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Article

Descriptions of five new species of *Neolissochilus* Rainboth, 1985 (Cypriniformes: Cyprinidae) from streams/rivers of the Western Ghats, peninsular India

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Abstract

The genus *Neolissochilus* was described by Rainboth, 1985 and currently includes 24 nominal taxa with distributions in southern and south-eastern Asia. Five new species of *Neolissochilus* are described herein from streams and rivers of the Western Ghats, peninsular India, one of the World's hotspots of biodiversity. The new species include *N. capudelphinus*, *N. minimus*, *N. micropthalmus*, *N. acutirostris* and *N. tamiraparaniensis*. *Neolissochilus wynaadensis* (Day, 1873), also from the Western Ghats is considered a valid species. The five new species are described based on meristic, morphometric characters, and molecular data. Relationships among the newly described species and the relationships of *Neolissochilus* with *Systomus* (=*Barbodes* /*Puntius*), *Hypselobarbus* Bleeker and *Tor* Gray, all presumed closely related lineages are discussed.

Keywords: Cyprinidae, *Neolissochilus capudelphinus*, *N. minimus*, *N. micropthalmus*, *N. acutirostris*, *N. tamiraparaniensis*.
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Introduction

Neolissochilus was described as a new genus by Rainboth (1985). With 24 nominal taxa, this genus is distributed in clear water streams and upper reaches of rivers in southern and south-eastern Asia. *Neolissochilus* and *Tor* have long been recognized as indigenous game fishes of southern Asia (Jhingran 1977). As described by Rainboth (1985), *Neolissochilus* is characterized by the development of a sharp, keratinous lower jaw, the inter-mandibular space being broader than the mandible, long maxillary and rostral barbels, thick lips, not hypertrophied, and 2-6 long and slender gill rakers on epibranchial segment and 7-12 gill rakers on the ceratobranchial segment of the anterior side of the first arch. More detailed generic characters are available in Rainboth (1985). The taxonomy of the genus is complex due to the lack of morphological variation among the species (Khaironizam et al. 2015) and also polymorphs were recorded in *N. soroides* (Duncker 1904) and *N. hendersoni* (Herre 1940) from Malaysia (Roberts and Khaironizam 2008). Also polymorphism in *N. stracheyi* from Vietnam is reported (Hoang et al. 2015). As a part of a major research program on fish habitats and communities in streams and rivers of the Western Ghats mountain ranges in the states Tamil Nadu, Kerala and Karnataka during 2001-2004, five new species *Neolissochilus* are described herein as new species (Fig. 1).

Material and Methods

Fish collections were carried out from 1996-2004 at river sites by earlier workers led by M. Arunachalam. Measurements were made point to point using digital caliper. Methods used for the meristic and morphometric characters are based on Hubbs and Lagler (1964). Morphometric characters from landmarks 9, 18-26, 29-31 and 34-35 (Table 1) were the additional truss measurements (Strauss and Bookstein 1982). Preanal scales (Jayaram 1991) are the scales from the anus to the isthmus. Body measurements are expressed as percentage of Standard

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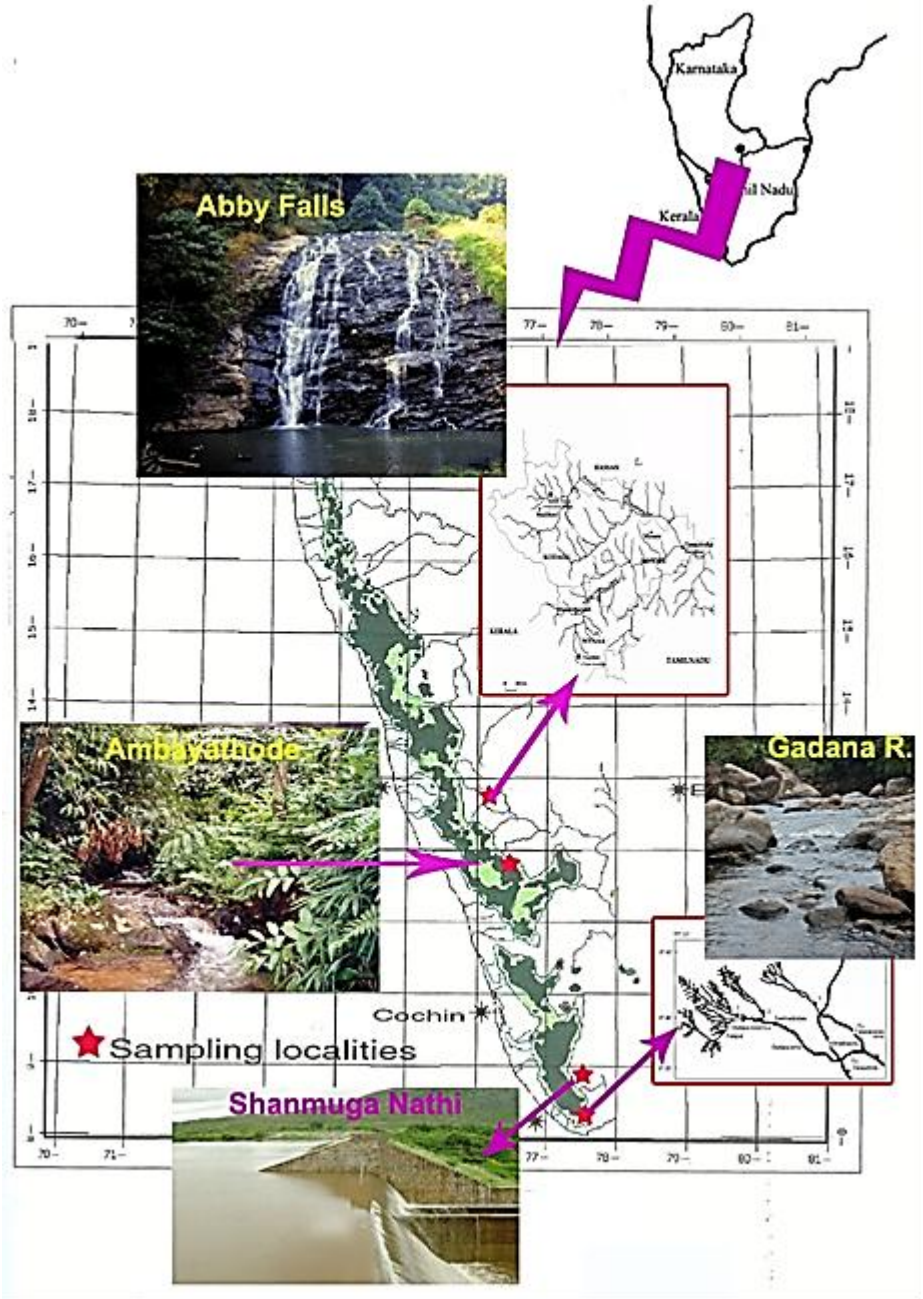

Figure 1. Collection sites of the five new species of *Neolissochilus* from Western Ghat mountain ranges, peninsular India.

Length (%SL); head measurements are expressed as percentage of Head Length (%HL).

For each description inter-landmark distances obtained from Truss Network were converted to X_1Y_1 coordinates by using IMP (Integrated Morphometric Package, Freeware). Raw coordinates of all specimens were aligned, translated, rotated and scaled to match one another using the Procrustes generalized orthogonal least squares (GLS) superimposition methods; these fit configurations over another by minimizing the sum of squared distances between homologous landmarks (Rohlf 1990; Rohlf and Slice 1990). Morphological differentiation using landmark-based technique is more effective in obtaining information regarding the shape or shape changes of organisms. This geometric morphometric method analysis (Cavalcanti et al. 1999), combined with the use of multivariate statistical procedure, is extremely useful in detecting variations in body form as well as a powerful tool for testing and graphically displaying differences in shape among target samples (Rohlf and Marcus 1993; Rohlf et al. 1996).

Shearing is used to eliminate the size variation as the first component PCA extracts size from the covariance matrix. Allometric normalization of size factor was carried out using PAST (Palaeontological Statistical Software package for education and data analysis, version 2.17). Allometric coefficients were calculated and estimated for 99% confidence limits using the same program. Bookstein coordinates were used for data input in IMP from TPS files. Coordinates of all aligned specimens were used for thin plate spline and relative warp analysis (Bookstein 1991; Rohlf 1993) to analyse and display the direction of shape differences among the five new species and *N. wynaadensis* and *N. hexagonolepis*. Thin plate splines (Bookstein 1989) allow for comparisons of landmark coordinates using a reference configuration to ensure that all landmarks coincide with hypothesized homologous points across specimens and species in analyses. The bending energy matrix resulting from the thin plate spline function, fitted to the reference configuration, is then converted to orthogonal axes called the principal (partial) warps describing shape deformation of the reference configuration at different spatial scales (Cavalcanti et al. 1999). The projection of the superimposed specimens onto partial warp scores, which describe their directions from the reference configuration, can be used as variables in subsequent multivariate analysis (Rohlf 1993; Rohlf et al. 1996). The relative warps are the principal components of the variation among the specimens in this space (Bookstein1991; Rohlf 1996). The average configuration in the relative warp analysis and the reference was aligned to its principal axis. The relative warps were computed in the full shape space including both the uniform components and non-uniform components. Deformation grids using the thin plate splines were used to graphically represent the patterns of shape variation among the landmarks for the seven valid Indian species.

DNA extraction, PCR, cloning, and sequencing Genomic DNA was isolated from ethanol-preserved muscle or fin clips using DNeasy tissue extraction kits (Qiagen, USA). The two mitochondrial genes were amplified and sequenced using primers and protocols from Yang et al. (2010). Adenosine triphosphate subunits six and eight (ATPase) from 465-taxon mt dataset and 791-taxon mt dataset were represented for the five new species of *Neolissochilus* described herein (Table 3) and the comparable data are from NCBI.

Abbreviations used: ZSI (Zoological Survey of India, Kolkatta), ZSI/SRS (Zoological Survey of India, Southern Regional Station, currently SRC, Southern Regional Centre Chennai), ZSI/WRS (Zoological Survey of India, Western Regional Station, Kozhicode), MSUMNH (Manonmaniam Sundaranar University Museum of Natural History) and CMA (collections of M. Arunachalam).

Comparative materials: *Barbus stracheyi*: Day, 1871 ZSI F 2175.

Barbus compressus: Day, 1869 ZSI F 5513.

Barbus dukai: Day, 1878 ZSI F 2388, 1, 103.9 mm SL.

Neolissochilus dukai: CMA 220, 3, 83.65-158.18 mm SL, Darjeeling (D.K), Teesta River Savoke, Othlavari M. Arunachalam and team, 27 November 2012.

Barbus blythii: 1869 ZSI F5553, 1, 46.37 mm SL.

Barbus innominatus: Day, ZSI F792, 1, 54.85 mm SL.

Neolissochilus wynaadensis: Day, CMA 345, 4, 78.09-114.24 mm SL, M. Arunachalam, P. Sivakumar, M. Muralidharan, and J.A. Johnson, 17 September 2001. - CMA 347, 3, 106.29-109.28 mm SL, from the same locality, B. Madhusoodana Kurup, Cochin University of Science and Technology, 12 June 2000. - MSUMNH196 (Fig. 2A), 1, 106.1 mm SL, Abby falls, Cauvery River basin, Karnataka, M. Arunachalam and team, 22 March 2004. - CMA175, 4, 87.97-105.22 mm SL, Abby falls, Karnataka, M. Arunachalam and team, 22 March 2004. - ZSI/WRC Kozhikode F6868, 3, 85.9-108.6 mm SL, Vattapoil, Wynaad, Kerala, P.M. Sureshan, 02 March 1994. - CMA346, 1, 205.2, mm SL, Abby falls, Karnataka, M. Arunachalam and team, 22 March 2004.

Neolissochilus hexagonolepis: ZSI/SRS F 7088, (Fig. 2B), 3, 185.95-285.75 mm SL, Tadi River in the mid hill of Nepal, D.B. Swar, June 2002. - CMA 217, 4, 207.55-317.11mm SL, Pasighat market, Arunachal Pradesh, M. Arunachalam and team, 13 November 2010. - CMA 218, 4, 137.84-233.73 mm SL, Ranga River at Beetapul

colony, Arunachal Pradesh, M. Arunachalam and team, 17 June 2011. - CMA 219, 4, 138.86-238.88 mm SL, Arunachal Pradesh, M. Arunachalam and team, 1 December 2011.

Neolissochilus hexasticus: CMA 221, 3, 102.11-135.66 mm SL, Ranga River at Beetapul colony, Arunachal Pradesh, M. Arunachalam and team, 17 June 2011.

Tor khudree: ZSI/SRC unreg, 1, 133.82 mm SL, Maharashtra, Dhom Reservoir on Krishna River and Vatali at Asani village, 8 km west of Wai Satara District, Krishna River, K.C. Jayaram, 7 May 1998.

Tor malabaricus: MSUMNH 170, 1, 147.99 mm SL, Keeriparai, tributary of Chittar River (west-flowing), Tamil Nadu, M. Arunachalam and team, 12 February 1998. - CMA119 4, 86.58-129.32 mm SL, Keeriparai, tributary of Chittar River (west-flowing), Tamil Nadu, M. Arunachalam and team, 12 February 1998. - MSUMNH 23, 1, 67.18 mm SL, Thenparai, North Kerala, M. Arunachalam and team, 14 April 2000. - CMA120, 3, 47.76-59.94 mm SL, Thenparai, North Kerala, M. Arunachalam and team, 14 April 2000. - MSUMNH 17, 1, 56.61 mm SL, Bollae, upstream of Bhadra River inside Kudremukh National Park, Karnataka, M. Arunachalam and team, 25 March 2002. - CMA121, 2, 39.46-47.53 mm SL, Bollae, upstream of Bhadra River inside Kudremukh Natural Park, Karnataka, M. Arunachalam and team, 25 March 2002.

Tor progenies: CMA133, 2, 198.8-226.5 mm SL, Arunachal Pradesh, Pasighat market collection, M. Arunachalam and team, 13 November 2010.

Puntius (=*Systomus*/*Barbodes*/*Hypselobarbus*) *carnaticus:* CMA344, 4, 205.28-241.31 mm SL, Pillur Dam, M. Arunachalam and team, 30 March 2002.

Results

Neolissochilus capudelphinus, sp. nov.

(Figs. 3A, 4A; Tables 1, 2).

