MORPHOLOGICAL AND ELECTRO-PHYSIOLOGICAL EVIDENCE FOR THE SYNONYMY OF TWO *MARCUSENIUS* SPECIES (OSTEOGLOSSOMORPHA, MORMYRIDAE) FROM WEST CENTRAL AFRICA

by

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ABSTRACT. - This is a detailed biometric study of 88 *Marcusenius* specimens (Mormyridae) originating from the Ntem River Basin in southern Cameroon and the Ivindo River in Gabon (West Central Africa) including the type material of *M. ntemensis* and *M. conicephalus*. It demonstrates that both nominal species are synonymous. A study of the electric organ and the electric organ discharge of specimens originating from both systems confirmed this. Due to nomenclatorial priority *M. ntemensis* is considered as the senior synonym.

RÉSUMÉ. - Synonymie entre deux espèces de *Marcusenius* (Osteoglossomorpha, Mormyridae) de l'Ouest de l'Afrique Centrale.

Une étude biométrique détaillée de 88 spécimens de *Marcusenius* (Mormyridae), provenant du bassin du Ntem dans le sud du Cameroun et la rivière Ivindo au Gabon (ouest de l'Afrique Centrale) et comprenant le matériel type de *M. ntemensis* et *M. conicephalus*, a démontré la synonymie entre ces deux espèces nominales. Une étude de l'organe électrique et de la décharge électrique de spécimens provenant des deux bassins a confirmé cette synonymie. Suite aux priorités de la nomenclature, *M. ntemensis* est considérée comme le synonyme senior.

Key words. - Mormyridae - *Marcusenius ntemensis* - *M. conicephalus* - Biometry - Electro-physiology - Synonymy - Cameroon - Gabon - Africa.

Mormyridae (Osteoglossomorpha) are primary freshwater fishes endemic to Africa. They are especially known for the presence of an electric organ of muscular origin, located in the caudal peduncle. With this organ they are able to emit weak electric discharges used for electro-location and communication.

Following Boden *et al.* (1997), 190 mormyrid species are recognised. Kramer and Van der Bank (2000) recently added a new one. The species are arranged in 18 genera (Gosse, 1984). One of the latter, the genus *Marcusenius* Gill, 1862, is diagnosed amongst others by an elongated body; a less well-developed snout, usually shorter than the postorbital segment; a rounded sub-mental swelling; a lower jaw slightly longer than the upper jaw; a caudal peduncle depth two to five times into its length; a distance between pectoral and pelvic fins shorter than the distance between pelvic and anal fins; 19 to 36 dorsal-fin rays; and 25 to 43 anal-fin rays (Taverne, 1971). Thirty-six species are presently recognised as valid (Boden *et al.*, 1997).

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The genus occurs throughout tropical Africa, from the Nilo-Sudan to South Africa.

As part of an ongoing project on the diversity of fresh- and brackish water fishes from the Lower Guinea ichthyofaunal area, including the coastal basins from Cameroon to Congo-Brazzaville, two nominal *Marcusenius* species, *M. ntemensis* (Pellegrin, 1927) and *M. conicephalus* Taverne *et al.*, 1976 showed to be problematic in their identification. The former species was described on a single specimen from the Ntem River in southern Cameroon, while the latter was described on 45 specimens from the same basin and two specimens from the neighbouring Ivindo River (Ogowe Basin) in northern Gabon.

According to Taverne *et al.* (1976), *Marcusenius ntemensis* differs from *M. conicephalus* by a much shorter caudal peduncle (2.5 times longer than deep compared to 3 to 4 times for *M. conicephalus*) and, as a consequence, by the anal fin origin which is two times closer to the caudal than to the pelvic fin origin.

In order to check the validity of the two species, a detailed biometric study was undertaken, including the type material of both species and the available *Marcusenius* collections from the Ntem and the Ivindo River Basins. A comparison between the electric organ of specimens originating from both basins as well as between their electric organ discharge was also made.

MATERIALS AND METHODS

Ninety-one specimens housed in the Musée Royal de l'Afrique Centrale, Tervuren (Belgium) (MRAC) and in the Muséum national d'Histoire naturelle, Paris (France) (MNHN) have been studied biometrically. The list of specimens examined with their locality and register number is given below.

