Taylor & Francis
Taylor & Francis Group

Redescription of *Mastacembelus ophidium* Günther, 1893 (Synbranchiformes: Mastacembelidae) and description of a new spiny eel from Lake Tanganyika

E. J. VREVEN

Africa Museum, Vertebrate Section, Tervuren, Belgium

Abstract

A detailed morphometric study was undertaken of collections of the Lake Tanganyika endemic *Mastacembelus ophidium*. On each specimen 27 measurements and 12 meristics were taken. Within the specimens previously identified as *M. ophidium* a new species was discovered. A redescription of *M. ophidium* and a description of the new species are provided.

Keywords: *Distribution patterns, Mastacembelus polli sp. nov., meristics, morphometrics, new species, taxonomy*

Introduction

Mastacembelidae are anguilliform fishes that can attain a maximum length of about 1 m. Very characteristic is the rostral appendage which bears the two tubulated nostrils, one on each side of the central rostral tentacle. The gill opening is reduced due to a connection of the opercular membrane with the lateral wall of the body. Mastacembelidae have a long series of well-separated dorsal spines, hence their name spiny eels. Further, they also have a short series of anal spines. Pelvic girdle and fins are absent. Most species are characterized by a large number of small cycloid scales. In all African members of the family the dorsal, caudal and anal fins are confluent.

Travers (1984a, 1984b) revised the suborder Mastacembeloidei and divided the family Mastacembelidae in two subfamilies: the Mastacembelinae occurring in Asia and the Afromastacembelinae in Africa. Travers (1984b) recognized two genera in the latter subfamily: *Caecomastacembelus* Poll, 1958 (type species *C. brichardi* Poll, 1958) and *Afromastacembelus* Travers, 1984b (type species *Mastacembelus tanganicae* Günther, 1893). In 1988, Travers mentioned that the types of *M. tanganicae*, in fact, display the generic characters of *Caecomastacembelus*. Thus, Travers (1988) synonymized *Afromastacembelus* with *Caecomastacembelus*. For the other species previously allocated to *Afromastacembelus*, a new genus, *Aethiomastacembelus*, was described and a new type species, *Mastacembelus*

marchei Sauvage, 1879, was designated. However, the generic position of many of these species subsequently was found to be confused (Seegers 1996; Vreven and Teugels 1996, 1997; Vreven 2004). Vreven and Teugels (1996) discussed the problems of the type material of both genera. This study revealed several inaccuracies and contradictions in the diagnoses of both genera. At present, there is no phylogenetic evidence supporting their validity (monophyly) and there are no straightforward diagnostic character(s) available for their diagnosis. The present status is harmful to the stability of the generic nomenclature of the African Mastacembelidae. Therefore, Vreven (forthcoming) proposed that the present use of both genera *Caecomastacembelus* and *Aethiomastacembelus* should be abandoned and that both genera are placed in synonymy with *Mastacembelus*.

Within Lake Tanganyika, based on meristic, morphometric and colour pattern data, at present, 12 endemic mastacembelid species, including the new species, are recognized (E. J. Vreven, personal observation): *Mastacembelus albomaculatus* Poll, 1953; *M. cunningtoni* Boulenger, 1906; *M. ellipsifer* Boulenger, 1899; *M. flavidus* Matthes, 1962; *M. moorii* Boulenger, 1898; *M. micropectus* Matthes, 1962; *M. ophidium*; *M. plagiostomus* Matthes, 1962; *M. platysoma* Poll and Matthes, 1962; *M. polli* sp. nov., *M. tanganicae* and *M. zebratus* Matthes, 1962.

Mastacembelus frenatus Boulenger, 1901 is not considered a member of the Lake Tanganyika ichthyofauna. It does seem to be present in affluent river basins but not in the lake itself (E. J. Vreven, personal observation).

In 1893 Günther described *Mastacembelus ophidium* as a new mastacembelid species endemic to Lake Tanganyika. Worthington and Ricardo (1936), based on their observations of a large variability in the dorsal spine numbers, were the first to report that more than one species might be included within the type series of *M. ophidium*.

Later, Poll (1953) described a few specimens of the lake as *Mastacembelus* sp. He recognized the juvenile character of these specimens and therefore preferred to postpone the formal description of this new species.

Matthes (1962) did not share the opinion of Poll (1953) and recognized the specimens of *Mastacembelus* sp. as juveniles of *M. ophidium*. In Matthes' (1962) opinion all characters, including the coloration, except the number of dorsal spines, perfectly agreed with those observed in *M. ophidium*. He pointed to the striking resemblance in head shape, with the very short snout, the eyes protruding on the surface of the skin and the very large mouth. In addition, he had identified a few intermediate specimens which he considered evidence confirming his opinion. Nevertheless, he referred to two specimens already recognizable as females, of 73.0 and 71.3 mm standard length (SL) (Matthes 1962, Table IX), respectively, as a "curious" fact. Matthes (1962) concluded that much more material would be necessary, especially specimens of intermediate size (100–150 mm), to allow a better supported conclusion on this subject and in this way expressed his own doubt about the fact that all specimens belonged to one and the same species.

Material and methods

The *Mastacembelus ophidium* specimens housed in the collections of the Natural History Museum (BMNH), London (UK), the Institut Royal des Sciences Naturelles de Belgique (IRSNB), Brussels (Belgium), the Harvard University, Museum of Comparative Zoology (MCZ), Cambridge, MA (USA), the Musée Royal de l'Afrique Centrale (MRAC), Tervuren (Belgium), the Royal Ontario Museum (ROM), Ontario (Canada), and the

South African Institute for Aquatic Biodiversity (SAIAB) Grahamstown (South Africa), were examined.

For the methods used I refer to Vreven and Teugels (1996, 1997, forthcoming).

Data were explored and analysed using Principal Component Analysis (PCA) on the correlation matrix of the log-transformed measurements and the raw meristics. PCA is used here as a model-free and distribution-free technique for exploring multivariate data sets (Marcus 1990). All fully examined specimens were included in the analyses. This method allows a size-free comparison of the specimens when the first factor, which accounts mainly for size, is discarded (Humphries et al. 1981; Bookstein et al. 1985). This was confirmed by plotting principal component I (PCI) versus SL.

Non-parametric Mann–Whitney U tests were used for univariate comparisons. As far as possible they were only done on samples of similar length classes and calculated on the relative measurements (percentages) and raw meristics.

For the statistical analyses Statistica for Windows, version 5.1 (1997 edition) from StatSoft., Inc. was used. Distribution maps were made with MapInfo Professional, version 4.0. Coordinates preceded by "±" are from country gazetteers or the MRAC locality database. All other coordinates were copied from the museum labels or listings, provided by the collectors.

Results

Analyses

Meristics. A first PCA performed on the correlation matrix, was carried out on nine meristics (see Table I) of all specimens identified as *M. ophidium* (Figure 1). A clear separation was found on PCI. The highest loadings on PCI are for the total, caudal and abdominal vertebrae, the anal soft fin ray, the dorsal spine and the dorsal soft fin ray numbers (Table I). This separation was confirmed by the bimodal distribution of the total vertebrae numbers (Figure 2a).

A histogram of the total (Figure 2a) and caudal (not illustrated) vertebrae numbers clearly illustrates that two discrete groups of specimens can be identified: the first one (Group I) with lower total (72–84) and caudal (48–58) vertebrae numbers including only the smallest of the *M. ophidium* syntypes; and the second one (Group II) with higher total (90–101) and caudal (63–70) vertebrae numbers including the remaining four syntypes of

Table I. Factor loadings for PCI and PCII of a PCA carried out on nine meristics of all examined specimens ($n=44$) (the most important loadings are in bold).

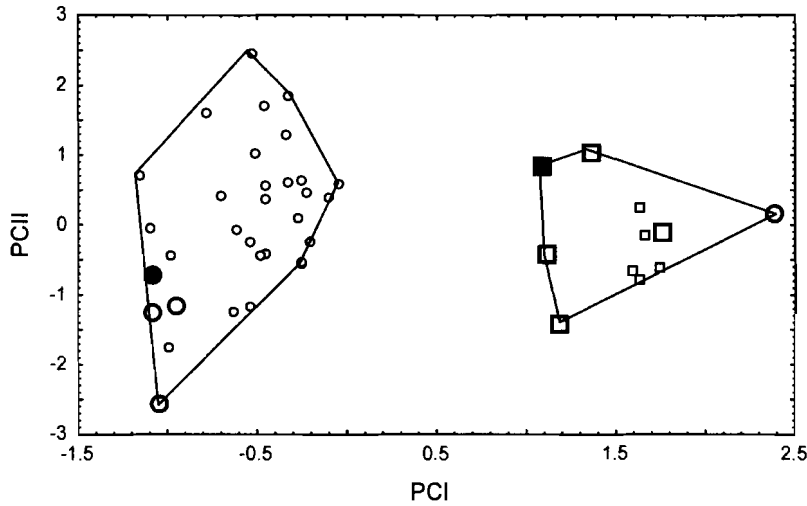|	PCI	PCII
Dorsal spines	−0.873	−0.374
Dorsal soft fin rays	−0.848	0.402
Anal soft fin rays	−0.907	0.240
Caudal soft fin rays	−0.604	0.346
Predorsal vertebrae	−0.359	−0.518
Abdominal vertebrae	**−0.937**	−0.123
Caudal vertebrae	**−0.970**	0.073
In-between vertebrae	0.287	**0.813**
Total vertebrae number	**−0.984**	0.024
Explained variance (% of total variance)	63.0	15.9

Figure 1. Plot of a PCA carried out on nine meristics for all examined specimens ($n=44$ specimens). (●) Lectotype, (○) paralectotype and (o) specimens of *Mastacembelus ophidium*; (■) holotype, (□) paratypes and (□) specimens of *M. polli* sp. nov.

