = 41)	27.38±0.57	209.68±16.96	0.86±0.02	0.61±0.02	0.31±0.01	0.18±0.01
Batrachocephalus mino (n = 18)	28.21±0.52	228.93±13.92	1.13±0.02	0.82±002	0.49±0.01	0.50±0.02

Table 2. Summary of the statistical analysis of otolith slopes, intercepts and $CI_{95\%}$ (in parentheses) for nine highly commercial fish species

Species	TL vs OL	TL vs OH	TL vs OT	BW vs OM
Netuma bilineat (373)	Y=3.61+1.30X (1.20–1.41) R^2=0.8	Y=3.93+1.34X (1.23–1.45) R^2=0.8	Y=4.26+0.77X (0.68–0.86) R^2=0.7	Y=7.70+1.49X (1.41–1.58) R^2=0.9
Plicofollis dussumieri (265)	Y=3.52+0.97X (0.86–1.08) R^2=0.7	Y=3.97+1.48X (1.40–1.56) R^2=0.90	Y=4.57+1.16X (1.09–1.23) R^2=0.9	Y=7.92+1.67X (1.59–1.75) R^2=0.9
Netuma thalassina (8)	Y=3.59+1.54X (1.27–1.80) R^2=0.9	Y=3.90+1.60X (1.29–1.91) R^2=0.9	Y=3.76+1.24X (0.82–1.66) R^2=0.9	Y=7.39+1.58X (0.57–2.60) R^2=0.8
Plicofollis layardi (18)	Y=3.49+1.71X (1.34–2.08) R^2=0.9	Y=3.91+1.62X (1.04–2.19) R^2=0.8	Y=4.60+1.22X (0.92–1.52) R^2=0.9	Y=7.02+1.21X (0.42–2.01) R^2=0.6
Arius gagora (76)	Y=3.28+0.97X (0.80–1.14) R^2=0.8	Y=3.50+0.77X (0.61–0.92) R^2=0.8	Y=3.26+0.06X (-0.03–0.15) R^2=0.2	Y=6.50+1.24X (0.88–1.60) R^2=0.6
Nemapteryx caelatus (27)	Y=3.32+0.92X (0.59–1.26) R^2=0.8	Y=3.57+0.91X (0.60–1.22) R^2=0.8	Y=3.82+0.59X (0.34–0.84) R^2=0.7	Y=7.08+1.70X (2.00–1.39) R^2=0.9
Sciades sona (6)	Y=3.24+1.63X (0.34–2.92) R^2=0.9	Y=3.87+2.90X (1.05–4.76) R^2=0.9	Y=4.53+1.66X (0.25–3.06) R^2=0.9	Y=7.01+1.85X (0.11–3.58) R^2=0.8
Osteogeneiosus militarus (41)	Y=3.43+0.83X (0.70–0.95) R^2=0.9	Y=3.54+0.47X (0.33–0.61) R^2=0.7	Y=3.91+0.51X (0.35–0.68) R^2=0.7	Y=7.18+1.08X (0.94–1.23) R^2=0.9
Batrachocephalus mino (18)	Y=3.24+0.81X (0.39–1.70) R^2=0.7	Y=3.49+0.81X (0.39–1.23) R^2=0.7	Y=4.20+1.21X, (0.54–1.87) R^2=0.7	Y=6.13+1.04X (0.38–1.70) R^2=0.6

Table 3. Detailed standardized Canonical Discriminant Function coefficients (Abbreviation: FL=Fork Length, HL=Head Length, EyeDia=Eye Diameter, PreOr+ Preorbital Length, PosOr=Postorbital Length, Gir=Girth, DFL= Dorsal Fin Length, PcFL= Pectoral Fin Length, PeFL=Pelvic Fin Length, AFL= Anal Fin Length, CFL= Caudal Fin Length, CFD=Caudal Fin Depth, AFR= Anal Fin Rays, CFR= Caudal Fin Rays, CPdL= Caudal Peduncle Length, CPdD Caudal Peduncle Depth, PreDFL=Pre-Dorsal Fin Length, PrePcFL=Pre-Pectoral Fin Length, PrePelFL= Pre-pelvic Fin Length, PreAnalFL=Pre-Anal Fin Length, AdpsFL= Adipose Fin Length, LMB=Length of Maxillary Barbel)

