

Description of a new *Fundulopanchax* species (Cyprinodontiformes : Aplocheilidae) from the Niger delta, with a redefinition of the genus *Fundulopanchax*

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Fundulopanchax powelli, new species, is described from the Niger delta (south east Nigeria). The new species is distinguished from its congeners by its almost black colour including absence of red pigmentation, anal radials without lateral processes, low number of dorsal-fin rays, small size of its sagittal otoliths provided with a large rounded area and deep incisions on dorsal, posterior and ventral rim. The genus *Fundulopanchax* is redefined and derived characters of chorion structure, anal fin skeleton, caudal peduncle scalation and sagittae morphology are presented. Composition of *Fundulopanchax* is discussed.

Description d'une nouvelle espèce de Fundulopanchax (Cyprinodontiformes : Aplocheilidae) du delta du Niger avec une rédéfinition du genre Fundulopanchax. Fundulopanchax powelli, sp. nov. est décrit du delta du Niger dans le sud-est du Nigéria. Cet nouvelle espèce se distingue de ses congénères par sa livrée quasi-noire (l'absence du pigmentation rouge), l'absence d'excroissances latérales sur les ptérygophores des rayons de l'anale, le nombre restreint de rayons dorsaux, la petite taille des otolithes sagittaux, ainsi par des sagittae ayant une large 'area' arrondie et de profondes incisions sur les bords dorsal, postérieur et ventral. Des nouvelles synapomorphies concernant la structure du chorion, les caractères ostéologiques du squelette caudal, les écailles du pédoncule caudal et la morphologie des otolithes sagittaux sont présentées pour le genre *Fundulopanchax* et la composition du genre est discuté.

Key-words : Teleostei, Aplocheilidae, systematics, new species, osteology, otoliths, chorion pattern.

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INTRODUCTION

In 1990 the second author received an extensive collection of preserved fishes intended for the collection of MRAC, originating from south eastern Nigeria. This collection, donated by C. B. Powell, University of Port Harcourt, included an unusual dark aplocheilid that differed at first sight from all known *Aphyosemion* and *Fundulopanchax*-species by its almost black colour and absence of red pigmentation.

Although this species showed the derived characters of the subfamily Nothobranchiinae Radda, 1981 (or the *Aphyosemion-Notobranchius* group sensu Parenti, 1981), its generic classification on external characters was problematic (the composition of the family Aplocheilidae is presented in table 4).

Due to the presence of a tubular preopercular neuromast system, provided with pores, it apparently belongs to either *Aphyosemion* or *Fundulopanchax* in the sense of Parenti (1981). Parenti used the following characters for

separating *Fundulopanchax* from *Aphyosemion*: 1. swimbladder not extending beyond the first hemal spine, 2. elongated dorsal fin with 14 or more rays.

Concerning the first character the new species had to be classified as a *Fundulopanchax* representative. The second character however indicates a possible inclusion in *Aphyosemion*.

To solve this problem an extensive study on osteology and otolith morphology was started in 20 *Aphyosemion* and 14 *Fundulopanchax* species, including the unusual dark species under study. For outgroup comparisons 42 species of 7 other Nothobranchiinae genera were studied.

As a result of these studies the new species is described as *Fundulopanchax powelli* and new diagnostic characters for the genus *Fundulopanchax* can be given. We also present results of a comparative egg-membrane (chorion) study. The chorion photographs were a secondary result of a study on comparative analysis of early development in annual fishes. This study was part of a research project focussed on cell behaviour during early development of annual fishes (Van Haarlem, 1981).

In the 1981 study on chorion structures it is shown that all species of the *Fundulopanchax* subgenera *Paraphyosemion*, *Paludopanchax* and *Fundulopanchax* have a derived chorion structure that clearly separate them from *Aphyosemion* species.

Osteological characters of cyprinodontiform fishes were studied by Parenti (1981). This study is valuable, being the most complete analysis of the Cyprinodontiformes above the genus level. With relation to Aplocheilidae, it was based on too limited material and too little derived characters, for a profound classification of this family.

As a result of our osteological study it was found that characters of the anal fin skeleton are very useful in separating *Fundulopanchax* from *Aphyosemion*.

The possibility of identifying fish species by their otoliths was indicated by the paleontologist Koken (1884). This method was regarded as useful for demonstrating intrafamilial relationships, as indicated by Schmidt (1969) and Gaemers (1976, 1985). Until now, the use of otolith characters in cyprinodontiform taxonomy has been restricted to (fossil) Cyprinodontidae species. Information on otoliths of Aplocheilidae is not available from literature.

In this paper the relevant results of a comprehensive study of aplocheilid otoliths (Van der Zee, in prep) are presented. It is shown that the genera *Aphyosemion* and *Fundulopanchax* can be separated and that otolith characters are species specific to a certain extent.

MATERIAL AND METHODS

This description of *Fundulopanchax powelli* is based on specimens collected and preserved in the field by C. B. Powell. Measurements and counts were made according to the procedure outlined by Miller (1948) for cyprinodont fishes. As Miller pointed out, killifishes do not possess a complete lateral line; therefore it is customary to count scales in a lateral series starting from the shoulder girdle to the end of the hypural plate, ascertained by bending the caudal fin. In this study comparative analysis of the subfamily Nothobranchiinae is concentrated on chorion structure, saggital otoliths and morphological characters of the anal fin skeleton.

For chorion studies, photographs of life eggs were taken by the first author in 1981 using an inverted microscope with facilities for bright field, phase contrast and Normanski differential interference

optics. Eggs were collected from breeding pairs that were spawning under laboratory conditions. The fishes were bred randomly in a climate controlled room with L/D-cycle of 12h light and 12h dark and a temperature of $25.0 \pm 0.5^\circ\text{C}$. They were kept in tap water containing 1 gram of artificial sea salt (Wimex) per litre and fed beef heart, mosquito larvae and *Artemia salina*. Eggs deposited in plastic trays filled with peat moss, were collected 1 to 20 hours after spawning, from full-grown fish, at least four months old, that already had been spawning for one month. The eggs were washed three times for two minutes in sterile tap water at $25.0 \pm 0.5^\circ\text{C}$ and were put in a home-made deep depression slide with a coverglass as bottom. Because of the difference in egg diameter between the species, a series of plastic slides (26 x 76 mm) with a hole of a diameter of 10 mm was made, stepwise increasing 0.1 mm in thickness to give the hole a depth between 0.6 and 1.4 mm. Thus, if the appropriate depth of the depression was selected, the egg could be rotated in the desired position by moving the top coverslip. The data presented here are based on the observation of at least ten eggs that have developed normally. Observation of chorion structures in life fish eggs was carried out up to the 10-somite stage of the developing embryo.

Otoliths were obtained by dissection after removal of the radii branchiostegi, gill arches and pharyngobranchial toothplate. Otoliths were measured using a microscope with an ocular micrometer. Otolith photographs were made by means of a Jeol JSM-840A scanning microscope. For the saccular otolith an extensive series of more or less useful morphological terms has been proposed by various authors. In Fig. 2 terms for otolith morphology as proposed by Nolf (1985) are indicated on a schematic drawing of a generalized cyprinodont otolith.

For osteological studies specimens were cleared and alizarin-stained.