On each specimen 27 point-to-point measurements were taken using callipers. Eleven meristic counts were taken on each fish. Measurements and counts follow Boden *et al.* (1997).

The data obtained were submitted to factor analysis using a principal component analysis (PCA) program from Statistica (StatSoft Inc.), version 5.0. Measurements were log-transformed before the PCA was run on the covariance matrix. An independent PCA was run on the correlation matrix from the untransformed count data. After examining the factor scores from these PCAs, we combined meristic and morphometric results into a single graph.

Material examined

Marcusenius ntemensis. - 61 specimens: MNHN 1927-162, Nyabessan, River Ntem (Cameroon); holotype. - MRAC 93-82-P-45, River Ntem, at 600 m of Nyabessan, towards Melem (Cameroon). - MRAC 93-82-P-46, River Ntem, near Oding (Cameroon). - MRAC 93-85-P-32-33, River Kyé, near Adjou'ou (Cameroon). - MRAC 93-108-P-33-35, Aboulou, River Kom (Cameroon). - MRAC 73-18-P-83, Village Aboulou, River Kom, affluent of the River Ntem (Cameroon); holotype of *M. conicephalus*. - MRAC 73-18-P-84, MRAC 73-18-P-85-93, MRAC 73-18-P-94-127 and MRAC 73-18-P-426-431, same data as holotype; paratypes of *M. conicephalus*. MRAC 75-24-P-3 and MRAC 75-24-P-423, Swampy area Bialé near M'Passa, Makokou (Gabon); paratypes of *M. conicephalus*. - MRAC 77-41-P-73-74. 8 km down from M'Passa, Makokou, River Ivindo (Gabon).

Marcusenius moorii. - 27 specimens : MRAC 73-18-P-13-18 and MRAC 73-18-P-19-25, Aboulou, River Ntem (Cameroon). - MRAC 73-18-P-76-77, Mvam, 5 km south of Oveng, River Yété, basin of River Ntem (Cameroon). - MRAC 73-29-P-36, Village Ngoazik, River Ntem (Cameroon). - MRAC 93-85-P-31, River Dasseu, Ntem, tributary Mboro, between

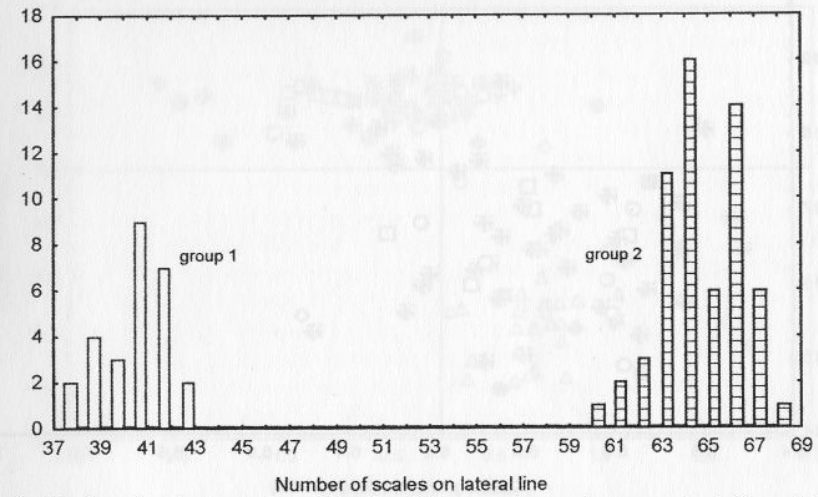

Fig. 1. - Number of scales in the lateral line in all *Marcusenius* specimens examined. Group 1: *Marcusenius moorii*; Group 2: *M. ntemensis*.

Akonekyé and Ngom Adjap (Cameroon). - MRAC 93-108-P-16, River Mvoé, after Ngbwassa, near Oveng (Cameroon). - MRAC 93-108-P-24-32, Aboulou, River Ntem (Cameroon).