M. ophidium. These bimodal distributions are not the result of geographical variation, as specimens of both groups occur sympatrically in the various regions of the lake (Figure 2b).

The distinctive meristics are correlated, as a higher abdominal vertebrae number implies a higher number of neural spines, a higher number of dorsal spine-supporting ptery-giophores and therefore also a higher number of dorsal spines. Further, a higher caudal vertebrae number implies a higher total vertebrae number. Finally, a larger caudal vertebrae number also implies a larger number of neural spines, haemal spines and pterygiophores, being a larger number of supporting elements for a larger number of dorsal and anal soft fin rays.

Mann–Whitney U tests (see Table II) were performed to further explore the differences between both groups for all nine meristics included in the PCA.
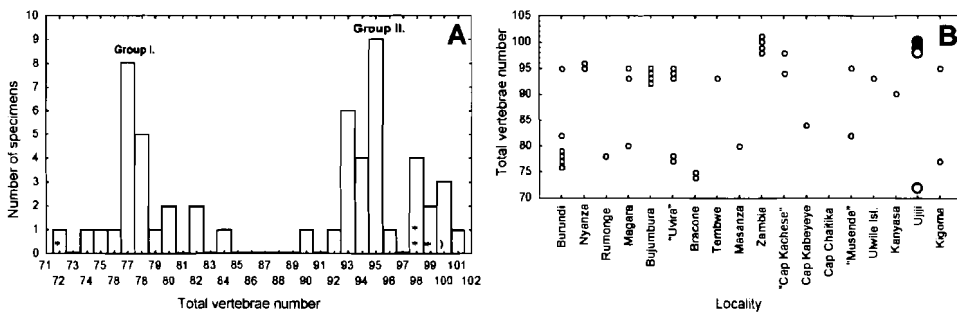

Figure 2. (A) Histograms of total vertebrae number for all specimens examined. (B) Scatterplot of total vertebrae number against the localities for all examined specimens. Specimens were classified into 18 different localities arranged in a counterclockwise geographical order within the lake starting from Nyanza (Burundi), over the Democratic Republic of Congo and the Zambian coast, to Kigoma (Tanzania). Two localities (Burundi? and Zambia?) have been added for those specimens for which a more detailed locality is unknown. (●) Lectotype and (○) paralectotypes of *Mastacembelus ophidium*.

Table II. Results of the Mann–Whitney U test with grouping variable species, being *Mastacembelus ophidium* and *M. polli* sp. nov., for all meristics included in the PCA.

	M. ophidium versus *M. polli* sp. n.	*M. ophidium* n	*M. polli* sp. n. n
Dorsal spines	0.000000	33	23
Dorsal soft fin rays	0.000000	32	14
Anal soft fin rays	0.000000	32	14
Caudal soft fin rays	0.000377	32	12
Predorsal vertebrae	0.002700	33	23
Abdominal vertebrae	0.000000	33	23
Caudal vertebrae	0.000000	32	23
In-between vertebrae	0.245908	33	23
Total vertebrae number	0.000000	32	23

All specimens identified as members of Group I (=*M. polli* sp. nov.) have a standard length of 54 up to 140 mm whereas all specimens identified as Group II (*M. ophidium*) have a standard length between 149 and 406 mm. Although Worthington and Ricardo (1936) stated that the number of dorsal spines increases with age, I have not found any evidence to support this statement in any of the other African Mastacembelidae species studied. A plot of the dorsal spine and total vertebrae numbers, respectively, shows that the difference is not related to size (Figure 3a, b). Unfortunately, the smallest examined *M. ophidium* specimen ($\pm$129 mm SL), with 27+1 dorsal spines and a total vertebrae number of 95, is a partially dissected cleared and stained specimen (BMNH 1968.12.30:4).

Morphometrics. Two PCAs on the correlation matrix were carried out, one on 24 log-transformed measurements and one on the measurements as percentages. The post-preorbital spine length has not been included as this spine is absent in both species. None resulted in any reasonable discrimination between both species as the cluster of *M. ophidium* specimens is almost entirely situated within the cluster of *M. polli* sp. nov. specimens.
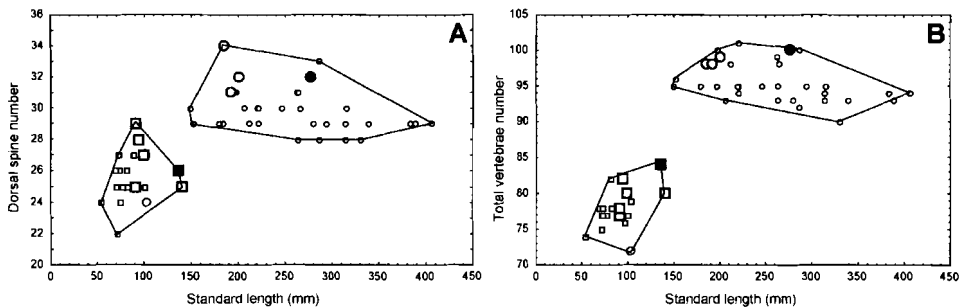

Figure 3. Scatterplots of SL against (A) dorsal spine number and (B) total vertebrae number. (●) Lectotype, (○) paralectotype and (o) specimens of *Mastacembelus ophidium*; (■) holotype, (□) paratypes and (□) specimens of *M. polli* sp. nov.

Mann–Whitney U tests were not performed as comparison between similar-sized specimens of both species was impossible. If performed, significant differences between examined morphometrics of the available samples might be due to size differences between the specimens of the samples of the two species (i.e. allometry), to real shape differences between both species (see below) or a combination of both.

Despite the size differences between the specimens in the samples of both species, possible diagnostic characters are the distance from anterior border of snout to last externally visible anal spine (% SL), the postanal length (% SL) and the body depth (% SL) (see Figure 4b–d).

A redescription of *M. ophidium* and a description of the new species *M. polli* sp. nov. are given below.

Species descriptions

Mastacembelus ophidium Günther, 1893
(Figure 6)

Synonyms and citations

Mastacembelus ophidium Günther, 1893: Pfeffer 1894: 8; Boulenger 1898: 5, 23; Boulenger 1899: 54; Boulenger 1901a: 492, 499; Boulenger 1901b: 141; Moore 1903: 216; Boulenger 1905: 60; Boulenger 1906: 542, 576; Boulenger 1912: 199, 203; Boulenger 1916: 115, 141, Figure 96; Cunnington 1920: 529; David 1936: 158; Worthington and
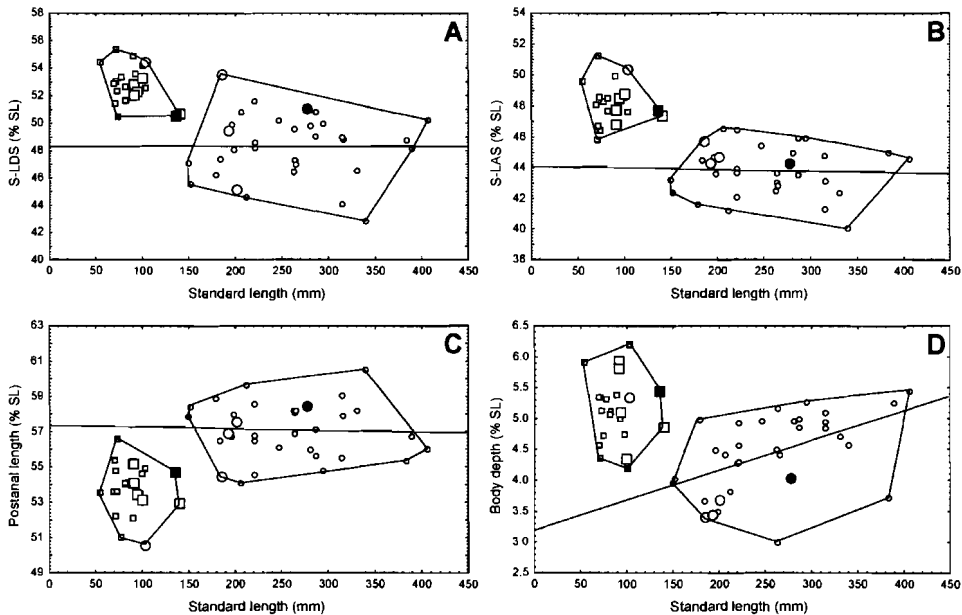

Figure 4. Scatterplots of SL against (A) anterior border of snout to last, externally visible, dorsal spine (% SL); (B) anterior border of snout to last, externally visible; dorsal spine (% SL); (C) postanal length (% SL); and (D) body depth (% SL). (●) Lectotype, (○) paralectotypes and (o) specimens of *M. ophidium*; (■) holotype, (□) paratypes and (⌐) specimens of *Mastacembelus polli* sp. nov. Full line: fitted function for *M. ophidium*.