Parameter	1	2	3	4	5	6	7	8	F-ratio
FL	0.396	-0.092	0.023	2.002	1.399	-1.154	-0.407	-0.569	4.591
HL	0.045	-0.1	0.185	-0.033	-0.463	-0.242	-0.083	0.058	6.782
EyeDia	0.098	-0.036	0.055	0.052	-0.189	0.015	0.045	-0.281	2.240
PreOr	0.03	-1.226	0.434	-0.319	-1.195	-1.508	-0.284	0.605	14.798
PosOr	-0.068	2.58	0.734	-1.973	0.771	0.952	2.538	0.42	7.564
Gir	0.045	-0.461	-0.222	-0.652	-0.708	0.234	-2.543	-0.078	6.365
DFL	0.177	0.053	-0.308	-0.078	-0.436	1.025	0.016	0.004	3.808
PcFL	0.033	0.046	-0.095	-0.712	0.359	0.224	0.251	0.084	7.110
PiFL	0.357	-0.414	-0.096	-0.15	0.063	0.981	0.306	0.02	3.599
AFL	-0.305	0.678	-0.157	0.271	-0.233	-0.164	-0.87	-0.616	7.407
CFL	1.243	-0.598	-1.689	0.009	-0.373	-0.289	0.624	0.924	11.777
CFD	0.013	0.037	0.331	-0.094	0.311	0.234	0.182	-0.534	12.688
AFR	0	0.083	-0.16	0.164	-0.32	0.159	0.278	0.163	10.168
CFR	0.126	0.259	0.959	0.932	-0.009	0.416	-0.011	0.678	.145
CPdl	-0.307	-0.174	-0.28	0.656	0.426	-0.266	0.287	-0.66	5.306
CPDd	0.293	0.301	2.076	2.393	0.248	1.147	-0.147	1.528	7.520
PreDFL	0.199	0.055	-0.056	0.053	-0.028	-0.148	-0.022	-0.109	3.215
PrePcFL	0.115	-0.184	0.171	-0.498	-1.399	-0.199	0.354	-0.53	10.546
PrePelv	0.03	-0.06	0.6	-1.203	0.989	0.426	0.528	1.045	10.137
PreAnal	0.352	-0.299	-0.455	0.346	0.649	-0.964	-1.182	-1.726	7.963
Adps	-1.013	1.261	-0.324	-0.091	0.052	-0.477	-0.066	0.449	47.753
LMB	-1.8	-1.395	-0.689	0.054	0.108	0.339	0.259	0.103	71.326