Marcusenius friteli. - 3 specimens: MNHN 1886-320, Alima at Diélé (Congo Brazzaville); holotype. - MRAC 73-23-P-909-910, Boendé, river Tshuapa (Congo).

RESULTS AND DISCUSSION

Morphology

A qualitative examination of all specimens examined, revealed the presence of two groups in the sample. Several characters, in particular meristic counts (Table I) permit separation into groups. Especially the number of scales is diagnostic: one group has eight large circumpeduncular scales and 38 to 43 lateral-line scales (large-scaled group), while the other has 12 circumpeduncular scales and 60 to 68 lateral line scales (small-scaled group) (Fig. 1).

Table I. - Meristic counts for the two *Marcusenius* groups present in the Ntem and Ivindo Basins. Group 1: *M. moorii*; group 2: *M. ntemensis*.

	Group 1 (n = 27) median (range)	Group 2 (n = 61) median (range)
Dorsal-fin rays	24 (23-25)	19 (18-21)
Anal-fin rays	30 (27-32)	30 (29-32)
Pectoral-fin rays	10 (9-10)	11 (10-12)
Pelvic-fin rays	6 (5-6)	6
Lateral-line scales	41(38-43)	64 (60-68)
Caudal peduncle scales	8	12
Scales between dorsal fin and lateral line	8 (7-9)	9 (9-10)
Scales between anal fin and lateral line	10 (8-10)	10 (9-11)
Teeth on upper jaw	5 (4-5)	5 (4-7)
Teeth on lower jaw	6 (5-7)	8 (5-9)

