J. Exp. Zool. India Vol. 24, No. 2, pp. 1409-1421, 2021 | www.connectjournals.com/jez | *ISSN 0972-0030*
DocID: https://connectjournals.com/03895.2021.24.1409 | eISSN 0976-1780

INTER AND INTRA VARIATION OF SCIAENID FISHES (TELEOSTEI : PERCIFORMES : SCIAENIDAE) THROUGH OSTEOLOGICAL AND MORPHOLOGICAL APPROACH FROM NORTH WEST COAST OF INDIAN WATERS, ARABIAN SEA

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(Received 11 April 2021, Accepted 6 June 2021)

ABSTRACT : The taxonomic ambiguity surrounding several prominent genera of sciaenid has been a long imepdiment to research to solve species-level confusion on this groups. This study has been conducted for a compehensive assessment of species and phylogenetic relationship within the species and between the species through a combined osteological and morpholigical approach. Twelve species belonging to seven genera of family Sciaenidae (Teleostei: Perciformes) from North West coast of Indian water were studied. A data set of 51 morphological characters (24 osteological, 23 morphometric and 4 meristic) was constructed. A cladistics analysis based on the osteological characters resulted in a single most-parsimonious tree of tree length of 63 steps, Consistency index (CI) = 0.6981 and Retention index (RI) = 0.6981. This cladogram did not support the monophyly of one of the seven genera, Otolithes. The osteological data set was then combined with a data set of 23 morphometric and 4 meristic characters that has been used for establishing phylogenetic relationship with greater nodal support of tree length of 124 steps, (CI=0.6855 and RI=0.7045). The topography of the cladogram is similar as obtained from osteological data alone except *Otolithes cuvieri* and *O. ruber* found closer than the *Otolithoides biauritus*.

Key words : Morphological, osteological, sciaenidae, consistency index and retention index.

How to cite : Suman Kumari, Ashok K. Jaiswar, Shrinivas Jahageerdar, Zeba J. Abidi, S. K. Chakraborty, Tarkeshwar Kumar and Uttam K. Sarkar (2021) Inter and intra variation of sciaenid fishes (Teleostei : Perciformes : Sciaenidae) through osteological and morphological approach from North West Coast of Indian waters, Arabian Sea. *J. Exp. Zool. India* **24**, 1409-1421. DocID: https://connectjournals.com/03895.2021.24.1409

INTRODUCTION

The family Sciaenidae (Acanthopterygii, Perciformes, Teleostei) is one of the largest families with 70 genera and 270 species (Chao, 1986), inhabiting edge of continental shelf to shallow coastal waters, from the depth of 50-70m in temperate to tropical coastal waters and estuaries throughout the world (Kamei *et al*, 2013). The Indian Ocean, 34 are considered Commercially important (Mohan, 1991). The external morphological features exhibited by the species of the family are diverse, especially in general body form and mouth position, which have enabled them to adapt to a wide range of habitats, from pelagic to benthic. The name croakers and drums refer to the characteristic vocalization of the species of the family. Further, the morphological structure related to sound production, swim bladder and otolith are also markedly diverse, a most distinctive feature of the group (Mohan, 1991).

In the taxonomic and phylogenetic studies of the family, the morphological variability of swim bladder and otolith has been primarily utilize to establish evolutionary grouping (Trewavas, 1962; 1977; Chu *et al*, 1963; Mohan, 1972; 1991; Chao, 1978). Further, the great diversity of sciaenid swim bladder and otolith morphology promises much in the study of relationship, limitations are apparent when considering "character polarity", according to usual cladistics methodology. Although a number of reports on sciaenid osteology are available (Dharmarajan *et al*, 1936;

Kim and Kim, 1965; Topp and Cole, 1968; Taniguchi, 1969a, 1970), they are either restricted to one or few species, or the findings have not been considered in the context of phylogenetic relationships.

In addition to the total reliance upon swim bladder and otolith morphology, the widespread geographical range of the family has hampered a phylogenetic analysis of entire group. Most of the research work has been limited to region specific of Eastern Atlantic and Indo-West Pacific by Trewavas (1962; 1977); Chinese water by Chu *et al* (1963); Western Atlantic by Chao (1978); Japanese water by Sasaki (1989). From Indian waters, there are few references on this aspect, which are limited to phylogenetic studies based on morphological studies (Mohan, 1972). Hence, the present study has undertaken to propose a hypothetical phylogenetic relationship of the species of the family Sciaenidae occurring in the North West coast of Indian water using osteological and morphometric data.

MATERIALS AND METHODS

Sample collection

Samples of 12 sciaenid species mainly were *Johnius glaucus*, *J. belangerii*, *J. dussumieri*, *J. macrorhynus*, *Johnieops sina*, *J. vogleri*, *Otolithoides biauritus*, *Pennahia aneus*, *Protonibea diacanthus*, *Paranibea semiluctuosa*, *Otolithes ruber* and *O. cuvieri* collected by shrimp trawlers operated from various fishing ground (Versova, New Ferry Wharf, Bombay Harbour, Sasson Docks) from North West coast of Indiain water, during October 2010 to April 2011 (Fig. 1). The species collected were identified using standard references including that of Chu *et al* (1963); Trewavas (1962); FAO (1983). Morphometric and meristic characters of 12 species were measured following criteria described by Hubbs and Lagler (1958).