Holotype: ZSI/SRS F 7152, 230.74 mm SL, upstream of the diverted water from Periyar River, 12 km from the town of Cumbum, Tamil Nadu (9°37'59.3"N, 77°11'52.8"E), and also from another location in a newly constructed dam called Shanmughanadhi Reservoir, Tamil Nadu (9°43'41.7"N, 77°21'31.2"E), M. Arunachalam and team, 16 March 2003.

Paratypes: MSUMNH191, 1, 216.21 mm SL; same as holotype. - CMA170, 23, 129.8-163.04 mm SL; same as holotype.

Diagnosis: *Neolissochilus capudelphinus* sp. nov. is distinguished from *N. hexasticus* by having more lateral-line scales (30-32 vs. 26), more pre-dorsal scales (11-12 vs. 9-10), and more upper transverse scale rows (6 vs.4.5). It is distinguished from *N. dukai* by having more lateral-line scales (30-32 vs. 28), more pre-dorsal scales (11-12 vs. 9-10), and more upper transverse scale rows (6 vs.3.5). It is distinguished from *N. stracheyi* by having more lateral-line scales (30-32 vs. 26), more pre-dorsal scales (11-12 vs. 7), more lateral line to pelvic scale rows (5 vs.4), more circumpeduncular scale rows (14 vs.12), and more circumferential scale rows (24 vs.18). It is distinguished from *N. compressus* by having more lateral-line scales (30-32 vs. 28), more pre-dorsal scales (11-12 vs. 9), and more upper transverse scale rows (6 vs. 4). It is distinguished from *N. blythii* by having more lateral-line scales (30-32 vs. 25), more pre-dorsal scales (11-12 vs. 5), more lateral line to pelvic scale rows (5 vs.3), more circumpeduncular scale rows (14 vs.11), and more circumferential scale rows (24 vs.17). It is distinguished from *N. wynaadensis* by having more lateral-line scales (30-32 vs. 28-29), more pre-dorsal scales (11-12 vs.10), more upper transverse scale rows (6 vs.4), more lateral line to pelvic scale rows (5 vs.4), more circumpeduncular scale rows (14 vs.12), more circumferential scale rows (24 vs.18-19), fewer epibranchial (2 vs. 3) and ceratobranchial (6 vs. 9) gill rakers on the posterior side of the first arch, more epibranchial gill rakers (5 vs. 2), fewer ceratobranchial gill rakers (9 vs. 12) on the anterior side of the first arch, and the morphometric

Figure 2. (A) *Neolissochilus wynaadensis* MSUMNH196, 106.01 mm SL, Abby Falls, M. Arunachalam, 22 March 2004 and (A) *Neolissochilus hexagonolepis* ZSI/SRS F 7088, 185.95 mm SL, Tadi River in the mid hill of Nepal, D.B. Swar, June 2002.

characters of pelvic fin length (18.15-20.12 vs.13.87-17.57 %SL), and dorsal origin to pectoral fin insertion (32.03-37.76 vs.28.22-31.28 %SL). It can be distinguished from its congener, *N. minimus* sp. nov. in having more pre anal scale rows (22-25 vs. 26-28), epibranchial gill rakers 2 and ceratobranchial gill rakers 6 on the posterior side of the first arch (vs. 3, 7*)* and more epibranchial 5 and ceratobranchial gill rakers 9 on the anterior side of the first arch (vs. 4, 10); rounded anal fin (vs. pointed); tubercles below nares (vs. tip of snout); scales of dorsum, anterior flank and caudal peduncle with distinct dark pigment forming hexagonal shape on scales (vs. presence of dark predorsal stripe, below which the second and third scale rows are pink, below which is black stripe two scale rows wide), scales of predorsal area emarginated and diamond shaped in two rows near dorsal fin (vs. rounded), intestine with 8 loops and 12 turns (vs. 5 loops and 11 turns). This species is further diagnosed from *N. minimus* sp. nov. by predorsal length (47.81-51.37 vs. 65.2-74.6 %SL) and pre-pectoral length (20.17-24.98 vs. 38.16-50.28 %SL).

It is distinguished from *N. micropthalmus* sp. nov. by having small tubercles mostly below nares (vs. below nares and on cheek), presence of dark lateral spot (absent), absence of caudal spot (vs. present), scale shape below predorsum with diamond shaped and emarginated (vs. hexagonal), 2 epibranchial and 6 ceratobranchial gill rakers on the posterior side of the first arch (vs. 2 epibranchial and 8 ceratobranchial gill rakers), 5 epibranchial and 9 ceratobranchial gill rakers on the anterior side of the first arch (vs. 4 epibranchial and 11 ceratobranchial rakers), gut loops and turns 8 and 12 (vs.6 and 9), more pre-dorsal scales (11-12 vs. 8-9), more lateral-line scales (30-32 vs. 28-29), more circumpeduncular scale rows (14 vs.12), more circumferential scale rows (24 vs. 18), more pre anal scale rows (22-25 vs. 20-22) and morphometric characters of head depth at pupil (68.35-82.00 vs. 46.69-68.00 %HL). It is distinguished from *N. acutirostris* sp. nov. by the absence of caudal spot, (vs. present), presence of tubercles below nares (vs. below nares and on cheek), scale shape of predorsum emarginated and diamond shaped (vs. hexagonal), epibranchial and ceratobranchial rakers on the posterior side of the first arch 2, 6 (vs. 3, 7), epibranchial and ceratobranchial gill rakers on the anterior side of the first arch 5, 9 (vs. 2, 12), gut with 8 loops and 12 turns (vs. 7,11), more pre-dorsal scales (11-12 vs. 10), more lateral line to pelvic scale rows (5 vs. 4), more circumpeduncular scale rows (14 vs. 12) and more circumferential scale rows (24 vs. 20), more pre anal scale rows (22-25 vs. 27-28) and the morphometric characters of pectoral insertion to anal fin origin (54.91-57.17 vs. 45.50-52.82 %SL), distance between pectoral fin origin and vent (51.86-55.64 vs. 44.88-48.78 %SL), head

Table 1. Morphometric characters variation in *Neolissochilus hexagonolepis*, *N. wynaadensis*, *N. caupudelphinus*, *N. minimus*, *Neolisochilus micropthalmus*, *N. acutirostris* and *N. tamiraparaniensis* .Body character measurements are represented as % standard length and head character measurements are represented as %head length.

Measurements from point to point	*N. hexagonolepis* ZSI/SRC F 7088 n=2	*N. wynaadensis* MSUMNH 196. - CMA 175. n=5	*N. capudelphinus* ZSI/SRC F 7152.- MSUMNH 191. - CMA 170. n=6	*N. minimus* ZSI/SRC F 7155. - MSUMNH 192. - CMA 171. n=14	*N. micropthalmus* ZSI/SRC F 7153. - MSUMNH 193. - CMA 172. n=12	*N. acutirostris* ZSI/SRC F 7152. - MSUMNH 194. -CMA 173. n=6	*N. tamiraparaniensis* ZSI/SRC F 7089, 7090. - MSUMNH 195. - CMA 174. n=40
Standard length (mm)	185.95-285.75	87.97-106.1	129.8-230.74	69.45-128.92	63.49-173.2	44.31-225.75	63.09-246.56
% of Standard Length							
Snout to urocentrum	91.51-93.06	91.83-94.04	90.20-93.66	91.05-94.71	90.09-94.83	92.18-95.85	91.02-96.14
Pre anal length	72.53-78.99	73.54-78.15	76.22-79.97	73.61-85.36	72.78-78.39	73.05-80.18	73.70-83.53
Pre dorsal length	48.35-49.50	48.19-51.67	47.81-51.37	65.20-74.60	47.31-52.90	47.50-51.48	47.06-56.15
Pre pelvic length	48.96-51.74	51.31-56.22	50.45-52.19	47.55-55.63	48.33-54.51	51.39-54.28	49.95-58.79
Pre pectoral length	22.39-24.43	24.88-32.16	20.17-24.98	38.16-50.28	23.61-29.18	23.74-30.74	19.53-32.64
Pre occipital length	19.80-24.43	24.60-26.76	21.78-24.45	22.15-30.18	23.42-28.94	19.94-25.59	23.11-34.08
Caudal peduncle length	16.31-19.06	13.17-19.32	12.38-16.08	11.13-16.71	12.82-17.43	10.99-13.79	13.11-23.51
Dorsal origin to pelvic insertion	23.31-25.04	22.31-25.97	25.07-30.23	11.02-34.81	25.11-30.38	23.18-28.56	23.59-29.00
Dorsal spinous height	10.78-28.32	13.90-16.62	14.32-17.25	15.82-27.82	12.63-18.19	11.21-22.25	11.82-24.87
Anal fin height	14.36-21.32	15.91-18.41	17.16-20.45	14.80-22.19	16.09-20.16	13.88-21.73	14.46-26.84
Depth of caudal peduncle	10.86-10.90	9.41-10.99	9.03-12.80	11.08-19.41	10.13-12.35	9.38-12.34	15.12-21.38
Caudal fin length	24.31-28.32	27.39-31.56	29.39-35.37	11.59-41.73	27.03-35.52	25.78-40.37	29.70-35.20
Dorsal fin height	15.12-21.32	19.99-24.38	20.22-23.65	21.90-31.40	20.03-25.86	19.60-29.67	20.53-31.90
Pectoral fin length	13.63-19.41	16.97-19.88	19.71-21.64	20.63-23.63	18.84-22.63	18.52-23.67	17.88-29.86
Pelvic fin length	11.73-15.92	13.87-17.57	18.15-20.12	17.66-21.81	16.31-19.67	16.12-20.23	12.30-25.65
Pelvic axiliary scale length	4.04-5.20	4.54-7.26	6.63-9.70	5.49-18.43	6.57-9.00	5.21-7.12	8.23-12.23
Occiput to dorsal fin origin	29.23-30.87	24.92-27.30	25.45-29.72	25.36-33.86	24.31-30.41	26.83-30.37	22.72-35.20
Occiput to pectoral fin insertion	14.79-16.17	16.19-19.15	18.47-20.12	18.36-27.23	16.56-22.02	15.12-38.21	17.62-32.12
Occiput to pelvic fin insertion	35.12-38.68	34.96-36.57	36.86-40.15	35.20-43.99	33.28-42.35	36.25-39.21	33.66-46.25
Dorsal insertion to pelvic fin insertion	22.65-24.41	20.89-24.81	24.95-29.83	24.67-37.90	22.94-28.45	22.89-32.31	22.18-32.87
Dorsal origin to pectoral fin insertion	30.23-33.43	28.22-31.28	32.03-37.76	24.69-40.21	30.06-34.73	28.79-34.97	31.75-41.44
Dorsal origin to anal fin origin	34.22-36.90	33.05-36.24	36.79-40.12	33.31-42.15	35.16-37.67	33.18-36.99	33.68-44.43
Dorsal fin insertion to caudal fin	41.02-43.37	36.97-40.82	36.97-39.65	34.65-40.20	37.26-41.59	34.26-37.55	34.92-45.89
Dorsal insertion to anal fin origin	23.85-25.19	21.27-24.22	22.80-27.80	22.00-33.19	21.85-23.84	21.30-25.12	21.79-34.96
Dorsal insertion anal fin insertion	26.45-26.62	23.26-26.64	26.62-29.44	24.53-30.01	23.42-27.05	24.15-27.59	25.15-37.13
Dorsal fin base length	13.13-14.69	12.59-16.85	15.45-16.99	14.87-26.24	14.29-18.38	12.81-19.08	13.12-23.05
Anal fin base length	7.12-7.90	5.07-8.94	7.99-11.17	6.65-13.76	7.12-9.86	5.46-13.92	6.64-17.75
Pectoral insertion to pelvic fin insertion	25.59-30.48	24.78-28.17	28.13-31.07	7.33-32.17	24.93-28.30	23.23-28.41	26.40-37.88
Pectoral insertion to anal fin origin	48.53-56.87	48.26-51.65	54.91-57.17	28.02-56.13	48.62-53.24	45.50-52.82	49.70-63.49
Pelvic insertion to anal fin origin	22.94-28.26	22.23-26.03	27.59-29.08	21.95-50.62	21.83-28.22	22.47-27.35	21.68-30.69
Post-dorsal length	35.82-36.78	33.12-39.28	32.28-35.17	30.04-37.76	30.90-36.87	30.38-33.88	29.17-42.80
Body depth	22.73-23.95	22.83-25.40	24.88-30.41	25.94-34.22	25.19-30.02	22.88-26.96	22.91-34.39
Distance from pectoral fin to vent	34.09-56.50	46.07-53.11	51.86-55.64	45.12-54.73	46.48-53.04	44.88-48.78	17.57-28.23
Distance from pelvic fin to vent	27.74-31.36	20.89-26.37	23.84-27.75	19.25-26.32	18.70-25.21	19.87-28.18	19.69-36.20
Head length (mm)	22.87-24.96	25.17-29.54	20.55-25.66	21.07-27.60	24.45-29.11	25.76-29.77	16.77-31.42
% of Head Length							
Snout to opercle	62.84-65.68	65.18-69.94	59.15-66.35	61.76-88.30	64.29-68.07	62.09-72.31	58.84-81.63
Snout length	27.67-35.63	30.81-40.28	36.24-61.50	29.07-43.53	34.61-44.89	29.71-40.81	32.13-58.87
Upper jaw length	22.19-31.08	24.04-34.54	23.69-41.41	26.89-64.99	29.70-37.38	25.75-42.00	24.76-50.20
Pre nasal length	19.28-25.59	20.02-23.65	22.85-34.59	18.97-37.85	19.68-30.91	19.38-25.31	18.05-48.40
Orbit width	16.40-18.09	18.30-23.67	16.80-33.21	20.06-42.76	17.21-29.00	17.18-30.17	21.34-42.21
Inter orbital width	29.71-39.03	30.42-38.79	42.35-65.22	25.22-32.20	35.84-64.88	35.46-49.78	34.61-65.20
Inter nasal width	19.07-22.10	16.60-22.34	21.87-30.91	18.28-55.55	18.83-25.62	20.53-24.50	19.84-35.12
Head width	60.76-63.12	53.54-60.08	70.84-88.34	42.20-77.30	55.28-75.39	50.47-61.06	54.95-88.24
Gape width	22.58-28.77	24.72-40.55	32.96-51.12	26.56-66.36	24.31-38.25	17.97-31.14	24.32-49.71

Table 1. Continued.