Abbreviations used:

| | |
|-----|---------------------------|
| BD | Body depth |
| OL | Otolith length |
| CD | Depth of caudal peduncle |
| PAL | Preanal length |
| CL | Length of caudal peduncle |
| PDL | Predorsal length |
| ED | Eye diameter |
| PPL | Prepelvic length |
| HL | Head length |
| SL | Standard length |
| IW | Interorbital width |
| SNL | Snout length |
| OH | Otolith height |
| OW | Otolith width |

The institutional abbreviation MRAC is Musée royal de l'Afrique centrale, Tervuren, Belgium. A list of studied material can be obtained on request (first author).

RESULTS

Fundulopanchax powelli n. sp.

(Fig. 1)

Types

Holotype. - MRAC 92-53-P-1, juvenile specimen of undetermined sex, 24.9 mm SL; Nigeria, Niger delta, Delta State, northwest of Bakakodia or Okoko-diagbene village, on the east bank of Nana Creek, approx. 20 km northeast of Escravos River mouth and 55 km west-northwest of Warri; approx. $05^\circ 40' 20''$ N, $05^\circ 19' 30''$ E; collected by C. B. Powell (5/6 VII 1988).

Paratypes. - MRAC 92-53-P-2-21, 20 juvenile specimens of undetermined sex, 20.7-28.4 mm SL; collected with the holotype, MRAC 92-53-P-22-23, 2 cleared and alizarine stained specimens collected with the holotype.

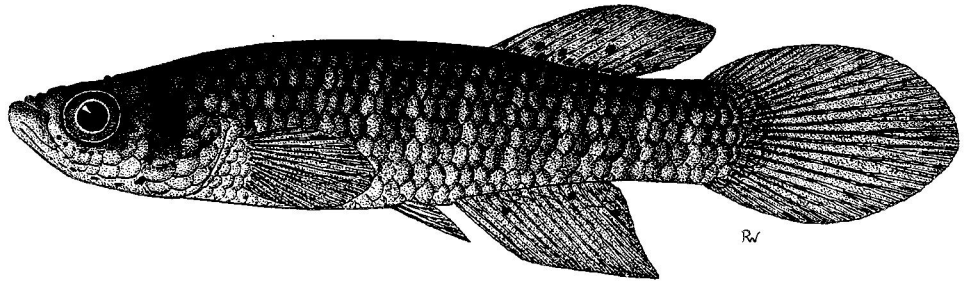


Fig. 1. - *Fundulopanchax powelli*, paratype, juvenile, 23.3 mm SL

Diagnosis

Rather slender *Fundulopanchax*, distinguished by the following characters: origin of the dorsal fin just in front, over, or just behind the beginning of the anal fin; low number of dorsal fin rays (12-15); dorsal fin rectangular; anal fin rectangular, somewhat pointed; no extensions at the unpaired fins; caudal fin lanceolate; dark brown to black colouration with no red markings, barely visible lighter cross bars on the sides; anal radials without lateral processes; small sagittal otoliths (2.3 - 2.9 % of SL) with large rounded area bordered by a thin crista superior and incisions on dorsal, posterior and ventral rim.

Description

A rather slender *Fundulopanchax*, with upward directed mouth. Dorsal fin

12-15 rays, anal fin 15-17 rays. Scales on the mid longitudinal series 30-32, plus 2-3 on the base of the caudal fin. Transverse rows of scales above the pelvic fins: 10, 16 scales around the caudal peduncle. Anterior supra orbital neuromast system in distinct grooves, lined with lobes and 3 neuromasts each. Posterior supra orbital neuromast system strongly curved, lined tubular with 6 pores. Cephalic squamation of the G-type, with 2 H-scales partly under epidermal tissue, no F-scales present. Branchiostegal membrane only projecting from the upper part of the operculum, its edge wrinkled.

Morphometric data of *F. powelli* are presented in table 1.

Colouration. - Specimens preserved in a 9 to 10 % formaldehyde solution and conserved for about 2 years in a 70-80%

Table 1. - Morphometric data of *Fundulopanchax powelli* expressed in % of SL (n : number of studied specimens; sd : standard deviation)

| | Holotype | Paratypes | mean | sd |
|---------|----------|-----------|------|------|
| SL (mm) | 24.9 | 20.7-28.4 | | |
| BD | 22.5 | 20.3-24.2 | 22.6 | 0.92 |
| HL | 30.9 | 26.2-36.1 | 31.1 | 2.28 |
| ED | 8.8 | 7.8-9.6 | 8.8 | 0.48 |
| IW | 14.1 | 12.6-16.0 | 14.5 | 0.76 |
| SNL | 10.4 | 7.3-10.0 | 8.7 | 0.90 |
| PDL | 64.7 | 59.9-66.5 | 63.3 | 1.83 |
| PAL | 65.1 | 57.9-66.9 | 61.2 | 1.95 |
| PPL | 51.4 | 48.2-52.4 | 50.3 | 1.22 |
| CL | 18.5 | 16.4-23.6 | 20.4 | 1.60 |
| CD | 12.0 | 12.4-15.4 | 13.6 | 0.87 |
| n | 1 | 22 | | |

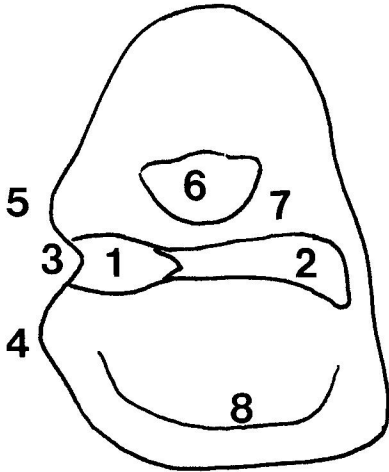


Fig. 2. - Morphological nomenclature of the inner face of a generalized cyprinodont sagitta. 1. ostium, 2. cauda, 1 + 2 = sulcus acousticus, 3. excisura, 4. rostrum, 5. antirostrum, 6. area, 7. crista superior, 8. ventral field.

alcohol solution. Dark brown, darker dorsally and lighter ventrally. Edges of the scale pockets with a wide dark brown to almost black margin. The tone of these margins varying locally, thus forming 10-12 barely visible lighter cross bars. Unpaired fins lighter brown, semi-transparent. At the base of the dorsal fin usually some dark spots, occasionally also at the base of the anal fin. The caudal fin of most specimens plain dark brown, but some individuals may have a somewhat darker crescent shaped bar at the base. According to information supplied by C. B. Powell the freshly collected specimens were almost black. No further information about the life colours of this species is available.