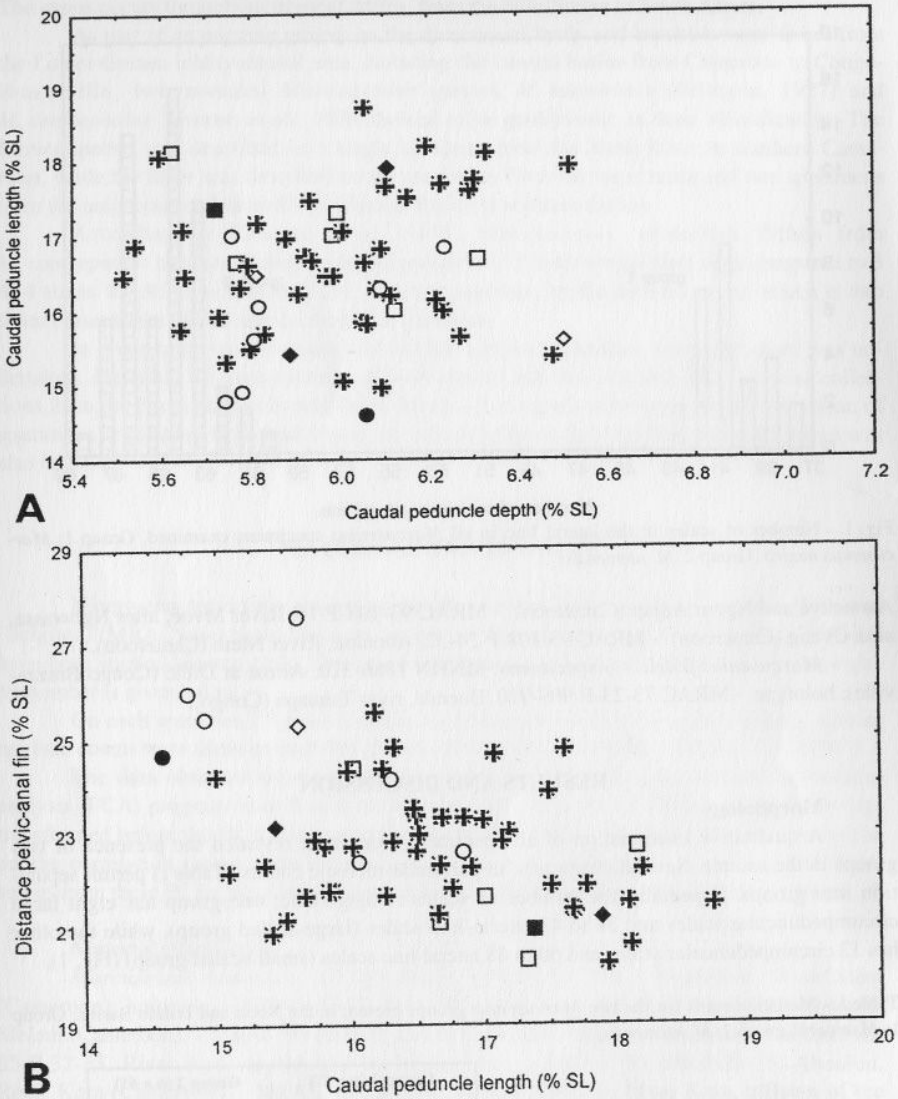

Fig. 2. - Characters used by Taverne *et al.* (1976) to distinguish *M. conicephalus* from *M. ntemensis*. **A**: Caudal peduncle length (% SL) *versus* caudal peduncle depth (% SL). **B**: Caudal peduncle length (% SL) *versus* distance between pelvic and anal fins (% SL). n = holotype of *M. conicephalus*; * = paratypes of *M. conicephalus* from the Ntem River; ♦ = paratypes from the Ivindo River; ○ = other *M. conicephalus* from the Ntem River (museum identifications); ◊ = other *M. conicephalus* from the Ivindo River (museum identifications); l = holotype of *M. ntemensis*; m = other *M. ntemensis* (museum identifications).

As indicated by Boden *et al.* (1997), nine out of 36 recognised species in the genus *Marcusenius* have eight scales on the caudal peduncle rather than 12 or 16, which is more typical of the genus. Of these nine species, only *M. moorii* (Günther, 1867) occurs in the

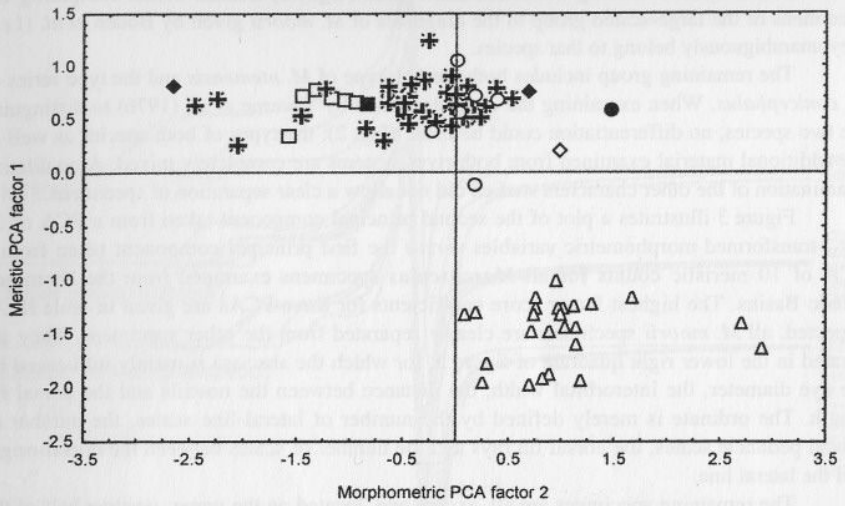

Fig. 3. - Plot of the second principal component taken from a PCA of 26 log-transformed morphometric variables *versus* the first principal component taken from a PCA of 10 meristic counts for all *Marcusenius* specimens examined from the Ntem and Ivindo Basins. n = holotype of *M. conicephalus*; * = paratypes of *M. conicephalus* from the Ntem River; ♦ = paratypes from the Ivindo River; ○ = other *M. conicephalus* from the Ntem River (museum identifications); ◊ = other *M. conicephalus* from the Ivindo River (museum identifications); l = holotype of *M. ntemensis*; m = other *M. ntemensis* (museum identifications); Δ = *M. moorii*.