Measurements from point to point	*N. hexagonolepis*	*N. wynaadensis*	*N. capudelphinus*	*N. minimus*	*N. micropthalmus*	*N. acutirostris*	*N. tamiraparaniensis*
Lower jaw to isthmus	52.04-62.38	51.51-71.25	59.27-68.78	48.20-74.89	59.28-67.77	66.27-72.98	55.49-87.66
Head depth at nostril	26.01-32.20	29.16-47.30	41.95-59.66	65.73-73.95	31.50-47.78	28.25-39.08	28.44-62.35
Head depth at pupil	69.38-69.62	51.16-65.25	68.35-82.00	36.07-75.08	46.69-68.00	45.88-61.42	57.23-92.77
Head depth at occiput	22.73-53.26	65.27-71.75	80.80-98.77	60.97-72.13	65.35-81.22	62.13-81.93	75.84-85.12
Maxillary barbel length	19.13-22.50	23.86-29.09	20.26-31.79	26.28-37.14	19.41-28.65	18.20-26.85	45.20-51.51
Rostral barbel length	15.71-23.19	16.72-22.55	14.80-26.74	22.01-34.28	13.68-25.93	10.99-22.33	40.20-51.69

Table 2. Meristic characters of *Neolissochilus hexagonolepis*, *N. wynaadensis*, *N. caupudelphinus*, *N. minimus*, *N. micropthalmus*, *N. acutirostris* and *N. tamiraparaniensis*.

Meristic characters	*N. hexagonolepis* ZSI/SRC F 7088 n=2	*N. wynaadensis* MSUMNH 196. - CMA 175. n=5	*N. capudelphinus* ZSI/SRC F 7152. - MSUMNH 191. - CMA 170. n=6	*N. minimus* ZSI/SRC F 7155. - MSUMNH 192. - CMA 171. n=14	*N. micropthalmus* ZSI/SRC F 7153. MSUMNH 193. CMA 172. n=12	*N. acutirostris* ZSI/SRC F 7152. MSUMNH 194. CMA 173. n=6	*N. tamiraparaniensis* ZSI/SRC F 7089, 7090. - MSUMNH 195. -CMA 174. n=40
Dorsal fin rays	iv.9	iv.9	iv.9	iv.9	iv.9	iv.9	iv.9
Anal fin rays	iii.5	iii.5	iii.5	iii.5	iii.5	iii.5	iii.5
Pelvic fin rays	i.8	i.8	i.8	i.8	i.8	i.8	i.8
Pectoral fin rays	i.14-15	i.15	i.13-14	i.13-15	i.14-15	i.15	i.13-15
Caudal fin rays	10+9	10+9	10+9	10+9	10+9	10+9	10+9
Upper transverse scale rows	4-5	4	6	5-6	4-5	5	5-6
Lower transverse scale rows	5-6	5-6	6	6	5	5-6	5-6
Lateral line to pelvic scale rows	4	4	5	4-5	4	4	4-5
Lateral-line scales	27	28-29	30-32	28-31	28-29	29-32	28-30
Pre-dorsal scales	9	10	11-12	11-13	8-9	10	11-12
Circumpeduncular scale rows	12	12	14	14	12	12	12-14
Circumferential scale rows	18-20	18-19	24	23-24	18	20	20-22
Transverse breast scale rows	7-8	7-8	7-8	7-8	7-8	9	7-9
Pre anal scale rows	27-28	25-26	22-25	26-28	20-22	27-28	23-25

Table 3. Details of ATPase 6 and 8 sequences used for the phylogenetic analyses presented in Figure 9.

Sl. No	Species Name	Accession No.
1	*Tor khudree* TKH1	EF588100.1
2	*Tor khudree* TKH4	EF588101.1
3	*Tor khudree* TKH5	EF588102.1
4	*Tor khudree* TKH3	EF588125.1
5	*Tor khudree* TKH2	EF588126.1
6	*Neolissochilus hexagonolepis*	EF588118.1
7	*Neolissochilus* sp. 2 TTTN-2007	EF588148.1
8	*Neolissochilus* sp. 1 TTTN-2007	EF588106.1
9	*Neolissochilus stracheyi*	EF588108.1
10	*Neolissochilus soroides*	EF588109.1
11	*Neolissochilus micropthalmus*	KY366320
12	*Neolissochilus minimus*	KY366318
13	*Neolissochilus capudelphinus*	KY366319
14	*Neolissochilus acutirostris*	KY366321
15	*Neolissochilus tamiraparaniensis*	HQ234746
16	*Tor* sp.	Banklt no.1968154
17	*Puntius tambraparniei*	Banklt no.1968192

length (20.55-25.66 vs. 25.76-29.77 %SL), gape width (32.96-51.12 vs. 17.97-31.14 %HL), head depth at nostril (41.95-59.66 vs. 28.25-39.08 %HL) and head depth at pupil (68.35-82.00 vs. 45.88-61.42 %HL). It can be diagnosed from *N. tamiraparaniensis* sp. nov. by presence of dark lateral stripe (vs. absent), presence of postorbital stripe (vs. absent), variation in color pattern in dorsal, anal, pelvic, pectoral, and caudal fins, presence of tubercles below nares (vs. snout), scale shape at predorsum emarginated and diamond shaped (vs. blunt end), scale shape near and below lateral line emarginated (vs. blunt), 2 epibranchial and 6 ceratobranchial gill rakers on the posterior side of the first arch (vs. 3, 9), and more circumferential scale rows (24 vs. 20-22). It is distinguished from *N. hexagonolepis* by weak (vs. strong) dorsal spine, fewer lateral-line scales (30-32 vs. 27), more pre-dorsal scales (11-12 vs. 9), fewer circumpeduncular scale rows (14 vs. 12) more circumferential scale rows (24 vs. 18-20), fewer pre anal scale rows (22-25 vs. 27-28) and morphometric characters of pelvic fin length (18.15-20.12 vs. 11.73-15.92 %SL), occiput to pectoral fin insertion (18.47-20.12 vs. 14.79-16.17 %SL), and dorsal fin insertion to caudal (36.97-39.66 vs. 41.02-43.37 %SL).

Description: Body moderately deep, 24.88 -30.41 %SL. Dorsal and ventral margins of body equal in curvature. Dorsal-fin origin is vertically two scale rows before pelvic fin origin with predorsal length 47.81-51.37 %SL which is more when compared to prepelvic length of 50.45-52.19 %SL. Anal fin long with 76.22-79.97 %SL with distance between pelvic-fin insertion and anal fin origin is less than the distance between the pectoral fin insertion and pelvic fin insertion. Pectoral to pelvic distance is 28.13-31.07 %SL and pelvic insertion to anal fin origin 27.59-29.08 %SL. Nape slightly convex behind a concavity after the occiput. Peduncle moderately deep 9.03-12.80 %SL, and its length, 12.38-16.08 %SL.

Head long 20.55-25.66 %SL, eyes relatively large 16.80-33.21 %HL, snout long 36.24-61.50 %HL. Mouth oblique and sub terminal with rostral cap overhanging the upper lip, upper jaw length 23.69-41.41 %HL. Gape width 32.96-51.12 %HL. Lower jaw keratinous and sharp. Barbels longer, the maxillary one is 20.26-31.79 %HL, and the rostral pair is 14.80-26.74 %HL.

Dorsal-fin rays iv-9(25) anal-fin rays iii-5(25), pelvic-fin rays i-8(25), pectoral-fin rays i-13(20) or 14(5). Dorsal fin height is 20.22-23.65 %SL with straight distal margin; last unbranched ray smooth, with wide base but not strong; with dorsal spinous height 14.32- 17.25 %SL. Anal fin deep and rounded with anal fin height 17.16-20.45 %SL extending to a distance of 4 lateral-line scales anterior to the base of the caudal fin rays; distal fin margin convex; three unbranched rays not equal in length. Length of anal-fin base 7.99-11.17 %SL. Pelvic fin long 18.15-20.12 %SL reaching the anal fin origin by a distance of 6-7 scales rows; distal margin of fin concave near tip, otherwise nearly straight; tip of fin slightly produced in adults. Pectoral fin long 19.71-21.64 %SL and moderately falcate, extending to a distance of 3 scales anterior to pelvic fin origin, distal margin of fin concave at branched rays 2-4, remainder of margin convex. Caudal fin long and deeply forked and more than 2.3 times the length of median fins. Marginal rays of both lobes are slightly produced; fin margin concave at second and third branched rays produced with fin margin concave at second and third branched ray of both lobes, remainder of margin nearly straight.

Lateral-line scales 30(15), 31(6) or 32(4), pre-dorsal scales 11(13) or 12(12), upper transverse scale rows 6(25), lateral line to pelvic scale rows 5(25), lower transverse scale rows 6(25) circumferential scale rows 24(25), circumpeduncular scale rows 14(25), transverse breast scale rows 7(20) or 8(5), and pre anal scale rows 22(15) or 25(10).

Scales of predorsal area emarginate and in two rows near dorsal fin, diamond shaped and in caudal peduncle it is oblique. Breast scale rows continuous with belly scale rows until first two sets posterior to gill opening near isthmus, which point additional four rows inserted and irregular.

Coloration: Scales of dorsum, anterior flank and caudal peduncle to a maximum of 3 scale rows below center golden with heavily pigmented and broad dark bases, creating distinct diamond-shaped pattern; 1.5 scale rows

below this scales all golden, no dark bases; upper half of lateral-line scales and lower half of scale row above darkly pigmented, creating very distinct lateral stripe; below lateral stripe body immaculate. Preserved specimens colored as above but silver is lost and scale pattern and lateral stripe prominent; venter grayish, dorsal black. Upper body golden with dark bases on scales 3 scale rows ventrally from center, below which scales are golden without dark bases for 1.5 scale rows; dark lateral stripe on upper half lateral line scale row and lower half of scale row above; body immaculate below dark lateral stripe; dark predorsal stripe; scales of dorsum, upper anterior flank and upper-most caudal peduncle with distinct dark bases forming noticeably distinct hexagonal shapes over scales, caudal red with black base and edges to upper and lower lobes of caudal; pectoral black.

Tuberculation: Males and females possessing very small tubercles or visible as minute scars mostly below nares.

Pharyngeal cavity: Posterior epibranchial gill rakers 2; ceratobranchial gill rakers 6 on first arch; anterior epibranchial gill rakers 5; ceratobranchial gill rakers 9.

Intestine: As with other cyprinids stomach absent; intestine with 8 loops and 12 turns.

Etmology: From Greek (*caput, delphinus*) allusion to dolphin headed appearance.

Distribution and Natural History: This species is represented by two populations, one at the upstream of the diverted water from Periyar River, 12 km from the town of Cumbum (9º37'59.3"N, 77º11'52.8"E). The other location is at a newly constructed Shanmughanadhi Reservoir (9º43'41.7"N, 77º21'31.2"E). Diverted water is used for drinking. At the former location mean stream width above the check dam is 31 m with 16.25 m wetted width. Riparian cover is 40% with natural forest. Mean flow is 0.40 m/s and the mean depth is 0.73 m. The substrata include boulders (54%), cobbles (27%), gravel (11%) and sand covered with leaf litter (8%). Dynamite fishing in these areas was very common. Average depth of the Shanmughanadhi Reservoir is 3.3 m and the altitude is 425 m above mean sea level. Water temperature was 29.9ºC and air temperature was 34.6ºC at time of capture.

Neolissochilus minimus, sp. nov.

(Figs. 3B, 4B; Tables 1, 2)

Holotype: ZSI/SRS F 7155, 128.92 mm SL, from the diverted water of Periyar River in the forest reserves of Cumbam Valley (9º37'59.3"N, 77º11'52.8"E) at an altitude of 455 m, M. Arunachalam and team, 03 March 2003.

Paratypes; MSUMNH192, 1, 127.34 mm SL**;** same as holotype. - CMA 171, 12, 69.45-126.14 mm SL; same as holotype.

Diagnosis: *Neolissochilus minimus* sp. nov. is distinguished from *N. hexasticus* by having more lateral-line scales (28-31 vs. 26), and more pre-dorsal scales (11-13 vs. 9-10). It is distinguished from *N. dukai* by having more pre-dorsal scales (11-13 vs. 9-10), and more upper transverse scale rows (5-6 vs.3.5). It is distinguished from *N. stracheyi* by having more lateral-line scales (28-31 vs. 26), more pre-dorsal scales (11-13 vs. 7), more lateral line to pelvic scale rows (5-6 vs.4), more circumpeduncular scale rows (14 vs. 12), and more circumferential scale rows (23-24 vs.18). It is distinguished from *N. compressus* by having more pre-dorsal scales (11-13 vs. 9), and more upper transverse scale rows (5-6 vs. 4). It is distinguished from *N. blythii* by having more lateral-line scales (28-31 vs. 25), more pre-dorsal scales (11-13 vs. 5), more lateral line to pelvic scale rows (4-5 vs. 3), more circumpeduncular scale rows (14 vs. 11), and more circumferential scale rows (23-24 vs.17).