Table 2.- *Fundulopanchax powelli*, otolith dimensions (in mm)

| SL | OH | OL | OL/SL (in %) | OL/OH |
|------|------|------|--------------|-------|
| 19.2 | 0.69 | 0.55 | 2.9 | 0.78 |
| 24.0 | 0.81 | 0.65 | 2.7 | 0.80 |
| 26.0 | 0.77 | 0.61 | 2.3 | 0.79 |
| 29.1 | 0.86 | 0.72 | 2.5 | 0.84 |
| 34.5 | 0.95 | 0.73 | 2.8 | 0.77 |

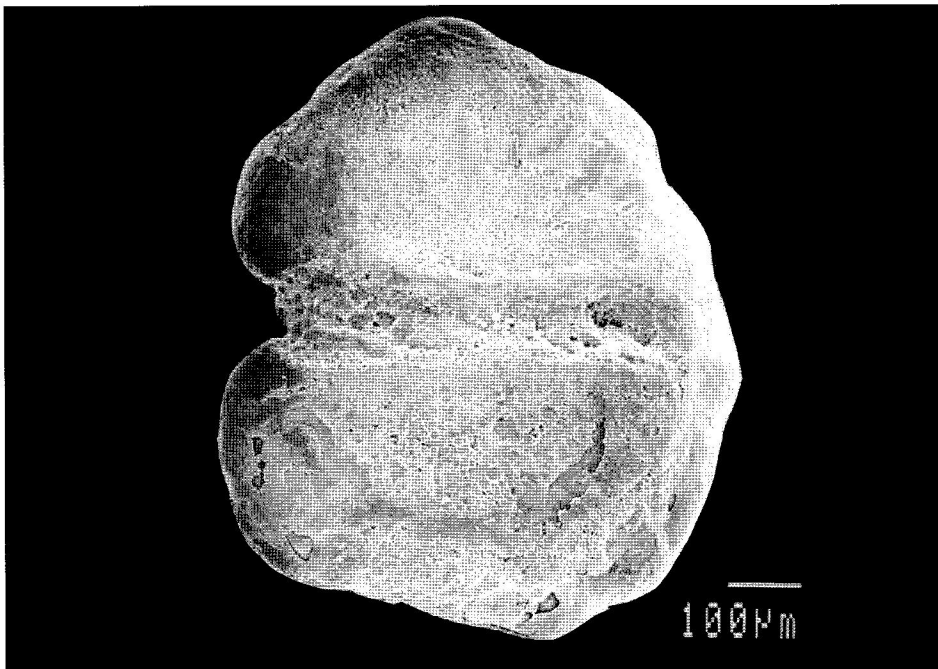


Fig. 3. - Sagittal otolith of *Fundulopanchax powelli*, Bakakodia, Nigeria. Right sagitta, inner face, area large and shallow, crista superior thin and straight, dorsal ridge obtuse

Otolith morphology (Table 2, Fig. 3). - Sagittae of *F. powelli* are small (2.3-2.9 % of SL), the smallest found in west African Aplocheilidae, oval in outline and undulated, caused by the presence of 5 or 6 incisions of the outer rim. Excisura sharp and deep. Rostrum and antirostrum rounded. Extremely wide, rounded and shallow area. Crista superior narrow. No ventral field present. Ventral border of sulcus acousticus almost straight. Maximum width just beneath sulcus acousticus.

Skeleton (Fig. 4A). - Three specimens of *F. powelli* were stained and cleared. One specimen was lost subsequently. All three specimens have 30 vertebrae. The supports of the caudal fin are symmetrical as in all cyprinodontiform fishes. There are two hypural plates, the dorsal one corresponding to fused hypurals 3, 4 and 5 and the ventral one to hypurals 1 and 2. Anal fin radials do not have lateral processes. Rarely a small reduced process is present at the basis of the radial (Fig. 4A: 4).

Ecological notes

The type-locality of *F. powelli* is situated on an unnamed island in the western Niger delta, surrounded by the Escravos River, Nana Creek and Jones Creek, west-north-west of Warri, at the edge of an isolated freshwater seasonal swamp forest, on an old beach ridge in the mangrove zone at Bakakodia. This name of the village is rejected by the local people, who call it Okokodiagbene. However the latter name is not used on detailed maps of this area. At the moment the specimens of *F. powelli* were collected (5 and 6 VII 1988), this locality was a pool several meters long and about 2 meters wide. Its depth, up to 1 meter, and its steep banks suggest it is artificial. It was probably dug out by the owners of an adjacent house, who might use this pool as a water supply. Apart from *F. powelli* only tadpoles and aquatic insects were caught. In the

adjacent forest many shallow puddles, only a few centimeters deep, and a freshwater swamp were present. From this swamp *Epiplatys grahami* and *Dormitator lebretoni* were obtained, as well as the freshwater shrimp *Potamalpheops monodi*. On 27 XI 1990 the type locality was revisited by C. B. Powell. This time the habitat was completely dry. During this collection trip another site was visited, opposite Bakakodia, across Nana Creek at the Abiteye oil flow station, north of Benikrukru village. Here *Fundulopanchax sjoestedti* was collected together with *Epiplatys sexfasciatus* and juvenile specimens of *Hemichromis fasciatus* or *H. elongatus*.

All *Fundulopanchax* species show an "annual" reproduction cycle. This means that the *Fundulopanchax* species are adapted to habitats that may dry up periodically. They deposit their eggs in the muddy bottom of the bodies of water in which they live. During the dry season these waters dry up and the fishes inhabiting it die. The population however will survive in the fertilized egg stage, buried in the damp soil. At the beginning of the rainy season the pools refill and the embryos hatch. Annual fish embryos, in contrast to those of non annual fish embryos, can undergo spontaneous developmental arrest, or diapause (Peters, 1963; Wourms, 1972).

That on Powell's second visit the type locality was dry, suggests an annual reproductive behaviour. Also that all collected specimens did not vary much in size and none of them showed developed gonads indicates simultaneous birth.

Taxonomic position of F. powelli

The available material of the new species consists only of non mature specimens. None of the examined specimens showed gonadal development.