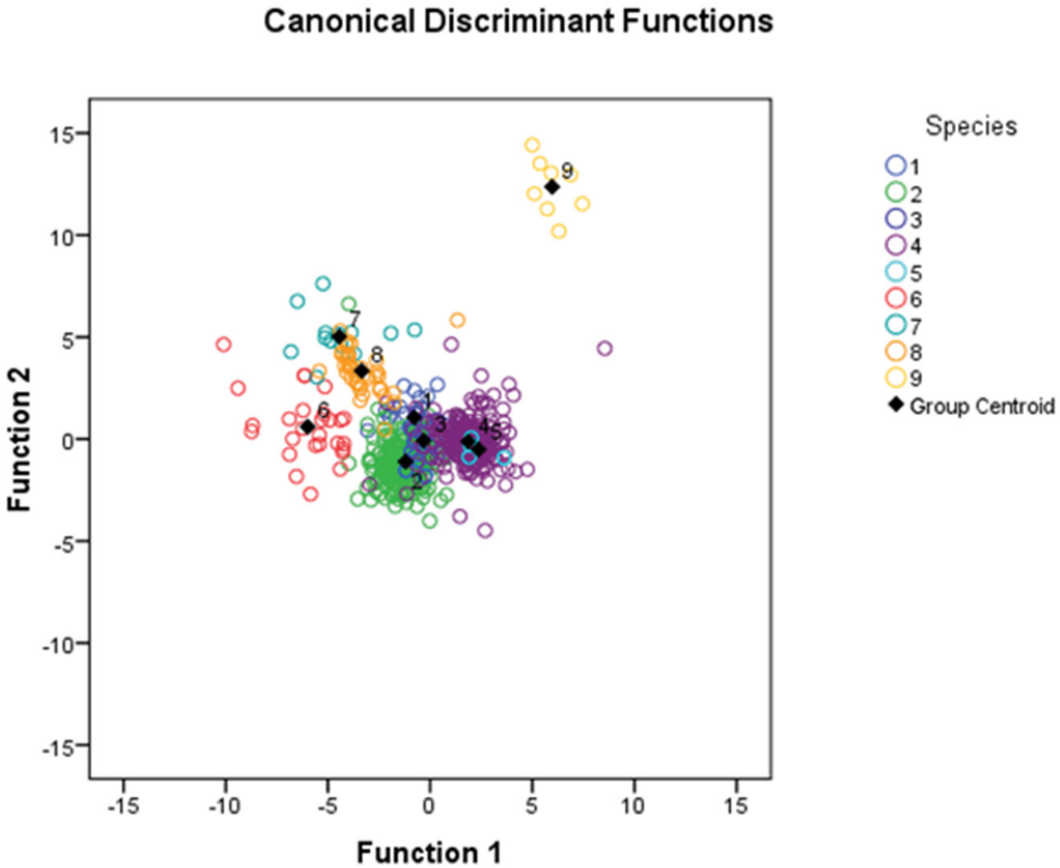

Fig 4. Two-dimensional ordination plot established from pooled morphometric data of nine sea catfishes, black-coloured crystals indicating class centroids per species (each species was allocated to the group within the nearest centroids). (1) *Arius arius*, (2) *Plicofollis dussumeiri*, (3) *Plicofollis tenuispinus*, (4) *Netuma bilineata*, (5) *Netuma thalassina*, (6) *Nemipteryx caelatus*, (7) *Scides sona*, (8) *Osteogeneosus militeris*, (9) *Batrachocephalus mino*.

Similarly, the high percentage of shared variance "eigenvalue" and total variation in the grouping of discriminant function I (4.863) in this study could be attributed to the differences among nine species of sea catfishes in their phenotypic trait and the evidence of high variability among them.

Morphological pattern of lapilli otoliths of ariid species

Arius arius lapilli (Fig. 5a): oval-shaped, dorsal view strongly convex and ventral slightly convex. Anterior anteromesial projection (*amp*) long and rounded, anterodistal ditch (*add*) prominent continuing to anterior margin. Mesial dent (*md*) weak, umbo located on anterior part of dorsal surface. Sulcus lapilli (*sl*) tubularly curved. Incisura linea basalis (*ilb*) shallow. The ratio lapillus length / height 1.1–1.5 and lapillus length / thickness 1.8–2.7 (n=76).

Batrachocephalus mino lapilli (Fig. 5b): oval-shaped, dorsoventral profile smoothly biconvex. Anterior anteromesial projection short and sharp, distal margin angulated, mesial margin straight. Posterior margin slightly rounded. Anterodistal ditch deep. Mesial dent clear. Umbo located on anterior part of dorsal surface. Sulcus lapilli tubularly strait. Incisura linea basalis deep and broad. The ratio lapillus length / height 1.3–1.4 and lapillus length / thickness 2.1–2.4 (n=18).