Neolissochilus minimus is distinguished from *N. wynaadensis* in having more pre-dorsal scales (11-13 vs. 10), more upper transverse scale rows (5-6 vs.4), more circumpeduncular scale rows (14 vs.12), more circumferential scale rows (23-24 vs.18-19), and morphometric character of predorsal length (65.20-74.60 vs. 48.19-51.67 %SL). It is distinguished from *N. micropthalmus* sp. nov. by the presence of tubercles below nares (vs. below nares and cheek), absence of caudal spot (vs. present), presence of narrow and dark lateral stripe (vs. absent), absence of postorbital stripe (vs. present), pigment at base of scale at mid dorsum and one row below (none), scale shape of

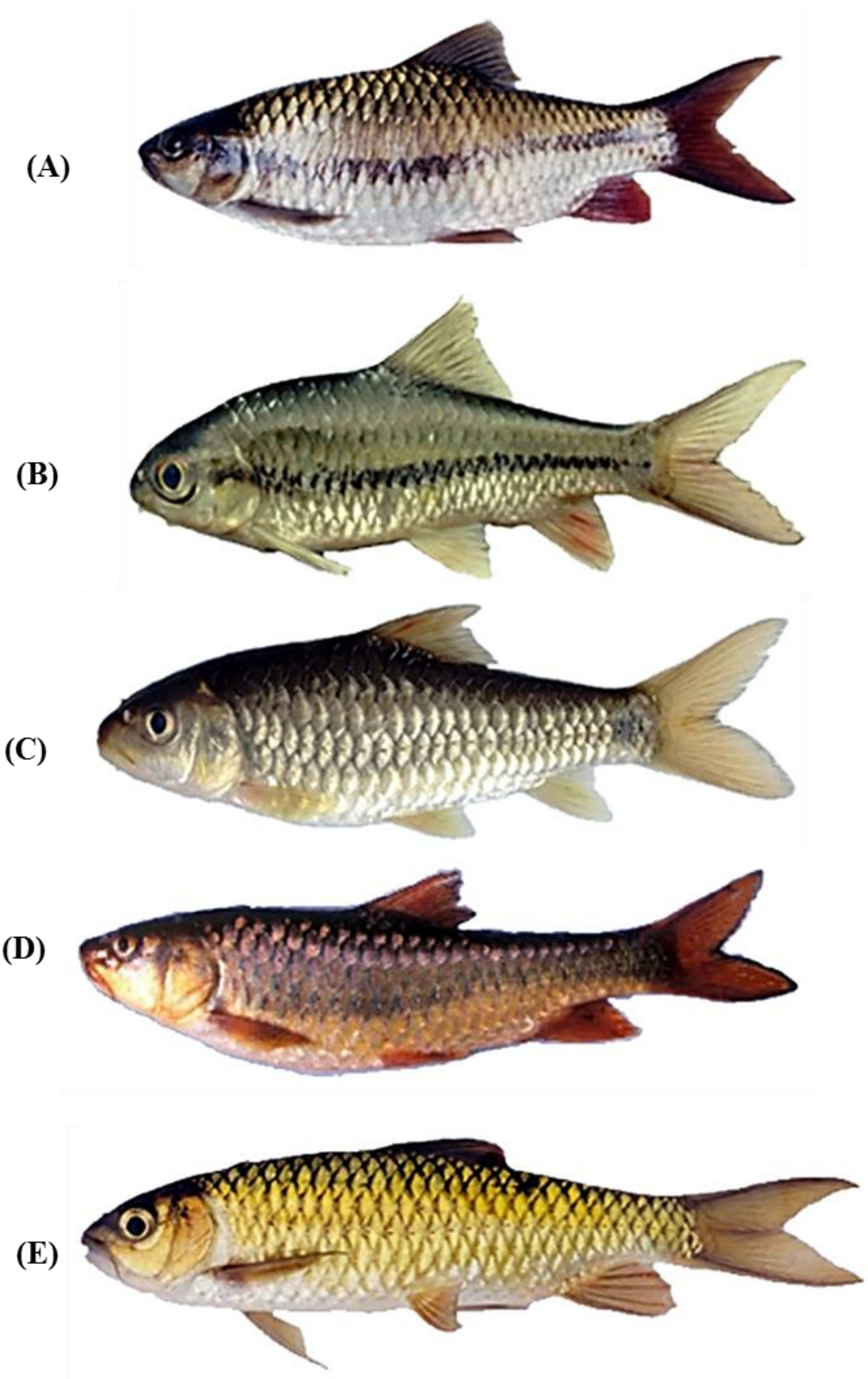

Figure 3. (A) Live specimens of *Neolissochilus capudelphinus* sp. nov. MSUMNH191, 216.21 mm SL, upstream of the diverted water from Periyar River, M. Arunachalam and team, 16 March 2003, (B) *Neolissochilus minimus* sp. nov. MSUMNH192, 127.34 mm SL, from the diverted water of Periyar River in the forest reserves of Cumbam Valley, M. Arunachalam and team, 03 March 2003, (C) *Neolissochilus micropthalmus* sp. nov. MSUMNH193, 163.72 mm SL, Ambayathode in the forest reserves in the Kannur District, Kerala, M. Arunachalam and team, 09 February 2003, (D) *Neolissochilus acutirostris*, sp. nov. MSUMNH194, 160.17 mm SL, Abby falls a stream in the Cauvery River drainage in Kodagu District, Karnataka, M. Arunachalam and team, 22 March 2004 and (E) *Neolissochilus tamiraparaniensis*, sp. nov. MSUMNH195, 246.56 mm SL, Gadana River of Tamiraparani River basin (east flowing in southern Tamil Nadu), M. Arunachalam and team, 24 February 2004.

predorsum rounded or emarginated (vs. hexagonal), scale shape below lateral line emarginated (vs. diamond shaped with pointed tips), dorsal fin edge round (vs. pointed and slightly convex), 3 epibranchial and 7 ceratobranchial gill rakers on the posterior side of the first arch (vs. 2, 8), 4 epibranchial and 10 ceratobranchial rakers on the anterior side of the first arch (vs. 4, 11), intestine with 5 loops and 11 turns (vs. 6 loops and 9 turns), having more lower transverse scale rows (6 vs. 5), more pre-dorsal scales (11-13 vs. 8-9), more circumpeduncular scale rows (14 vs. 12), more circumferential scale rows (23-24 vs. 18), more pre anal scale rows (26-28 vs. 20-22) and morphometric characters of predorsal length (65.20-74.60 vs. 47.31-52.90 %SL), and prepectoral length (38.16-50.28 vs. 23.61-29.18 %SL). It is differentiated from *N. acutirostris* sp. nov. by presence of narrow and light lateral stripe (vs. wide and dark), absence of postorbital stripe (vs. presence of large black stripe), presence of tubercles at tip of snout (vs. tip of snout and cheek), scale shape of predorsum rounded or emarginated (vs. hexagonal), scale shape below lateral line emarginated (vs. hexagonal), 4 epibranchial and 10 ceratobranchial rakers on the anterior side of the first arch (vs. 2, 12), more pre-dorsal scales (11-13 vs. 10), more circumpeduncular scale rows (14 vs. 12), more circumferential scale rows (23-24 vs. 20), fewer transverse breast scale rows (7-8 vs. 9) and the morphometric characters of pre-dorsal length (65.20-74.60 vs. 47.50-51.48 %SL), and pre pectoral length (38.16-50.28 vs. 23.74-30.74 %SL). It is distinguished from *N. tamiraparaniensis* sp. nov. by the presence of light lateral stripe (vs. absent), pigment at base of scale rows along mid dorsal and one row below (vs. all over body), scale shape of predorsum rounded or emarginated (blunt end), scale shape on lateral line emarginated (vs. blunt end), 3 epibranchial and 7 ceratobranchial gill rakers on the posterior side of the first arch (vs. 3, 9), 5 epibranchial and 11ceratobranchial rakers on the anterior side of the first arch (vs. 3-5, 9-13). Intestine loops 4 and 10 turns (vs. 8, 12), having more circumferential scale rows (23-24 vs. 20-22), more preanal scale rows (26-28 vs. 23-25) and the morphometric characters of pre dorsal length (65.20-74.60 vs. 47.06-56.15 %SL), and interorbital width (25.22-32.20 vs. 34.61-65.20 %HL). It is distinguished from *N. hexagonolepis* by having weak dorsal spine (vs. strong spine), more lateral-line scales (28-31 vs. 27), more pre-dorsal scales (11-13 vs. 9), more upper transverse scale rows (5-6 vs. 4-5), more circumpeduncular scale rows (14 vs.12), more circumferential scale rows (23-24 vs. 18-20) and the morphometric characters of predorsal length (65.20-74.60 vs. 48.35-49.50 %SL), and occiput to pectoral fin insertion (18.36-27.23 vs. 14.79-16.17 %SL).

Description: Body elongate 25.94-34.22 %SL, with predorsal length 65.20-74.60 %SL, compared to prepelvic length 47.55-55.36 %SL, distant between preanal length 73.61-85.36 %SL with distance between pectoral insertion and anal fin origin, is 28.02-56.13 %SL and pectoral insertion to pelvic fin insertion 7.33-32.17 %SL. Trunk and peduncle are compressed. Peduncle moderately shallow with peduncle length 11.13-16.71 %SL.

Head relatively short 21.07-27.60 %SL. Head depth at nostril 65.73-73.95 %HL, at pupil 36.07-75.08 %HL and occiput 60.97-72.13 %HL, respectively. Eyes large, 20.06-42.76 %HL. Mouth subterminal, its lower jaw to isthmus 48.20-74.89 %HL, snout moderate in length 29.07-43.53 %HL, gape width 26.56-66.36 %HL. Lower jaw keratinous and sharp. Barbels moderately long, maxillary pair 26.28-37.14 %HL, and rostral pair 22.01-34.28 %HL.

Dorsal-fin rays iv-9(14), anal-fin rays iii-5(14), pelvic-fin rays i-8(14), pectoral-fin rays i-13(7), 14(6) or 15(1). Dorsal fin moderately high 21.90-31.40 %SL, with a concave distal margin. Last unbranched ray smooth and moderately strong, its dorsal spinous length 15.82-27.90 %SL. Anal fin deep and pointed exceeding to 2 lateral line body scales anterior to the base of the caudal fin rays. Last unbranched ray longest, margin of fin pointed and anal fin height 14.80-22.19 %SL. Pelvic fin extending to 4½ scale rows before anal-fin origin and pelvic fin length 17.66-21.81 %SL. Pectoral fin extending to third scale row before pelvic fin origin and its length 20.63-23.63 %SL. Caudal fin deeply forked its length 11.59-41.73 %SL, with marginal rays of upper lobe longest and more than 3 times the length of median rays. Marginal rays of both lobes slightly produced with fin margin becoming concave at 3rd and 4th branched rays of both lobes, and remainder of margin nearly straight.

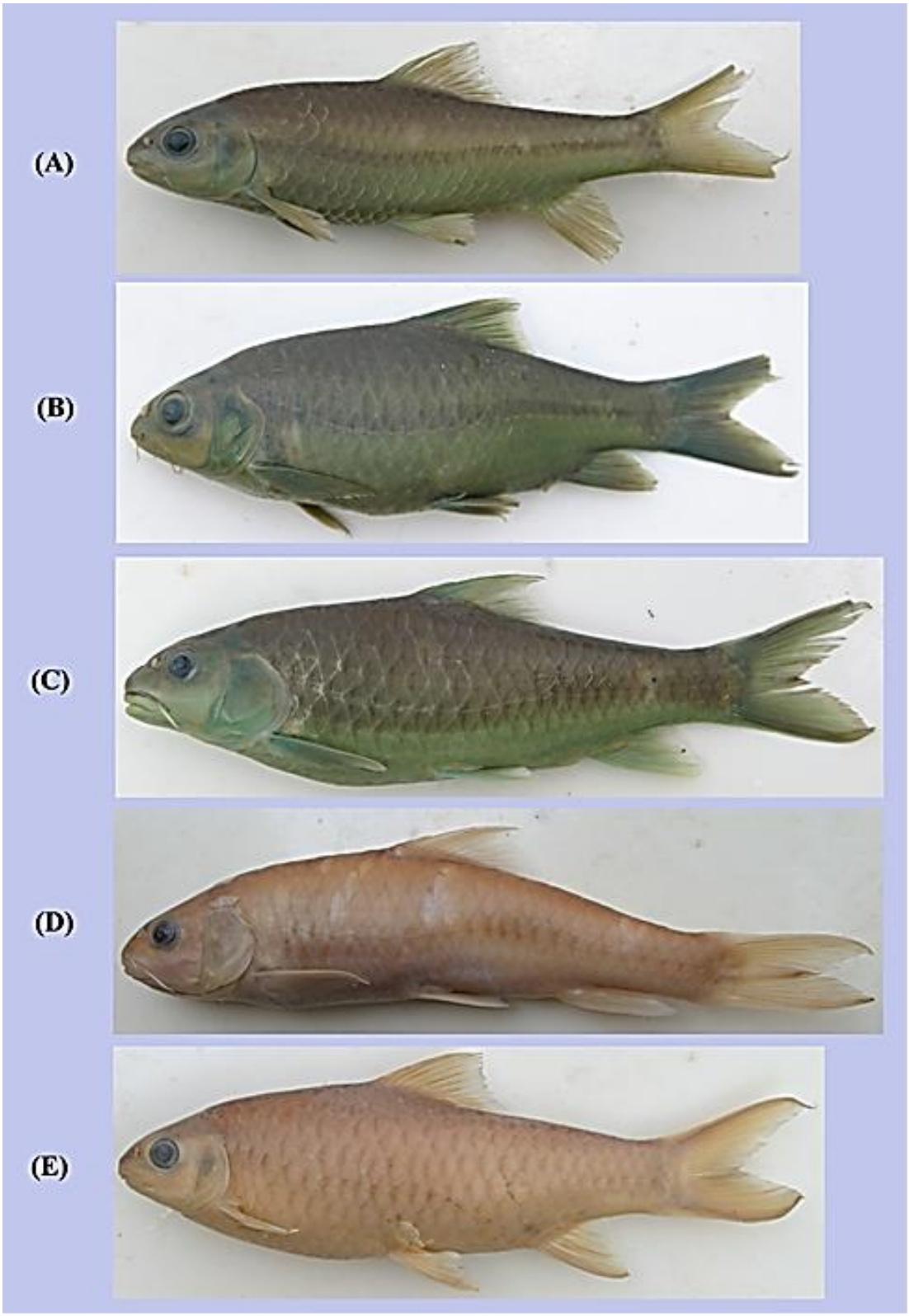

Figure 4. (A) Preserved specimen of *Neolissochilus capudelphinus* sp. nov. CMA170, 138.42 mm SL, upstream of the diverted water from Periyar River, M. Arunachalam and team 16 March 2003, (B) *Neolissochilus minimus* sp. nov. CMA171, 126.14 mm SL, from the diverted water of Periyar River in the forest reserves of Cumbam Valley, M. Arunachalam and team, 03 March 2003, (C) *Neolissochilus micropthalmus* sp. nov. CMA172, 160.98 mm SL, Ambayathode in the forest reserves in the Kannur District, Kerala, M. Arunachalam and team, 09 February 2003, (D) *Neolissochilus acutirostris* sp. nov. CMA173, 206.34 mm SL, Abby falls a stream in the Cauvery River drainage in Kodagu District, Karnataka, M. Arunachalam and team, 22 March 2004 and (E) *Neolissochilus tamiraparaniensis* sp. nov.CMA174, 160.80 mm SL, Gadana River of Tamiraparani River basin (east flowing in southern Tamil Nadu), M. Arunachalam and team, 24 February 2004.