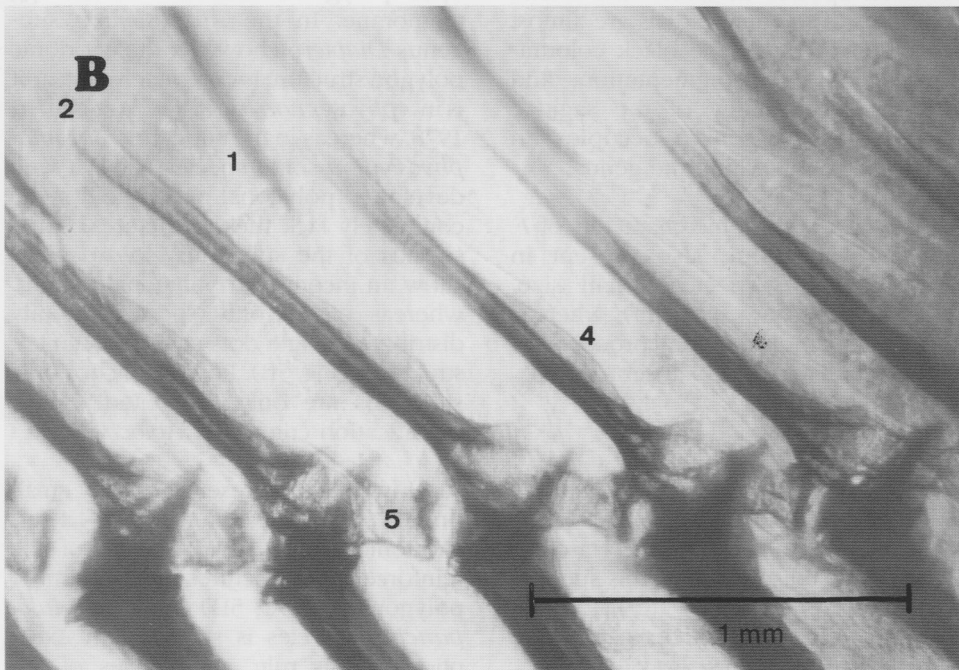
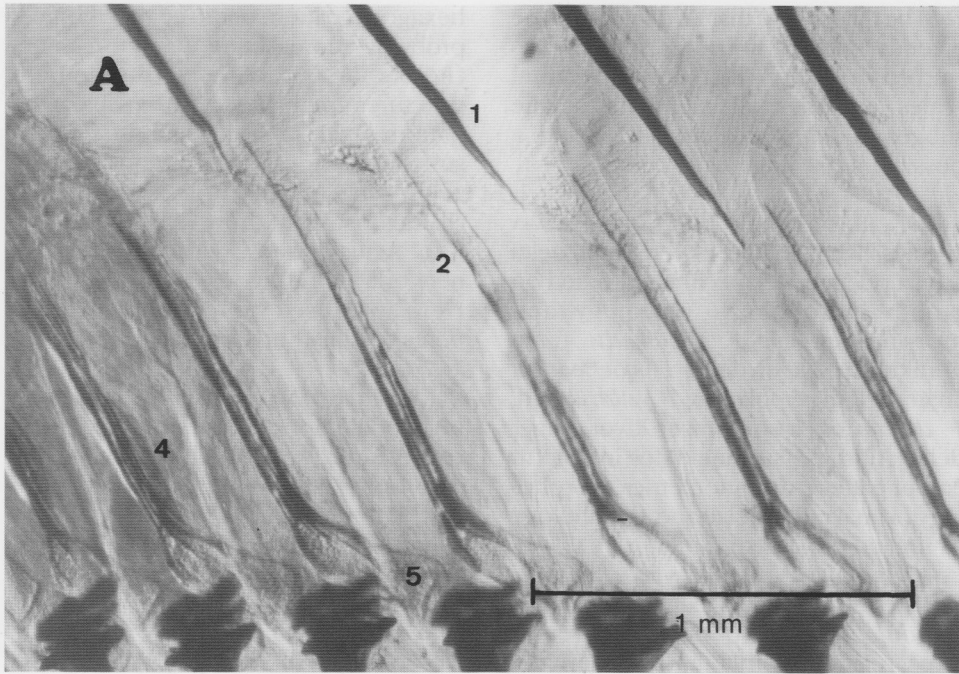


Fig. 4. - Anal fin skeleton. (A) *Fundulopanchax powelli*, Bakakodia, Nigeria. (B) *Fundulopanchax gularis*, Orashi river, Nigeria. 1. hemal spine 2. anal radial 3. anterior lateral process 4. posterior lateral process 5. mesonost

The possibility that *F. powelli* is the juvenile stage of a known species was studied carefully. The number of lateral scales excludes all members of the subgenus *Paludopanchax* of being a possible adult stage of *F. powelli*.

Of all sympatric *Fundulopanchax* species living in the lower Niger delta adult and juvenile specimens studied on otolith morphology, osteology and morphometrics: *F. sjoestedti* from Benikrukru, Niger delta; *F. sjoestedti* of an aquarium population; *F. gularis* (syn. *F. deltaensis*) from Orashi River, Niger delta. All these species differ in colour, colour pattern, morphometrics, morphology of anal radials, size and morphology of sagittal otoliths.

There is no doubt that *F. powelli* is a *Fundulopanchax* species, however its direct relations within this genus are not clear. *F. powelli* is the only *Fundulopanchax* species in which the lateral processes of the anal radials are almost completely absent. The black colouration, lack of red pigmentation, and aberrant morphology of the sagittae indicate that *F. powelli* occupies an isolated position within the genus.

Striking is that some characters of *F. powelli* otoliths are also present in *Nothobranchius* species (small size, shallow area, sharp excisura), whereas in the latter genus the lateral processes of the anal radials are also absent.

Etymology

The name *Fundulopanchax powelli* is given in honour of C. B. Powell, lecturer at the University of Port Harcourt (Nigeria) and discoverer of this species.

Diagnostic characters of the genus *Fundulopanchax*

Chorion structure

Most Aplocheilidae show a regular

hexagonal pattern of the egg membrane, probably representing a reinforcement (Peters, 1963). The reinforcement structures are thicker at the angles of the pattern. Although in literature these structures are called hexagons (Peters, 1963; Scheel, 1968) a great number of "hexagons" only show five angles (Fig. 5A). Actually these structures form a network of hexagons and pentagons. Here we use "polygon" for these pentagons and hexagons.

Nothobranchius does not develop a polygonal chorion pattern. The eggs of representatives of this genus are provided with a large number of randomly distributed filaments (Fig. 6). Length and number of these filaments are characteristic for the majority of species.

Most species of *Aphyosemion* and *Fundulopanchax* show a fully developed polygonal structure on the egg membrane. In the *Aphyosemion* subgenus *Diapteron* however the chorionic polygon structure is completely lost, as it is in *Aphyosemion thyssi* Radda & Huber, 1978, whereas in the subgenus *Chromaphyosemion* some species show a well developed polygonal pattern and some completely lack these structures. Some species of the subgenus *Aphyosemion* show an incomplete polygonal pattern, whereas others only show randomly distributed single dots as reinforcement structures (Fig. 5B). Polygonal chorionic structures are only of limited use as classification criteria for *Aplocheilidae*.

However the presence of very small dot-like spiky structures (called chorionic puncti here) on top of the reinforcement-structures and within the polygons (Fig 5C, 5D) in all *Fundulopanchax* species is striking. An exception to this rule, are species of the *Fundulopanchax* subgenus *Raddaella*. *Callopanchax* wick also lacks chorionic puncti is not considered as a member of the genus *Fundulopanchax* (see page