Ricardo 1936 (in part): 1068, 1077, 1109; David and Poll 1937: 275; Poll 1946: 157, 245, 250–251; Hulot 1950: 172; Poll 1953: 9, 19, 236–237, 250, Plate 11 Figure 2; Matthes 1962 (in part): 77–80; Bell-Cross and Kaoma 1971: 243; Brichard 1978: 75, 381 (two photographs), 438, 440; Bernacsek 1980: 62; Travers 1984a, 1984b (in part).
Afromastacembelus ophidium (Günther, 1893): Travers 1984b: 145; Travers et al. 1986: 419; Eccles 1992: 84, 128, figure; Kawabata and Mihigo 1982: 138.
Caecomastacembelus ophidium (Günther, 1893): Coulter 1991: 266; Abe 1997: 246–247, 249, 251, Figure 12-1a; Abe 1998: 273, 278; De Vos and Snoeks 1998: 31, Figure 2.
Aethiomastacembelus ophidium (Günther, 1893): De Vos et al. 1996: 17.

Type material

Lectotype (designated in this paper): BMNH 1889.1.30:22 (from 22–24); near Ujiji (Tanzania) (Udjidji ±4°56′S, 29°40′E), coll. E. C. Hore (287 mm TL). Paralectotypes (designated in this paper): BMNH 1889.1.30:23 (from 22–24); same data as for lectotype (three specimens, 191–208 mm TL).

Since none of the type specimens has ever been illustrated (see recommendation ICZN 1999) the largest of the syntypes is here designated as the lectotype. Of the remaining four syntypes, three paralectotypes are here considered conspecific with the lectotype while the smallest paralectotype belongs to the new species described below. Worthington and Ricardo (1936) stated that the description of *M. ophidium* was based only on the larger syntypes. This can certainly be confirmed, for example, by the fact Günther (1893) gave a variation of 31 up to 32 dorsal spines for *M. ophidium* while the smallest syntype possesses only 23+1 dorsal spines. For more details see *M. polli* sp. nov.

Etymology

From the Greek "οφιδιον" ("opidion") diminutive of the Greek "οφιζ" (serpent, reptile) referring to the snake-like appearance of this species.

Diagnosis

Within Lake Tanganyika, *M. ophidium* can be distinguished from all other species, except *M. polli* sp. nov., by a relatively long postanal length [54.1–60.5 (57.1)% SL versus 53.5%
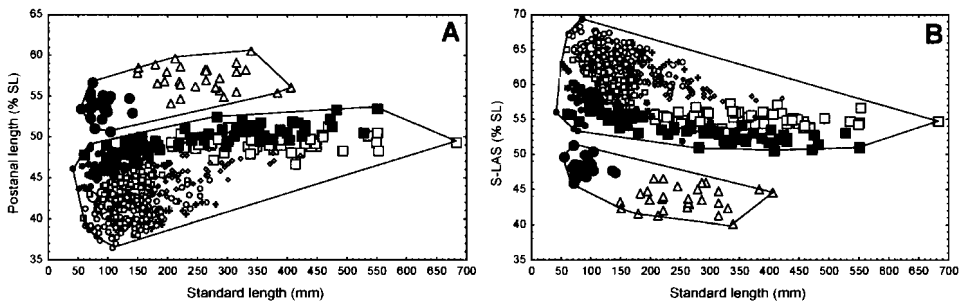

Figure 5. Scatterplots of SL against (A) postanal length (% SL) and (B) distance from anterior border of snout to last, externally visible, anal spine (S-LAS) (% SL). (o) *Mastacembelus albomaculatus*; (□) *M. cunningtoni*; (◇) *M. ellipsifer*; (★) *M. flavidus*; (●) *M. micropectus*; (■) *M. moorii*; (△) *M. ophidium*; (+) *M. plagiostomus*; (○) *M. platysoma*; (●) *M. polli* sp. nov.; (⊓) *M. tanganicae*; and (◆) *M. zebratus*.

SL or less] increasing with size (Figure 5a), which is longer than the preanal length, itself being relatively short [38.3–45.0 (41.6)% SL versus 46.1% SL or more] and decreasing with size; by a relatively short distance from snout to last, externally visible, anal spine [40.0–46.6 (43.8)% SL versus 50.6% SL or more] (Figure 5b); and by its protruding eyes, protruding lower jaw, pointed caudal fin, posterior angle of lips situated below eye, from about one-third of the eye diameter, or even behind the posterior border of the eye (versus posterior angle of lips situated more anterior). From the highly similar *M. polli* sp. nov. it can be distinguished mainly by its greater dorsal spine number [27+1 to 33+1 (median 28+1) versus 21+1 to 28+1 (24+1)], its greater caudal vertebrae number [63–70 (66) versus 48–58 (53)]; and its related greater total vertebrae number [90–101 (95) versus 72–84 (77)].

Description

Meristics and morphometrics are given respectively in Tables III and IV. A representative specimen of this species is illustrated in Figure 6a–c.

Mastacembelus ophidium has protruding eyes, a small rostral appendage, a protruding lower jaw, a pointed caudal fin and a relatively elongated pectoral-fin shape (i.e. not so rounded as in many other species). Posterior angle of lips situated below the region from the middle of the eye up to a distance of about one-third of eye diameter behind posterior border of eye. For the majority of the specimens the posterior angle of lips is situated below the posterior edge of the eye. *Mastacembelus ophidium* together with *M. polli* sp. nov. are the only African spiny eels in which the posterior angle of lips is situated so far posteriorly (Figure 6b). Upper corner of gill opening and the dorsal edge of pectoral-fin base approximately at same level, clearly anterior to ventral edge of pectoral-fin base. Dorsal edge of pectoral-fin base situated above upper corner of the gill opening. Upper corner of gill
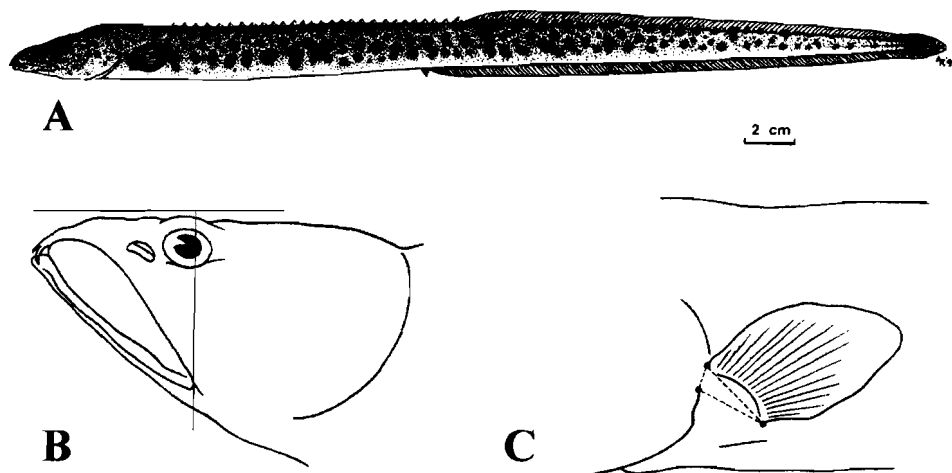

Figure 6. *Mastacembelus ophidium* Günther, 1893, 326 mm TL, "8 km. au Sud de Bujumbura, Lac Tanganyika" (Burundi) (MRAC 75-01-P-199–123). (A) Lateral view. (B) Position of posterior angle of lips to posterior nare and eye. Vertical line is perpendicular to a horizontal line parallel with upper surface of head. (C) Detail of pectoral fin region. Upper tip of gill slit, dorsal edge of pectoral-fin base and ventral edge of pectoral-fin base connected by dashed lines.

Table III. Meristic data for types and the other examined specimens of *Mastacembelus ophidium*.

	Tanzania, Ujiji lectotype	All specimens examined			
		Min	Max	*n*	Median
Predorsal vertebrae	6	5	6	33	6
Abdominal vertebrae	32	28	32	33	29
In-between vertebrae	−3	−5	−1	33	−2
Caudal vertebrae	68	63	70	32	66
Vertebrae total	100	90	101	32	95
Dorsal spines	31+1	27+1	33+1	33	28+1
Anal spines	1+1	1+1	1+1	33	1+1
Dorsal fin rays	100	91	126	32	103
Anal fin rays	118	107	136	32	118
Caudal fin rays	7	5	8	32	7
Preopercular spines	0L/0R	0L/0R	0L/0R	33	0L/0R

Table IV. Morphometric data for types and other examined specimens of *Mastacembelus ophidium*.

