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# Note

# Morphological differentiation of catfishes of the family Ariidae occurring along the west coast of India

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## ABSTRACT

Analysis of morphometric and meristic traits of twelve species of ariid catfishes occurring along the west coast of India indicated that these species can be differentiated based on morphological characteristics. Higher F-ratio for inter-nostril length, mouth width and adipose fin length signifies their role in species separation either alone or in combination with other morphometric characters. Stepwise discriminant function analysis (SDFA) included all considered variables showing their taxonomic significance with inter-nostril length, snout length and adipose fin length, as the most important discriminating characters. The first two discriminant functions accounted for the explanation of 89.44% of total variation. SDFA gives correct classification in 99.55% cases with only two misclassified cases among 447 specimens. Meristic features were found to be overlapping except in few instances and hence are less discriminating than morphometric variables.

Keywords: Ariidae, Meristics, Morphometry, Stepwise discriminant function analysis, Taxonomy

Marine catfishes especially species of the family Ariidae form important component of demersal fish landings in India with a contribution of 68675 t in 2014 (CMFRI, 2015). Family Ariidae was originally described as Arii (Bleeker, 1862) which was hypothesised to be primitive (Regan, 1911). Ariidae is arguably the most poorly resolved family among catfishes in phylogenetic terms and hence attempts were made to establish sound species classification based on phylogenetic studies (Kailola, 2004; Acero, 2004; Acero *et al.*, 2007; Marceniuk and Menezes, 2007; Marceniuk *et al.*, 2012). The number of valid ariid species is uncertain and estimates range from 120-200 (Teugels, 2003; Kailola, 2004; Acero *et al.*, 2007). The family is reported to have 26 valid genera and 133 valid species including fossil taxa (Ferraris, 2007; Marceniuk and Menezes, 2007). As per the online database, Catalog of Fishes, there are 145 valid species in the family, with 9 species described in the last 10 years (Eschmeyer and Fong, 2015). A detailed description of 27 species of ariid catfishes from the Indian sub-continent was given by Day (1889). Menon and Bande (1987) gave field identification characters of 21 ariid catfishes from Indian waters along with their distribution. As of now, ariids are represented by 9 genera and 25 valid species in Indian waters, with the validity of certain species like *Arius malabaricus* and *Arius gagora* and presence of *Plicofollis nella* and *Plicofollis argyropleuron* being doubtful in Indian waters.

Ariid catfishes are mostly distributed in coastal waters with some species preferring deeper waters and a few are reported from freshwater ecosystems. The significant species diversity and declining abundance of the group, due to human interference, warrants immediate management measures that requires sound taxonomic footings to begin with. In this context, taxonomic works related to ariid catfishes, carried out so far, revolved around features like fin rays counts, head shield pattern, vomerine and palatine teeth patch shape and number of barbels and their length (Bleeker, 1858; Gunther, 1864; Day, 1889; Weber and de Beaufort, 1913; Jayaram, 1977; Rao *et al*., 1977; Jayaram and Dhanze, 1978, 1981a, b; Dhanze and Jayaram 1979, 1983; Menon *et al.*, 1982; Kailola, 1999).

Meristic characters correspond to any countable feature of a taxon *viz.*, number of fin rays, gill rakers, lateral line scales and so on. These characters are very easy to record, define and compare between taxa. These characters, being discrete in features, are recorded with absolute precision. Statistical computation and interpretation in these cases are simple and direct, respectively. Morphometric measurements on the other hand, being a continuous feature can be recorded only with variable degree of precision. Analysis of

morphometric characters is not as direct as in the case of meristic characters, as the phenomenon of allometry is not uncommon. But size compensated morphometric variables (variables after allometric correction) could find possible application in species differentiation even in groups with pronounced allometry like catfishes. Most of the taxonomic works on ariid catfishes intensively explored meristic characters, whereas, similar stress was not given to morphometric features. Researchers from other countries have tried to differentiate ariid catfishes based on morphometric characters (Al-Hassan *et al*., 1988; Singh *et al.*, 2003; Dan *et al.,* 2005a, b). But similar works of species differentiation based on morphometric characters have not been attempted from Indian waters, barring the work of Dhanze and Jayaram (1982), who separated out 4 species of closely resembling maculates complex based on selected morphometric variables. Considering this void in catfish taxonomy from Indian waters, the present work is an attempt to differentiate ariid catfishes occurring along the west coast of India based on morphological features, with special emphasis on morphometric variables. In addition, an attempt was also made to prepare a key based on few morphological features for rapid field identification of ariid catfishes occurring along the west coast of India.