Osteological preparation

The osteological observations were based on cleared and stained bone prepared by followingmethodology given

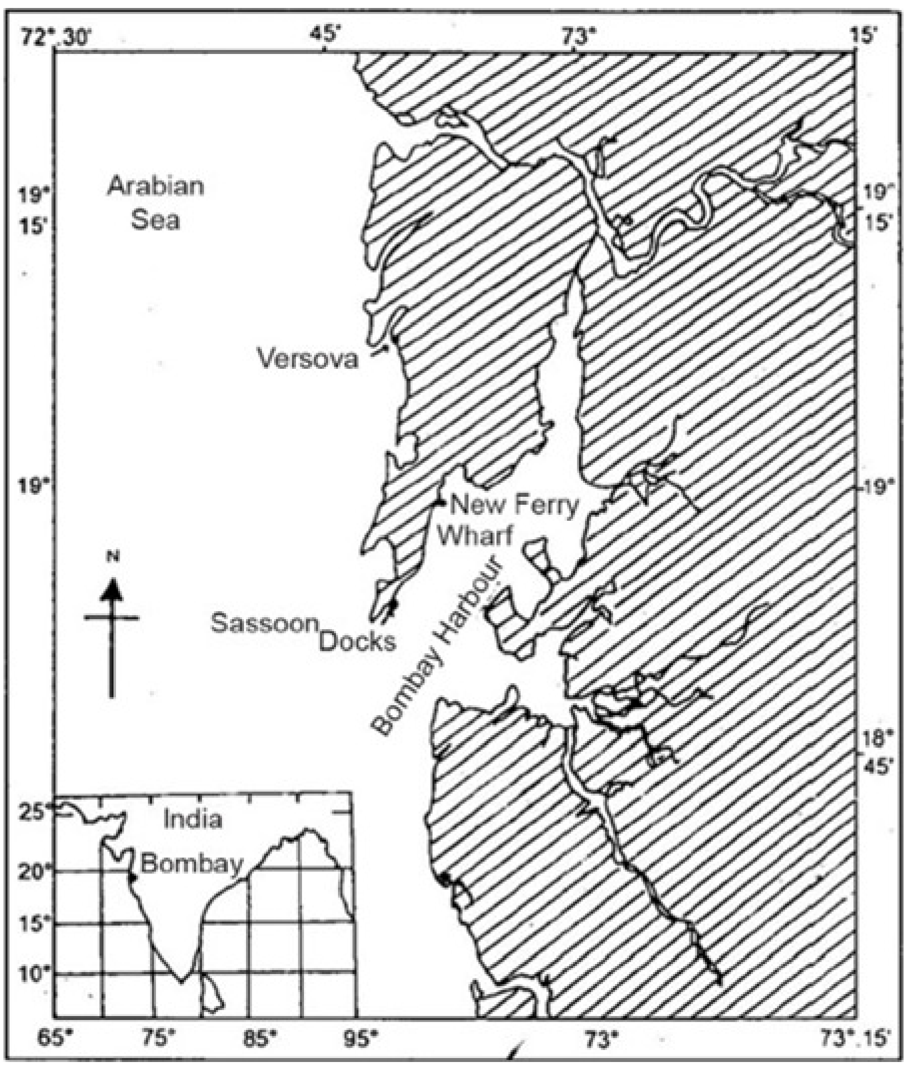


Fig. 1 : Map of Mumbai showing sampling sites.

by James (1985). Alizarin staining technique described by Hollister (1934); Clothier (1950) was used for studying the skeleton. The parts of bones were labeled by following Weitzman (1962); Taniguchi (1969a; 1969b; 1970); Sasaki (1989); James (1985).

Phylogenetic analysis

In order to generate a hypothetical phylogenetic relationship, osteological morphometric and meristic characters of sciaenids were analyzed following the principles of phylogenetic relationship (cladistics) outlined by Henning (1966) and subsequently modified by several authors of which most notable are Wiley (1982), Trewavas (1977), Chao (1978), Sasaki (1989). A data set of 24 osteological characters, 24 morphometric and 4 meristic characters were included in the analysis. As these characters are heterotrophic for at least one genera, all characters were included in analysis. The character list with score was generated following Sasaki (1989) methodology. Based on Sasaki scoring has been given to Polymorphic character states that, scored of 0, indicates most similar characters among the groups; 1, lesser number of groups having this characters: 2, 3, 4……… as number increase similarities decreases. The data matrix was prepared by methodology given by Santini and Tyler (2002) and Sasaki (1989) was analysed using Past 1.34 Hammer (2001). The consistency index (CI) and retention index (RI) was calculated for each analysis by Klunge and Farris (1969), Farris (1989). The character matrix was studied using algorithm Branch-and–bound, while Fitch optimization option of Past 1.24 (Hammer, 2001) was used to produce cladogram. To assess the degree of support for the individual clades in the cladogram, the number of extra steps was calculated for tree of the minimum length of cladogram.

RESULTS

Based on Sasaki scoring for polymorphic characters the results are shown in Tables 1-3. The following scores were observed for the characters studied.

Neurocranium (Figs. 2 & 2a)

1. Lateral ethmoid: Outer margin of lateral ethmoid
   a. Gently curved outward (0)
   b. Nearly straight (1)
2. Frontal covers the neurocranium
   a. It covers 2/3rd of the neurocranium (0)
   b. It covers more than 2/3rd of the neurocranium (1)
   c. It covers less than 2/3rd of the neurocranium (2)
3. Frontal
   a. Frontal projecting downward (0)
   b. Frontal nearly straight (1)
4. Frontal (Fig. 2a, Table 1)

A = Length of frontal along median line

B = Length of anterior median line of frontal

   a. B/A = 0.41-0.50 (0), > 0.50 (1), < 0.41 (2)

5. B/A = B/A = A = Length of frontal along median line

C = Width between right and left supraorbital ridge and accessory supraorbital ridge

   a. C/A = 0.20-0.24 (0), > 0.24 (1), <0.20 (2)

6. Frontal
   a. Anterior end of supraorbital ridge join with lateral part of anterior transverse ridge (0)
   b. Anterior end of supraorbital ridge join with anterior wall of orbital (1)
7. Extention of frontal
   a. Forward extension of frontal covers ethmoid region (0)
   b. Forward extension of frontal not covers ethmoid region (1)
8. Parietal
   a. Parietal crest well developed (0)
   b. Parietal crest less developed or vestigial (1)
9. Epiotic
   a. Bifurcated (0)
   b. Not bifurcated (1)
10. Epiotic
   a. Inner process well developed (2)
   b. Inner process reduced (0)
   c. Inner process absent (1)
11. Pterotic
   a. Two complete articulation (0)
   b. Three complete articulation (3)
   c. One complete articulation (1)
   d. No complete articulation (2)
12. Intercalar
   a. Intercalar projecting downward and not forming the lateral wall of auditory bulla (0)
   b. Intercalar projecting downward and forming the lateral wall of auditory bulla (1)

Table 1 : Ratios of B/A and C/A calculated of the premaxillary of 12 species of sciaenidae.