Netuma bilineata lapilli (Fig. 5c): clam-shaped, dorsal view strongly convex and weak ventrally. Anterior anteromesial projection long and sharp. Anterodistal ditch narrow. Distal margin deeply dome-shaped. Mesial and posterior margins strongly angulated. Mesial dent small and sharp. Umbo located in middle of dorsal surface. Sulcus lapilli tubularly curved. Incisura linea basalis deep. The ratio lapillus length / height 1.1–1.5 and lapillus length / thickness 1.8–3.4 (n=373).

Netuma thalassina lapilli (Fig. 5d): macula-shaped, dorsal side strongly convex and weakly convex ventrally. Anterior anteromesial projection short and round, anterodistal ditch clear. Distal margin dome-shaped. Mesial and posterior margins somewhat angulated. Mesial dent small and sharp. Umbo located slightly towards anterior part of dorsal surface. Sulcus lapilli tubularly straight. Incisura linea basalis shallow. The ratio lapillus length / height 1.2–1.4 and lapillus length / thickness 2.2–2.8 (n=8).

Nemipteryx caelatus lapilli (Fig. 5e): oval-shaped. Dorsal view irregularly convex, ventral view slightly convex. Anterior anteromesial projection long and rounded. Distal margin angulated. Mesial margin somewhat straight.