Commercial fish landing centres of Maharashtra, Karnataka and Kerala *viz*., Sassoon Dock, New Ferry Wharf, Versova, Mirkarwada (Maharashtra), Malpe, Mulki and Bandar in Mangalore (Karnataka), Thoppumpady and Munambam in Kerala as well as small fish markets in Kochi and Mumbai were explored to collect specimens of catfishes representing family Ariidae from August 2013 to May 2014. During the period, 16 species belonging to six genera were recorded. Since *Arius arius* (Hamilton, 1822), *A. sumatranus* (Anon. [Bennet], 1830), *A. venosus* Valenciennes, 1840 and *Sciades sona* (Hamilton, 1822) were collected in very few numbers, they were not included in statistical analyses. Remaining twelve species were represented in sufficient numbers. 28 nos. of *Netuma bilineata* (Valenciennes, 1840), 15 *N. thalassina* (Ruppell, 1837), 32 *Plicofollis platystomus* (Day, 1877), 40 *P. dussumieri* (Valenciennes, 1840), 80 *P. tenuispinis* (Day, 1877), 30 *P. tonggol* (Bleeker, 1846), 20 *Arius subrostratus* Valenciennes, 1840, 54 *A. maculatus* (Thunberg, 1792), 15 *A. jella* Day, 1877, 46 *Nemapteryx caelata* (Valenciennes, 1840), 30 *N. macronotacantha* (Bleeker, 1846) and 51 *Osteogeneiosus militaris* (Linnaeus, 1758) were collected for the study. A total of 13 morphometric measurements *viz.,* Standard length, SL (1); Pre-dorsal fin length, PDFL (2); Pre-adipose fin length, PAFL (3); Pre-pectoral fin length, PPCL (4); Pre-pelvic fin length, PPL (5); Pre-anal fin length, PAL (6); dorsal fin length, DFL (7); Adipose fin length, AFL (8); Head length, HL (9); Mouth width, MW (10); Snout length, SNL (11); Pre-nostril length, PNL (12); and Inter-nostril length, INL (13); were recorded to the nearest of 0.01mm (Fig. 1). Eight morphometric variables were scaled to SL and four were scaled to HL. Means of the twelve morphometric ratios were compared for differentiation of species. Multivariate analysis was performed based on twelve morphometric variables which were log transformed and corrected for allometry using the equation given by Claytor and MacCrimmon (1987).

$$AC_i = Log\ (OC_i) - [\beta * (Log\ SL_i - Log\ MSL)]$$

where, $AC_i$ = Adjusted value, $OC_i$ = Observed value, $\beta$ = within group regression slopes, $SL_i$ = Standard length and MSL= Overall mean standard length.

The transformed variables were subjected to forward stepwise discriminant function analysis (FSDFA).

Morphological characters like number of teeth patches, shape of teeth patches, type of teeth, barbels, and median longitudinal groove were used to generate a field identification key.

Numbers of rays on dorsal, pectoral, pelvic, anal and caudal fin and gill rakers on first gill arch were recorded. The rays on dorsal, pelvic and caudal fins were found to

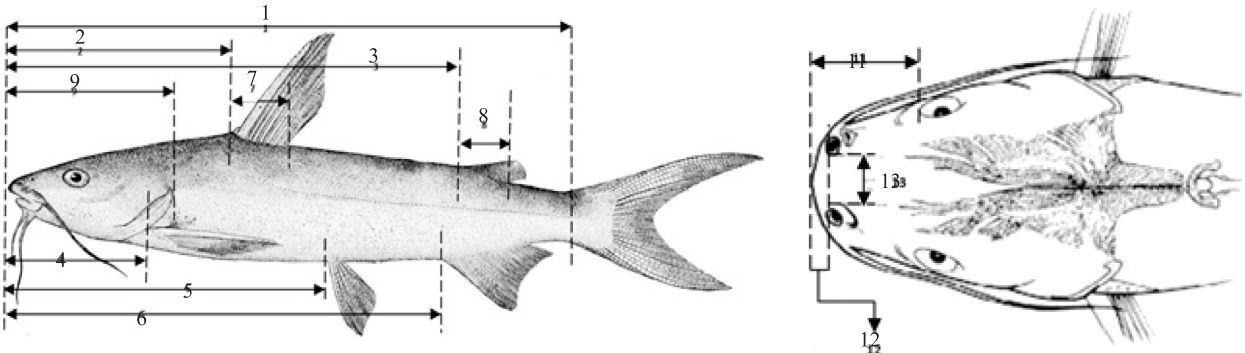


Fig. 1. Morphometric characters of ariid catfishes. 1: SL, 2: PDFL, 3: PAFL, 4: PPCL, 5: PPL, 6: PAL, 7: DFL, 8: AFL, 9: HL, 10: MW, 11: SNL, 12: PNL, 13: INL

be consistent throughout the family and hence were not included in statistical analysis. A descriptive analysis of remaining meristic characters was carried out to find the presence of differentiating traits among the species. All statistical analyses were performed using statistical software package "Statistica".