	Tanzania, Ujiji lectotype	All specimens examined				
		Min	Max	*n*	Mean	SD
Standard length, SL (mm)	277	149	406	33	256	67
In percentage of HL						
Snout length	18.4	15.1	22.4	33	18.0	1.5
Eye diameter	8.9	6.9	10.1	33	8.7	0.9
Minimum interorbital distance	3.0	2.1	3.9	33	2.9	0.5
Rostral appendage length	3.9	2.9	6.9	33	4.1	0.9
Postorbital length	76.1	72.3	79.9	33	76	1.8
Angle of jaws to dorsal edge of pectoral fin base	69.2	66.8	73.9	33	69.9	2.1
Posterior tip of preorbital spine to dorsal edge of pectoral fin base	–	–	–	33	–	–
Upper tip of gill slit to pectoral fin origin	4.6	4.4	9.3	30	6.2	1.0
Upper jaw length	32.8	27.0	36.2	32	31.8	2.7
Lower jaw length	31.8	25.3	35.7	32	30.5	2.5
Pectoral-fin length	32.5	15.0	36.9	33	27.4	4.5
Dorsal edge of pectoral fin base to anterior base of first dorsal spine	50.2	33.5	50.2	33	41.7	4.8
Ventral edge of pectoral fin base to anterior base of first dorsal spine	41.6	23.9	45.9	33	34.6	5.1
Posterior edge pectoral fin to anterior base of first dorsal spine	12.1	−6.8	23.2	33	8.3	6.9
Angle of jaws to eye	–	17.5	28.3	32	22.0	2.8
Angle of jaws to posterior external nare	25.9	19.3	30.1	32	25.2	2.7
Anterior border posterior external nare to eye	6.2	4.7	7.3	33	6.2	0.7
In percentage of SL						
Head length	11.0	10.6	13.3	33	11.8	0.7
Snout to first dorsal spine	16.8	15.1	18.8	33	16.9	0.8
Snout to last externally visible dorsal spine	51.1	42.8	53.5	33	48.3	2.3
Snout to first anal spine	42.8	39.5	46.1	32	42.6	1.5
Snout to last externally visible anal spine	44.3	40.0	46.6	32	43.8	1.6
Preanal length	42.2	38.3	45.0	33	41.6	1.5
Postanal length	58.5	54.1	60.5	33	57.1	1.6
Body depth at anus	4.0	3.0	5.4	33	4.4	0.6

opening situated between one-quarter and half (exceptionally three-quarters) of the vertical distance between the dorsal and ventral edge of the pectoral-fin base (Figure 6c). Lateral line continuous from posterior border of head up to region of anus; further posteriorly, it becomes more and more discontinuous.

Preanal length always shorter than postanal length; distance from anterior border of snout to last externally visible dorsal spine always longer than distance from anterior border of snout to last externally visible anal spine, and consequently origin of soft dorsal fin always posterior compared to origin of soft anal fin.

A high number of dorsal spines, XXVII+I to XXXIII+I, with spines increasing in size from first to last. Usually a very small, almost entirely reduced spine hidden under the skin, and situated anterior to the base of the first dorsal-fin ray. Nevertheless, the dorsal spine formula is standardized as X+I.

One well-developed, externally visible, anal spine. In addition, a very small almost entirely reduced spine, hidden under the skin, and situated anterior to the base of the first anal-fin ray can be present. First anal pterygiophore well developed, supporting only the first anal spine. Second anal pterygiophore very small, sometimes supporting an almost entirely reduced anal "spine". Nevertheless, the anal spine formula is standardized as I+I.

In all specimens the neural spine-supporting pterygiophore of the last externally visible dorsal spine and the haemal spine-supporting pterygiophore of the first anal spine are situated on two different vertebrae and are separated by one to three vertebrae (named in-between vertebrae hereafter). The vertebra with the neural spine supporting the pterygiophore of the last externally visible dorsal spine is always situated posterior to the vertebra whose haemal spine supports the first anal spine.

All specimens lack preopercular and preorbital spines.

Maximal observed standard length: 406 mm (422 mm TL).

Coloration (see also Figure 6a)

Based on MRAC 75-01-P-119–123 unless otherwise stated. Uniformly light brown background colour with generally numerous small, round, dark brown spots on lateral sides and back of head, body and tail. Spots may be far less abundant or even absent on entire tail, or more posterior part of tail. Exceptionally, spots restricted to head region (MRAC 92-081-P-1441). Further, spots mainly limited to three series, one on the dorsal midline and one on each lateral line forming nearly continuous bands, especially on the tail region (MRAC 90973). In another specimen spots found on each side of dorsal midline and on anterior part of dorsal fin base. Remaining spots far less contrasted with the background colour than in other specimens examined (see also MRAC 85-12-P-7). Background colour lighter, more yellowish white on lips, ventral region of head, belly and most ventral part of tail. Pectoral fins whitish transparent without spots or eventually only spotted at their base. Dorsal fin light brown with a series of numerous small, round, dark brown spots at its base, outer margin white. Caudal fin light brown at its base and yellowish white towards its outer margin. Anal fin yellowish white.

Distribution (see Figure 7)

Mastacembelus ophidium is endemic to Lake Tanganyika and confirmed locality records indicate a circumlacustrine coastal distribution. However, at present, it has not been found over large parts of the Democratic Republic of Congo coastline, but this part of the lake is
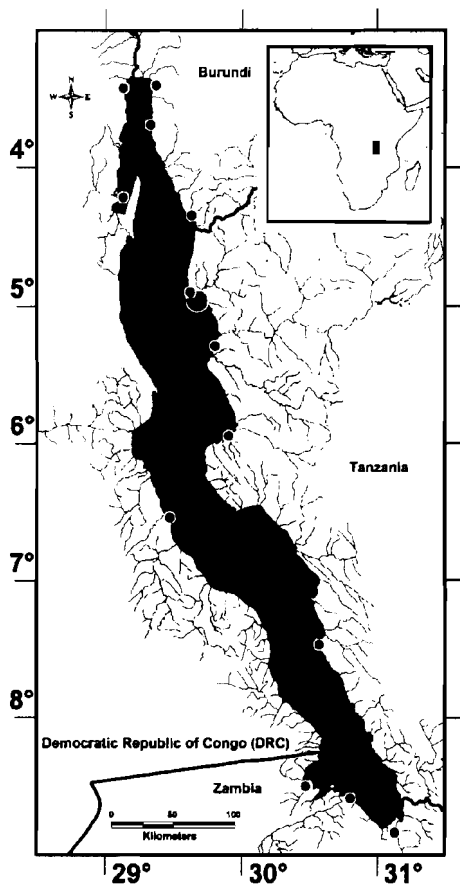
Figure 7. Geographical distribution of *Mastacembelus ophidium* based on the localities of the examined specimens. (●) Lectotype and paralectotypes, and (•) specimens of *M. ophidium*.

poorly sampled. Kawabata and Mihigo (1982) reported *M. ophidium* from around the Ruzizi River estuaries.

The species is reported to be rare (Poll 1953).

Generic status

Günther (1893) described *M. ophidium* as a new member of the genus *Mastacembelus*. Travers (1984b) placed *M. ophidium* within the genus *Afromastacembelus* (see also Travers et al. 1986). Travers (1988) revealed that the type species of the genus *Afromastacembelus*, *A. tanganicae* (Günther, 1893) in fact belongs to the genus *Caecomastacembelus* and created a new genus *Aethiomastacembelus* to allocate most of the species previously in *Afromastacembelus*. However, Travers (1988) did not mention to which genus *M. ophidium* was allocated. Subsequently, Coulter (1991) and Abe (1997, 1998) placed it in the genus *Caecomastacembelus*. Vreven and Teugels (1996) revealed several inaccuracies and contradictions between the type material and the diagnosis of both genera. Vreven (forthcoming) placed *Caecomastacembelus* and *Aethiomastacembelus* in synonymy with *Mastacembelus*.

Based on the meristic, morphometric and colour pattern evidence *M. ophidium* seems to be most closely related to *M. polli* sp. nov. The more distant affinities of both species remain, at present, unresolved and need additional research.

Biology and ecology

Note. The literature data on *M. ophidium* provided here need to be handled with care as *M. ophidium* and *M. polli* sp. nov. have not been distinguished in the past. Therefore, misidentification of specimens mentioned in the literature can certainly be expected (see Synonyms and Citations).