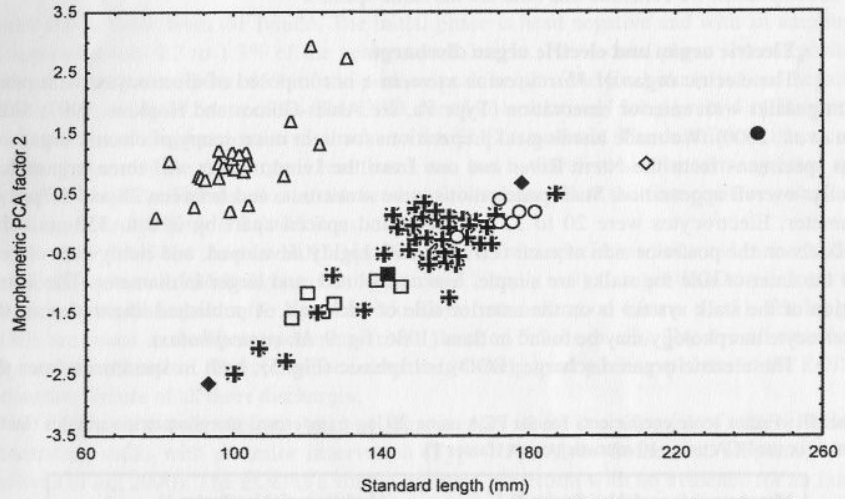

Fig. 4. - Plot of the second principal component taken from a PCA of 26 log-transformed morphometric variables *versus* the standard length (in mm). n = holotype of *M. conicephalus*; * = paratypes of *M. conicephalus* from the Ntem River; ♦ = paratypes from the Ivindo River; ○ = other *M. conicephalus* from the Ntem River (museum identifications); ◊ = other *M. conicephalus* from the Ivindo River (museum identifications); l = holotype of *M. ntemensis*; m = other *M. ntemensis* (museum identifications); Δ = *M. moorii*.

Lower Guinea area, including the Ntem and Ivindo (Ogowe) Basins. When comparing the specimens of the large-scaled group to the diagnosis of *M. moorii* given by Boden *et al.* (*l.c.*), they unambiguously belong to that species.

The remaining group includes both the holotype of *M. ntemensis* and the type series of *M. conicephalus*. When examining the characters used by Taverne *et al.* (1976) to distinguish the two species, no differentiation could be made (Fig. 2): the types of both species as well as the additional material examined from both river systems are completely mixed. A qualitative examination of the other characters studied did not allow a clear separation of specimens.

Figure 3 illustrates a plot of the second principal component taken from a PCA of 26 $\log_{10}$-transformed morphometric variables *versus* the first principal component taken from a PCA of 10 meristic counts for all *Marcusenius* specimens examined from the Ntem and Ivindo Basins. The highest factor score coefficients for these PCAs are given in table II. As expected, all *M. moorii* specimens are clearly separated from the other specimens. They are located in the lower right quadrate of figure 3, for which the abscissa is mainly influenced by the eye diameter, the interorbital width, the distance between the nostrils and the dorsal fin length. The ordinate is merely defined by the number of lateral-line scales, the number of caudal peduncle scales, the dorsal fin rays and the number of scales between the dorsal-origin and the lateral line.

The remaining specimens are all, except one, located on the upper, positive half of the graph and are influenced by high meristic counts. The holotype of *M. ntemensis* belongs to this second group, although it and two other specimens are somewhat dislocated from others. However, when plotting the second factor of the PCA of the measurements against the standard length, it is evident that this is due to differences related to the size of the specimens (Fig. 4), and the holotype of *M. ntemensis* is the largest specimen examined.

As no differences could be found to distinguish *Marcusenius ntemensis* from *M. conicephalus*, we conclude that both are the same species.

Electric organ and electric organ discharge

The electric organ of *Marcusenius ntemensis* is composed of electrocytes with penetrating stalks with anterior innervation (Type Pa, see Alves-Gomes and Hopkins, 1997; Sullivan *et al.*, 2000). We made histological preparations for light microscopy of electric organs of two specimens from the Ntem River and one from the Ivindo River. All three organs had similar overall appearance. Stalk penetrations were numerous, and between 28 and 50 µm in diameter. Electrocytes were 20 to 32 µm thick, and spaced apart by 310 to 550 µm. The stalklets on the posterior side of each cell are small, highly developed, and richly convoluted. On the anterior side the stalks are simple, less convoluted, and larger in diameter. The innervation of the stalk system is on the anterior side of each cell. A published illustration of the electrocyte morphology may be found in Bass (1986, fig. 9, *M. conicephalus*).