All the 12 morphometric ratios showed significant difference between species (Table 1) which may find application in species differentiation. Several morphometric variables like inter-nostril length, snout length, pre-dorsal length, head length and pre-anal length were used in earlier studies (Dhanze and Jayaram, 1982; Singh *et al*., 2003; Dan *et al.*, 2005a, b) for differentiating species of the family. Relatively higher F-ratio of more than 200 was recorded for AFL/SL, MW/HL and INL/HL, emphasising strong discriminating power of these characters.

Members of genus *Netuma* can be separated from rest of the species based on shorter adipose fin length (AFL/SL<0.05). *N. thalassina* can be easily separated from *N. bilineata* in having longer pre-nostril length and comparatively shorter adipose fin. No single morphometric character in consideration was found to be sufficient to separate the entire genus *Plicofollis* from the rest of the members of the family. Different members of the genus *Plicofollis* can be differentiated from each other by the combination of INL/HL and MW/HL. *P. platystomus* has significantly longer adipose fin and wide mouth than the rest of the species. *P. tenuispinis* and *P. tonggol* showed significantly smaller mouth width than the other two members.

*Arius subrostratus* can be separated from rest of the ariid species based on very small mouth width and smaller inter-nostril length. *A. maculatus* and *A. jella* closely resemble each other in morphometric terms but in *A. jella* fins are inserted relatively posteriorly as evident by higher values of PDFL/SL, PAFL/SL, PPL/SL and PAL/SL. In addition, the proportion of head length to standard length was also found to be higher in case of *A. jella*. Genus *Nemapteryx* can be easily separated from rest of the ariid catfishes based on the presence of longer adipose fin, wider mouth and widely separated nostrils. The two species, *N. caelata* and *N. macronotacantha* closely resemble each other both in external appearance and morphometric measurements except having relatively widely placed nostrils in *N. caelata* which distinguishes it from *N. macronotacantha*. *O. militaris* can be easily distinguished from the rest of the species by using combination of longer adipose fin and narrow inter-nostril length. This species can also be easily identified based on the presence of only one pair of stiff maxillary barbels.

Table 1. Means of morphometric proportions of twelve species of ariid catfishes occurring along the west coast of India