Lateral-line scales 28(2), 29(4), 30(6) or 31(2), pre-dorsal scales 11(6), 12(6) or 13(2), upper transverse scale rows 5(4) or 6(10), scale rows from lateral line to pelvic fin 4(6) or 5(8), lower transverse scale rows 6(14) circumferential scale rows 23(6) or 24(8), circumpeduncular scale rows 14(14), transverse breast scale rows 7(6) or (8) and preanal scales rows 26(4), 27(4) or 28(6).

Tuberculation: Tubercles small and across tip of the snout.

Coloration: First row of scales of dorsum dark with predorsal stripe; second and third scale rows pink, and following two scale rows black. Belly whitish with dull yellow. Fins reddish with distal black margin. Cheek, opercle, subopercle, and preopercle light silver-gold. Large caudal spot absent. Upper body golden-yellow from dorsum and extending to 4½ scale rows to upper flank. Sides with distinct brown lateral stripe on upper half of lateral line and extending posterior to 25th lateral-line scale; dark predorsal stripe, second and third scale rows of ventrolateral to predorsal stripe pink, below which is black stripe two scale rows wide; above lateral stripe, secondary stripe formed that is darkest anteriorly where forming postorbital blotch; stripe separate from dark lateral stripe by posterior to postorbital blotch by one lighter colored scale row, broadens anteriorly and tapering to narrow line near caudal base, dorsal, pectoral and pelvic fins light golden; anal red and base and center of caudal red, with thin dark distal edge and darker dorsal and ventral edges to lobes. Following preservation, specimens darker up to lateral line scale row; belly grayish. Preserved specimens colored as above but silver is lost and scale pattern and lateral stripe prominent.

Pharyngeal cavity: Posterior epibranchial and ceratobranchial gill rakers 3 and 7, and anterior epibranchial and ceratobranchial gill rakers 4 and 10, respectively.

Intestine: As with other cyprinids stomach absent; gut with 5 loops and 11 turns.

Etymology: From the Greek *minima* (small) allusion to smaller size among the *Neolissochilus* species of Western Ghat mountain ranges, a noun in apposition.

Distribution and Natural History: Two populations are known for this species. One population is from the diverted water of Periyar River in the forest reserves of Cumbam Valley (9º37'59.3"N, 77º11'52.8"E) at an altitude of 455 m. Juveniles were found in stream run habitat with sandy substrates, at areas of riparian vegetation with 40% cover. The other population is from Shanmughanadhi Reservoir and the details are given for its congener *N. capudelphinus.* At both the locations *N. minimus* occurs sympatrically with *N. capudelphinus*.

Neolissochilus micropthalmus, sp. nov.

(Figs. 3C, 4C, Tables 1, 2)

Holotype: ZSI/SRS F 7153, 173.2 mm SL, Ambayathode in the forest reserves in the Kannur District, Kerala, M. Arunachalam and team, 09 February 2003.

Paratypes: MSUMNH193, 1, 163.72 mm SL; same as holotype. - CMA172, 10, 63.49-160.80 mm SL; same as holotype.

Diagnosis: *Neolissochilus micropthalmus* sp. nov. is distinguished from *N. hexasticus* by having more lateral-line scales (28-29 vs. 26), more lateral line to pelvic scale rows (4 vs. 2.5) and more lower transverse scale rows (5 vs. 3.5). It is distinguished from *N. dukai* by having more upper transverse scale rows (4-5 vs.3.5), more lateral line to pelvic scale rows (4 vs. 2.5) and more lower transverse scale rows (5 vs. 3.5). It is distinguished from *N. stracheyi* by having more lateral-line scales (28-29 vs. 26), and more pre-dorsal scales (8-9 vs. 7). It is distinguished from *N. compressus* by having more transverse breast scale rows (7-8 vs. 6) and the morphometric characters of distance between pre anal length (72.78-78.39 vs. 80.96 % SL) and snout to opercle (64.29-68.07 vs. 89.58 %HL). It is distinguished from *N. blythii* by having more lateral-line scales (28-29 vs. 25), more pre-dorsal scales (8-9 vs. 5) and more lateral line to pelvic scale rows (4 vs. 3). It is distinguished from *N. wynaadensis* more closely in shape but can be distinguished from this species based on fewer pre-dorsal scales (8-9 vs. 10),

fewer pre anal scale rows (20-22 vs. 25-26); posterior epibranchial and ceratobranchial gill rakers on the first arch 2 (vs. 3) and 8 (vs.9), respectively; anterior epibranchial and ceratobranchial gill rakers on the first arch 4 (2) and 11 (vs. 12). It is differentiated from *N. acutirostris* sp.nov. by absence of dark lateral stripe (vs. present), no pigment at base of scale below lateral line (vs. heavily pigmented below lateral line), 2 epibranchial and 8 ceratobranchial gill rakers on the posterior side of the first arch (vs. 3, 7), 4 epibranchial and 11 ceratobranchial rakers on the anterior side of the first arch (vs. 2, 12), gut with 6 loops and 9 turns (vs. 7, 11), fewer pre-dorsal scales (8-9 vs. 10), fewer circumferential scale rows (18 vs. 20), fewer transverse breast scale rows (7-8 vs. 9) and fewer pre anal scale rows (20-22 vs. 27-28). It is distinguished from *N. tamiraparaniensis* sp. nov. by presence of postorbital stripe (vs. absent), presence of caudal spot (vs. absent), presence of tubercles below nares and cheek (vs. snout), lip color yellow (vs. dusky gray brown), absence of pigment base of scale (vs. presence all over body), scale shape at predorsum and lateral line hexagonal (vs. blunt end), 2 epibranchial and 8 ceratobranchial gill rakers on the posterior side of the first arch (vs. 3, 9), 4 epibranchial and 11 ceratobranchial rakers on the anterior side of the first arch (vs. 3-5, 9-13), gut loops 6 and turns 9 (vs. 8, 12), fewer pre-dorsal scales (8-9 vs. 11-12), fewer circumferential scale rows (18 vs. 20-22) and pre anal scale rows (20-22 vs. 23-25) and the morphometric characters of distance between pectoral fin origin and vent (46.48-53.04 vs. 17.57-28.23 %SL), maxillary barbel length (19.41-28.65 vs. 45.20-51.51 %HL), and rostral barbel length (13.68-25.93 vs. 40.20-51.69 %HL). It is distinguished from *N. hexagonolepis* by having weak dorsal spine (vs. strong spine), more lateral-line scales (28-29 vs. 27), fewer pre anal scales (20-22 vs. 27-28) and the morphometric characters of distance between pelvic fin origin and vent (18.70-25.21 vs. 27.21-31.36 %SL) and head depth at occiput (65.35-81.22 vs. 22.73-53.26 %HL).

Description: Body slender 25.19-30.02 %SL with the predorsum having a slight convex dorsal profile in comparison to the well-curved ventral margin. Profile is not pronounced. Dorsal fin origin anterior to pelvic fin insertion vertically by a width 1½ scales; predorsal length, 47.31-52.90 %SL. Distance between pelvic and pectoral fin insertions 24.93-28.30 %SL. Dorsal-fin base decreasing more sharply in height than the body margin. Ventral margin curved and ventral profile rising sharply at base of anal fin; more posterior venter less inclined to the narrowest part of the caudal peduncle. Shallowest part of the caudal peduncle 1.8 times distance from anal fin origin and base of nearest principal ray. Caudal peduncle shallow with peduncle length 12.82-17.43 %SL

Head long 24.45-29.11 %SL. Head depth at nostril, pupil and occiput 31.50-47.78, 46.69-68.00 and 65.35-81.22 %HL, respectively. Head width variable with 55.28-75.39 %HL. Interorbital width variable 35.84-64.88 %HL and about 2 times width of eye in largest specimen. Eye width from 17.21-29.00 %HL, lower jaw thick, keratinous and sharp. Upper lip distant from jaw. Maxillary barbels 19.41-28.65 %HL, and rostral barbels 13.68-25.93 %HL.

Dorsal-fin rays iv-9(12), anal-fin rays iii-5(12), pelvic-fin rays i-8(12), pectoral-fin rays i-14(8) or 15(4). Dorsal fin origin slightly anterior to pelvic fin origin by one scale. Fin sharply pointed at apex, last unbranched ray smooth, moderately strong and longest, its dorsal spinous height 12.63-18.19 %SL and length of dorsal-fin base 14.29-18.38 %SL. Anal fin moderately deep its anal fin height 16.09-20.16 %SL, and depressed fin extending to base of procurrent rays; distal margin of erect fin slightly convex; length of posterior-most ray short, not equaling fourth branched ray. Length of anal-fin base 7.12-9.86 %SL, pelvic fin length 16.31-19.67 %SL, 4 scale rows anterior to vent; distal margin of fin concave near tip but nearly straight otherwise; tip slightly procured. Depressed pectoral fin extending to 3 scale rows anterior to pelvic fin origin, its pectoral fin length 18.84-22.63 %SL. Caudal fin moderately forked, its length 27.03-35.52 %SL, outer rays about 1.7 times as long as the median rays. Upper and lower forks nearly equal; dorsal lobe slightly longer. Distal margin of each lobe nearly curved from fork to tip.

Scales hexagonal in shape near dorsum and emarginate nearer to lateral line. Below lateral-line scales diamond

shaped with pointed tips. Breast scale rows extending to head with 3 irregularly inserted scale rows near gill membrane. Belly scales are nearly hexagonal in shape.

Lateral-line scales 28(10) or 29(2), pre-dorsal scales 8(2) or 9(10), upper transverse scale rows 4(10) or 5(2), lateral line to pelvic scale rows 4(12), lower transverse scale rows 5(12), circumferential scale rows 18(12), circumpedunclar scale rows 12(12), pre anal scale rows 20(4), 21(2) or 22(6) and transverse breast scale rows 7(3) or 8(9).

Coloration: Dorsum dark from first three scale rows on center heavily pigmented. Below dorsum flank golden silver to white venter. Fins, lips, and lower opercle and preopercle yellow. Anterior membranes of dorsal fin red; posterior membranes dusky. Large squarish dark blotch on caudal peduncle at terminus of lateral line, anterior to base of caudal fin. In formalin preserved specimens more darkly pigmented and without colors. Body light gold to silver; dorsum to 3 scale rows from center with scales fully darkly pigmented, providing black dorsum; ventrally to 1/2 scale row below lateral line scale bases only dusky, no distinct dark base, venter immaculate yellowish, dorsal with red anterior; caudal yellowish pink.

Tuberculation: Tubercles small and restricted mostly to below nares and on cheeks.

Etymology: From the Latin (*micros*) (*opthalmus*) allusion to small eyes. A noun in apposition.

Intestine: gut with 6 loops and 9 turns.

Gill rakers: Posterior side of the first arch with 2 and 8 gill rakers on epibranchial and ceratobranchial segments, respectively; anterior side with 4 and 11 gill rakers on epibranchial and ceratobranchial segments, respectively.

Distribution and Natural History: This species has been found at only one location, a stream called Ambayathode in the forest reserves in the Kannur District, Kerala. This stream flows west and confluences with Valapatnam River.

Neolissochilus acutirostris, sp. nov.

(Figs. 3D, 4D)

Holotype: ZSI/SRS F 7152, 225.75 mm SL, Abby falls (11˚40'38.2"N, 75˚43'8.0"E; altitude, 963 m), a stream in the Cauvery River drainage in Kodagu District, Karnataka, M. Arunachalam and team, 22 March 2004.

Paratypes: MSUMNH194, 1, 160.17 mm SL; same as holotype. - CMA173, 18, 44.31-206.34 mm SL; same as holotype.

Diagnosis: *Neolissochilus acutirostris* sp. nov. is distinguished from *N. hexasticus* by having more lateral-line scales (29-32 vs. 26), more lateral line to pelvic scale rows (4 vs. 2.5) and circumferential scale rows (20 vs. 18). It is distinguished from *N. dukai* by having more lateral-line scales (29-32 vs. 28) and more upper transverse scale rows (5 vs. 3.5). It is distinguished from *N. stracheyi* by having more lateral-line scales (29-32 vs. 26), more pre-dorsal scales (10 vs. 7), and more circumferential scale rows (20 vs.18). It is distinguished from *N. compressus* by having more lateral-line scales (29-32 vs. 28), more pre-dorsal scales (10 vs. 9), and more upper transverse scale rows (5 vs. 4). It is distinguished from *N. blythii* by having more lateral-line scales (39-32 vs. 25), more pre-dorsal scales (10 vs. 5), more lateral line to pelvic scale rows (4 vs. 3) and more circumferential scale rows (20 vs. 17).

Neolissochilus acutirostris sp. nov. resembles most closely in shape and color to *N. wynaadensis* but can be distinguished from this species by more upper transverse scale rows (5 vs. 4) and more pre anal scale rows (27-28 vs. 25-26). It is distinguished from *N. tamiraparaniensis* sp. nov. by presence of wide dark black lateral stripe (vs. absent), presence of postorbital stripe (vs. absent), presence of tubercles on tip of snout and cheek (vs. snout), lip color reddish orange (vs. dark gray brown), scale shape at predorsum and lateral line hexagonal (vs. blunt end), pigment at base of scales below lateral line (vs. all over body), fewer pre-dorsal scales (10 vs.11-12), more pre anal scale rows (27-28 vs.23-25) and the morphometric characters of peduncle depth (9.38-12.34 vs. 15.12-

21.38 %SL), distance between pectoral fin origin and vent (44.88-48.78 vs. 17.57-28.27 %SL). It is distinguished from *N. hexagonolepis* by having weak dorsal spine (vs. strong), more lateral-line scales (29-32 vs. 27), more pre-dorsal scales (10 vs. 9), more transverse breast scale rows (9 vs. 7-8) and morphometric characters of peduncle length (10.99-13.79 vs. 16.31-19.06 %SL) and pelvic fin length (16.12-20.23 vs. 11.73-15.92 %SL).

Description: Body elongate 22.88-26.96 %SL. Dorsal fin origin anterior to pelvic fin origin by 2 scale rows and predorsal length 47.50-51.48 %SL, compared to prepelvic length 51.39-54.28 %SL. Anal fin distant with preanal length 73.05-80.18 %SL, with distance between the pectoral fin insertion and anal fin origin 45.50-52.82 %SL, nearly 2 times more than the distance between the pectoral fin insertion and pelvic fin insertion 23.23-28.41 %SL. Dorsal and ventral margin convex. Trunk and peduncle compressed, peduncle moderately shallow, its peduncle length 10.99-13.79 %SL, at shallowest region 2.3 times the distance from the anal fin insertion to caudal fin base, at 3rd lateral line body scale.