	A	B	C	B/A	C/A
J. belangerii	1.25-1.90	0.65-0.90	0.30-0.46	0.47-0.52	0.20-0.26
J. glaucus	1.70-1.95	0.75-0.95	0.40-0.42	0.44-0.51	0.21-0.25
J. dussumieri	1.80-2.10	0.68-1.00	0.40-0.47	0.48-0.53	0.23-0.28
J. macrorhynus	2.10-2.84	0.92-1.20	0.45-0.58	0.40-0.45	0.20-0.24
J. sina	1.50-1.81	0.65-0.79	0.53-0.69	0.42-0.44	0.35-0.40
J. vogleri	1.35-2.51	0.62-1.19	0.38-0.61	0.44-0.52	0.24-0.30
O. cuvieri	1.40-2.20	0.63-0.76	0.53-0.78	0.36-0.46	0.34-0.39
O. ruber	1.60-2.60	0.65-0.92	0.50-0.71	0.35-0.41	0.27-0.33
P. diacanthus	1.70-2.15	0.65-0.89	0.29-0.40	0.39-0.44	0.18-0.19
P. aneus	1.68-2.10	0.66-0.90	0.30-0.39	0.40-0.45	0.20-0.23
P. semiluctuosa	2.40-2.71	1.10-1.22	0.62-0.71	0.45-0.47	0.26-0.27
O. biauritus	1.95-2.55	0.78-1.21	0.51-0.85	0.39-0.48	0.29-0.35

A : Length of frontal along dorsal median line
B : Length of anterior median line of frontal
C : Width between right and left supraorbital ridges at the point of intersection of supraorbital and accessory supraorbital ridge.

Table 2 : Ratios of M/L and N/L calculated of the premaxillary of 12 species of sciaenidae.

	L	M	M/L	N	N/L
J. belangerii	0.60-0.90	0.43-0.72	0.68-0.78	0.29-0.43	0.41-0.48
J. glaucus	0.89-1.10	0.75-0.85	0.77-0.90	0.33-0.40	0.34-0.40
J. dussumieri	1.00-1.20	1.05-1.20	0.95-1.00	0.54-0.55	0.46-0.47
J. macrorhynus	0.91-1.32	0.82-1.05	0.38-0.43	0.35-0.51	0.38-0.44
J. sina	1.20-1.57	0.57-0.81	0.47-0.54	0.51-0.75	0.43-0.47
J. vogleri	1.15-2.10	0.55-1.00	0.45-0.53	0.50-0.71	0.43-0.47
O. cuvieri	1.41-2.30	061-1.00	0.39-0.44	0.68-1.11	0.43-0.48
O. ruber	1.35-2.10	0.70-1.12	0.51-0.54	0.53-0.90	0.37-0.42
P. diacanthus	1.31-1.80	0.62-0.80	0.45-0.47	0.55-0.71	0.38-0.42
P. aneus	1.60-1.70	0.72-0.80	0.44-0.49	0.69-0.75	0.42-0.45
P. semiluctuosa	1.89-2.00	1.12-1.18	0.59-0.61	0.90-0.95	0.47-0.48
O. biauritus	1.2-2.5	0.78-1.05	0.40-0.47	0.70-1.10	0.41-0.47

L = Length of the lower margin of the horizontal part of the premaxillary
M = Length of the vertical part of the premaxillary along the ascending process
N = Length from anterior corner of the premaxillary process to posterior tip of the horizontal part of the premaxillary.

13. Intercalar
    a. Intercalar narrowly in contact with bassioccipital (0)
    b. Intercalar broadly in contact with bassioccipital (1)
14. Exoccipital
    a. Exoccipital condyle broadly joined with each other (2)
    b. Exoccipital condyle narrowly joined with each other (0)
    c. Exoccipital condyle completely separated from each other (1)
15. Prevomer
    a. Lateral expansion of prevomer curved (0)
    b. Lateral expansion of prevomer nearly straight (1)
16. Parasphenoid
    a. Horizontal ridge present (0)
    b. Horizontal ridge absent (1)
17. Supraoccipital
    a. Lateral ridge is present on inferior part of Supraoccipital (1)
    b. Lateral ridge is present on superior part of Supraoccipital (2)
    c. Lateral ridge is present on middle part of Supraoccipital (0)
18. Basisphenoid
    a. Present (0)

b. Absent (1)

19. Ethmoid

a. Upper, median, keel-like portion tends to hang forward (0)

b. Upper, median, keel-like portion not tends to hang forward (1)

Jaws

20. Teeth

a. Canine teeth absent (0)

b. Canine teeth present (1)

21. Teeth

a. Lower jaw with uniform band of villiform teeth (0)

b. Lower jaw with differential teeth (2)

c. Teeth differentiated in both jaw (1)

d. Teeth spaced in both jaws (3)

22. Teeth

a. Canine teeth absent (0)

b. Canine teeth present on both jaws (1)

c. Canine teeth present on upper jaw only (2)

23. Maxillary (Figure 3, Table 2)

a. M/L = 0.68-1.00 (0), 0.44-0.54 (1), < 0.44 (2), 0.55-0.62 (3)

24. Maxillary

a. N/L= < 0.44(0), > 0.44(1)

Swimbladder

25. Swimbladder

a. Lateral arborescent tubules present (0)

b. Lateral arborescent tubules absent (1)

26. Swimbladder (FAO,1983)

a. Number of arborescent appendages 10 – 15 pairs (0)

b. Number of arborescent appendages 15-20 pairs (1)

c. Number of arborescent appendages 20-30 pairs (2)

d. Number of arborescent appendages >30 pairs (3)

e. Number of arborescent appendages 2 pairs (4)

27. Swimbladder

a. Swimbladder hammer shaped (0)

b. Swimbladder carrot shaped (1)

Otolith

28. Otolith

a. Sagitta Johnius type (0)

b. Sagitta Otolithes Type (1)

c. Sagitta other type (2)

29. Sagitta

a. Distal end of sulcus tail is expended and deepened as a hollow cone (0)

b. Sulcus tail weakly curved (1)

c. Sulcus tail well curved (2)

30. Sagitta

a. Sagitta notched posteriorly (1)

b. Sagitta is not notched posteriorly (0)

31. Sulcus

a. Distal end of sulcus tail is not circular (0)

b. Distal end of sulcus tail is circular (1)

Morphometric characters (Table 3)

32. Mouth

a. Mouth inferior (0)

b. Mouth sub-terminal/ terminal (1)

33. Snout

a. Snout overhanging lower jaw (0)

b. Snout not overhanging jaw (1)

34. Mental barbel

a. Lower jaw with mental barbel (1)

b. Lower jaw without mental barbel (0)

35. Head length in proportion to the standard length

a. Head length: 24-28% (0), 29-30% (1), 31-34% (2).