| Variable | | a | b | c | d | e | f | g | h | i | j | k | l | F-ratio | P-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PDFL/SL | Mean | 0.371 | 0.412 | 0.392 | 0.412 | 0.432 | 0.433 | 0.429 | 0.377 | 0.416 | 0.381 | 0.366 | 0.386 | 181.00 | <0.01 |
| | St. dev. | 0.009 | 0.004 | 0.008 | 0.014 | 0.012 | 0.007 | 0.008 | 0.012 | 0.012 | 0.010 | 0.015 | 0.011 | | |
| PAFL/SL | Mean | 0.850 | 0.866 | 0.836 | 0.855 | 0.857 | 0.853 | 0.846 | 0.824 | 0.826 | 0.803 | 0.760 | 0.796 | 147.23 | <0.01 |
| | St. dev. | 0.009 | 0.013 | 0.013 | 0.015 | 0.018 | 0.013 | 0.006 | 0.015 | 0.012 | 0.013 | 0.022 | 0.014 | | |
| PPCL/SL | Mean | 0.230 | 0.249 | 0.272 | 0.258 | 0.292 | 0.268 | 0.273 | 0.240 | 0.273 | 0.235 | 0.227 | 0.237 | 143.27 | <0.01 |
| | St. dev. | 0.006 | 0.008 | 0.012 | 0.013 | 0.015 | 0.005 | 0.006 | 0.014 | 0.016 | 0.012 | 0.011 | 0.010 | | |
| PPL/SL | Mean | 0.612 | 0.633 | 0.595 | 0.621 | 0.618 | 0.596 | 0.604 | 0.590 | 0.611 | 0.596 | 0.584 | 0.540 | 88.91 | <0.01 |
| | St. dev. | 0.013 | 0.012 | 0.015 | 0.013 | 0.015 | 0.010 | 0.005 | 0.013 | 0.015 | 0.023 | 0.026 | 0.016 | | |
| PAL/SL | Mean | 0.794 | 0.807 | 0.775 | 0.801 | 0.796 | 0.775 | 0.780 | 0.768 | 0.777 | 0.765 | 0.732 | 0.729 | 99.27 | <0.01 |
| | St. dev. | 0.008 | 0.011 | 0.014 | 0.015 | 0.016 | 0.013 | 0.007 | 0.019 | 0.010 | 0.015 | 0.024 | 0.013 | | |
| DFL/SL | Mean | 0.113 | 0.123 | 0.131 | 0.118 | 0.104 | 0.101 | 0.108 | 0.117 | 0.114 | 0.126 | 0.120 | 0.104 | 91.52 | <0.01 |
| | St. dev. | 0.006 | 0.005 | 0.005 | 0.006 | 0.005 | 0.005 | 0.005 | 0.007 | 0.006 | 0.009 | 0.007 | 0.005 | | |
| AFL/SL | Mean | 0.049 | 0.041 | 0.096 | 0.056 | 0.053 | 0.052 | 0.065 | 0.075 | 0.067 | 0.093 | 0.104 | 0.091 | 242.22 | <0.01 |
| | St. dev. | 0.004 | 0.002 | 0.007 | 0.011 | 0.007 | 0.003 | 0.004 | 0.016 | 0.005 | 0.009 | 0.012 | 0.010 | | |
| HL/SL | Mean | 0.293 | 0.322 | 0.350 | 0.322 | 0.347 | 0.343 | 0.346 | 0.309 | 0.340 | 0.311 | 0.290 | 0.290 | 165.52 | <0.01 |
| | St. dev. | 0.007 | 0.014 | 0.017 | 0.010 | 0.011 | 0.006 | 0.009 | 0.013 | 0.008 | 0.013 | 0.009 | 0.010 | | |
| MW/HL | Mean | 0.434 | 0.426 | 0.449 | 0.380 | 0.327 | 0.297 | 0.291 | 0.385 | 0.370 | 0.515 | 0.523 | 0.402 | 471.64 | <0.01 |
| | St. dev. | 0.014 | 0.006 | 0.022 | 0.022 | 0.015 | 0.006 | 0.009 | 0.023 | 0.022 | 0.027 | 0.031 | 0.022 | | |
| SNL/HL | Mean | 0.294 | 0.347 | 0.318 | 0.354 | 0.359 | 0.365 | 0.439 | 0.342 | 0.368 | 0.297 | 0.297 | 0.305 | 100.31 | <0.01 |
| | St. dev. | 0.022 | 0.007 | 0.013 | 0.030 | 0.023 | 0.005 | 0.012 | 0.025 | 0.020 | 0.024 | 0.030 | 0.015 | | |
| PNL/HL | Mean | 0.048 | 0.088 | 0.064 | 0.050 | 0.056 | 0.062 | 0.073 | 0.055 | 0.052 | 0.043 | 0.039 | 0.039 | 137.00 | <0.01 |
| | St. dev. | 0.005 | 0.003 | 0.002 | 0.009 | 0.007 | 0.002 | 0.003 | 0.003 | 0.002 | 0.005 | 0.006 | 0.005 | | |
| INL/HL | Mean | 0.278 | 0.287 | 0.233 | 0.195 | 0.154 | 0.132 | 0.116 | 0.171 | 0.187 | 0.283 | 0.228 | 0.107 | 686.86 | <0.01 |
| | St. dev. | 0.008 | 0.014 | 0.010 | 0.017 | 0.016 | 0.002 | 0.005 | 0.013 | 0.010 | 0.015 | 0.027 | 0.006 | | |

(a) *N. bilineata*, (b) *N. thalassina*, (c) *P. platystomus*, (d) *P. dussumieri*, (e) *P. tenuispinis*, (f) *P. tonggol*, (g) *A. subrostratus*, (h) *A. maculatus*, (i) *A. jella*, (j) *N. caelata*, (k) *N. macronotacantha*, (l) *O. militaris*

Forward stepwise discriminant function analysis (FSDFA) showed that the morphometric measurements considered are useful in discrimination of the ariid catfishes. All the considered morphometric variables are included in the model with INL entering first followed by SNL, AFL, PNL, PDFL, HL, MW, PPL, PPCL, DFL, PAFL and PAL. Eleven discriminant functions (roots) were generated with first two roots accounting for the explanation of 89.44% of the total variation. The means of canonical variables explains the sufficiency of Root 1 and Root 2 in separation of the species (Table 2). The mean values of different species for Root 1 are quite distinct from each other, enabling clear discrimination between most of the species. Root 2 also clearly separates out *O. militaris, N. thalassina* and *P. platystomus*.