Head long 25.76-29.77 %SL, head depth 28.25-39.08, 45.88-61.42 and 62.13-81.93 %HL at nosril, pupil and occiput, and interorbital is moderate to narrow 35.46-49.78 %HL, eyes moderate 17.18-30.17 %HL. Mouth subterminal with lower jaw sub equal. Snout long and pointed 29.71-40.81 %HL, and gape width 17.97-31.14 %HL, lower jaw keratinous and sharp. Barbels moderately long and variable, the maxillary pair from 18.20-26.85 %HL, and the rostral pair from 10.99-22.33 %HL.

Dorsal-fin rays iv-9(20), anal-fin rays iii-5(20), pelvic-fin rays i- 8(20), pectoral-fin rays i-15(20). Dorsal fin originating two scale rows before origin of pelvic fin vertically, and moderate, its height 19.60-29.67 %SL, with a concave distal margin. Last unbranched ray smooth and moderately strong its dorsal spinous height 11.21-22.25 %SL. Anal fin deep 13.88-21.73 %SL, exceeding to 4 lateral line body scales anterior to the base of the caudal fin rays. Last unbranched ray longest, margin of fin pointed but not falcate tip its base length 5.46-13.92 %SL. Pelvic fin extending to three scale rows before vent, its pelvic fin length 16.12-20.23 %SL, pectoral fin extending to third scale row before pelvic fin origin, its length 18.52-23.67 %SL, with tip slightly produced and distal margin nearly straight when fin is erect. Caudal fin moderately forked 25.78-40.37 %SL, with marginal rays of upper lobe longest and slightly more than 1.8 times the length of median rays. Marginal rays of both lobes slightly produced, with fin margin becoming concave at 3rd and 4th branched rays of both lobes and remainder of margin nearly straight.

Lateral-line scales 29(5), 30(11), 31(3) or 32(1), pre-dorsal scales 10(20) upper transverse scale rows 5(20), lateral line to pelvic scale rows 4(20), lower transverse scale rows 5(12) or 6(8) circumferential scale rows 20(20), circumpeduncular scale rows 12(20), transverse breast scale rows 9(20) and pre anal scale rows 27(18) or 28(2). Squamation of upper trunk and peduncle composed of hexagonal shaped scales. Scales of predorsal area in first five scales elliptical and rest of the scales wavy and few emarginated. Scale rows from prepelvic scale rows origin three distinct types; four rows from pelvic fin origin bigger and regular, next seven rows of smaller scales with additional insertion of two rows, scales up to isthmus are small.

Tuberculation: Small tubercles present across the tip of snout and cheek.

Coloration: Central dorsal scale row dark, forming predorsal stripe, below which second and third scale rows pink, followed by two bluish scale rows. Bases of scales darkly pigmented from dorsum to ½ scale row below lateral line. Lateral-line scales darkly pigmented, especially anteriorly, creating dark lateral stripe. Scales golden orange for 2½ scale rows below lateral line. Caudal fin base and posterior extent of caudal peduncle with large black blotch. Dorsal and caudal fins red with narrow black distal margins; pectoral and pelvic fins red and with heavily pigmented anterior rays and membranes medially, most noticeable anteriorly. Cheek, opercle, preopercle, interopercle golden yellow. Lips reddish orange. Belly whitish to dull yellow. Preserved specimens lacking colors, body tannish to brown with areas with greatest melanophore distribution being darkest; belly grayish. Central predorsal scale row and adjacent scale row darkly pigmented; predorsal stripe present; ventro-laterally to

dark scales scale rows with pink line, followed by blue line; below blue wide dark lateral stripe 2.5 scale rows deep anteriorly (lateral line scale row plus one scale row above and dorsal half of scale row below lateral line) and narrowing on caudal peduncle to lateral line scale row and adjacent dorsal scale row; below lateral stripe body golden to vent were immaculate.

Intestine: gut with 7 loops and 11 turns.

Etymology: From the Latin (*acute* and *rostral*) allusion to the sharp pointed snout. A noun in apposition.

Pharyngeal cavity: *Neolissochilus acutirostris* have 3 gill rakers on epibranchial segments and 7 on ceratobranchial segments of the posterior side and 2 on epibranchial and 12 on ceratobranchial segments in the anterior side.

Distribution and Natural History: This species is represented by one population in Abby falls (11°40'38.2"N, 75°43'8.0"E; altitude, 963 m), a stream in the Cauvery River drainage in Kodagu District, Karnataka. The area of the pool where all of the specimens were collected was 120 m^2 and had a mean depth of 1.2 m, mean flow was 0.21 m/s. This area had at least 30% riparian cover. Substrate types in the pool included bedrock (35%), boulders (40%), gravel (10%), and sand covered with leaf litter (15%). Along with the populations of *Neolissochilus acutirostris*, *N. wynaadensis* was sampled here, indicating that this species exists in sympatry. This record of *N. wynaadensis* represents a range extension outside Wynaad District of Kerala as the species has never been reported in this district (Arunachalam et al. 2005). In this area natural forests are disturbed by coffee plantations.

Neolissochilus tamiraparaniensis, sp. nov.

(Figs. 3E, 4E, Tables 1, 2)

Holotype: ZSI/SRS F 7089, 174.33 mm SL; Gadana River of Tamiraparani River basin (east flowing in southern Tamil Nadu, 08°47'59.3"N, 77°11'18'0.11"E), M. Arunachalam and team, 24 February 2004.

Paratypes: ZSI/SRS F 7090, 4, 108.7-166.30 mm SL; same as holotype. - MSUMNH195. 1, 246.56 mm SL, same as holotype. - CMA174. 34, 63.09-238.24 mm SL; same as holotype.

Diagnosis: *Neolissochilus tamiraparaniensis* sp. nov. is distinguished from *N. hexasticus* by having more lateral-line scales (28-30 vs. 26) and more pre-dorsal scales (11-12 vs. 9-10). It is distinguished from *N. dukai* by having more pre-dorsal scales (11-12 vs. 9-10) and more upper transverse scale rows (5-6 vs.3.5). It is distinguished from *N. stracheyi* by having more lateral-line scales (28-30 vs. 26), more pre-dorsal scales (11-12 vs. 7), and more circumferential scale rows (20-22 vs. 18). It is distinguished from *N. compressus* by having more pre-dorsal scales (11-12 vs. 9), and more upper transverse scale rows (5-6 vs. 4). It is distinguished from *N. blythii* by having more lateral-line scales (28-30 vs. 25), more pre-dorsal scales (11-12 vs. 5), more lateral line to pelvic scale rows (4-5 vs. 3) and more circumferential scale rows (20-22 vs. 17). It is distinguished from *N. wynaadensis* by more pre-dorsal scales (11-12 vs. 10), more upper transverse scale rows (5-6 vs.4) and more circumferential scale rows (20-22 vs. 18-19). Both the species have 3 gill rakers on the epibranchial segment and 9 on the ceratobranchial segment of the posterior side of first arch and the anterior side of *N. wynaadensis* has 2 on epibranchial and 12 on ceratobranchial segment and in *N. tamiraparaniensis*, it has 3-5 on epibranchial and 9-13 on ceratobranchial segments and the morphometric characters of peduncle depth (15.12-21.38 vs. 9.41-10.99 %SL), distance between pectoral fin origin and vent (17.57-28.23 vs. 46.07-53.11 %SL). It is distinguished from *N. hexagonolepis* by having weak dorsal spine (vs. strong), more lateral-line scales (28-30 vs. 27), more pre-dorsal scales (11-12 vs. 9), more pre anal scale rows (23-25 vs. 27-28) and morphometric characters of peduncle depth (15.12-21.38 vs.10.86-10.90 %SL) and caudal fin length (29.70-35.20 vs. 24.31-28.32 %SL).

Description: Body elongate and extent 22.91-34.39 %SL, with the dorsal and ventral profiles curved. Dorsal fin origin anterior to pelvic fin by the width of 2½ scale rows, with predorsal length 47.06-56.15 %SL. Ventral margin slightly curved, ventral profile rising sharply at the anal base, and from there a less inclined line extends

to the narrowest part of the peduncle. Shallowest part of the peduncle 1.3 times less than the distance from anal fin insertion to the base of the nearest principal ray. Peduncle moderately deep 15.12-21.38 %SL and length short 13.11-23.51 %SL.

Head moderate 16.77-31.42 %SL, with long cranium 23.11-34.08 %SL. Head depth at nostril, pupil and occiput 28.44-62.35, 57.23-92.77 and 75.84-85.42 %HL, respectively, and snout to opercle 58.84-81.36 %HL. Similarly, interorbital width variable, from narrow to broad, 34.61-65.20 %HL. Eye width moderate 21.34-42.21 %HL. Snout long, 32.13-58.87 %HL with mouth sub terminal, upper jaw length 24.76-50.20 %HL, and gape width 24.32-49.71 %HL, upper jaw with lower jaw keratinous and sharp. Barbels long and variable, the maxillary pair from 45.20-51.51 %HL and the rostral pair from 40.20-51.69 %HL.

Dorsal-fin rays iv-9(40), anal fin rays iii-5(40), pelvic fin rays i-8(40), pectoral fin rays i-13(6), 14(30) or 15(4), dorsal fin height 20.53-31.90 %SL, distal margin of fin concave with posterior its dorsal spinous height 11.82-24.87 %SL, anal fin shallow, its height 14.46-26.84 %SL, extending, when depressed to base of anterior procurrent caudal fin rays. Distal margin irregular when fin is erect, the length of most posterior ray equal to that of the fourth branched ray. Length of anal-fin base, 6.64-17.75 %SL. Pelvic fin extending to the vent, its length 12.30-25.65 %SL. Distal margin concave near tip, but nearly straight otherwise. Tip slightly produced. Pectoral fin long, extending to 4th scale row anterior to pelvic fin origin its length 17.88-29.86 %SL. Distal margin nearly a straight line when fin is erect and tip is produced and concave in second and third branched rays. Caudal fin long and moderately forked 29.70-35.20 %SL, with outer rays only about 2 times as long as middle rays. Upper and lower forks nearly equal.

Lateral-line scales 28(16), 29(10) or 30(14), pre-dorsal scales 11(20) or 12 (20), upper transverse scale rows 5(19) or 6(21), lateral line to pelvic fin scale rows 4(20) or 5(20), circumpeduncular scale rows 12(10), 13(16) or 14(14), circumferential scale rows 20(18), 21(10) or 22(12), lower transverse scale rows 5(26) or 6(14), transverse breast scale rows 7(7), 8(14) or 9(19), and pre anal scale rows 23(12), 24(10) or 25(18).

Squamation composed almost entirely of scales with blunt end. Near dorsum scales are diamond shaped and in the next rows irregular pattern of hexagonal shaped scales present. Last few scales of midline rows have wavy margins. Most scales have widths greater than half their heights.

Coloration: Dorsum and flanks ventrally to near bases of paired and anal fins golden; bases of scales darkly pigmented for three rows from center; remainder of scale rows, including lateral line (punctated) with bases of scale rows lighter and more dusky in coloration; melanophores at bases of scale creating noticeable diamond-shaped pattern; venter immaculate and yellowish-red dorsal and ventral edges of caudal lobes lined in black.

Tuberculation: Tubercles are medium sized and occur only on snout region.

Pharyngeal cavity: Gill rakers have 3 on epibranchial, 9 on ceratobranchial segment of the posterior side of the first arch and 3-5 on epibranchial and 9-13 on ceratobranchial segment of anterior side.

Gastro intestinal tract: Entire gut has 8 loops and 12 turns.

Etymology: This species is endemic to Tamiraparani River basin and hence named after the river.

Distribution and Natural History: Currently known from two streams in Gadana River, Tamiraparani River flowing east in southern Tamil Nadu. Adults of *N. tamiraparaniensis* prefer deep pools with varied microhabitats. (pool area in Gadana River (186-307 m^2). Juveniles are confined to shallow areas with high velocity in riffles and riffle pool transition. Microhabitat preference of fish depth is between 0.3-0.6 m/s. Microhabitat preference of this species in a different name is discussed elaborately (Arunachalam 2000). During wet season *N. tamiraparaniensis* prefers benthic invertebrates and a small portion of periphytic algae as food.

Detailed information is available on the habitat use of *N. tamiraparaniensis* (Arunachalam and Sankaranarayanan 1999; Arunachalam and Sankaranarayanan 2000). It should be noted that the senior author referred to this species, using a different name (*Hypselobarbus dobsoni*) in two publications (Arunachalam and

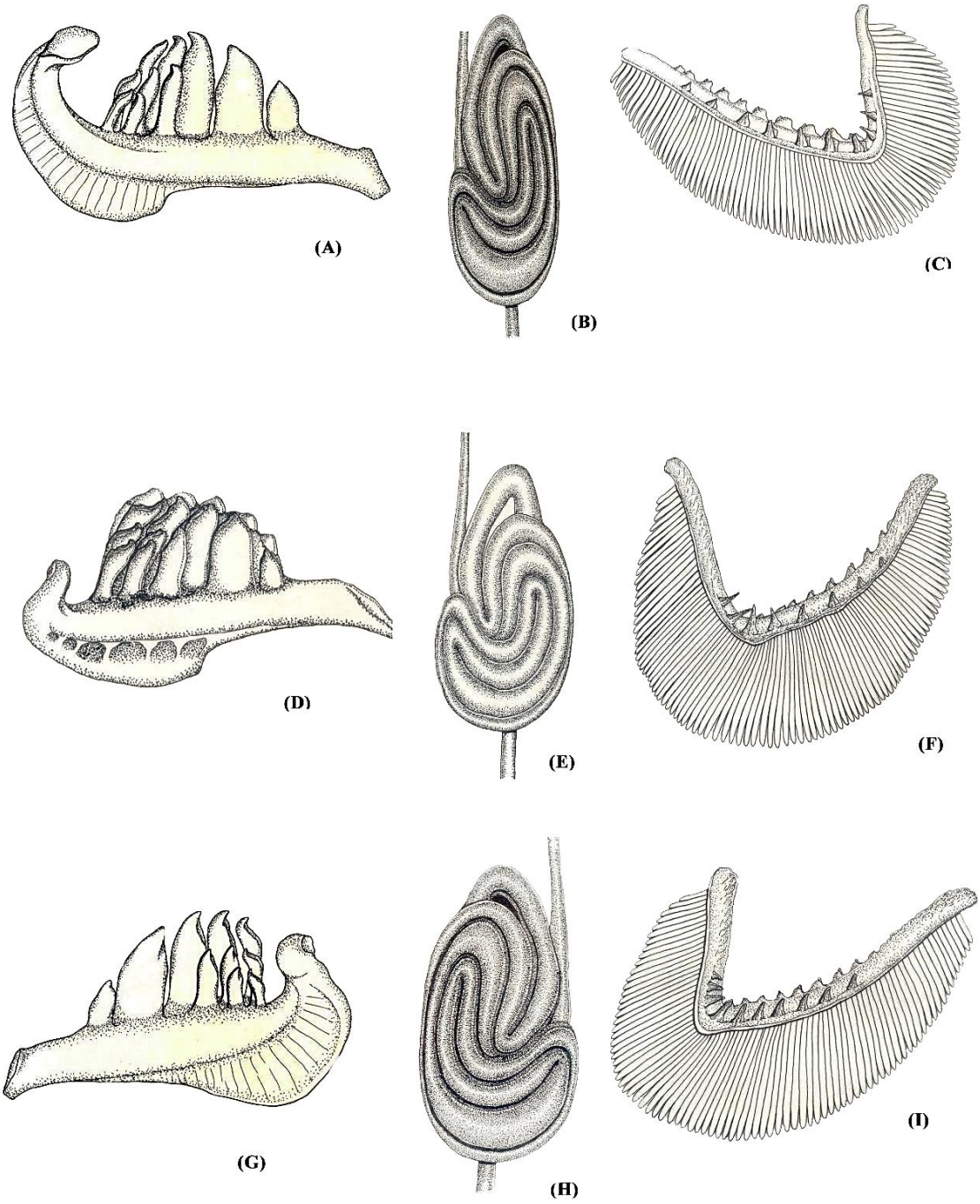

Figure 5. Pharyngeal teeth, gut and gill rakers of (A to C) *Neolissochilus wynaadensis*, (D to F) *Neolissochilus capudelphinus* sp. nov. and (G to I) *Neolissochilus minimus* sp. nov.