Habitat. Poll (1953) mentioned *M. ophidium* occurring in coastal regions of the lake up to a depth of 10 m. Matthes (1962) reported two specimens (verified) as *M. ophidium* from rocky bottoms. However, most of the other specimens identified by himself as *M. ophidium* from rocky bottoms are *M. polli* sp. nov. (see below). Also Brichard (1978) reported the species living in rocky habitats. However, Travers et al. (1986) and Eccles (1992) reported that the species inhabits sandy shores. In addition, *M. ophidium* was reported as a sand-dwelling species occasionally found on rocky slopes (sand/rock) by Brichard (1989). Finally, Abe (1997) also reported that *M. ophidium* occupies sandy bottoms. Hence, *M. ophidium* is most probably a sand-dwelling species occasionally found on rocky bottoms (see also under Discussion).

It is well known that sand-dwelling fluviatile species of spiny eels bury themselves in the sand to lay in ambush waiting for prey to pass by, or to do so as a protection against predators (Brichard 1989). Brichard (1989) suggested that it would not be surprising to find also that sand-dwelling Lake Tanganyika species bury themselves in the sand (Brichard 1989). Indeed, this burying and ambush behaviour was confirmed and illustrated by Jäger (2002) based on aquarium observations.

De Vos et al. (1996) reported *M. ophidium* from the sub-littoral (10–40 m depth) as well as from the deeper benthic (40–60 m depth) environment.

Food. Worthington and Ricardo (1936) mentioned that one specimen had been feeding on small prawns. Poll (1953) reported the presence of one *Lamprologus* sp. of 5 cm in the stomach of one of the specimens studied by himself. Indeed, based on X-ray data of many specimens, the presence of fish(es) in the stomach of some of the examined specimens is confirmed.

Reproduction. Vast numbers of *M. ophidium* fry have been noted periodically near the shore at the north of the lake (Coulter 1991), indicating mass spawning (Brichard 1978). It is the only species from which concentrations of thousands of young fry a few centimetres long have been observed in quiet bays during some months of the year (Brichard 1989). Following Brichard (1989) it therefore appears that the spiny eels might migrate and have synchronous spawning, but as yet this observation applies only to *M. ophidium* and not to any other species (see also below under Discussion).

Poll (1953) reported an immature male (MRAC 90973, 349 mm TL, 20 December 1946) and a mature female (ISNB 9431, 332 mm SL, 25 January 1947). Other specimens (MRAC 91643, 400 mm TL, 3 November 1949; MRAC 92-081-P-1441, 341 mm TL, 1 June 1992) are here identified as a "nearly ripe" females. Based on these reported data it is obvious that additional specimens will be necessary to identify reproduction period(s).

Abe (1998) reported that the oocytes of *M. ophidium* are small when compared to the oocytes of *M. albomaculatus*, *M. micropectus*, *M. plagiostomus*, and *M. tanganicae* which have an oocyte diameter larger than or equal to 1.5 mm. Nevertheless, for both specimens I examined (MRAC 91643, 400 mm TL; MRAC 92-081-P-1441, 341 mm TL) the egg diameter is around 1.5 mm.

Fisheries

Mastacembelus ophidium is of little value as food (Poll 1953; Eccles 1992). According to Eccles (1992), their shape makes them difficult to net, although they can be taken with a small hook. Eccles (1992) mentioned that *M. ophidium* might be of some interest to aquarists. Indeed, *M. ophidium* is presently available in Germany (www.pet2get.dk/stockliste 2003).

Other specimens examined

All specimens originated from Lake Tanganyika. For samples with more than one specimen and without separate numbering the exact number is provided. All lengths are total lengths.

Country unknown. BMNH 2003.3.23:3 (from 1919.7.24:35–42), ditch near Lake Tanganyika ($\pm$323 mm). BMNH 1936.6.15:1753 (from 1753–1756) (170 mm). BMNH 1936.6.15:1757, Lake Tanganyika ($\pm$296 mm).

Burundi. MCZ 50841, between Mutumba and Magara among rocks, depth 0–10 m ($\pm$3°40'S, 29°20'E) (two specimens, 213–254 mm). MRAC 39044–045, Nyanza ($\pm$4°20'S, 29°38'E) (156–185 mm). MRAC 73-68-P-550, Bujumbura ($\pm$3°23'S, 29°22'E) (229 mm). MRAC 75-01-P-119–123, 8 km au Sud de Bujumbura ($\pm$3°23'S, 29°22'E) (229–326 mm). MRAC 76-09-P-216, côte du Burundi (204 mm). MRAC 85-12-P-7, Bujumbura ($\pm$3°23'S, 29°22'E) (422 mm).

Democratic Republic of Congo. BMNH 1906.7.8:278, Burton Gulf ($\pm$4°12'S, 29°08'E) (315 mm). BMNH 1968.12.30:4, Kirambo Lagoon ($\pm$7°25'S, 30°36'E) ($\pm$130 mm) (cleared and stained). MRAC 90973, Stat. 27, Baie de Tembwe, le long de la rive Sud, sur la plage, senne ($\pm$6°31'S, 29°28'E) (349 mm). MRAC 91643, Uvira ($\pm$3°24'S, 29°08'E) (400 mm). MRAC 93639, Uvira ($\pm$3°24'S, 29°08'E) (271 mm). MRAC 130379–380, Uvira, digue I.R.S.A.C. ($\pm$3°24'S, 29°08'E) (I.R.S.A.C.) (326–395 mm).

Tanzania. BMNH 1982.4.13:4821, Karago Bay ($\pm$5°16'S, 29°48'E) (176 mm). IRSNB 9431, Baie de Karago, senne, Stat. 89 ($\pm$5°16'S, 29°48'E) (345 mm). MRAC 92-81-P-1441, Kanyasa ($\pm$5°56'S, 29°54'E) (341 mm). MRAC 92-81-P-1442, Ulwile Island, northern shore ($\pm$7°27'4"S, 30°34'2"E) (274 mm). SAIAB 56007, Kigoma, Kigoma Bay below hill to Hotel (4°53'03"S, 29°37'11"E) (230 mm).

Zambia. MRAC 78-25-P-39, Cap Chaitika ($\pm$8°34'S, 30°48'E) (183 mm). MRAC 78-25-P-40, Cap Kachese ($\pm$8°29'S, 30°29'E) (220 mm). ROM 28166 (two specimens, 229–270 mm); ROM 28181, Lake Tanganyika ($\pm$?) (three specimens, 204–296 mm). SAIAB 41260, Kombe ($\pm$8°49'S, 31°08'E) (153 mm). SAIAB 42334, Ndole Bay ($\pm$8°29'S, 30°28'E) (323 mm).

Mastacembelus polli sp. nov.
(Figure 8)

Synonyms and citations

Mastacembelus ophidium non Günther 1893 (in part): Günther 1893, p 630; Worthington and Ricardo 1936, p 1109; Matthes 1962, p 77–80.
Mastacembelus sp. Poll 1953, p 240, Figure 33C.

Type material

Only a small sample (i.e. the specimens⩾95 mm TL) of the examined specimens identified as *M. polli* sp. nov. has been designated as type material of the new species. All specimens from Lake Tanganyika.

Holotype: MRAC 78-25-P-41, Cap Kabeyeye (Zambia) (±8°32'S, 30°43'E), coll. P. Brichard, April 1978 (143 mm TL). Paratypes: MRAC 128687, Kalundu (Democratic Republic of Congo) (±3°26'S, 29°08'E), coll. H. Matthes (I.R.S.A.C.), 27 October 1960 (95 mm TL). MRAC 128688, Rumonge (Burundi) (±3°58'S, 29°25'E), coll. H. Matthes (I.R.S.A.C.), 24 November 1960 (95 mm TL). MRAC 84-23-P-638, 2me crique au N. de Masanza (Democratic Republic of Congo) (±7°34'S, 30°13'E), coll. P. Brichard, 13 June 1984 (144 mm TL). MCZ 162850 (ex 50841), between Mutumba and Magara among rocks, depth 0–10 m (Burundi) (±3°40'S, 29°20'E), coll. D. J. Stewart, October 1973 (104 mm TL). SAIAB 42477, Musende Rocks (Zambia) (±8°42'S, 31°07'E), coll. R. Bills, 27 March 1993 (98 mm TL).
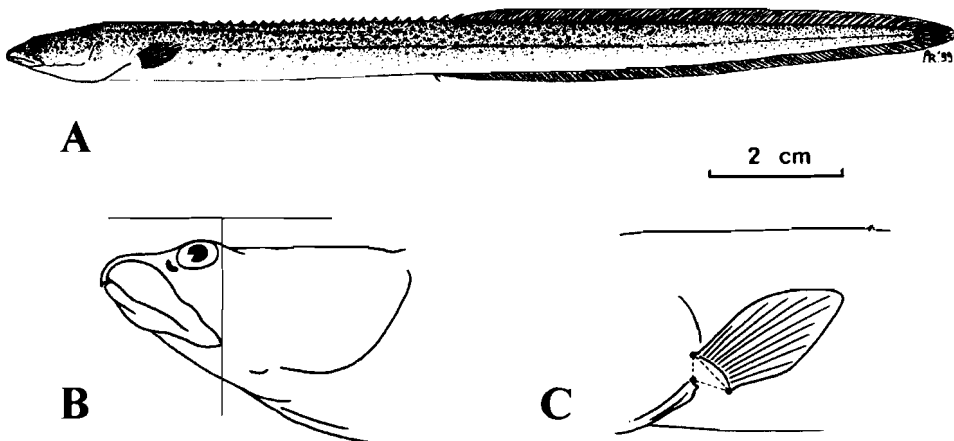

Figure 8. *Mastacembelus polli* sp. nov., holotype, 143 mm TL, from "Cap Kabeyeye, Lac Tanganyika" (Zambia) (MRAC 78-25-P-41). (A) Lateral view. (B) Position of the posterior angle of lips to posterior nare and eye. Vertical line is perpendicular to a horizontal line parallel with upper surface of the head. (C) Detail of pectoral fin region. Upper tip of gill slit, dorsal edge of pectoral-fin base and ventral edge of pectoral-fin base connected by dashed lines.