The scatter plot of the canonical scores of all the specimens for Root 1 and Root 2 shows clear demarcation between the species in the form of separate clusters with only few instances of overlaps between members of different species (Fig. 2). The factor structure matrix showed higher contribution of INL and MW to Root 1 and INL, AFL and PNL to Root 2 emphasising their significance in separating the different species (Table 3).

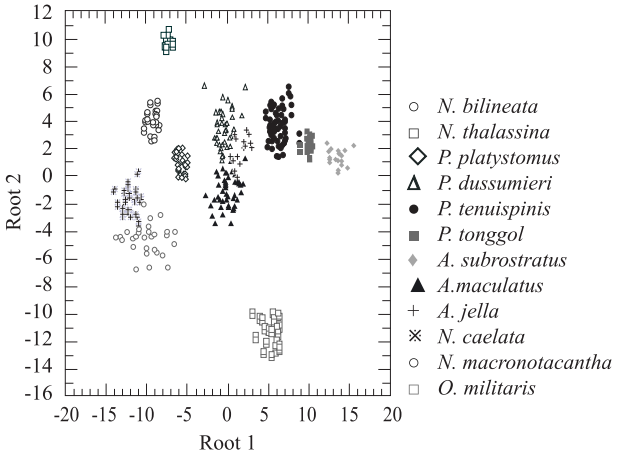


Fig. 2. Scatter plots of canonical scores for Root 1 and Root 2 of the morphometric variables of twelve ariid species

The squared Mahalanobis distance (Table 4) shows close morphometric resemblance between the members of genus *Nemapteryx*. *N. bilineata* and *N. thalassina* are relatively easily separable from each other, supported by the moderately higher values of squared Mahalanobis distance. *A. jella* and *A. maculatus* also showed significant morphometric similarity. Among the members of genus *Plicofollis*, *P. tenuispinis* and *P. tonggol* are relatively similar to each other whereas the other pairwise comparison showed marked difference between species. *A. subrostratus* was found to be significantly distinct from other species except *P. tenuispinis* and *P. tonggol* with which it shows morphometric similarity.

The classification matrix generated by FSDFA successfully classifies the specimens in 99.55% cases, with only 2 instances of misclassification. One misclassification was observed in case of *A. jella* which is predicted as *A. maculatus* by the model and second was reported in case of *N. macronotacantha* which was predicted as *N. caelata*. The satisfactorily correct classifications of specimens by the model highlights the importance of morphometric variables considered in this study, in differentiating the species of family Ariidae.

The meristic features showed overlapping ranges (Table 5) among the different species and were found to have less discriminating power than morphometric variables barring few cases. *N. thalassina* have fewer counts of anal fin rays and gill rakers than *N. bilineata*. Among species of genus *Plicofollis,* lesser number of anal fin rays was recorded for *P. dussumieri* whereas, *P. tonggol* possess fewer number of gill rakers on first gill arch than other members of the genus. Members of genus *Arius* showed overlapping values for meristic characters with an exception of *A. subrostratus* which has more number of gill rakers on first gill arch than rest of the members of the family, considered in the study. There was nothing to discriminate between *N. caelata* and *N. macronotacantha*