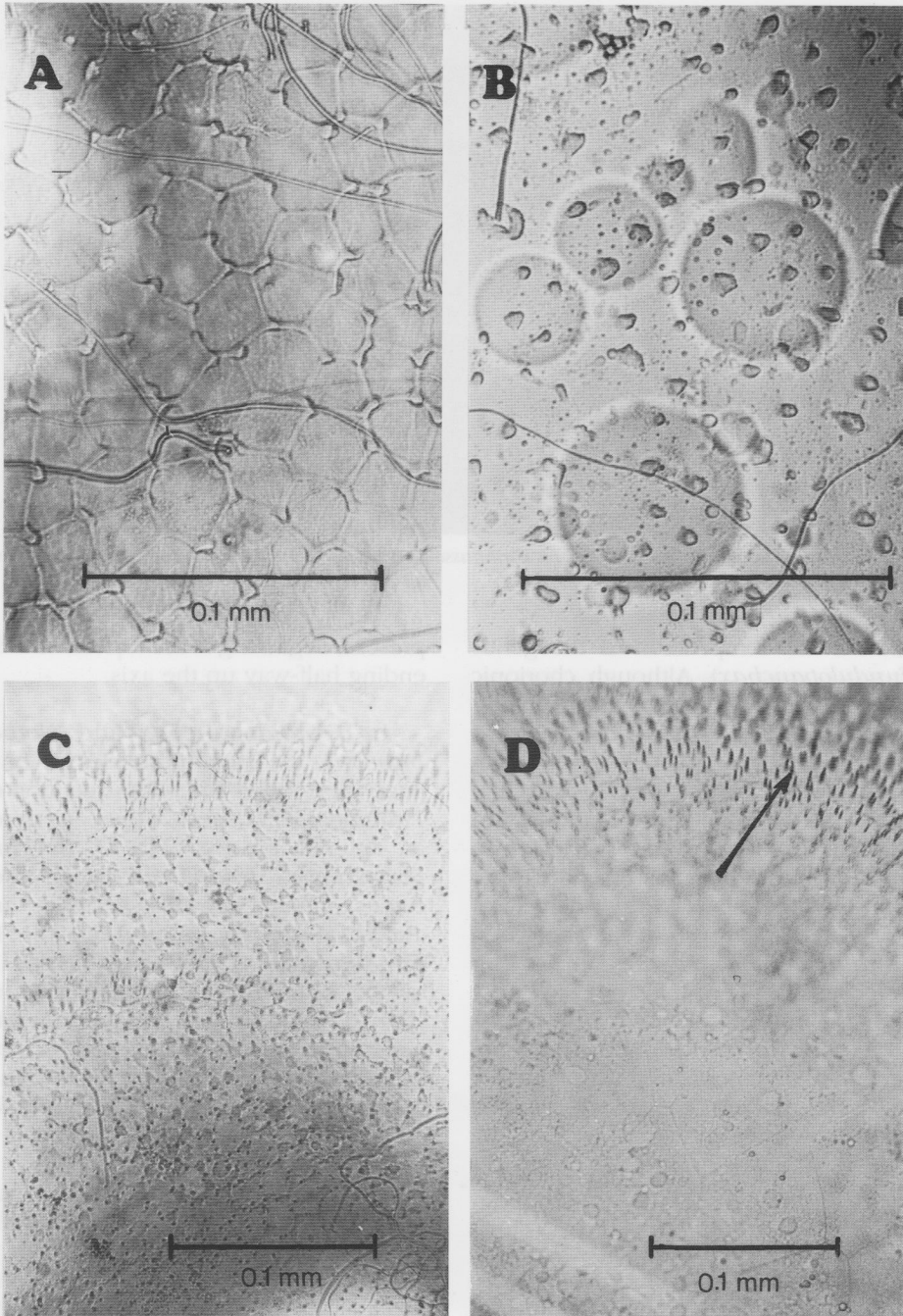


Fig. 5. - Chorion structures. (A) *Aphyosemion amoenum*, type locality, Cameroon : polygonal-network, thickening of reinforcement structures on angles, no chorionic puncti. (B) *Aphyosemion cognatum*, SW of Kinshasa, Zaire : randomly distributed reinforcement structures, no network pattern, no chorionic puncti. (C) *Fundulopanchax robertsoni*, Bolifamba, Cameroon, polygonal-network, thickening of reinforcement structures on angles, chorionic puncti (black dots) mainly on the reinforcement structures, rarely inside a polygon. (D) *Fundulopanchax puerzli*, N. E. of Edea, Cameroon. Centre : yolk surrounded with enveloping cell layer (ECL) inside the egg membrane, top : chorionic puncti (black dots) within and upon polygonal reinforcement structures (grey) on the surface of egg membrane.

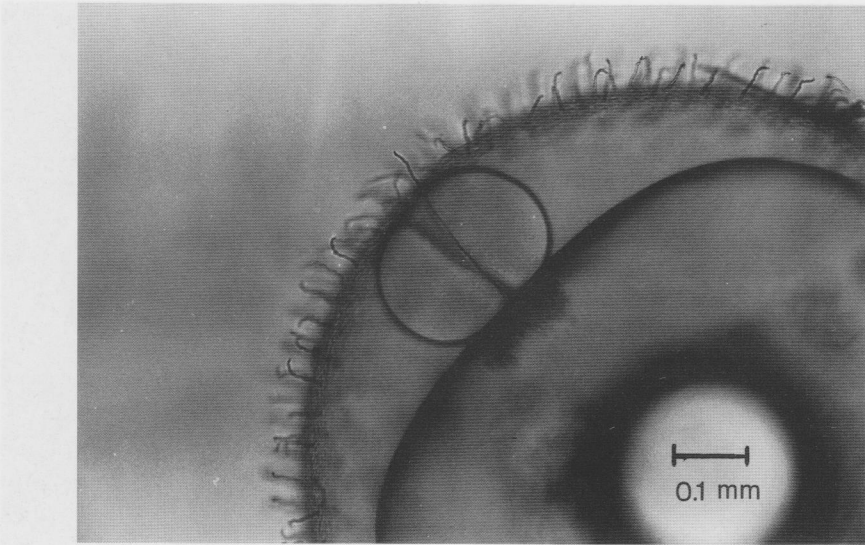


Fig. 6. - Chorion structure. *Notobranchius korthausae*, Mafia island, Tanzania : two cell stage. Randomly distributed filaments on chorion

431 on the composition of the genus *Fundulopanchax*). Although chorionic puncti are visible in a published photograph of a *F. filamentosus* egg in Scheel (1968: p. 54), they have never been used in systematics of Aplocheilidae. All studied *Aplocheilidae*, including representatives of all *Aphyosemion* subgenera, lack chorionic puncti. With respect to this character a clear discontinuity exists between *Fundulopanchax* species and other *Aplocheilidae*.

As only preserved immature specimens of *F. powelli* were available for study, this character could not be verified in this new species.

Anal-fin skeleton

In all Aplocheilidae, with exception of *Fundulopanchax* and *Notobranchius*, the proximal radial of the anal fin support consists of a bony axis provided with lateral processes (Fig. 7A). These processes are always present at the posterior side of the axis, beginning at the top of the axis and ending at the basis. Often also an anterior process is

present, beginning at the top and mostly ending half-way up the axis.

In *Fundulopanchax* and *Notobranchius* the lateral processes are only partly developed and with exception of *Paludopanchax*-species there is never an anterior process (Fig. 4). In *Fundulopanchax powelli* the lateral processes (anterior as well as posterior) are almost completely absent (Fig. 4A). In *Fundulopanchax*, the axis of the radial is of the same relative size as it is in *Aphyosemion*. In *Notobranchius*, with exception of representatives of the subgenus *Aphyobranchius*, where anal radial morphology is more *Fundulopanchax*-like, the axis is flattened.

The genus *Notobranchius* also has another derived character of the anal fin skeleton. In all Cyprinodontiformes a bony joint is present between the proximal radial and the fin ray, called the mesonost. This mesonost is absent in all *Notobranchius* species with exception of representatives of the subgenus *Aphyobranchius* (Fig. 7B), in which the mesonost is reduced in size.