36. Snout Length in proportion to the standard length

a. Snout Length: 5-6.5 % (0), 6.5- 7 % (1), < 5% (2), >7% (3).

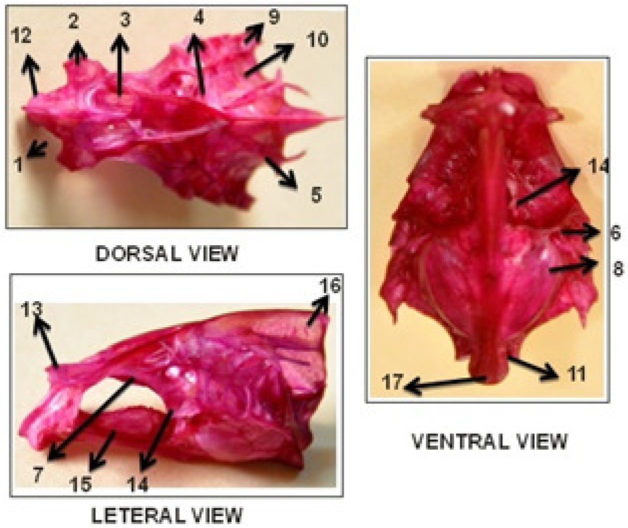
37. Orbit Diameter in proportion to the standard length

a. Orbit Diameter: 6-8% (0), 8-10% (2), <6% (1).

38. Caudal depth in proportion to the standard lengths

a. Caudal depth: 8-10 % (0), 10-12%(1), 10-12%(1), < 8 % (2).

39. Caudal peduncle length in proportion to the standard length



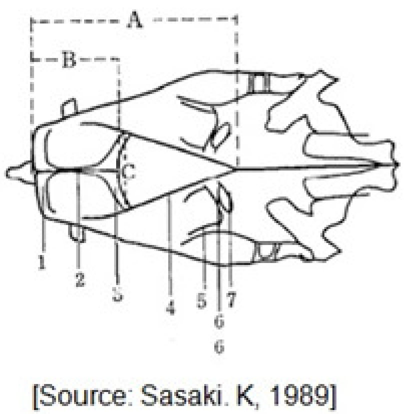
Paired

1. Nasal
2. Lateral ethmoid
3. Frontal
4. Parietal
5. Epiotic
6. Sphenotic
7. Pterosphenoid
8. Prootic
9. Pterotic
10. Intercalar
11. Exoccipital

Unpaired

12. Prevomer
13. Ethmoid
14. Basisphenoid
15. Parasphenoid
16. Supraoccipital
17. Basioccipital

Fig. 2 : General description of neurocranium of sciaenid fishes.



1. Anterior transverse ridge
2. Anterior median line
3. Accessory supraorbital ridge
4. Supraorbital ridge
5. Lateral ridge
6. Posterior transverse ridge
7. Accessory posterior transverse ridge

A: Length of frontal along dorsal median line.
B: Length of anterior median line of frontal.
C: Width between right and left supraorbital ridges at the point of intersection of supraorbital and accessory supraorbital ridge

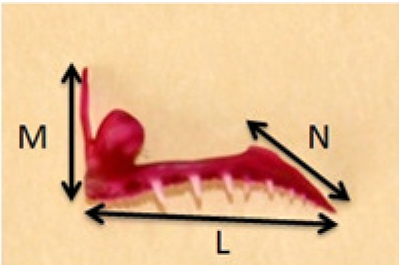
Fig. 2a : Dorsal view of neurocranium showing frontal ridges and parts measured.

a. Caudal peduncle length: 8-10% (0), > 10(1).

40. Cleft Length in proportion with head length
    a. Cleft Length: 30-36% (0), > 36% (1), < 30% (2)
41. Body depth in proportion to the standard length
    a. Body depth: 28-30% (0), <28% (1), > 30% (2)
42. Inter orbital distance in proportion to the standard length
    a. Inter orbital distance: 6-8% (0), 8-10% (1), < 6% (2)
43. Inter orbital in proportion to the head length
    a. Inter orbital distance: 25-30% (0), < 25% (1), > 30% (2)
44. Second anal spine length in proportion to the standard length
    a. Second anal spine length: > 12% (0), 8-12% (1), 6-8% (2), <6% (3)
45. Second anal spine length in proportion to the head length
    a. Second anal spine length: 38-51% (0), 24-38% (1), < 24% (2)
46. Caudal fin shape
    a. Rhomboid (0)
    b. Truncate (1)
    c. Acutely pointed (2)

Meristic characters

46. Gill rakers
    a. No. of gill rakers on lower arm of first arch > 10 (0), < 10 (1)
47. Dorsal fin
    a. No. of dorsal fin soft rays: 28-30 (0), 25-27 (1), < 25(2)

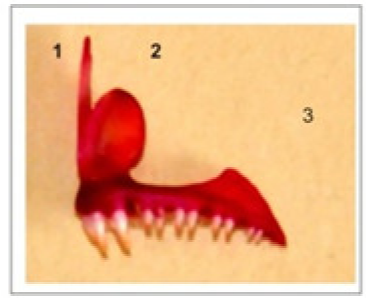


L= Length of the lower margin of the horizontal part of the premaxillary

M= Length of the vertical part of the premaxillary along the ascending process

N= Length from anterior corner of the premaxillary process to posterior tip of the horizontal part of the premaxillary

General description of premaxillary



1. Ascending process
2. Articular process
3. Postmaxillary process

Fig. 3 : Lateral view of premaxillary.