Etymology

Named in honour of the late Prof. Dr M. Poll (1908–1991), a famous Belgian ichthyologist who pioneered ichthyological studies on Lake Tanganyika and who first drew attention to the fact that his *Mastacembelus* sp. (Poll 1953) might well be a new species.

Diagnosis

Within Lake Tanganyika, *M. polli* sp. nov. can be distinguished from all other species, except *M. ophidium*, by a relatively long postanal length [50.6–56.6 (mean 53.7)% SL versus 53.5% SL or less] increasing with size (Figure 5a), which is longer than preanal length, itself being relatively short [42.7–47.6 (44.7)% SL versus 46.1% SL or more] and decreasing with size; by a relatively short distance from anterior border of snout to the last, externally visible, anal spine [45.9–51.3 (48.3)% SL versus 50.6% SL or more] (Figure 5b); and by protruding eyes, protruding lower jaw, "pointed" caudal fin, posterior angle of lips situated below eye, from about one-third of eye diameter, or even behind posterior border of eye (versus posterior angle of lips situated more anterior). From the highly similar *M. ophidium* it can be distinguished mainly by its smaller dorsal spine number [21+1 to 28+1 (median 24+1) versus 27+1 to 33+1 (28+1)], its smaller caudal vertebrae number [48–58 (53) versus 63–70 (66)], and its related smaller total vertebrae number [72–84 (77) versus 90–101 (95)].

Description

Meristics and morphometrics are given in Tables V and VI, respectively. The holotype is illustrated in Figure 8a–c.

Mastacembelus polli sp. nov. has protruding eyes, a small rostral appendage, a protruding lower jaw, a pointed caudal fin and a more elongated pectoral-fin shape (i.e. not so rounded as in many other species). Posterior angle of lips situated below the region from the middle of the eye up to a distance of about one-third of the eye diameter behind posterior border of eye. For the majority of the specimens the posterior angle of lips is situated below the posterior edge of the eye. *Mastacembelus polli* sp. nov. together with *M. ophidium* are the only African spiny eels in which the posterior angle of lips is situated so far posteriorly (Figure 8b). Upper corner of gill opening and dorsal edge of pectoral-fin base

Table V. Meristic data for the types and other examined specimens of *Mastacembelus polli* sp. nov.

	Zambia, Cap Kabeyeye holotype	All specimens examined			
		Min	Max	*n*	Median
Predorsal vertebrae	5	5	6	23	5
Abdominal vertebrae	26	22	27	23	25
In-between vertebrae	−2	−3	−1	23	−2
Caudal vertebrae	58	48	58	23	53
Vertebrae total	84	72	84	23	77
Dorsal spines	25+1	21+1	28+1	23	25+1
Anal spines	1+1	1+1	1+1	23	1+1
Dorsal fin rays	83	68	87	14	82
Anal fin rays	90	70	98	14	87
Caudal fin rays	7	4	8	12	5
Preopercular spines	0L/0R	0L/0R	0L/0R	23	0L/0R

Table VI. Morphometric data for types and other examined species of *M. polli* sp. nov.

	Zambia, Cap Kabeyeye holotype	All specimens examined				
		Min	Max	*n*	Mean	SD
Standard length, SL (mm)	136	54	140	22	88	21
In percentage of HL						
Snout length	15.7	11.5	15.7	22	14.0	1.0
Eye diameter	8.7	8.5	12.6	22	10.4	1.1
Minimum interorbital distance	2.7	1.7	3.2	22	2.4	0.4
Rostral appendage length	3.8	2.0	5.3	22	3.7	0.8
Postorbital length	78.4	74.8	82.1	22	78.2	2.0
Angle of jaws to dorsal edge of pectoral fin base	72.4	70.1	76.1	22	73.1	1.4
Posterior tip of preorbital spine to dorsal edge of pectoral fin base	–	–	–	22	–	–
Upper tip of gill slit to pectoral fin origin	6.0	3.0	7.8	22	5.6	1.2
Upper jaw length	28.1	23.0	30.2	22	27.2	1.5
Lower jaw length	27.6	22.1	28.8	22	25.7	1.8
Pectoral-fin length	28.1	16.2	35.2	22	23.8	5.3
Dorsal edge of pectoral fin base to anterior base of first dorsal spine	37.8	32.4	54.3	22	40.4	5.7
Ventral edge of pectoral fin base to anterior base of first dorsal spine	33.5	26.1	46.9	22	35.5	5.3
Posterior edge pectoral fin to anterior base of first dorsal spine	5.4	−1.4	26.5	22	12.8	7.3
Angle of jaws to eye	20.0	16.5	23.0	22	19.3	1.8
Angle of jaws to posterior external nare	22.7	18.6	24.6	22	21.9	1.6
Anterior border posterior external nare to eye	4.3	3.2	5.5	22	4.4	0.6
In percentage of SL						
Head length	13.6	12.4	14.8	22	13.3	0.6
Snout to first dorsal spine	18.5	17.5	21.3	22	18.9	1.0
Snout to last externally visible dorsal spine	50.5	50.5	55.4	22	52.8	1.4
Snout to first anal spine	45.3	43.3	49.1	22	46.2	1.3
Snout to last externally visible anal spine	47.7	45.9	51.3	22	48.3	1.3
Preanal length	44.3	42.7	47.6	22	44.7	1.3
Postanal length	54.7	50.6	56.6	22	53.7	1.4
Body depth at anus	5.4	4.2	6.2	22	5.2	0.5

approximately at same level, clearly anterior to ventral edge of pectoral-fin base. Dorsal edge of pectoral-fin base situated above upper corner of the gill opening. Upper corner of gill opening situated between one-quarter and half (exceptionally three-quarters) of the vertical distance between the dorsal and ventral edge of pectoral-fin base (Figure 8c). Lateral line continuous from posterior border of head up to one-third or half of distance between head and anus, discontinuous more posteriorly.

Preanal length always shorter than postanal length; distance from anterior border of snout to last externally visible dorsal spine always longer than distance from anterior border of snout to last externally visible anal spine, and as a result origin of soft dorsal fin always posterior compared to origin of soft anal fin.

A relatively low number of dorsal spines, XXI+I to XXVIII+I, with spines increasing in size from first to last. Usually a very small almost entirely reduced spine hidden under the skin, and situated anterior to the base of the first dorsal-fin ray. Nevertheless, dorsal spine formula standardized as X+I.

One well-developed, externally visible anal spine. In addition, a very small almost entirely reduced spine, hidden under the skin, can be present, situated anterior to the base of the first anal-fin ray. First anal pterygiophore well developed, supporting only the first anal spine. Second anal pterygiophore very small, sometimes supporting an almost entirely reduced anal "spine". Nevertheless, the anal spine formula is standardized as I+I.

In all specimens the neural spine-supporting pterygiophore of the last externally visible dorsal spine and the haemal spine-supporting pterygiophore of the first anal spine are situated on two different vertebrae and are separated by one to five in-between vertebrae. The vertebra with the neural spine supporting the pterygiophore of the last externally visible dorsal spine is always situated posterior to the vertebrae whose haemal spine supports the first anal spine.

All specimens lack preopercular or preorbital spines.

Maximal observed standard length: 140 mm (144 mm TL).

Coloration (Figure 8a)

Based on the holotype unless otherwise stated. Uniformly light brown overall background colour with numerous small, round, dark brown spots on dorsal part (approximately from around the lateral line up to more dorsal) of head, body and tail. Sometimes, spots larger and more irregularly shaped (MRAC 128687; MRAC 84-23-P-638) or less abundant and less contrasted with the overall background colour (MRAC 128688). Spots may be limited to three series, one on the dorsal midline and one on each lateral line (MRAC 128685–686). Some specimens only lack spots on tail region (MRAC 76-09-P-222–230: 107, 96, 92, 85, and 84 mm TL) whereas others entirely lack spots (MRAC 76-09-P-222–230: 104, 101, 75, and 72 mm TL). Background colour lighter, more yellowish white on lips, ventral region of head, belly and most ventral part of tail. Pectoral fins whitish transparent without spots. Dorsal, caudal and anal fins also whitish transparent.