The electric organ discharge (EOD) is triphasic (Fig. 5), both in specimens from the

Table II. - Factor score coefficients for the PCA using 26 log-transformed morphometric variables (factor 2) and for the PCA using 10 meristic counts (factor 1).

Morphometric variables (factor 2)		Meristic variables (factor 1)	
log eye diameter	0.82	Lateral-line scales	0.97
log interorbital width	0.36	Caudal peduncle scales	0.97
log nostril Distance	- 0.31	Dorsal- fin rays	- 0.91
log dorsal-fin length	0.30	Scales between dorsal fin and lateral line	0.89

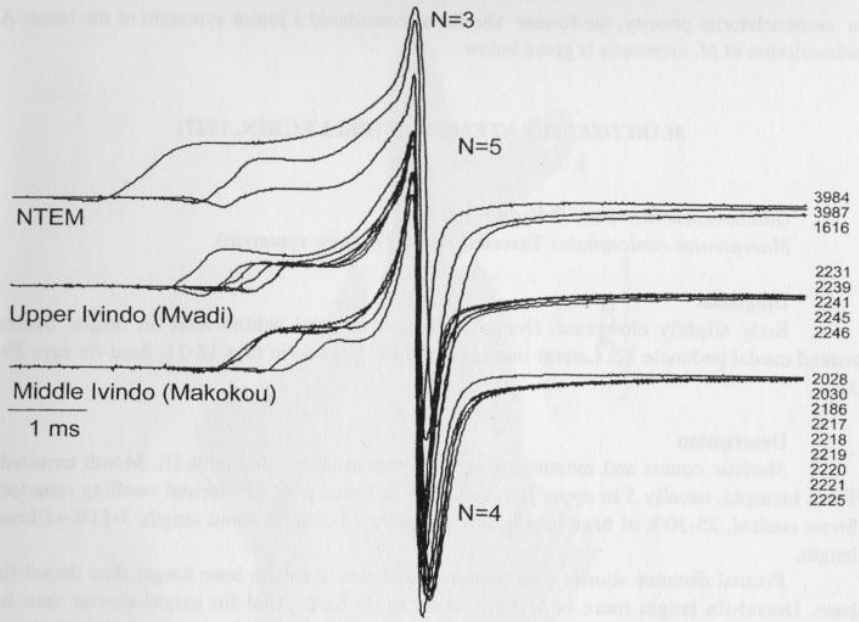

Fig. 5. - Electric organ discharges recorded from *M. ntemensis/M. conicephalus* from the Ntem and Ivindo River basins. Code numbers refer to individual field identification numbers.

Ntem and in those from the Ivindo. The initial phase is head negative and with an amplitude of approximately 0.7 to 1.3% of the peak-to-peak height. The second phase is head positive with an amplitude of 36 to 45% of the peak-to-peak height. The final phase is head negative with an amplitude of 54 to 63%. The EOD duration is relatively long [over 4 milliseconds (ms)] and has a long head positive plateau to the EOD waveform. The duration of the second and third phase of the discharge is less than 1 ms, and is therefore similar to many other species of mormyrids. The duration of the head positive phase, from the first positive going zero crossing to the first peak is 2.0 to 2.7 ms.

In figure 5 the shortest EODs appear to come from specimens collected in the Middle Ivindo River around Makokou (mean duration 3.7 ms, n = 9). Longer EODs are from the specimens originating from the Upper Ivindo River (mean duration 4.0 ms, n = 5). The longest EODs are found in the Ntem specimens (mean duration 5.5 ms, n = 3). The overall waveform appears monomorphic. The conspicuous and long-lasting head positive plateau in the EOD is a constant feature of all three discharges.

By contrast, the electric organ of *Marcusenius moori* is composed of cells with non-penetrating stalks with posterior innervation (Type NPp, Alves-Gomes and Hopkins, 1997; Sullivan *et al.*, 2000). The EOD is a simple biphasic waveform with no evidence for an initial head-negative phase (see Hopkins, 1981; Bass, 1986).