48. Rostral pore (FAO)
    a. No. of rostral pore: 5 (0), 3 (1), absent (2)
49. Marginal pore (FAO)
    a. No. of marginal pore: 5 (0), 3 (1)
50. Mental pore (FAO)
    a. No. of mental pore 5 (0), 3 pairs (1), indistinct (2), 4-6 pairs (3)

The cladistic analysis of the 24 osteological characters produce one most-parsimonious tree with a tree length of 62 steps, Consistency index (CI) = 0.6981 and retension index (RI)=0.6981 (Fig. 4). Within the family Sciaenidae, only one monophyletic group of which each species of genera Johnius was found well separated but closer within the species. Hence these osteological character can be used to separate these species of genera Johnius. The latter clade, genera Johnieops is the first lineage to split off; *Johnieops sina* and *J. vogleri*. The next clade was five genera- Otolithes, Otolithoides, Protonibea, Pennahia and Paranibea; Based on these osteological character *Otolithes cuvieri* was found more closely related with *Otolithoides biauritus* than *Otolithes ruber*; *Protonibea diacanthus* observed more closely related with *Paranibea semiluctuosa* than the *Pennahia aneus*.

Analysis of the full data set of 51 morphometric characters (Osteological, morphometric and meristic) yielded one most-parsimonious tree with a tree length of 124 steps (CI = 0.6855 and RI = 0.7045). The topography of the cladogram is the same as that obtained from the analysis of osteological data alone (Fig. 5). The only difference resulting from the inclusion of morphometric and meristic data was *Otolithes cuvieri* and *Otolithe ruber* was found closer than the *Otolithoides biauritus.*

This particular single cladogram for family Sciaenidae clearly bifurcates into two clades .Clade A includes *Johnius glaucus*, *J. belangerii*, *J. dussumieri*, *J. macrorhynus*, *Johnieops sina* and *J. vogleri*. Monophyly of this branch is supported by 20 synapomorphies: 3(0) frontal projecting downward, 6(0) anterior end of supraorbital ridge join with lateral part of anterior transverse ridge, 12(0) intercalar projecting downward and not forming the lateral wall of auditory bulla, 13(0) intercalar narrowly in contact with bassioccipital, 16(0) horizontal ridge present, 18(0) present, 20(0) canine teeth absent, 22(0) canine teeth absent, 25(0) lateral arborescent tubules present, 27(0) swimbladder hammer shaped, 28(0) sagitta *Johnius* type, 29 (0) distal end of sulcus tail is expended and deepened as a hollow cone, 30 (0) sagitta is not notched posteriorly, 31 (0) distal end of sulcus tail is not circular, 32 (0) mouth inferior, 33 (0) snout overhanging lower jaw, 37 (0) orbit diameter: 6-8%, 39 (0) caudal peduncle length: 8-10%, 46 (0) rhomboid and 50 (0) number of marginal pore 5.

Clade A falls into two sister groups. One group *Johnius* and other group *Johnieops.* The Monophyly of the *Johnieops sina* and *J. vogleri* are supported by 9 synapomorphies: 5 (1) C/A = > 0.24, 7(1) forward extension of frontal do not cover the ethmoid region, 17(1) lateral ridge is present on inferior part of supraoccipital, 19(1) upper, median, keel-like portion not tends to hang forward, 26(1) number of arborescent appendages 15-20 pairs, 35(1) head length: 29-30%, 40(1) cleft Length: > 36%, 41(2) inter orbital distance: < 6% and 51(2) mental pore indistinct.

Johnieops sina and *J. vogleri* are separated by 8 autopomorphies : *Johnieops sina* is supported by 2 autapomorphies: 2(2) it covers less than 2/3rd of the neurocranium, 43(2) inter orbital distance: > 30% and *Johnieops vogleri* is supported by 6 autapomorphies: 9(1) not bifurcated, 10(1) inner process absent, 11(1) one complete articulation, 36(1) snout Length6.5- 7 %, 38(1)

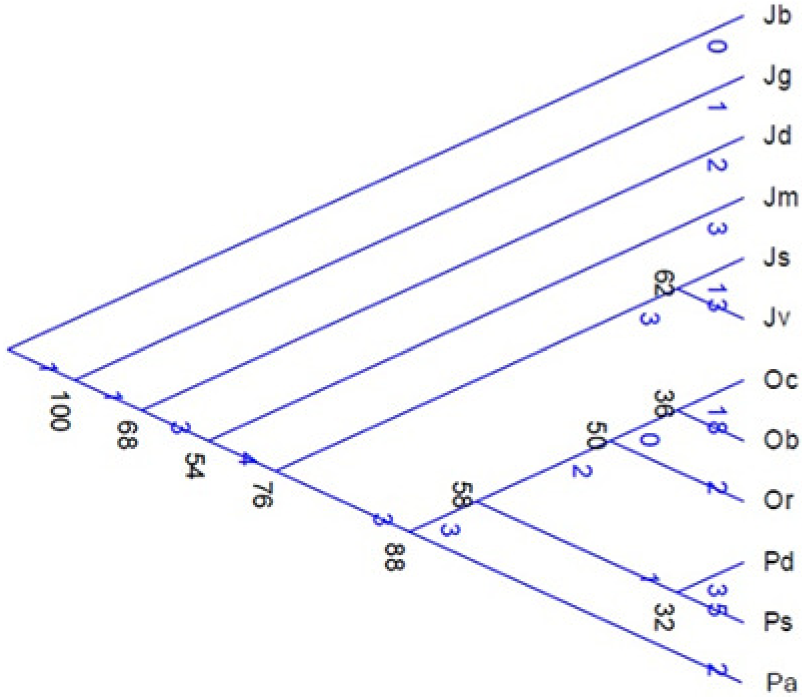


Fig. 4 : A most-parsimonious cladogram obtained from the analysis of 24 osteological data set the branch length are indicated below the each branches; Oc, *Otolithes cuvieri*; Jv, *Johnieops vogleri*; Js, *Johnieops sina*; Ob, *Otolithoides biauritus*; pa, *Pennahia aneus*; Pd, *Protonibea diacanthus*; Ps, *Paranibea semiluctuosa*; Or, *Otolithes ruber*; Jm, *Johnius macrorhynus*; Jb, *Johnius belangerii*; Jd, *Johnius dussumieri*; Jg, *Johnius glaucus.*