Distribution (see Figure 9)

Mastacembelus polli sp. nov. is endemic to Lake Tanganyika and appears to have a circumlacustrine shore distribution. However, it has not been found over large parts of the Tanzanian–Zambian and Democratic Republic of Congo coastline. I suspect this is due to poor sampling of these parts of the lake rather than to the real distribution of the species.

Mastacembelus polli sp. nov. was mentioned by Poll (1953) as rare.

Generic status

Similar to *M. ophidium*, *M. polli* sp. nov. is placed within the genus *Mastacembelus*.

Mastacembelus polli sp. nov. seems, based on the meristic, morphometric and colour pattern evidence, to be most closely related to *M. ophidium*. The more distant affinities of both species remain unresolved at present and need additional research.

Biology and ecology

Habitat. Coastal in distribution (Poll 1953). For several specimens listed by Matthes (1962) additional information on the habitat of the material was provided: rocky bottom, flagstone; rocky bottom, rock slides and pebbles; and pebble bottom.
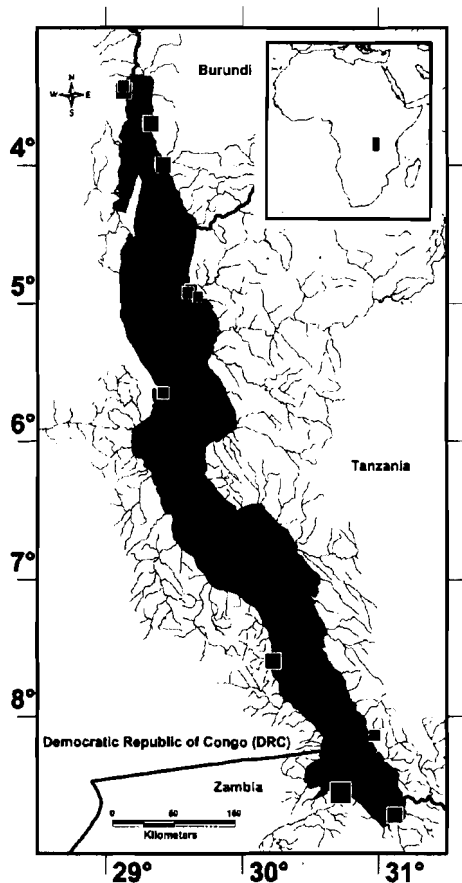
Figure 9. Geographical distribution of *Mastacembelus polli* sp. nov. based on the localities of the examined specimens. (■) Holotype, (■) paratypes and (·) specimens of *M. polli* sp. nov.

In addition, another sample of specimens was reported from a sandy bottom with snails, depth 20–40 m (Matthes 1962). These specimens are most probably *M. polli* sp. nov. (23–26 dorsal spines, according to Matthes 1962). Due to the small size of the latter material I was unable to make sharp X-rays, and make accurate counts of all vertebrae. Therefore, I consider the identification of the latter specimens as tentative. These specimens are the smallest ones reported for *M. polli* sp. nov.

Reproduction. According to Matthes two specimens of respectively 73.0 and 71.3 mm SL (see Matthes 1962, Table IX) were already recognizable as immature females (Matthes 1962) (MRAC 128685–686, confirmed). Poll (1953) mentioned that the specimens he examined were obviously juveniles. Based on my own observations the holotype of *M. polli* sp. nov. and another specimen (MRAC 76-09-P-222-230, 103 mm SL) are both nearly ripe females illustrating maturation at small size.

Fisheries and aquaculture

The capture method is variable (Poll 1953).

Other specimens examined

All specimens from Lake Tanganyika.

Country unknown. BMNH 1936.6.15:1754–1756 (ex 1753–1756) (91–107 mm); BMNH 2003.3.23:1 (ex 1936.6.15:1757) (80 mm).

Burundi. MRAC 76-09-P-222-230, côte Burundi (72–107 mm).

Democratic Republic of Congo. IRSNB 9438, Kalume, baie et rivière Lubumba, dist. Tanganyika, Congo Belge, Stat. 263, petite drague, baie à l'ancre (±5°20′S, 29°13′E) (54 mm). MRAC 90974–90975, Stat. 93, baie de Bracone, île de Kavala, senne (±5°38′S, 29°25′E) (56–73 mm). MRAC 128685–686, Uvira (±3°24′S, 29°08′E) (72–77 mm). MRAC 130719, Uvira, digue I.R.S.A.C. (±3°24′S, 29°08′E) (70 mm).

Tanzania. BMNH 1889-1-30:24 (from 22–24) (paralectotype of *M. ophidium*), near Ujiji (Udjidji ± 4°56′S, 29°40′E) (106 mm). BMNH 1955.12.20:1687, Kala (±8°07′S, 30°58′E) (49 mm). IRSNB 9437, Udjiji bords du lac et flaques de la plage, Tanganyika Territory (Ujiji ± 4°56′S, 29°40′E) (64 mm). SAIAB 56006, Kigoma, Kigoma Bay below hill to Hotel (4°53′03″S, 29°37′11″E) (two specimens, 75–80 mm). SAIAB 56008, Kigoma, Jacobsen's beach (4°54′31″S, 29°36′02″E) (76 mm). SAIAB 70800, Kigoma, Kigoma Bay below hill to Hotel (4°53′03″S, 29°37′11″E) (two specimens: 65–80 mm).

Additional specimens (most probably M. polli *sp. nov.).* MRAC 128684, Uvira (Democratic Republic of Congo) (±3°24′S, 29°08′E) (11 specimens, 45–55 mm) (only 11 of the 16 specimens as mentioned by Matthes 1962).

Discussion

Contrary to Poll (1953), Matthes (1962) used the absence of large individuals with less than 27 dorsal spines as an argument not to recognize the existence of a new species within the collections of *M. ophidium*. However, I found in that collection a specimen of 136 mm SL, a nearly ripe female, that I designated as the holotype of *M. polli* sp. nov. From my observations it is clear that *M. polli* sp. nov. is a small-sized species. At present small-sized juveniles of *M. ophidium* have not been collected. Their discovery would further confirm the presence of two species. However, the lack of such juveniles in the collections is not that surprising as small specimens of many other spiny eel species are very rare or absent in our present collections.

Adjustments in developmental rates or timing may be a major way in which new species and even higher taxa evolve from old (Cohen 1984; Mabee 1993). Indeed, it is possible that heterochronic events are at the basis of the evolution of a small-sized species *M. polli* sp. nov. from a *M. ophidium*-like common ancestor species. Whether paedomorphosis or neoteny, or a related heterochronic phenomenon (see Helfman et al. 1997), produces this particular condition cannot be determined at present.

Several authors, for instance Landrum and Dark (1968), have reported on the independence of the total vertebrae number from the length of the fish. Indeed, there is no evidence for size-related changes of the meristics in this and any of other spiny eel species studied by myself.

Abe (1997) reported rock and sand or mud habitats for *M. ophidium*. This literature statement is probably based on the data provided by Matthes (1962). However, most of the specimens identified as *M. ophidium* by Matthes (1962) and collected on a rock habitat bottom are in fact *M. polli* sp. nov. (except for MRAC 130379–380). Based on his own observations Abe (1997) stated that *M. ophidium* occupies the sand bottom. Also Brichard (1989) reported this species as living mainly on sand. Therefore, both species seem to live in a different habitat with *M. ophidium* mostly on sandy bottoms and *M. polli* sp. nov. more restricted to the rock, rock/sand habitat types.

Acknowledgements

References

Abe N. 1997. Ecology of non-cichlids in the littoral zone of Lake Tanganyika. In: Kawanabe H, Hori M, Nagoshi M, editors. Fish communities in Lake Tanganyika. Kyoto: Kyoto University Press. p 43–256.

Abe N. 1998. Parental care and social organisation of the spiny eel, *Aethiomastacembelus platysoma*, in Lake Tanganyika. Environmental Biology of Fishes 52:217–280.

Bell-Cross G, Kaoma J. 1971. Additions and amendments to the checklist of the fishes of Zambia, 3. Fisheries Reseach Bulletin, Zambia 5:235–244.

Bernacsek GM. 1980. Introduction to the freshwater fishes of Tanzania. Dar Es Salaam: University of Dar Es Salaam, Department of Zoology. 78 p.

Bookstein F, Chernoff B, Elder R, Humphries J, Smith G, Strauss R. 1985. Morphometrics in evolutionary biology. The Academy of Natural Sciences of Philadelphia, Special Publications 15:1–277.

Boulenger GA. 1898. Report on the collection of fishes made by Mr. J. E. S. Moore in lake Tanganyika during his expedition 1895–1896, with an appendix by J. E. S. Moore. Transactions of the Zoological Society of London 15:1–30.