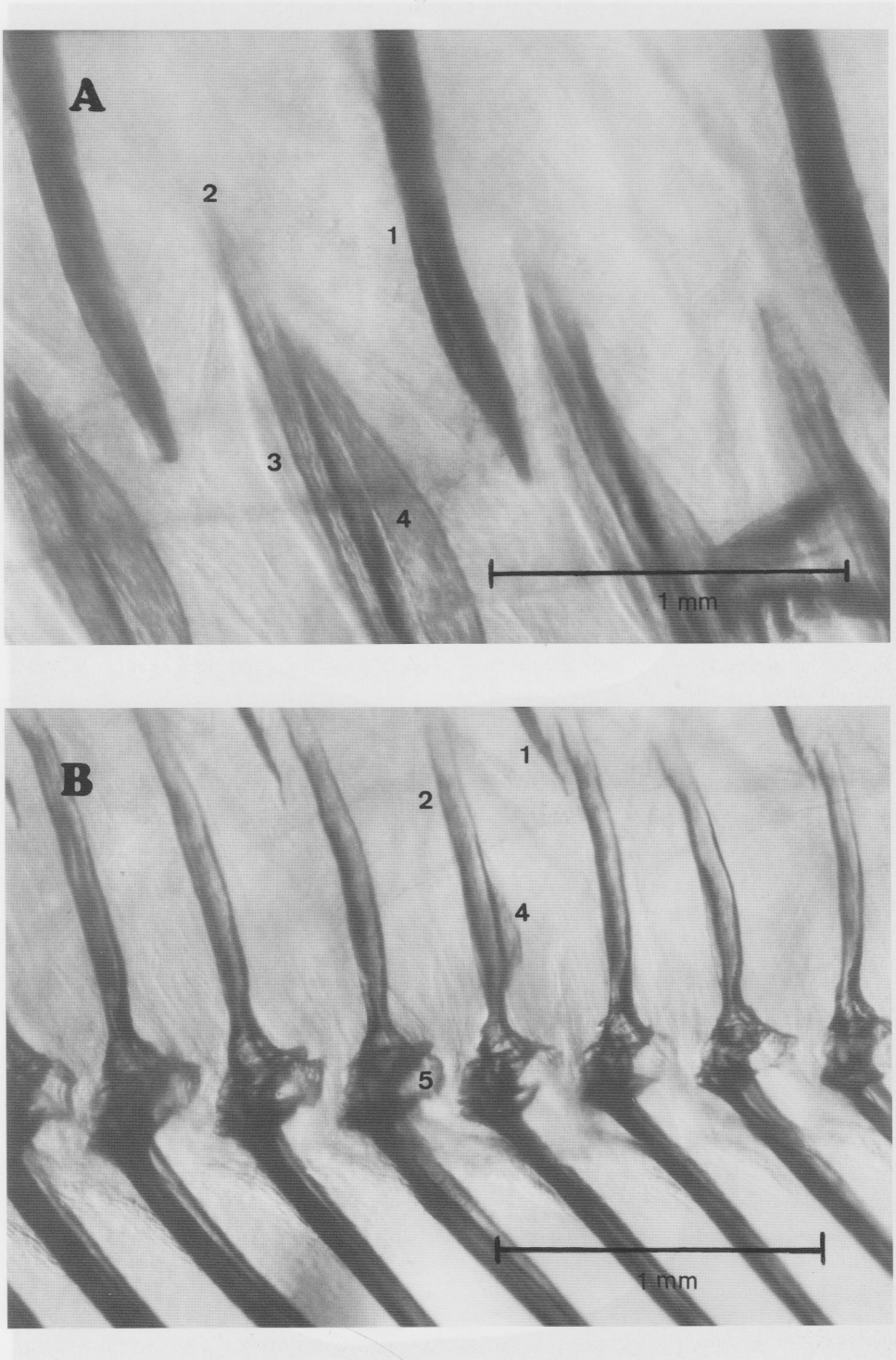


Fig. 7. - Anal fin skeleton. (A) *Aphyosemion elberti*, Diang, Cameroon. (B) *Notobranchius (Aphyobranchius) luekei*, 40 km S. Dar es Salaam, Tanzania. 1. hemal spine 2. anal radial 3. anterior lateral process 4. posterior lateral process 5. mesonost.

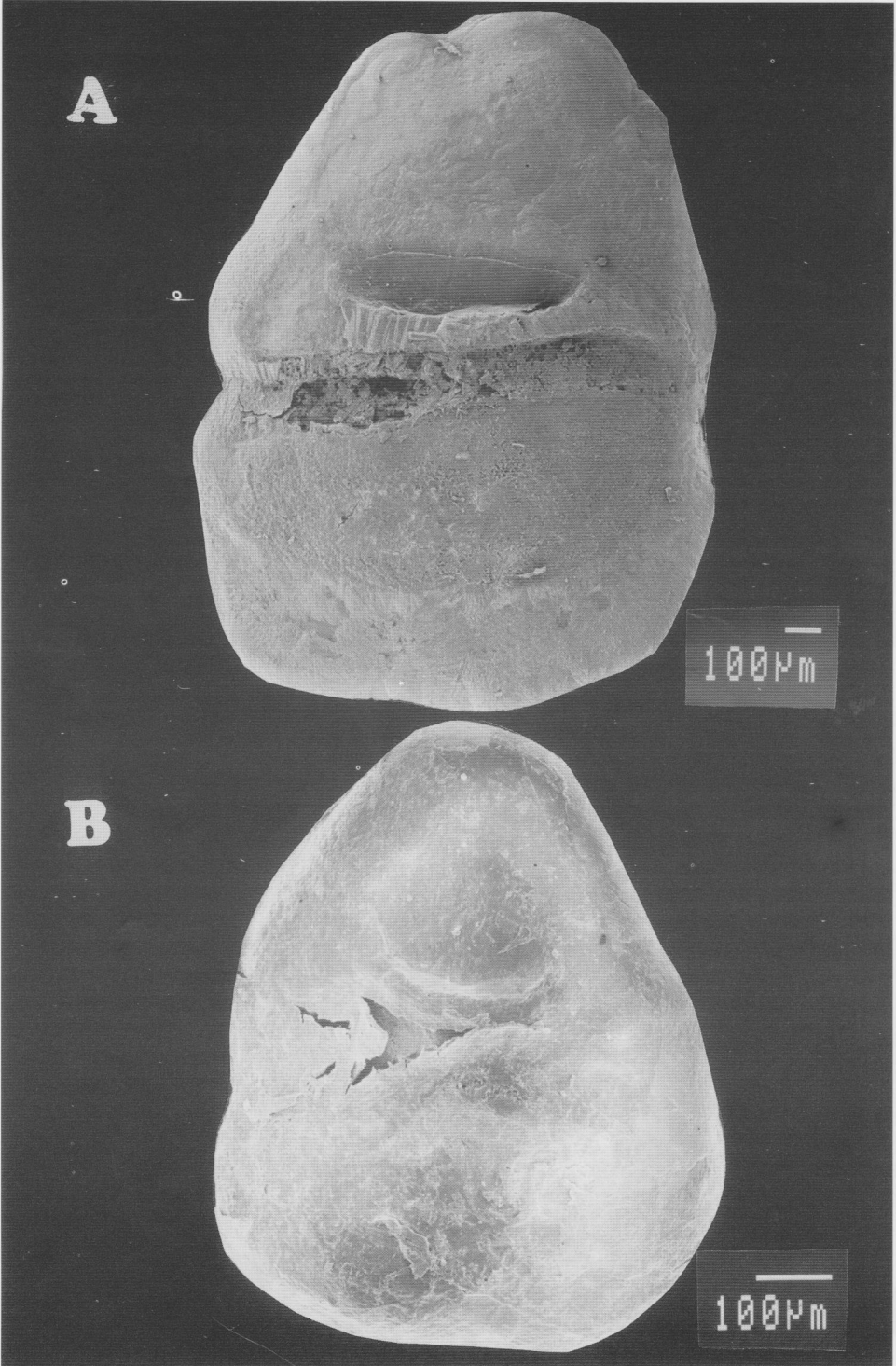


Fig. 8. - Sagittal otoliths. (A) *Fundulopanchax fallax*, Malende, Cameroon. Right sagitta, inner face, area elongate, crista superior straight, dorsal ridge obtuse. (B) *Aphyosemion christyi* Kisangani, Zaire. Right sagitta, inner face (damaged), area rounded, crista superior rounded, dorsal ridge tapering.