Sankaranarayanan 1999; Arunachalam and Sankaranarayanan 2000) and other usage was in an unpublished doctoral dissertation (Vijayakumar 2002). Developmental stages from the fertilized egg to juvenile period is 8-31 days. Detailed information is available in the doctoral dissertation of Vijayakumar (2002). The gill rakers, pharyngeal teeth and the intestine of all the five new species of *Neolissochilus* and *N. wynaadensis* are given Figures 5 and 6.

Comparisons using geometric morphometry: The relative warp extracted from the matrix of partial warp scores accounted for 89% of the variation, of which the first relative warp accounted for 67.8% of the variation. The

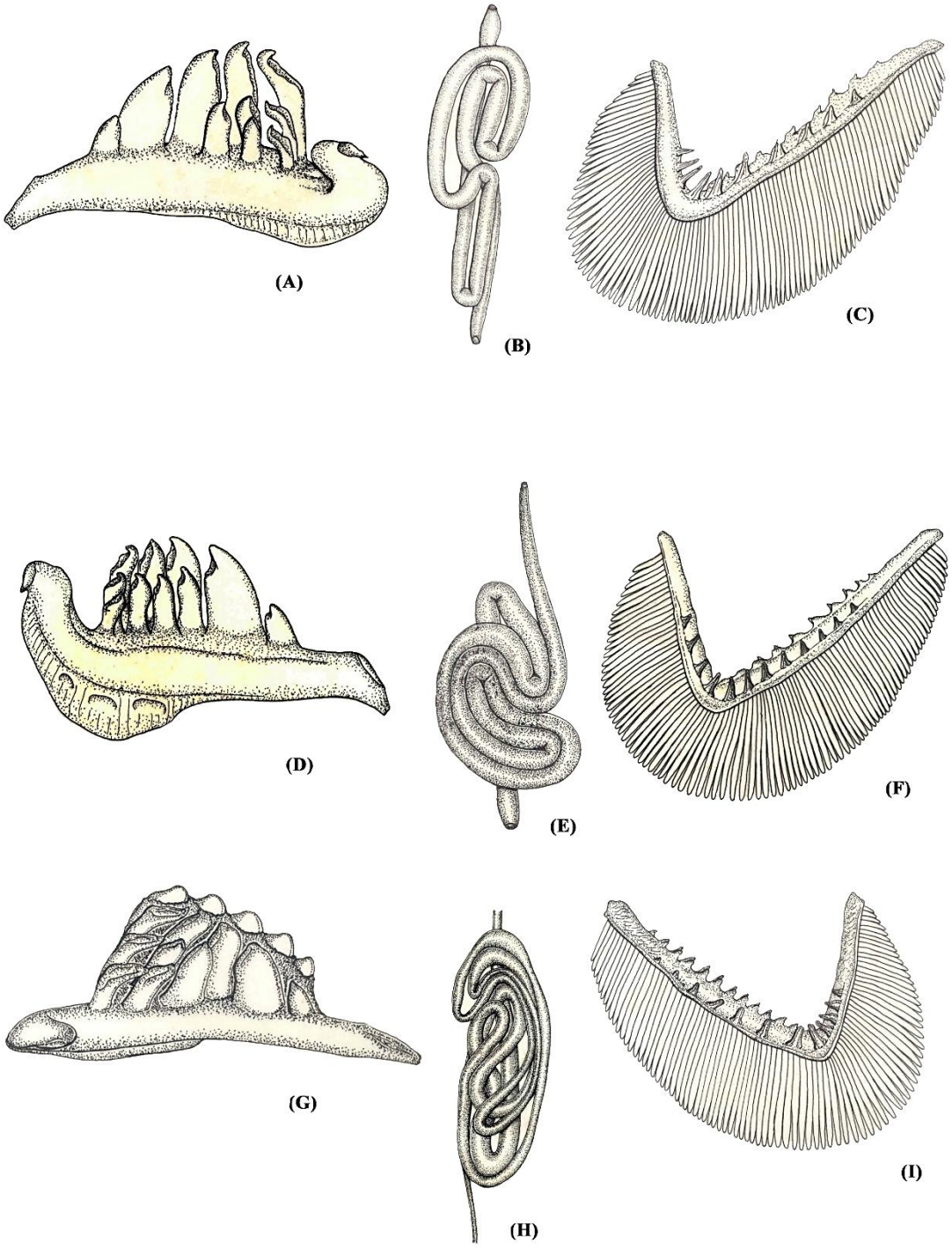

Figure 6. Pharyngeal teeth, gut and gill rakers of (A to C) *Neolissochilus micropthalmus* sp. nov., (D to F) *Neolissochilus acutirostris* sp. nov. and (G to I) *Neolissochilus tamiraparaniensis* sp. nov..

second relative warp accounted for 21.2% of the total non-affine shape variation. Ordination of the scatter plot for the first two relative warp scores corroborates the hypothesis that all five species are distinct. The pattern of shape change on the first two relative warps (Fig. 7) illustrates that *N. capudelphinus* scored the highest value and the other four new species showed the lower values in warp scores 1. The relative warps were also shown as thin plate splines, illustrating deformations implied by positive and negative displacements along the first two relative warps. Shape analysis of each species was identified using the deformation grid (Fig. 8). Based on the

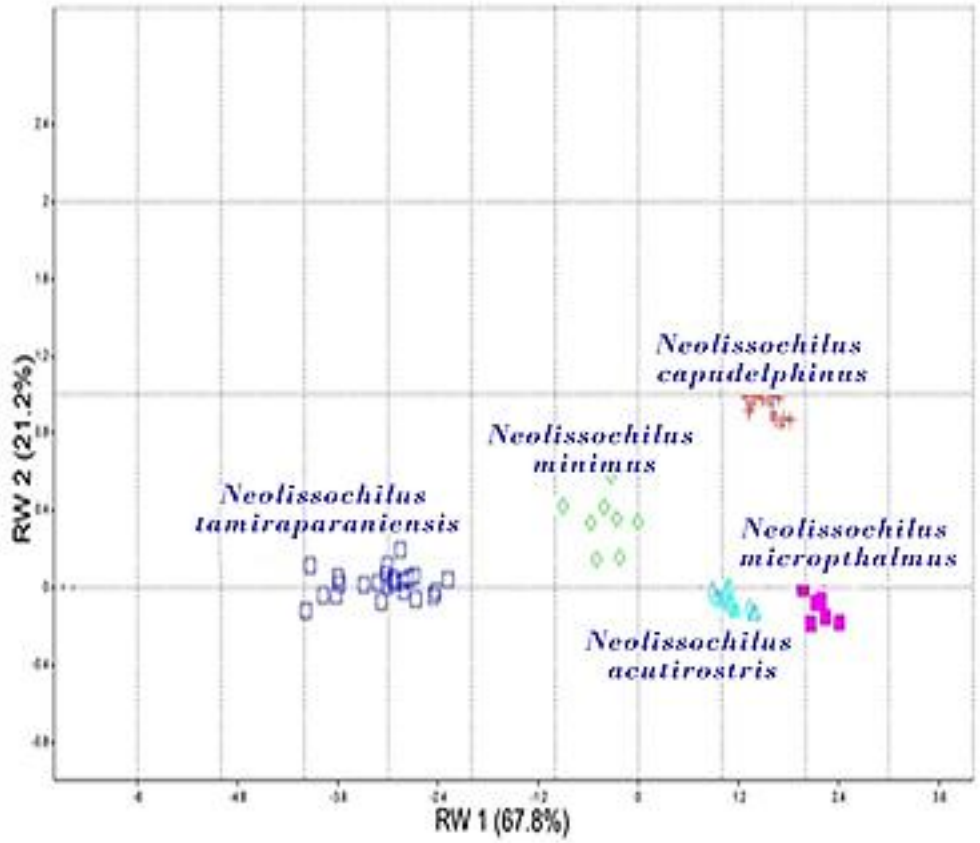

Figure 7. Scatter plot of individual scores from the relative warps analysis of *Neolissochilus capudelphinus*, *Neolissochilus minimus*, *Neolissochilus micropthalmus*, *Neolissochilus acutirostris* and *Neolissochilus tamiraparaniensis* with the uniform component included $\alpha = 0$.

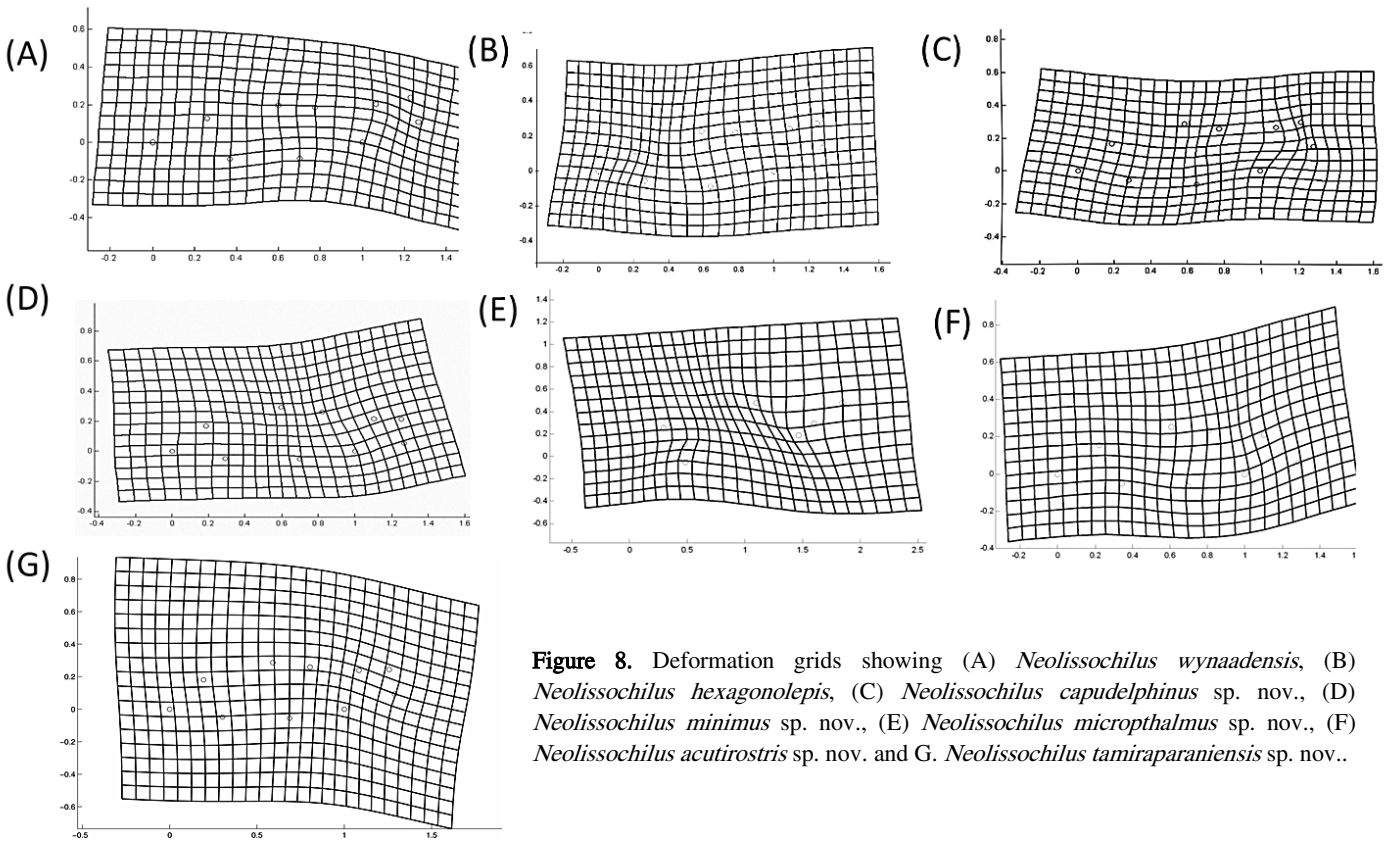

Figure 8. Deformation grids showing (A) *Neolissochilus wynaadensis*, (B) *Neolissochilus hexagonolepis*, (C) *Neolissochilus capudelphinus* sp. nov., (D) *Neolissochilus minimus* sp. nov., (E) *Neolissochilus micropthalmus* sp. nov., (F) *Neolissochilus acutirostris* sp. nov. and G. *Neolissochilus tamiraparaniensis* sp. nov..