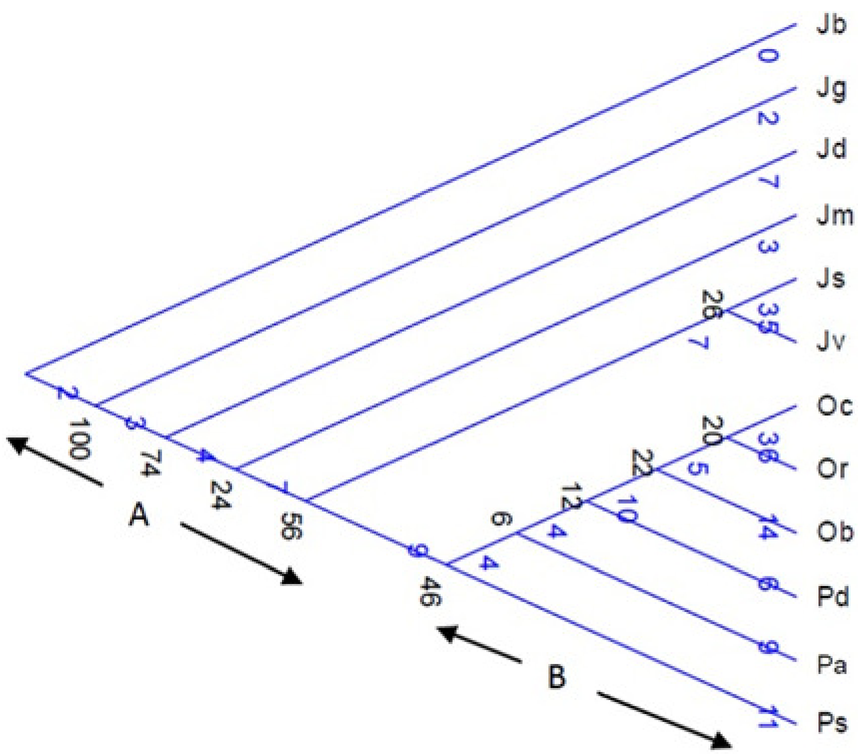


Fig. 5 : A most-parsimonious cladogram obtained from the analysis of complete data set the branch length are indicated below the each branches; Oc, *Otolithes cuvieri*; Jv, *Johnieops vogleri*; Js, *Johnieops sina*; Ob, *Otolithoides biauritus*; pa, *Pennahia aneus*; Pd, *Protonibea diacanthus*; Ps, *Paranibea semiluctuosa*; Or, *Otolithes ruber*; Jm, *Johnius macrorhynus*; Jb, *Johnius belangerii*; Jd, *Johnius dussumieri*; Jg, *Johnius glaucus*.

Table 3 : Proportion (%) of head length, orbit diameter, snout length, caudal depth, caudal peduncle length, body depth, inter orbital distance and second and anal spine length to the standard length or head length for 12 species of Sciaenidae.

Species	% (HL/SL)	% (OD/SL)	% (OD/HL)	% (SNL/SL)	% (CD/SL)	% (CPL/SL)	% (BD/SL)	% (IOD/SL)	% (IOD/HL)	% (IIND ASL/SL)	% (IIND ASL/HL)
Johnius glaucus	24-30	7-8.5	26-32	5-6.5	9-11	8-10	28-31	6-8	25-33	10-13	39-51
J. belangerii	27-30	7-9	25-31	6-7	9-11	7.5-11	28-32	6-8	19-28	11-14	38-52
J. dussumieri	27-32	6-8	21-30	6-9	9-11	9-13	26-30	9-10	27-37	8-11	24-36
J. macrorhynus	26-30	6-8	23-28	6-8	8-11	9-11	26-31	6-8	23-27	6-8	24-31
Johnieops sina	28-32	6-8	21-30	5-7	9-11	8-11	26-32	9-11	30-37	7-10	26-33
J. vogleri	29-32	6-9	21-30	6-8	10-12	8-11	29-33	7-10	23-31	6-11	24-31
Otolithes cuvieri	28-33	6-8.5	22-26	5-7	8-10	8-10	20-31	7-9	23-31	6-7	16-21
O. ruber	27-32	5-7	17-25	5-6	8-9	8-9.5	24-30	6-7	21-29	4-6	16-23
Otolithoides biauritus	26-28	3-5	13-17	3-5	6-8	8-11	19-22	6-9	24-35	5-7	15-21
Protonibea diacanthus	28-31	5-7	18-23	5-7	7-9	8-10	27-32	5-7	16-22	8-10	27-31
Pennahia aneus	31-34	8-10	22-29	7-8	8.8-10	8-10	29-34	9-10	26-30	8-10	24-30
Paranibea semiluctuosa	28-31	6.5-8	21-25	6-7	9.5-10.5	9.5-10.5	29.5-34	6-8	22-24	12-15	43-48

Caudal depth 10-12%, 43(1) inter orbital distance: < 25% and 49(1) No. of rostral pore 3.

The second (*Johnius*) group within the branch A, comprising *J. glaucus*, *J. belangerii*, *J. dussumieri*, *J. macrorhynus* are supported by 4 synapomorphies: 9(0) bifurcated, 10(0) inner process reduced, 38(0) caudal depth: 8-10 %, 49(0) caudal peduncle length: 8-10%. The sister group *Johnius glaucus*, *J. belangerii* and *J. macrorhynus* shares the following 5 characters: 4(0) B/A = 0.41-0.50, 11(0) two complete articulation, 21(0) lower jaw with uniform band of villiform teeth, 34(0) lower jaw without mental barbel, 42(0) interorbital distance: 6-8% In addition to this *Johnius glaucus* and *J. belangerii* both possess: 36(0) snout length: 5-6.5% and 44(0) second anal spine length: > 12%. *Johnius glaucus* has no autapomorphies, whereas *J. belangerii* has 4 autapomorphies: 8(1) parietal crest less developed or vestigial, 24(1) N/L= > 0.44, 43(1) inter orbital distance: < 25%, 47(1) number of gill rakers on lower arm of first arch more than < 10 and *J. macrorhynus* has 5 automorphies: 1(0) nearly straight, 2(0) it covers 2/3rd of the neurocranium, 14(0) exoccipital condyle narrowly joined with each other, 15(0) lateral expansion of prevomer curved and 23(2) M/L = < 0.44.