Table 2. Means of canonical variables of the twelve species of ariid catfishes

| Species | Root 1 | Root 2 | Root 3 | Root 4 | Root 5 | Root 6 | Root 7 | Root 8 | Root 9 | Root 10 | Root 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *N. bilineata* | -9.2388 | 4.0754 | 4.31567 | -1.47155 | -1.48781 | 0.46844 | -0.29160 | 0.736488 | 0.06691 | 0.122750 | -0.070495 |
| *N. thalassina* | -7.3043 | 9.7509 | 2.59649 | -0.56910 | 3.66615 | 2.10717 | 1.07573 | -0.451828 | 0.30022 | -0.064526 | 0.007460 |
| *P. platystomus* | -5.6913 | 0.8065 | -5.53185 | -0.69538 | -0.55042 | 1.62903 | -0.14276 | 0.053309 | -0.71639 | 0.021776 | -0.011102 |
| *P. dussumieri* | -0.3772 | 3.5474 | 1.71949 | 0.03496 | 0.17170 | -1.12819 | -0.44284 | -0.242925 | -1.23581 | -0.114860 | 0.017141 |
| *P. tenuispinis* | 6.1938 | 3.6394 | 0.10325 | 1.44505 | -0.61634 | 0.14815 | 0.39909 | -0.492232 | 0.13438 | 0.072760 | 0.005841 |
| *P. tonggol* | 10.0359 | 2.2874 | 0.11114 | -0.04405 | -0.25142 | 0.62428 | -0.67551 | 1.635638 | 0.37251 | -0.144140 | 0.071124 |
| *A. subrostratus* | 13.6004 | 1.3795 | -2.39082 | -1.71816 | 1.87962 | -1.61789 | 0.10535 | 0.821154 | -0.11126 | 0.252858 | -0.052676 |
| *A. maculatus* | -0.0708 | -1.0644 | -0.47034 | -2.33307 | -0.45005 | -0.50408 | 0.03972 | -0.825613 | 0.50887 | -0.051696 | 0.034528 |
| *A. jella* | 1.6837 | 1.9123 | -2.28881 | 1.15600 | 0.12406 | -0.70548 | -0.44433 | -0.087432 | 0.72549 | -0.339004 | -0.176519 |
| *N. caelata* | -11.9249 | -1.9401 | -0.69910 | 1.37086 | 0.63389 | -0.61220 | -1.37748 | 0.046264 | 0.38516 | 0.075848 | 0.027002 |
| *N. macronotacantha* | -9.6542 | -4.6495 | -0.53524 | 0.64996 | -0.17854 | -0.89110 | 2.49928 | 0.800912 | -0.00001 | -0.042263 | 0.015950 |
| *O. militaris* | 5.4207 | -11.3678 | 1.80398 | 0.15865 | 0.37268 | 0.82078 | -0.17542 | -0.181457 | -0.20794 | 0.001837 | -0.019378 |

Table 3. Factor structure matrix for the twelve species of ariid catfishes (Pooled within group correlations)

| Variable | Root 1 | Root 2 | Root 3 | Root 4 | Root 5 | Root 6 | Root 7 | Root 8 | Root 9 | Root 10 | Root 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| INL | -0.571398 | 0.594156 | -0.370126 | 0.291242 | -0.064953 | -0.015419 | -0.106837 | 0.074183 | 0.052501 | -0.026152 | 0.127210 |
| SNL | 0.234205 | 0.296261 | -0.453511 | 0.081460 | 0.106578 | -0.603905 | 0.218465 | 0.058157 | -0.105605 | 0.146331 | -0.162052 |
| AFL | -0.136297 | -0.408822 | -0.566238 | -0.033957 | 0.020183 | -0.034005 | -0.031123 | -0.105248 | 0.116140 | 0.325890 | 0.559641 |
| PNL | 0.135611 | 0.356859 | -0.519869 | -0.425244 | 0.389920 | 0.427342 | 0.075823 | 0.115149 | 0.114506 | 0.121771 | -0.025805 |
| PDFL | 0.223799 | 0.258135 | -0.059470 | 0.603712 | 0.329934 | 0.094631 | -0.229238 | 0.031703 | -0.406209 | 0.271901 | 0.307728 |
| HL | 0.144930 | 0.251737 | -0.542641 | 0.331086 | -0.397752 | 0.069235 | -0.139399 | 0.028508 | -0.258299 | 0.364867 | 0.001654 |
| MW | -0.348653 | -0.089951 | -0.394604 | 0.313700 | 0.094056 | 0.053588 | 0.310801 | 0.126599 | -0.439298 | 0.293111 | -0.435720 |
| PPL | -0.013028 | 0.337789 | 0.038318 | 0.066390 | 0.032174 | -0.157944 | 0.274098 | -0.175820 | -0.151116 | 0.466961 | 0.476967 |
| PPCL | 0.136956 | 0.228664 | -0.265935 | 0.552873 | -0.003950 | 0.330037 | 0.263960 | -0.474050 | -0.327439 | -0.126789 | -0.109153 |
| DFL | -0.183322 | 0.004174 | -0.338293 | -0.263606 | 0.151266 | -0.363080 | -0.265069 | -0.177314 | -0.543214 | -0.393591 | 0.127363 |
| PAFL | 0.087864 | 0.316769 | 0.071693 | -0.048131 | -0.264479 | 0.157343 | 0.212459 | 0.036712 | -0.750922 | 0.224006 | 0.359194 |
| PAL | 0.021941 | 0.324049 | 0.087721 | 0.012620 | -0.056359 | -0.006967 | -0.208513 | -0.471498 | -0.421935 | 0.660085 | 0.026550 |