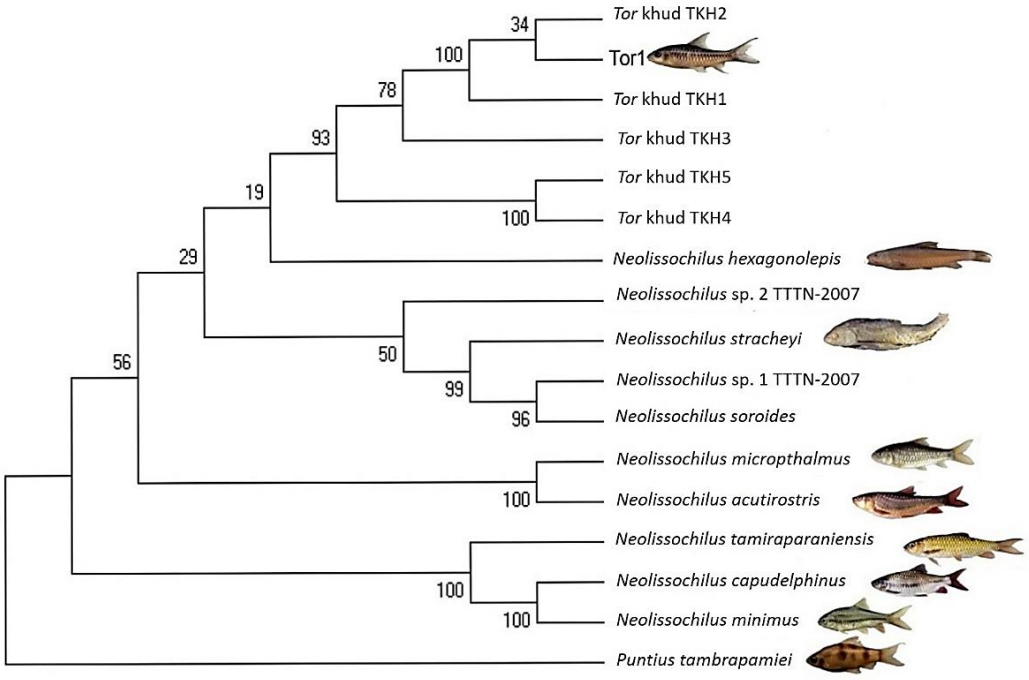

Figure 9. Cladogram showing topologies of Maximum Likelihood trees resulting from 465-taxon mt dataset (full tree embedded) and 791-taxon mt dataset.

square in shrinkage and enlargement, the character differs from the reference specimen of *N. wynaadensis* and the five new species.

Neolissochilus hexagonolepis is compared with *N. wynaadensis.* The grid shows the shape variation on the morphology by means of reduction and expansion in its normal structure to analyzed structure. Based on the coordinate values, the grid shape was generated. Head is sharper in *N. hexagonolepis* than *N. wynaadensis,* but body is condensed and broader.

Grid analysis of *N. capudelphinus* showed that the peduncle length expansion was more and dorsal-fin base was reduced. The caudal length was also expanded. Distance between pelvic and anal fins was condensed, but expansion was observed in the pectoral to pelvic distance. In this species, body depth was considerably enlarged from *N. wynaadensis*. The head shape of this species was sharp, illustrating the characteristic feature of the genus.

The grid analysis of *N. capudelphinus* showed that peduncle length, occiput length and dorsal base are slightly condensed as in *N. wynaadensis* but expanded structures were observed in the pectoral to anal region and in the head characters, though it showed slender body. Among all the five new species of *Neolissochilus,* this species showed minimal variation in total length, caudal length and dorsal base. Grid shape also showed that variation in head length was slightly enlarged. The body characters such as occiput to dorsal and standard length showed high degree of condensation. The condensation in the body length is not affecting the proportional rate of caudal region of this species.

In *N. acutirostris,* the occiput region to dorsal insertion showed slight expansion while reduction of the distance was observed in the peduncle length. The grid analysis of *N. tamiraparaniensis* showed that the caudal length and shape were condensed and body depth, head length, and occiput to caudal base length are broad, which revealed that this species is having a bigger body shape compared to the other four new species of *Neolissochilus.*

Comparisons using genetic variation: The evolutionary history was inferred using the Neighbor-Joining method (Saitou and Nei, 1987). The optimal tree showed a sum of branch length=0.54454572. The percentage of replicate

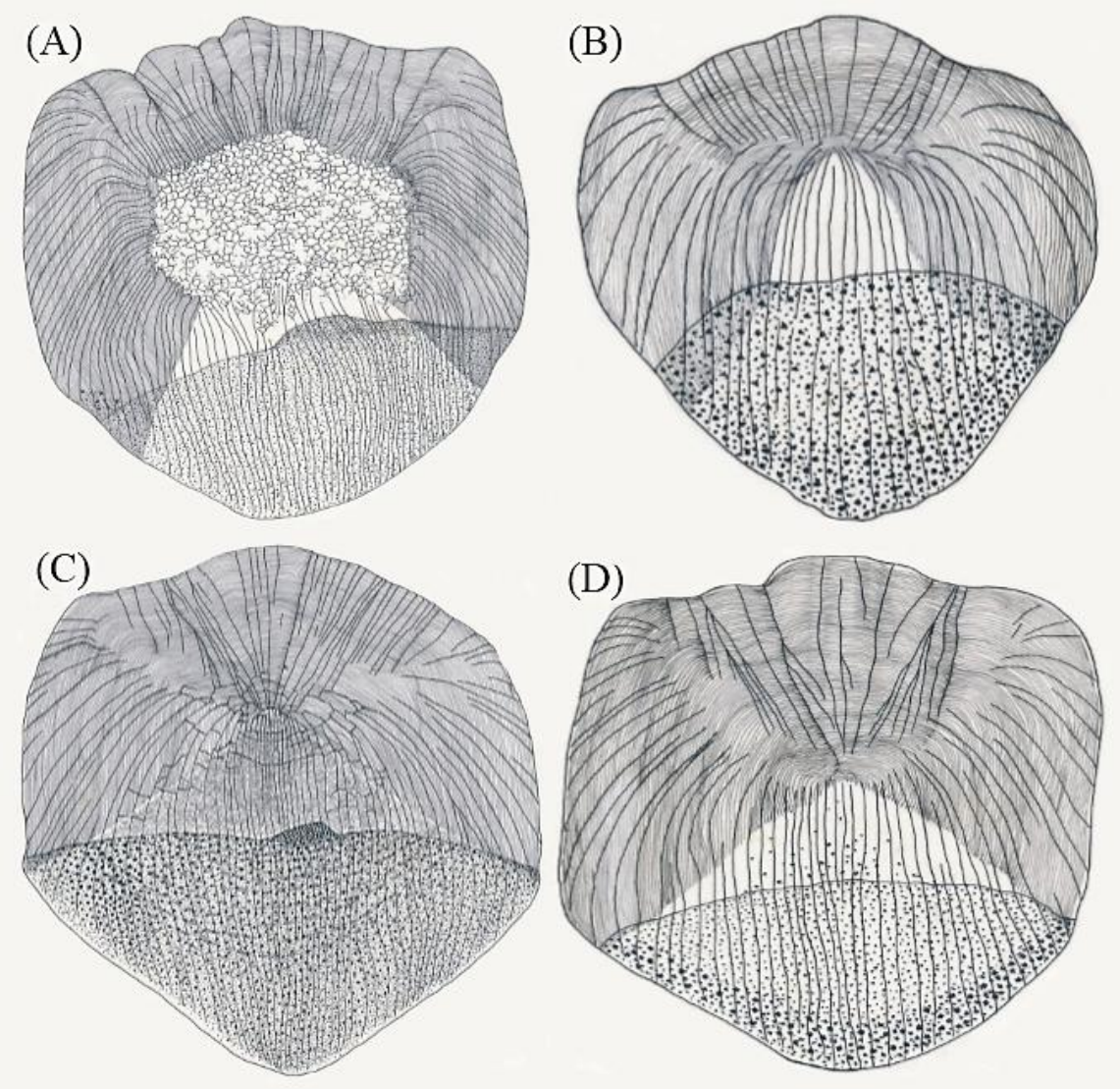

Figure 10. Scale structure of (A) *Puntius carnaticus*, (B) *Neolissochilus wynaadensis*, (C) *Neolissochilus hexagonolepis* and (D) *Neolissochilus capudelphinus* sp. nov.

trees in which the associated taxa clustered together in the bootstrap test (500 replicates) is shown next to the branches (Felsenstein 1985). The tree is drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. Codon positions included were 1st+2nd+3rd+ noncoding. All positions containing gaps and missing data were eliminated from the dataset (complete deletion option). There were a total of 728 positions in the final dataset. Data from the present study revealed high levels of genetic variation and clear patterns in *N. capudelphinus* and *N. micropthalmus*, while little variation and no apparent pattern were observed between *N. acutirostris* and *N. tamiraparaniensis.* In the MP tree, the genus *Tor* formed a monophyletic lineage with 93% bootstrap support. The cluster of *N. capudelphinus*, *N. minimus* and *N. tamiraparaniensis* is a sister group of *N. micropthalmus* and *N. acutirostris* forms a separate lineage (Fig. 9).

Interraltionships: *Neolissochilus capudelphinus* is closely related to *N. minimus,* a co-occurring species in diverted water of Periyar River. *Neolissochilus minimus* and *N. micropthalmus* are closer to *N. wynaadensis.* Also *N. acutirostris* resembles more closely in shape with *N. wynaadensis* and it co-occurs with *N. acutirostris* outside its range of distribution (Arunachalam et al. 2005). *Neolissochilus tamiraparaniensis* showed its range of distribution from Tamiraparani River basin in the southernmost tip of the peninsula. *N. capudelphinus* and *N. minimus* co-occurred in Vaigai River basin, 250 km north of Tamiraparani River. *Neolissochilus minimus*

showed its distribution in and around Cumbum Valley of Western Ghats and *N. capudelphinus* occurred in diverted water of Periyar River. The distributional range of *N. tamiraparaniensis* and *N. wynaadensis* is far apart with more than 600 km.

All the five new species of *Neolissochilus* collected under a research project and hence were reported in two progress reports, one in June 2003 and another in March 2004 to the National Bureau of Fish Genetic Resources, Lucknow as this was the Lead Centre for the project funded by World Bank under Government of India. Raghavan et al. (2013) and Ali et al. (2014) stating that all the names of the five new species are nomina nuda. As per the code of nomenclature, the first author gave the names earlier and now all the species are described here. Menon (1999) synonymized *N. spinulosus* (McClelland, 1845) and *N. dukai* with *N. hexagonolepis* and there is no mention about *N. hexasticus* but he also synonymized *N. hexasticus* reported from Abor hills, Assam (Chaudhuri 1913) from Naga Hills and Manipur Valley (Hora 1921), and from Indawgyi Lake, Myanmer (Prashad and Mukerji 1929). Jayaram (2000) considered *N. hexagonolepis, N. hexasticus, N. dukai* and *N. spinulosus* as distinct species. The redescription of *N. hexasticus* and *N. dukai* is under publication by the senior author. There is only one report of *N. spinulosus* from Sikkim, India since its description by Mc Clelland (1845) but the voucher specimen was not traceable (Kundu 2000) and hence comparison was not done with the five new species. Also in the syntype of *Barbus* (=*Neolissochilus*) *innominatus* (Day, 1870) only the meristic counts of lateral line scales (24) and the scale row from lateral line pelvic (3) were possible and the morphometric characters were not measured due to the bad condition of the type specimen. These two characters distinguish all the new species described herein.

Genus *Neolissochilus* is closely related to *Tor* and this has been elaborately discussed by Rainboth (1985). However, the juveniles of all the species of *Tor* and *Neolissochilus* from Western Ghats streams of peninsular India showed much resemblance with a caudal spot in juvenile stages. In underwater observation (personal observation by senior author), it is hard to differentiate the juveniles of both *Tor* and *Neolissochilus.* Rainboth (1985) doubted that *T. progenius* (McClelland 1839), a member of the genus of *Tor* as this species has 8-10 gill rakers and the absence of median lobe on the lower lip (characteristic of *Tor* and distinguishing character of *Tor* and *Neolissochilus*); all other species of *Tor* have 10-16 gill rakers. Interestingly, in recent collections of fresh materials of *Tor progenius* from the Brahmaputra River of Arunachal Pradesh, these specimens clearly possess the characteristic median lobe to the genus of *Tor*.

In peninsular India, *Neolissochilus* can be a close relative to *Puntius carnaticus* Jerdon (1849) but Menon (1999) included this genus under *Barbodes* though it is a name used for a variety of Cyprinid fishes in Southeast Asia (Rainboth 1981, 1996; Kottelet 1989; Kottelat et al. 1993) and China (Wu 1997; Chu and Chen 1989). However, the generic identity of *P. carnaticus* is out of scope of the present study though it is tentatively placed under the genus *Hypselobarbus* (Arunachalam et al. 2012). The Carnatic carp is closely related and have major overlap in meristic counts and morphomeric characters of the genus *Neolissochilus* except the strong dorsal spine in *P. carnaticus*. Based on this character, the identity of *N. minimus* into the genus *Neolissochilus* was tested with the study of chromosome number. In *N. minimus* population was tested and compared with the chromosome number of *P. carnaticus* collected from the type locality (Bhavani River, Cauvery Basin). The karyological study revealed that the chromosome 2n=88 in *P. carnaticus* whereas, 2n=78 in *N. minimus*. *Tor* sp. from Western Ghats showed the number of chromosome as 2n=100 (Arunachalam and Murugan 2007). This clearly proves that *Tor* and *Neolissochilus* have two lineages and polyploidy might have occurred in these two genera.

Another distinguishing character is the structure of scales. Scales of *Neolissochilus* was exactly similar as described by Rainboth (1985) with apical radii converging and the lateral field radii originating along full latero-basal field margins and arching smoothly and the scales of *P. carnatius* showed a distinct pattern with a large circuli area there was no converging of anterior and posterior radii. Antero lateral and postero lateral radii are

convex (Fig. 9). Another interesting peninsular endemic genus closely related to *Neolissochilus* is *Hypselobarbus*. The wrong placement of *N. tamiraparaniensis* as *H. dobsoni* (Arunachalam and Sankaranarayanan 1999; Arunachalam and Sankaranarayanan 2000) was because of these two species had major overlapping meristic and morphometric characters. A thorough study on food and feeding, feeding ecology, captive breeding, embryonic development and cryopreservation was carried out in a doctoral program with a name *H. dobsoni* (Vijayakumar 2002).

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