Boulenger GA. 1899. Matériaux pour la faune du Congo. Poissons nouveaux du Congo. 3e partie: Silures, Acanthoptérygiens, Mastacembles, Plectognathes. Annales du Musée du Congo, Zoologie, Bruxelles, Série I 1(3):39–58.

Boulenger GA. 1901a. Les poissons du bassin du Congo. Brussels, 532 p.

Boulenger GA. 1901b. Third contribution to the ichthyology of lake Tanganyika. Report on the collection of fishes made by Mr. J. E. S. Moore in lakes Tanganyika and Kivu during his second expedition, 1899–1900. Transactions of the Zoological Society of London 16:137–178.

Boulenger GA. 1905. A list of freshwater fishes of Africa. Annals and Magazine of Natural History, London (7)16(91):36–60.

Boulenger GA. 1906. Fourth contribution to the ichthyology of lake Tanganyika. Report on the collection of fishes made by Dr. W. A. Cunnington during the third Tanganyika expedition 1904–1905. Transactions of the Zoological Society of London 17:537–619.

Boulenger GA. 1912. A synopsis of the fishes of the genus *Mastacembelus*. Journal of the Academy of Natural Sciences of Philadelphia 2(15):197–203.

Boulenger GA. 1916. Catalogue of the freshwater fishes of Africa in the British Museum (Natural History). Volume 4., London: printed by order of the Trustees. 392 p.

Brichard P. 1978. Fishes of Lake Tanganyika. Neptune City, NJ: T.F.H. Publications. 488 p.

Brichard P. 1989. Cichlids and all the other fishes of Lake Tanganyika. Neptune City, NJ: T.F.H. Publications. 544 p.

Cohen DM. 1984. Ontogeny, systematics and phylogeny. In: Moser HG, Richards WJ, Cohen DM, Fahay MP, Kendall AW Jr, Richardson SL, editors. Ontogeny and systematics of fishes. American Society of Ichthyologists and Herpetologists. Special Publication 1. Lawrence, KS: Allen Press. p 7–11.

Coulter GW. 1991. Zoogeography, affinities and evolution, with special regard to the fish. In: Coulter GW, editor. Lake Tanganyika and its life. London: Natural History Museum Publications, Oxford University Press. p 275–305.

Cunnington WA. 1920. The fauna of the African lakes: a study in comparative limnology with special references to Tanganyika. Proceedings of the Zoological Society of London 1:507–622.

David L. 1936. Contribution à l'étude de la faune ichthyologique du Lac Tanganika. Revue de Zoologie et de Botanique africaines 28(2):149–160.

David L, Poll M. 1937. Contribution à la faune ichthyologique du Congo belge: collections du Dr. H. Schouteden (1924–1926) et d'autres récolteurs. Annales du Musée du Congo Belge, Zoologie, Tervuren (Belgique) (1)3(5):189–294.

De Vos L, Nshombo M, Thys van den Audenaerde DFE. 1996. *Trematocara zebra* (Perciformes, Cichlidae), nouvelle espèce du Nord-Ouest du Lac Tanganyika (Zaïre). Belgian Journal of Zoology 126(1):3–20.

De Vos L, Snoeks J. 1998. Die Nicht-Cichliden des Tanganjikasee-Beckens. D.A.T.Z., Sonderheft 30–35. (Translated from Eng).

Eccles DH. 1992. Field guide to the freshwater fishes of Tanzania. FAO species identification sheets for fishery purposes. Rome: FAO. 145 p.

Günther A. 1893. Descriptions of the reptiles and fishes collected by Mr. E. Coode-Hore on Lake Tanganika. Proceedings of the Zoological Society of London, 628–632.

Helfman GS, Bruce B, Facey DE. 1997. The diversity of fishes. Cambridge (MA): Blackwell Science. 528 p.

Hulot A. 1950. Le régime alimentaire des poissons du Centre africain. Intérêt éventuel de ces poissons en vue d'une zootechnie économique au Congo belge. Bulletin agricole du Congo belge, Bruxelles 41(1):145–176.

Humphries JM, Bookstein FL, Chernoff B, Smith GR, Elder RL, Poss SG. 1981. Multivariate discrimination by shape in relation to size. Systematic Zoology 30:291–308.

Jäger D. 2002. *C. ophidium*—ein kurioser Vertreter der Stachelaale, Dutzende Ratschläge und Tipps zur Aquarist [online]. http://www.drta.de/artikel/staal.php.

Kawabata M, Mihigo NYK. 1982. Littoral fish fauna near Uvira, Northwestern and of Lake Tanganyika. African Study Monographs 2:133–143.

Landrum BJ, Dark TA. 1968. The distribution of mature western Alaskan and Kamchatkan sockeye salmon (*Oncorhynchus nerka*) in the North Pacific Ocean and Bering Sea. Bulletin International North Pacific Fisheries Commission 24:1–110.

Mabee PM. 1993. Phylogenetic interpretation of ontogenetic change: sorting out the actual and artefactual in an empirical case study of centrarchid fishes. Zoological Journal of the Linnean Society 107:175–291.

Marcus LF. 1990. Traditional morphometrics. In: Rohlf FJ, Bookstein FL, editors. Proceedings of the Michigan Morphometrics Workshop, Special Publication Number 2. Ann Arbor, MI: The University of Michigan Museum of Zoology. p 77–117.

Matthes H. 1962. Poissons nouveaux ou intéressants du lac Tanganika et du Ruanda. Musée Royal de l'Afrique Centrale, Tervuren (Belgique) Sciences Zoologiques 111:27–88.

Moore JES. 1903. The Tanganyika problem: an account of the researches undertaken concerning the existence of marine animals in Central Africa. London: Hurst and Blackett. 371 p.

www.pet2get.dk/stockliste. 2003. Medimportliste [online]. http://www.pet2get.dk/stockliste.htm.

Pfeffer GJ. 1894. Fische. In: Möbius K, editor. Deutsch-Ost-Afrika Bd. IIII: Die Thierwelt Ost-Afrikas. Volume 1, Wirbelthiere. Hamburg: Dietrich Reimer. 72 p.

Poll M. 1946. Révision de la faune ichthyologique du lac Tanganika. Annales du Musée du Congo Belge, C— Zoologie, Tervuren (Belgique) (1)4(3):141–364.

Poll M. 1953. Poissons non Cichlidae. Exploration Hydrobiologique du Lac Tanganika (1946–1947). Résultats Scientifiques, Institut Royal des Sciences naturelles de Belgique (ISNB), Bruxelles 3(5A):1–251.

Seegers L. 1996. The fishes of the Lake Rukwa Drainage. Annales Musée Royal de l'Afrique Centrale. Sciences Zoologiques 278:1–407.

Travers RA. 1984a. A review of the Mastacembeloidei, a suborder of synbranchiform teleost fishes, Part I: Anatomical descriptions. Bulletin of the British Museum (Natural History) Zoological Series 46(1):1–133.

Travers RA. 1984b. A review of the Mastacembeloidei, a suborder of synbranchiform teleost fishes, Part II: phylogenetic analysis. Bulletin of the British Museum (Natural History) Zoological Series 47(2):83–150.

Travers RA. 1988. Diagnosis of a new African Mastacembelid spiny-eel genus *Aethiomastacembelus* gen. nov. (Mastacembeloidei: Synbranchiformes). Cybium 12(3):255–257.

Travers RA, Eynikel G, Thys van den Audenaerde DFE. 1986. Mastacembelidae. In: Daget J, Gosse J-P, Thys van den Audenaerde DFE, editors. Check-list of the freshwater fishes of Africa, CLOFFA. Volume II. Brussels: ISNB; Tervuren: MRAC; Paris: ORSTOM. p 15–427.

Vreven EJ. 2004. *Aethiomastacembelus shiloangoensis*, a new spiny-eel from the Shiloango River basin, Africa (Synbranchiformes: Mastacembelidae). Ichthyological Explorations of Freshwaters 15(2):97–104.

Vreven EJ, Mastacembelidae (Teleostei; Synbranchiformes) subfamily division and African generic division: an evaluation. Journal of Natural History. Forthcoming.

Vreven EJ, Teugels GG. 1996. Description of a new Mastacembelid species (Synbranchiformes; Mastacembelidae) from the Zaïre River Basin in Africa. Copeia 1:130–139.

Vreven EJ, Teugels GG. 1997. *Aethiomastacembelus traversi*, a new spiny-eel from the Zaïre River basin, Africa (Synbranchiformes: Mastacembelidae). Ichthyological Exploration of Freshwaters 8(1):81–87.

Vreven EJ, Teugels GG. Redescription of *Mastacembelus liberiensis* Boulenger, 1898 and description of a new West African spiny-eel (Synbranchiformes: Mastacembelidae) from the Konkoure River basin, Guinea. Journal of Fish Biology. Forthcoming.

Worthington EB, Ricardo CD. 1936. The fish of Lake Tanganyika (other than *Cichlidae*). Proceedings of the Zoological Society of London 2(4):1061–1112.