As no difference could be found in the electric organ and in the electric organ discharge between *M. ntemensis/M. conicephalus* specimens from the Ntem and the Ivindo Rivers, the electro-physiological study supports the conclusion of the morphological study: *M. conicephalus* and *M. ntemensis* should be considered as representing the same species. Due

to nomenclatorial priority, the former should be considered a junior synonym of the latter. A redescription of *M. ntemensis* is given below.

MARCUSENIUS NTEMENSIS (PELLEGRIN, 1927)

(Fig. 6)

Gnathonemus ntemensis Pellegrin, 1927.
Marcusenius conicephalus Taverne *et al.*, 1976 (new synonym).

Diagnosis

Body slightly elongated. Dorsal-fin origin situated behind anal-fin origin. Scales around caudal peduncle 12. Lateral-line scales 60-68. Dorsal-fin rays 18-21. Anal-fin rays 29-32.

Description

Meristic counts and measurements are given in table I and table III. Mouth terminal. Teeth bicuspid, usually 5 in upper jaw, usually 8 in lower jaw. Sub-mental swelling rounded. Snout conical, 25-30% of head length. Eye diameter 25-39% of snout length, 7-11% of head length.

Preanal distance shorter than predorsal distance. Anal-fin base longer than dorsal-fin base. Dorsal-fin height more or less the same as its base. Anal-fin height shorter than its length. Pectoral fin twice as long as pelvic fin and reaching a little further than pelvic-fin base. Pelvic-fin base closer to pectoral-fin base than to anal-fin origin. Posterior end of pelvic fin at 0.37-0.5 the distance between pelvic-fin base and anal-fin origin. Caudal peduncle depth 29-42% of its length.

Low number of dorsal-fin rays (18-21). Anal-fin rays 29-32. High number of lateral-line scales (60-68). Scales between dorsal-fin origin and lateral line 9-10; scales between anal-fin origin and lateral line 9-11. Twelve scales around caudal peduncle.

The maximum size is 243 mm standard length.

Distribution

This species is present in the Ntem River and the Ivindo River, both located in the Lower Guinea Ichthyofaunal Province. Important faunal similarities have been observed between these two rivers. While the fish may be unable to pass between the systems in the current geological configuration, this passage must have existed in the past.

Affinities

Within *Marcusenius*, *M. ntemensis* belongs to the group of small-scaled species (see Boden *et al.*, 1997). Whether this scale character reflects an evolutionary trend or just delineates artificial groups, is not known at present because phylogenetic relationships in *Marcusenius* are unclear.

Taverne *et al.* (1976) considered *M. conicephalus* (= *M. ntemensis*) as closely related to *M. friteli* (Pellegrin, 1904) described from the Alima River, a tributary of the Congo Basin, relatively close to the Ogowe (Ivindo) Basin. We examined the holotype and other specimens of this species, also belonging to the small-scaled *Marcusenius*. We confirm that both species can easily be distinguished amongst others by a shorter pectoral fin not reaching the pelvic fin in *M. friteli*.