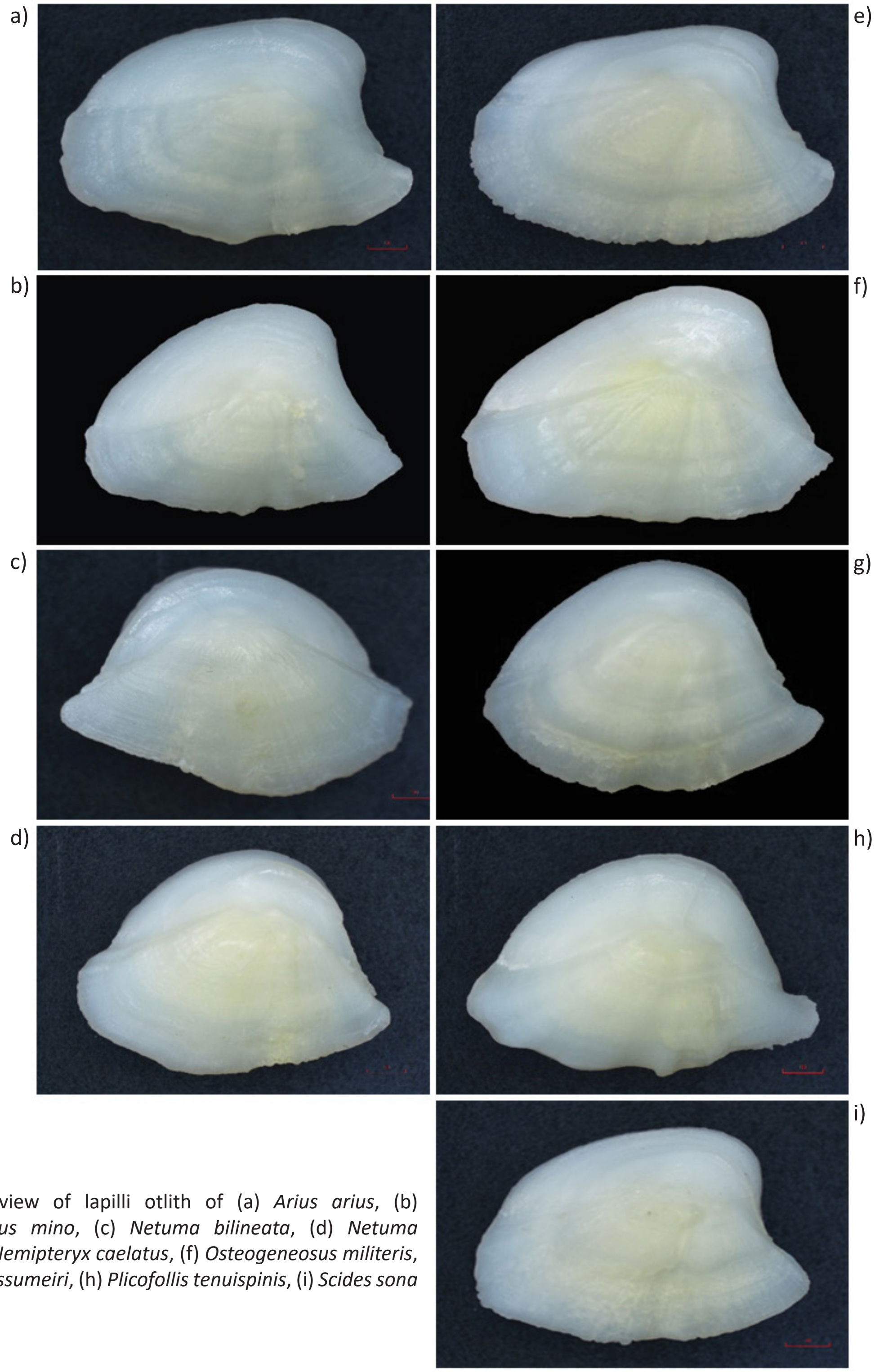

Fig 5. Dorsal view of lapilli otlith of (a) *Arius arius*, (b) *Batrachocephalus mino*, (c) *Netuma bilineata*, (d) *Netuma thalassina*, (e) *Nemipteryx caelatus*, (f) *Osteogeneosus militeris*, (g) *Plicofollis dussumeiri*, (h) *Plicofollis tenuispinis*, (i) *Scides sona*

Posterior region rounded. Anterodistal ditch deep. Distal margin angulated. Mesial margin somewhat straight. Mesial dent clear. Umbo located on anterior part of dorsal surface. Sulcus lapilli tubularly curved. Incisura linea basalis shallow. The ratio lapillus length / height 1.2−1.4 and length / thickness 2.0−2.6 (n=27).

Osteogeneosus militeris lapilli (Fig. 5f): oval-shaped. Smoothly biconvex dorsoventrally. Anterior anteromesial projection short and pointed. Anterodistal ditch narrow. Distal and posterior margins angulated. Mesial margin straight. Mesial dent (md) weak. Umbo located slightly towards anterior part of dorsal surface. Sulcus lapilli tubularly straight. Incisura linea basalis shallow. The ratio lapillus length / height 1.2−2.3 and lapillus length / thickness is 1.6−3.5 (n=41).

Plicofollis dussumeiri lapilli (Fig. 5g): macula-shaped. Dorsal view strongly convex, while a little convex ventral view. Anterior anteromesial projection long and rounded.

Anterodistal ditch clear. Distal margin dome-shaped. Mesial margin rounded. Posterior margin tapered. Mesial dent deep. Umbo located on anterior part of dorsal surface. Sulcus lapilli tubularly curved. Incisura linea basalis shallow. The ratio lapillus length / height 1.1−1.6 and lapillus length / thickness 1.8−3.4 (n=265).

Plicofollis tenuispinis lapilli (Fig. 5h): macula-shaped. Dorsal view strongly convex and slightly convex ventrally. A large and rounded anterior anteromesial projection. Anteromesial dent clear. Anterodistal ditch weak. Distal margin dome-shaped. Mesial margin slightly rounded with regular wavy edges. Umbo located on anterior part of dorsal surface. Sulcus lapilli tubularly straight. Incisura linea basalis shallow. The ratio lapillus length / height is 1.1−1.5 and lapillus length/ thickness 2.3−3.2 (n=18). This lapillus somewhat resembles lapilli of *P. dussumieri* but distinguishable in having a large *amp* and continuous wavy mesial edges.