The sister group *J. dussumieri* shares character with *J. macrorhynus:* 36(1) Snout length: 6.5- 7%. In addition to this *J. dussumieri* possess: 11(1) one complete articulation, 21(1) teeth differentiated in both jaw, 34(1) lower jaw with mental barbel, 42(1) interorbital distance: 8-10%, 43(2) interorbital distance: > 30%, 44(1) second anal spine length: 8-12% and 48(1) No. of dorsal fin soft rays: 25-27.

Clade B comprise of *Otolithes cuvieri*, *O. ruber*, *P. diacanthus*, *P. aneus*, *P. semiluctuosa* and *O. biauritus.* Monophyly of this group supported by 7 synapomorphies: 9(0) bifurcated, 14(2) exoccipital condyle broadly joined with each other, 19(1) upper, median, keel-like portion not tends to hang forward, 27(1) swimbladder carrot shaped, 32(1) mouth sub-terminal/ terminal, 33(1) snout not overhanging jaw and 34(0) lower jaw without mental barbel.

Clade B falls into two sister groups. One group- *O. cuvieri*, *O. ruber*, *P. diacanthus*, *P. aneus*, *P. semiluctuosa* and the other *O. biauritus*–supported by 6 synapomorphies: 12(1) intercalar projecting downward and forming the lateral wall of auditory bulla, 13(1) intercalar broadly in contact with bassioccipital, 16(1) horizontal ridge absent, 18(1) absent, 25(1) lateral arborescent tubules absent and 39(1) caudal peduncle length: > 10.

Table 4 : Data set for the twelve taxa (Sciaenidae) analyzed. The number of each character (1-55) mentioned above.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
J. glaucus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J. belangerii	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
J. dussumieri	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0
J. macrorhynus	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2	0	0
J. sina	0	2	0	0	1	0	1	0	0	0	2	0	0	1	0	0	1	0	1	• 0	1	0	1	1	0
J. vogleri	0	0	0	0	1	0	1	0	1	1	1	0	0	1	0	0	1	0	1	0	1	0	1	1	0
O. cuvieri	0	2	0	2	1	0	1	0	0	2	0	0	0	2	1	0	2	0	1	1	1	1	2	1	0
O. ruber	1	2	1	2	1	0	1	0	0	2	0	0	0	2	1	0	2	0	1	1	1	1	2	0	0
O. biaurites	1	2	0	0	1	0	1	1	0	2	0	1	1	2	1	1	2	1	1	1	3	2	2	1	1
P. diacanthus	1	2	0	2	2	0	1	0	0	2	3	0	0	2	1	0	0	0	1	0	1	0	2	0	0
P. aneus	0	1	0	2	1	0	1	0	0	2	0	0	0	2	1	0	0	0	1	0	2	0	1	1	0
P. semiluctuosa	1	1	0	0	1	1	1	0	0	2	3	0	0	2	1	0	2	0	1	0	0	0	3	1	0

Table 4 continued...

Species	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
J. glaucus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
J. belangerii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
J. dussumieri	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	2	1	1	0	1	1	0	0	0
J. macrorhynus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	1	0	1	0	0	0	0
J. sina	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2	1	2	1	1	0	0	0	0	0	1
J. vogleri	1	0	0	0	0	0	0	0	0	1	1	0	1	0	1	2	1	0	1	1	0	0	0	1	0	1
O. cuvieri	2	1	1	1	0	1	1	1	0	0	0	0	0	0	2	1	0	0	2	2	0	0	0	2	0	2
O. ruber	3	1	1	1	0	1	1	1	0	1	0	1	0	0	2	1	0	0	3	2	0	0	1	2	1	2
O. biaurites	4	1	2	1	0	1	1	1	0	0	2	1	2	1	2	1	0	2	3	2	2	1	0	1	0	3
P. diacanthus	1	1	2	1	0	0	1	1	0	1	0	0	2	0	0	1	2	1	1	1	0	1	1	1	0	3
P. aneus	1	1	2	1	0	0	1	1	0	2	3	2	0	0	2	2	1	0	1	1	1	0	1	2	0	3
P. semiluctuosa	1	1	2	2	1	0	1	1	0	1	1	0	0	0	2	2	0	1	0	0	0	1	0	0	0	0

The first group within the branch B has two sister groups. Sub-group one – *O. cuvieri*, *O. ruber*, *P. diacanthus*, *P. aneus* and other *P. semiluctuosa*- supported by 4 synapomorphies: 4(2) B/A = < 0.41, 6(0) anterior end of supraorbital ridge join with lateral part of anterior transverse ridge, 29(1) sulcus tail weakly curved and 30(0) sagitta is not notched posteriorly.

The monophyly of genera *Otolithes* has two species *O. cuvieri* and *O. ruber*- supported by 6 synapomorphies: 2(2) it covers less than 2/3rd of the neurocranium, 22(1) canine teeth present on both jaws, 28(1) sagitta otolithes Type, 31(1) distal end of sulcus tail is circular, 45(0) second anal spine length: 38-51% and 51(2) mental pore indistinct. *Otolithes ruber* supported by 8 autapomorphies: 1(1) nearly straight, 3(1) frontal nearly straight, 26(3) number of arborescent appendages >30 pairs, 35(1) head length: 29-30%, 37(1) orbit diameter: <6%, 44(3) second anal spine length: <6%, 48(1) No. of dorsal fin soft rays: 25-27 and 50(1) number of mental pore 3 pairs.