Otolith morphology

Aplocheilid otoliths are rather variable in morphology, but these variations often do not represent derived characters on the species level. Usually a species shows a slightly different morphology of the saggital otolith at the population level.

However several taxonomical isolated Aplocheilid species have otoliths that differ significantly in their general appearance (e. g. *Foerschichthys flavipinis*, *Pronothobranchius kiya-wensis*, *Epiplatys annulatus*, *Aphyosemion bamilekorum*, *Fundulopanchax powelli* and *Notobranchius furzeri*). Most higher taxa show derived characters in otolith morphology (Van der Zee, in prep.).

Fundulopanchax otoliths can be discriminated from *Aphyosemion* otoliths by two derived characters: 1. long area, generally 50% or more of sulcus length; and 2. crista superior in area region not curved

The general shape of *Fundulopanchax sagittae* is shown in Fig. 8A and that of *Aphyosemion* in Fig. 8B

Otoliths of the subgenera *Callopanchax*, *Archiapphyosemion* and *Scriptapphyosemion* (together the former genus *Roloffia*) show derived characters of the sulcus acousticus (e. g. large size of the ostium) and lack the typical *Fundulopanchax*-characters.

On the species level the morphology of *Notobranchius* otoliths is much more variable than in *Aphyosemion*- and *Fundulopanchax* species. *Notobranchius* has smaller otoliths that usually have a sharp excisura, an absent or almost invisible shallow area and a crista superior that is not developed posteriorly.

Caudal peduncle squamation (Table 3)

With exception of the subgenera *Paludopanchax* and *Raddaella* all *Fundulopanchax* species have 16 or more scales around the caudal peduncle.

Table 3.- Number of circumcaudal peduncular scales

| Taxon | pop. | n | range | mean | SD |
|------------------------|------|----|-------|------|-----|
| <i>A. aureum</i> | 1 | 3 | 13-14 | 13.3 | 0.6 |
| <i>A. cameronense</i> | 2 | 6 | 13-15 | 14.2 | 0.8 |
| <i>A. christyi</i> | 2 | 8 | 11-12 | 11.8 | 0.7 |
| <i>A. escherichi</i> | 1 | 5 | 14 | 14.0 | 0.0 |
| <i>A. gabunense</i> | 2 | 6 | 12 | 12.0 | 0.0 |
| <i>A. marmoratum</i> | 1 | 3 | 16 | 16.0 | 0.0 |
| <i>A. oeseri</i> | 1 | 3 | 16 | 16.0 | 0.0 |
| <i>A. scheeli</i> | 1 | 3 | 16 | 16.0 | 0.0 |
| <i>F. arnoldi</i> | 4 | 7 | 11-12 | 11.9 | 0.4 |
| <i>F. filamentosus</i> | 4 | 10 | 11-14 | 12.0 | 0.8 |
| <i>F. batesii</i> | 2 | 5 | 11-14 | 14.0 | 0.0 |
| <i>F. gardneri</i> | 4 | 6 | 16-17 | 16.2 | 0.4 |
| <i>F. gularis</i> | 3 | 9 | 16-17 | 16.3 | 0.5 |
| <i>F. mirabilis</i> | 2 | 6 | 16-18 | 16.8 | 0.8 |
| <i>F. ndianum</i> | 2 | 5 | 16-17 | 16.2 | 0.4 |
| <i>F. puerzli</i> | 2 | 6 | 16 | 16.0 | 0.0 |
| <i>F. sjoestedti</i> | 3 | 4 | 16 | 16.0 | |

All investigated material : MRAC collection

Taxon, number of studied populations, number of studied specimens, minimum and maximum value of scale number, mean and standard deviation are given.

This number is also present in the *marmoratum/oeseri/scheeli*-complex of the genus *Aphyosemion*, which however does not share the other uniquely derived *Fundulopanchax*-characters. All other lower Guinea Aplocheilidae, as well as all *Nothobranchius*-species, show a lower number of circumcaudal peduncular scales.

DISCUSSION

Diagnostic characters of the genus *Fundulopanchax*

Fundulopanchax was described by Myers in 1924 as a subgenus in *Aphyosemion* Myers, 1924. It was given genus status by Parenti (1981) based on the diagnostic characters of a more elongated dorsal fin with 14 or more fin rays and the swimbladder not extending beyond the first hemal spine. The latter is accepted here as a distinguishing character for separating *Fundulopanchax* from *Aphyosemion*, but it is not considered a uniquely derived character for the genus *Fundulopanchax*, since *Nothobranchius* species also show this character. The former character is not accepted here because at least 5 species of the genus *Fundulopanchax* show an upper limit of the dorsal-fin ray number of less than 14 (down to 12 in *F. gardneri*). This implies that the diagnostic character of 14 or more rays in the dorsal fin may apply to a less inclusive group of species.

From the comparative analysis of the subfamily Nothobranchiinae new, derived, diagnostic characters can be formulated for the genus *Fundulopanchax*: 1. egg-membrane provided with small spikey structures upon and within the polygonal pattern; 2. lateral processes of proximal radial of anal fin reduced or absent, axis of radial thin; and 3. crista superior of sagittal otolith straight caused by an elongated area. A fourth derived character for the genus

Fundulopanchax has already been mentioned by Amiet (1987): "the front rays of the anal (and in some species in the dorsal) are longer than those which follow and even, in several species, clearly hypertrophied, thus forming a rounded or angular lobe". Amiet considered *Fundulopanchax* being a subgenus of *Aphyosemion* and did not include the "*A. gardneri*" and "*A. ndianum*" species groups. Although this character is not very well developed in these species groups, it is definitely present in older males. Elongated anal front-rays are indeed very striking in most of the greater *Fundulopanchax* species and in the subgenus *Paludopanchax*.

Although not unique for the genus the following characters are useful in discriminating *Fundulopanchax* from the genus *Aphyosemion*:

1. elongated dorsal fin, the origin just in front of the origin of the anal fin or the origin of the dorsal over one of the first four anal fin rays (shared by *Diapteron*, *Chromaphyosemion*, *Callopanchax*, *Fundulosoma*, *Pronothobranchius* and *Nothobranchius*).
2. swimbladder not extending beyond the first hemal spine (shared by *Nothobranchius*).
3. annual reproduction pattern with three diapause stages in embryogenesis. Within the subfamily Nothobranchiinae this character is also shared by the genera *Fundulosoma*, *Pronothobranchius*, *Nothobranchius* and *Callopanchax*.
4. 16 or more scales around the caudal peduncle This character is also shared by a cluster of three closely related *Aphyosemion* species from the coastal plains in the Nigeria-Cameroon border area and Bioko Island (*marmoratum/oeseri/A. scheeli*-complex). This species cluster does not share the other derived *Fundulopanchax* characters.