Scides sona lapilli (Fig. 5i): macula-shaped, dorsoventrally irregularly biconvex. Anterior anteromesial projection is short and sharp. Anterodistal ditch weak. Distal, mesial and posterior margins slightly angulated. Mesial dent clear, umbo located on anterior part of dorsal surface. Sulcus lapilli tubularly curved. Incisura linea basalis deep. The ratio lapillus length / height 1.2 −2.0 and lapillus length / thickness 1.6−3.5 (n=6).

DISCUSSION

Our results demonstrate that otolith shape and fish taxonomy provide a robust, rapid and simple approach for differentiating nine sympatric catfishes living in the coastal waters of Pakistan, western Indian Ocean Region (wIOR). In a seminal article, Lombarte and Lieonart (1993) concluded that fish taxonomic data with otolith morphometric data are more than enough to discriminate fish species or populations based on their high morphological specificity. Earlier attempts made to differentiate ariids from different geographical locations used pre-AL, pre-DL, HL, inter-nostrils and snout length to delineate species-specific variability (Dhanze and Jayaram, 1982; Singh et al., 2003; Dan et al., 2005a, b). The morphometric parameters of *Batrachocephalus mino* are significantly far from the rest of the species. However, parameters of species of genus *Netuma* and *Plicofollis* were overlapping due to short adipose fin length. *Arius arius*, *Sciades sona*, *Osteogeneiosus militaris* and *Nemapterxy caelatus* are characterised by the moderate length of the adipose fin. However, *Osteogeneiosus militaris* can be classified with other species that have stiff maxillary barbels. Detailed information on the discriminant analysis of twelve sea catfish species, obtained from Indian waters, is provided (Kumar et al., 2015). The practicability of discrimination function is commonly used to classify and define organisms more efficiently than the traditional measurements of organisms. Inter-species morphometric variability of otoliths showed that the position of the umbo, structure of anterior mesial projection (*amp*), incisura linea basalis (*ilb*) and sulcus lapilli marks (*slm*) are the key varying parameters. Anterior mesial projection is long and rounded in species *A. arius*, *N. caelatus*, *P. dussumieri* and *P. tenuispinus*, while long and sharp in *N. bilineata*. Similarly, it is short and sharp in species *B. mino*, *O. militeris* and *S. sona*, whereas short and rounded in *N. thalassina*. Moreover, the ratio of lapillus length and thickness differs significantly among nine species with individuals of the same length. The new data may facilitate the recognition of fossil species of ariid catfishes. In order to determine interspecific comparisons between and among species, affiliation based on the otolith is widely used (Sadighzadeh et al., 2012; Bani et al., 2013). Otolith weight is most sensitive to growth rate and is a powerful discriminator of fish populations (Tuset et al., 2006). Moreover, methods for analysing otolith shape have frequently been used to study inter- and intraspecific population variations (Stransky, 2014). Otolith shape analysis can be widely used for solving basic problems (determination of boundaries of natural populations and conservation) and purely applied problems (Cadrin et al., 2005). The method is most effective when it is used in combination with other approaches to the study of the population structure of a species. Thus, a study of such a complex and important issue as distinguishing the fishing stock management units (commercial populations) requires a comprehensive approach, which has become very popular (Cadrin et al., 2005). The estimated coefficient of determination for all species was within the proposed range (Froese, 2006) and showed strong linearity among parameters. The strong linearity between otolith and fish body parameters can be interpreted as influencing the somatic growth of fish and the otolith shape (Munk, 2012). A curvilinear pattern resulted from the biometric relationship found mainly in the larval and juvenile phases of fishes (Campana, 2004). In the present work, despite the presence of large intervals in the species *Netuma bilineata*, *N. thalassina*, *Plicofollis dussumieri*, *P. liyardi* and *Sciades sona*, the linear model was best fitted in relation to body size and otoliths, and can be interpreted from the coefficient of determination $R^2 > 0.8$. A notable work of Freire et al. (2017) on ariid catfish *Sciades proops* is similar to the results of the present study. The value of slope (b) of TL/OL (in the case of *A. arius* and *O. militaris*) and TL/OT (in the case of *A. arius* and *N. caelatus*) was less than 1.0, showing that the growth of otoliths was inversely related to their length and thickness as the fish size and weight increased. Variability in otolith dimensions may be attributed to ontogeny and demersal environment where sea catfishes live (Dantas et al., 2013), such as coastal, estuarine and freshwater systems. Moreover, otolith shape can be influenced by the temperature and availability of carbonate in water (Lombarte and Lleonart, 1993) and also by the habitat, physiological changes, feeding, environmental factors, age and hereditary characteristics (Vignon and Morat, 2010). Therefore, temperature and carbonate variation in water can help differentiate populations from different locations. The infrequent information on morphometry of lapillus otolith of ariid species impedes comparisons between regressions obtained by other authors. The structural matrix and standard coefficient of the canonical discriminant function revealed that the length of the maxillary barbel, adipose length and preorbital length were the strongest discriminators and predictors. The species without barbels, *Batrachocephalus mino* and *Osteogeneiosus militaris*, were distant. Conversely, parameters of species of genus *Netuma* and *Plicofollis* were overlapping due to short adipose fin length. Three species, *Arius arius*, *Sciades sona* and *Nemapterxy caelatus*, are characterized by a moderate length of the adipose fin. Preorbital length distinguishes the species within the genus, for example, *N. bilineata* has a short and round snout, while *N. thalassina* has a long and pointed snout. The present study highlights the prospective use of otolith shape and fish taxonomy coincidently as an effective tool for assessing the accuracy of species reorganization of sea catfishes which could be useful in fisheries sampling programs and the conservation of scaleless fishes in the western Indian Ocean.