The Monophyly of *P. diacanthus* and *P. aneus* is supported by 5 characters: 3(0) frontal projecting downward, 28(2) sagitta other type, 45(1) second anal spine length: 24-38%, 48(1) number of dorsal fin soft rays: 25-27 and 51(3) Indistinct mental pore 4-6 pairs. *P. aneus* supported by 13 autapomorphies: 1(0) gently curved outward, 2(1) it covers more than 2/3rd of the neurocranium, 5(1) C/A = > 0.24, 11(0) two complete articulation, 21(2) canine teeth present on upper jaw only, 24(1) N/L= > 0.44, 25(1) lateral arborescent tubules absent, 35(2) Head length: 31-34%, 36(3) snout Length: >7% (3), 37(2) orbit diameter: 8-10%, 38(0) caudal depth: 8-10%, 40(2) cleft Length: < 30% and 41(2) interorbital distance: < 6%.

DISCUSSION

Present study revealed that the 24 osteological characters are interspecifically distinct in the shape of the frontal, parasphenoid, basisphenoid and intercalar, as well as minor variation in other characters. Sasaki (1989) worked on 70 species from Indo-Pacific Ocean and reported that the frontal bone is projecting downward and associated with the lateral ethmoid and parasphenoid in *Johnius* and *Johnieops,* hence both the genera have closely related species. However, this character is possibly related to their inferior mouth and feeding habit. Carnivorous and benthic habitat is confirmed by the evidence of polychaetes, gastropod shells, sand grains and mud in the stomach (Suseelan and Nair 1969). Studies on the other sciaenid species indicated similar interspecific relationship (Taniguchi 1969; Sasaki, 1989). Kim and Kim (1965) worked on 7 species of Sciaenidae and reported frontal, basisphenoid, parasphenoid and supraoccipital bone were helpful to locate the intraspecific variation of the species, whereas Sasaki (1989) reported that in most of sciaenids, the basisphenoid is articulated with parasphenoid ventrally, with a ridge. He also stated that in genus *Otolithoides,* the absence of basiphenoid bone separates *Otolithoides* from *Johnius* and *Johnieops.* The observation made by these workers is compatible to the present study with substantial significance. The intercalar bone projecting downward and connects with the basioccipital bone in most of the sciaenids (Sasaki, 1989). In the present study also, similar result was observed in sciaenids except in *Pennahia aneus*, hence the species is separated, with these monophyletic characters from the rest of the species studies. Similar observation was made by Taniguchi (1969). Exoccipital condyle was found to be completely separated from each other in *Johnieops sina* and *Johnius macrorhynus* while narrowly joined in other species of *Johnius;* therefore, the characteristics of exoccipital condyle is synapomorphic character (Sasaki, 1989). The presence of canine teeth in *Otolithes* and *Otolithoides,* and absence in the other species are related to their feeding pattern. Jacob (1948) and Chacko (1949) reported that the fish is carnivorous and predacious, at surface and midwaters, feeding with help of its conspicuous canines.

Kim and Kim (1965) described the characteristics of jaw bone (pre-maxillaries) and compared for the same from seven species of sciaenids based on the angle formed by the ascending process and the horizontal bar. Taniguchi (1970) described premaxillary bone of 16 species of Japanese sciaenid fishes and reported phylogenetic significance in relation to other cranial characters. In their interspecific relationship of sciaenid fishes, neurocranium has been found to be more important than the premaxillary, on account of comparatively lower variations in the characteristics of premaxillary bone among these 12 species.

Chu *et al* (1963) reported the sagitta and gasbladder of 37 sciaenid fishes and described four types of sagitta and five types of gas bladder; however, they found significant uses of the characters of the gas bladder than in the sagitta. Sasaki (1989) also confirmed importance of the structure of otolith and swimbladder in the phylogeny of family Sciaenidae. Mohan (1984, 1991) worked extensively on classification of sciaenids found in Indian Ocean based on based swimbladder and otoliths, and cleared some of ambiguity in differentiation of sciaenid species. Otolith morphology was used as a species level character in systematics (Pawan *et al*, 2012).

The contribution of Chu *et al* (1963), Talwar (1970), Mohan (1972, 1976, 1982, 1984), Druzhinin (1974), Trewavas (1977) and Sasaki (1989) on the systematic and taxonomy of Indian Ocean sciaenids have established a base for the phylogenetic relationship among the species of family Sciaenidae. The proportion of eye diameter with respect to standard length of the *Pennahia aneus* was observed to be highest among the studied species, which is possibly related to feeding habit. Rao (1980) have confirmed that *Pennahia aneus* feeds mainly on the pelagic and mid water fishes by sight because, they found very few item of the fishes in the stomach content. Caudal depth, in proportion to standard length, was found to be very less for *Otolithoides* and *Protonibea* due to their less swimming speed (Sambilay, 1990) and feeding habit, feeding mainly on crustaceans (Jayaprakash, 1974).

The meristic characters such as number of gill rakers present on lower limb of first arch and number of soft rays present on second dorsal fin are of taxonomic interest (Trewavas, 1977; Fisher and Bianchi, 1984). In *Otolithes cuvieri*, comparatively higher number of gillrakers was recorded than *Johnius* spp. Sandhya *et al* (2014) reported *Otolithes cuvieri* to feed on wide range of food, mainly teleost and prawns, while polychaetes, gastropod shells, sand grains and mud were preffered by *Johnius* sp. Hence these characters are very important in the establishment of phylogenetic relationship among the species of family Sciaenidae.

CONCLUSION

Taxonomy and phylogenetic studies of species Scienidae family have been analysed based variations in swimmbladder to establish its evolutionary grouping and later Otolith morphometry. In the present study, we have included all variations morphometric, meristic, otoliths, swimbladder and most variable bony parts such as neurocranium and premaxillary for establishing the evolutionary relationship of the species found in the North West Coast of Indian waters. Consequently, an overall view of sciaenid phylogenetic and evolutionary relation of all Indian and adjacent countries are yet to be established. The study will be very useful for taxonomist and fisheries biologist.

ACKNOWLEDGEMENT

The authors are thankful to Dr. W. S. Lakra, Director, CIFE, Mumbai for providing necessary facilities for carrying out the research work. The first author acknowledges the financial assistance provided in form of fellowship by Indian council of Agricultural Research, New Delhi, India.

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