It is striking that the species of the subgenus *Paludopanchax* differ by having a lower number of circumcaudal peduncular scales. As these taxa share all the other derived characters of the genus *Fundulopanchax* this exception is regarded as a reversed character.

Status and composition of the genus *Fundulopanchax*

Recently several classifications have been presented for Aplocheilidae (Parenti, 1981; Radda, 1987; Amiet, 1987)

or its counterpart "old world" Rivulinae (Scheel, 1990). In these classifications only Parenti raised *Fundulopanchax* to the rank of genus, whilst Radda, Amiet and Scheel regard *Fundulopanchax* being a subgenus in *Aphyosemion* (Table 4).

It is difficult to decide which taxonomic rank must be given to a group of related species: genus, subgenus or an infrasubgeneric category (species group, superspecies, ultraspecies, supraspecies), since there are no generally

Table 4. - Classification of African Aplocheilidae (alphabetical order).

| Parenti, 1981 | |
|---|---|
| <i>Aplocheilus</i> , <i>Pachypanchax</i> , <i>Epiplatys</i> group | <i>Aphyosemion</i> , <i>Fundulopanchax</i> , <i>Nothobranchius</i> group |
| Genus <i>Epiplatys</i> | Genus <i>Adamas</i> |
| Subgenus <i>Aphyoplatys</i> | Genus <i>Aphyosemion</i> |
| Subgenus <i>Parepiplatys</i> | Subgenus <i>Archiaphyosemion</i> |
| Subgenus <i>Pseudepiplatys</i> | Subgenus <i>Chromaphyosemion</i> |
| Subgenus <i>Lycocyprinus</i> | Subgenus <i>Kathetys</i> |
| Genus <i>Pachypanchax</i> | Subgenus <i>Mesoaphyosemion</i> |
| | Genus <i>Fundulopanchax</i> |
| | Subgenus <i>Callopanchax</i> |
| | Subgenus <i>Gularopanchax</i> |
| | Subgenus <i>Paludopanchax</i> |
| | Subgenus <i>Paraphyosemion</i> |
| | Subgenus <i>Raddaella</i> |
| | Genus <i>Nothobranchius</i> |
| Radda, 1987 | |
| Subfamily Aplocheilinae | Subfamily Nothobranchiinae |
| Genus <i>Epiplatys</i> | Genus <i>Adamas</i> |
| Subgenus <i>Aphyoplatys</i> | Genus <i>Aphyosemion</i> |
| Subgenus <i>Epiplatys</i> | Subgenus <i>Aphyosemion</i> |
| Subgenus <i>Lycocyprinus</i> | Subgenus <i>Archiaphyosemion</i> |
| Subgenus <i>Pseudepiplatys</i> | Subgenus <i>Callopanchax</i> |
| Genus <i>Episemion</i> | Subgenus <i>Chromaphyosemion</i> |
| Genus <i>Pachypanchax</i> | Subgenus <i>Diapteron</i> |
| | Subgenus <i>Fundulopanchax</i> |
| | Subgenus <i>Gularopanchax</i> |
| | Subgenus <i>Kathetys</i> |
| | Subgenus <i>Mesoaphyosemion</i> |
| | Subgenus <i>Paludopanchax</i> |
| | Subgenus <i>Paraphyosemion</i> |
| | Subgenus <i>Raddaella</i> |
| | Subgenus <i>Scriptaphyosemion</i> |
| | Genus <i>Foerschichthys</i> |
| | Genus <i>Fundulosoma</i> |
| | Genus <i>Nothobranchius</i> |
| | Genus <i>Pronothobranchius</i> |

accepted definitions for supra specific taxonomic ranks.

In contrast to the high number of papers devoted to the discussion of the species concept only few publications have been devoted to the study of the genus concept in the existing scientific literature. An inventory of these publications and a profound discussion of the fundamental problem of the genus concept is presented by Dubois (1988). In this study it is suggested that genera should be defined as genetic, phylogenetic and ecological discontinuous units. Dubois proposes a new criterion to define genera, that of hybridizability: whenever two species can give viable adult hybrids, they should be included in the same genus. If hybridizability is considered, *Fundulopanchax* must have the rank of subgenus, since it can give viable adult hybrids with some *Aphyosemion* taxa. Defining a genetic discontinuous unit by hybridizability can be used in classifying Amphibia (Dubois' major field of research), in bony fishes however this criterion is doubtful. Spillmann crossed a female *Carassius auratus* (tetraploid: $2n = 100$) to a male *Rutilus erythrophthalmus* (diploid: $2n = 50$) and obtained many fertilized eggs, but only three of these were viable. The karyotypes ($2n = 125$) of these hybrids were studied by Scheel (1990). With respect to hybridizability *Carassius* and *Rutilus* should be included in the same genus, although they belong to two different subfamilies (Cyprininae and Leuciscinae). Cross-generic hybrids are common in Cyprinidae (Schwartz 1972, 1981).

Although *Fundulopanchax* cannot be defined as a genetic discontinuous unit with respect to hybridizability, it definitely represents a genetically specialized unit. According to Scheel (1990) the most important karyotypic characters are the number of chromosome arms, independent of their size, and the length of the longest arm. Scheel

plotted these characters in one graphic (Scheel, 1990) in which *Fundulopanchax* species are grouped together due to karyotypic specialization. Karyotypic specialization of this group is moderate to high when the number of arms is considered and is very high with respect to the length of the longest arm.

Fundulopanchax is a discontinuous unit with respect to morphology and ecology and shows karyotypic specialization. Morphology of the anal fin skeleton and the annual mode of reproduction are synapomorphies that *Fundulopanchax* shares with *Nothobranchius*. For the time being we prefer to adopt Parenti's vision and consider *Fundulopanchax* as a genus within Nothobranchiinae, until a profound classification is presented in which all taxa are reconsidered and a redefinition of most taxa will be presented. Most supra-specific taxa within Aplocheilidae are based on inaccurate definitions. These definitions are mainly ad hoc classifications, generally based on overall similarity, that represent the authors subjective vision and are not accompanied by exact diagnostic data. The methodological insufficiencies in taxon definition in *Aphyosemion* and its relatives are criticized by Guguen-Douchement (1983).

The phyletic intra-generic relations of the genus *Fundulopanchax* will be presented in a subsequent paper (Van der Zee in prep.) in which also the position of *Pronothobranchius*, *Fundulosoma*, *Nothobranchius*, *Callopanchax*, *Archiaphyosemion* and *Scriptaphyosemion* is discussed.

The following subgenera are placed in *Fundulopanchax* by Parenti: *Paludopanchax* Radda, *Paraphyosemion* Kottelat, *Gularopanchax* Radda, *Callopanchax* Myers and *Raddaella* Huber. The present authors do not agree with the inclusion of *Callopanchax*, because representatives of this subgenus

do not show any of the derived *Fundulopanchax*-characters. On the other hand *Callopanchax* shows at least five derived characters which it shares with *Archiaphyosemion* and *Scriptaphyosemion*, thus forming a monophyletic group of Nothobranchiinae living west of the Dahomey gap, for which the generic name *Roloffia* was used.

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