ACKNOWLEDGEMENTS

The research was funded by the HEC, Islamabad under NRPU-2618 as part of a Ph. D dissertation of Ms Noureen.

TAKSONOMIJA I PARAMETRI OBLIKA OTOLITA DEVET VRSTA SOMOVA IZ UZGOJA U PAKISTA-NU

SAŽETAK

Točna reorganizacija uzgojnih vrsta ključna je za odgovarajuće praćenje ribarstva, ali se često na bilježi. U ovoj studiji pokušalo se dati točan opis vrsta na temelju taksonomije riba i parametara oblika otolita devet vrsta morskih somova iz Pakistana. Lapilus, najveći otolit somova, uključuje položaj umba, strukturu prednje mezijalne projekcije (amp), incisura linea basalis (ilb) i oznake sulcus lapilli (slm) kod devet ariidnih somova. Analiza diskriminativne funkcije provedena je pomoću dvadeset i dva morfometrijska parametra devet vrsta, a pokazala je značajne varijacije između duljine maksilarih brkova, adipozne duljine i preorbitalne duljine, koji su istaknuti kao osnovni diskriminirajući znakovi. Za vrste bez brkova, kao što su *Batrachocephalus mino* i *Osteogeneiosus militaris*, utvrđeno je da su udaljene. Taksonomska svojstva rodova *Netuma* i *Plicofollis* preklapaju se zbog kratke duljine masne peraje. Ipak, vrste *Arius arius*, *Sciades sona* i *Nemapterxy caelatus* razlikovale su se po umjerenoj duljini masne peraje. Preorbitalna duljina *Netuma bilineata* ima kratku i zaobljenu njušku, dok *N. thalassina* ima dugu i šiljastu njušku, što je karakteristika obje vrste. Podudarna upotreba taksonomije riba i parametara oblika otolita učinkovit je alat za identifikaciju soma koji pomaže u odgovarajućim programima uzorkovanja i upravljanju ribarstvom u Pakistanu.

Ključne riječi: taksonomija riba, lapilus otoliti, segregacija vrsta, somovi, Ariidae, multivarijatni pristup

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