Table 4. Squared Mahalanobis distances for twelve ariid catfishes

| Species | a | b | c | d | e | f | g | h | i | j | k | l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *N. bilineata* (A) | 0.00 | 72.35 | 124.19 | 95.86 | 267.46 | 397.12 | 589.84 | 138.93 | 179.84 | 84.06 | 115.72 | 466.89 |
| *N. thalassina* (B) | 72.35 | 0.00 | 169.48 | 114.99 | 252.50 | 387.82 | 553.18 | 206.83 | 192.26 | 195.53 | 251.64 | 623.48 |
| *P. platystomus* (C) | 124.19 | 169.48 | 0.00 | 97.46 | 189.13 | 286.91 | 400.93 | 70.26 | 77.81 | 83.19 | 86.79 | 328.05 |
| *P. dussumieri* (D) | 95.86 | 114.99 | 97.46 | 0.00 | 52.72 | 122.04 | 226.04 | 36.16 | 28.38 | 175.19 | 170.17 | 261.08 |
| *P. tenuispinis* (E) | 267.47 | 252.50 | 189.13 | 52.72 | 0.00 | 24.96 | 87.45 | 76.82 | 31.83 | 365.71 | 328.29 | 232.34 |
| *P. tonggol* (F) | 397.12 | 387.82 | 286.91 | 122.04 | 24.96 | 0.00 | 33.84 | 126.87 | 82.25 | 508.18 | 449.94 | 215.01 |
| *A. subrostratus* (G) | 589.84 | 553.19 | 400.93 | 226.04 | 87.45 | 33.84 | 0.00 | 206.81 | 156.67 | 680.61 | 596.77 | 259.89 |
| *A. maculatus* (H) | 138.93 | 206.83 | 70.27 | 36.16 | 76.82 | 126.87 | 206.81 | 0.00 | 28.74 | 159.04 | 122.77 | 151.10 |
| *A. jella* (I) | 179.84 | 192.26 | 77.81 | 28.38 | 31.83 | 82.25 | 156.67 | 28.74 | 0.00 | 204.09 | 185.16 | 211.55 |
| *N. caelata* (J) | 84.06 | 195.54 | 83.19 | 175.19 | 365.72 | 508.19 | 680.61 | 159.04 | 204.09 | 0.00 | 29.54 | 401.46 |
| *N. macronotacantha* (K) | 115.72 | 251.65 | 86.79 | 170.17 | 328.29 | 449.95 | 596.78 | 122.77 | 185.16 | 29.54 | 0.00 | 289.50 |
| *O. militaris* (L) | 466.89 | 623.49 | 328.05 | 261.09 | 232.34 | 215.02 | 259.90 | 151.11 | 211.55 | 401.46 | 289.50 | 0.00 |

Table 5. Descriptive statistics of meristic character of 12 species of ariid catfishes

| Species | No. of specimens | Anal fin rays | | | Pectoral fin rays | | | Gill rakers | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Range | Mode | Frequency of mode | Range | Mode | Frequency of mode | Range | Mode | Frequency of mode |
| *N. bilineata* | 28 | 16-19 | 16,17,18 | 8 | 10-12 | 11 | 14 | 12-16 | 14 | 12 |
| *N. thalassina* | 15 | 13-15 | 15 | 8 | 11-12 | 12 | 9 | 12-14 | 13 | 10 |
| *P. platystomus* | 32 | 19-21 | 19 | 14 | 10-11 | 11 | 18 | 13-15 | 14 | 13 |
| *P. dussumieri* | 40 | 14-18 | 16 | 19 | 11-12 | 12 | 29 | 14-17 | 14,15 | 16 |
| *P. tenuispinis* | 86 | 15-19 | 18 | 44 | 9-12 | 11 | 68 | 10-15 | 15 | 33 |
| *P. tonggol* | 30 | 18-20 | 20 | 22 | 11-12 | 11 | 20 | 9-11 | 11 | 21 |
| *A. subrostratus* | 20 | 18-19 | 18 | 16 | 11-12 | 11 | 16 | 21-25 | 21 | 10 |
| *A. maculatus* | 54 | 18-22 | 20 | 28 | 9-12 | 11 | 28 | 15-20 | 16 | 21 |
| *A. jella* | 15 | 18-20 | 19 | 9 | 10-12 | 11 | 9 | 17-19 | 17 | 8 |
| *N. caelata* | 46 | 18-22 | 20 | 20 | 9-11 | 9 | 42 | 13-15 | 15 | 30 |
| *N. macronotacantha* | 30 | 18-22 | 19 | 14 | 9-11 | 10 | 20 | 14-17 | 15 | 13 |
| *O. militaris* | 51 | 18-22 | 22 | 20 | 9-10 | 10 | 39 | 9-11 | 11 | 28 |