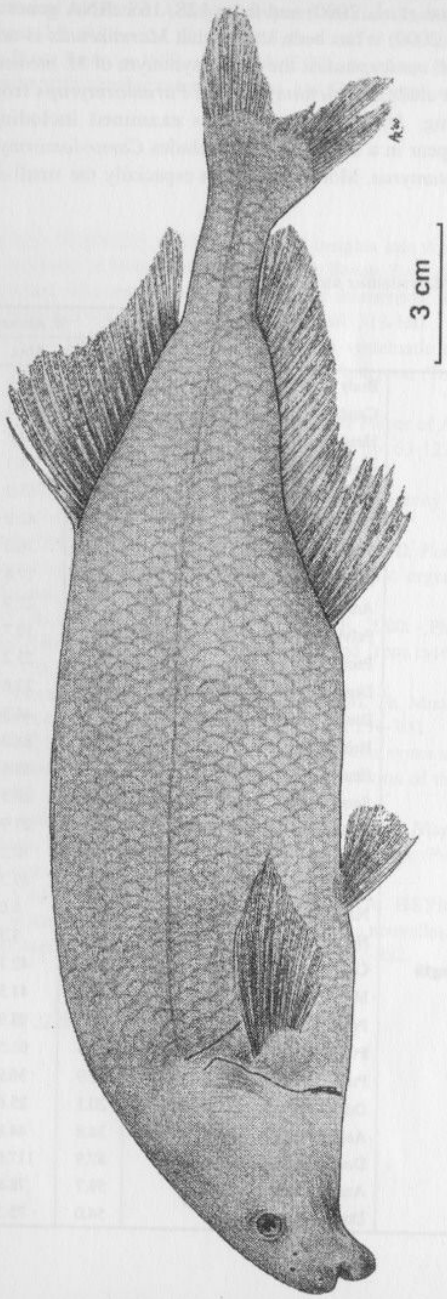

Fig. 6. - *Marcusenius ntemensis*, holotype, 243 mm SL.

In recent studies of phylogenetic relationships of mormyrid fish inferred from cytochrome b sequences (Lavoué *et al.*, 2000) and from 12S, 16S rRNA genes and RAG2 nuclear sequences (Sullivan *et al.*, 2000) it has been shown that *Marcusenius* is not monophyletic. In particular the position of *M. conicephalus*, the junior synonym of *M. ntemensis* is problematic, as it is the sister taxon to a clade of *Brienomyrus* and *Paramormyrops* from Gabon; it is distant from the remaining *Marcusenius* species examined including *M. moori* and *M. senegalensis*, which appear in a clade that also includes *Campylomormyrus*, *Gnathonemus*, *Genyomyrus*, and *Hippopotamyrus*. More research on especially the small-scaled *Marcusenius* species is necessary.

Table III. - Measurements of *Marcusenius ntemensis*.

		M. ntemensis (n = 61)			
		Min	Max	Mean	St. dev.
in % of standard length	Body depth	19.1	25.6	21.9	1.4
	Caudal peduncle length	14.6	18.8	16.6	1.0
	Head length	23.4	28.3	25.5	1.0
	Predorsal distance	66.4	74.3	69.5	1.8
	Preanal distance	59.1	65.2	62.3	1.4
	Prepelvic distance	36.2	42.2	39.9	1.1
	Prepectoral distance	22.4	26.2	24.2	0.8
	Dorsal-fin length	13.9	17.6	15.6	0.9
	Anal-fin length	22.2	27.9	24.6	1.2
	Pelvic-fin length	9.2	10.7	10.2	0.4
	Pectoral-fin length	17.4	23.2	19.1	0.9
	Distance pelvic-anal fin	20.3	27.6	22.9	1.5
	Distance pectoral-anal fin	36.1	44.3	39.4	1.8
in % of head length	Head depth	62.3	81.2	69.1	3.7
	Head width	30.8	49.6	35.6	2.9
	Snout length	25.0	29.5	26.9	1.1
	Interorbital width	19.7	27.9	23.8	1.6
	Eye diameter	7.6	10.2	9.0	0.5
	Postorbital length	59.9	69.3	65.6	1.6
	Nostril distance	4.2	6.0	5.0	0.4
	Nostril-eye distance	4.2	8.3	6.2	0.7
in % of caudal peduncle length	Caudal peduncle depth	30.9	42.1	36.2	2.4
	Middle caudal peduncle depth	29.8	41.5	35.0	2.4
in % of predorsal distance	Preanal distance	82.6	95.9	89.7	3.3
	Prepelvic distance	52.5	61.5	57.4	1.8
	Prepectoral distance	31.9	36.9	34.8	1.1
	Dorsal-fin length	20.1	25.6	22.4	1.2
in % of preanal distance	Anal-fin length	34.8	44.8	39.5	2.2
in % of dorsal-fin length	Dorsal-fin height	87.9	117.6	103.7	6.3
in % of anal-fin length	Anal-fin height	59.7	78.8	67.4	3.8
	Dorsal-fin length	54.0	75.3	63.4	4.7

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