based on meristic features. *O. militaris* is characterised by higher number of anal fin rays count and fewer number of gill rakers than the rest of the members of the family Ariidae included in the study.

Among the external morphological features, teeth are considered to be the most important. Number of teeth patches, type of teeth and arrangements of teeth patches were found to have significant field importance. Teeth characteristics along with barbels, median groove and spine length were used to generate the following identification key for 16 recorded species for field identification:

A. One pair of teeth patches on palate and teeth peg like or globular ..... 1

B. One pair of teeth patches on palate and teeth villiform ..... .....2

C. Two pairs of teeth patches on palate and teeth peg like or globular ..... 3

D. Two pairs of teeth patches on palate and teeth villiform…….....…….4

E. Three pairs of teeth patches on palate and teeth villiform ..... 5

1. One pair of teeth patches on palate and teeth peg like or globular.

a. Broad and elongated teeth patches with prominent dorsal fin filament and 3 pairs of barbels.
   i. Teeth densely arranged, gap between teeth patches less, dorsal spine longer than pectoral .....*A. maculatus*
   ii. Teeth loosely packed in patches, gap between teeth patches less, dorsal spine longer than pectoral, relatively large eyes ..... *A. arius*
   iii. Teeth loosely packed in patches, gap between teeth patches more, dorsal spine shorter than pectoral ..... .....*A. jella*

b. Shoe-shaped teeth patches placed far back, converging posteriorly and 3 pairs of barbels ..... .....*P. tenuispinis*

c. Elongated teeth patches, 3 pairs of fleshy barbels. ..... .....*P. platystomus*

d. Elongated teeth patches with only one pair of stiff maxillary barbels.....*O. militaris*

2. One pair of teeth patches on palate and teeth villiform

a. Barbels long and filament like, reaching well beyond origin of pectoral fin
   i. Teeth patches triangular. .....*N. caelata*
   ii. Teeth patches transversely oblong. ..... ..... *N. macronotacantha*

b. Barbels medium sized (reaching slightly beyond or lagging behind the origin of pectoral fin)
   i. Medial longitudinal groove broad and running up to nostrils and teeth patch oval to oblong ..... .....*A. sumatranus*
   ii. Median longitudinal groove broad and running up to nostrils and teeth patch triangular .....*A. venosus*

c. Barbels very small hardly crossing the eye and small widely separated oval teeth patch. .....*A. subrostratus*

3. Two pairs of teeth patches on palate and teeth peg like

a. Two pairs of teeth patches arranged longitudinally
   i. Anterior pair longitudinally oblong, posterior pair shoe shaped and converging posteriorly ..... *P. tonggol*
   ii. Anterior pair round, posterior pair elongated and diverging posteriorly. ..... *P. dussumieri*

4. Two pairs of teeth patches and teeth villiform arranged transversely, inner pair of patches round, outer pair of patches triangular ..... *S. sona*

5. Three pairs of teeth patches on palate and teeth villiform

a. Inner patches of teeth are most often joined along mesial line, snout rounded, distance between posterior triangular patch relatively large. .....*N. bilineata*

b. Inner patches of teeth never joined along mesial line, snout pointed, distance between posterior triangular patch relatively small. ..... ..... *N. thalassina*

The current study establishes the sufficiency of morphological variables in discrimination of species of catfishes belonging to family Ariidae. Morphometric characters alone were able to differentiate among the species, though after allometric compensation. Substantial contribution of variables like inter-nostril length, snout length, pre-nostril length, mouth width and head length in successful discrimination of the species signifies that morphometric measurements related to head portion of ariid catfishes have higher taxonomic value. The current study has shortlisted the important morphometric variables which could be further explored with more number of species. As the current study revolves around the specimens collected from west coast of India, a reassessment with specimens from other bio-geographic region could further refine the results.

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