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Morphological comparison for the dorsal fin of *Chrysichthys auratus*, *Synodontis schall*, and *Synodontis serratus* (Teleosti: Siluriformes) collected from the Lake Nasser and the River Nile, Egypt

by

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Abstract

The anatomy, growth, and differentiation of the dorsal fin spines of three catfish species collected from the Nile River and Lake Nasser. Egyptian waters are described, and terminology is suggested for their parts. Features of the dorsal fin spine that change with growth are also described. The results showed that in all species studied, the dorsal spine is an elongate, compressed, tapered, slightly arched, osseous structure, bearing a series of retrorse dentations along the anterior and posterior surfaces and has a sharp sagittate tip. The retrorse, anterior dentations are most pronounced in the upper third of the spine and gradually alter in form until they appear as a series of distinct notches on the basal third of the spine. The anterolateral surfaces of the dorsal spine are marked by numerous short, irregular, shallow, anastomosing, longitudinal furrows. In three species (*C. auratus, S. schall, S. serratus*), the posterior process is poorly developed and directed laterally in young individuals and well produced and directed posteriorly in older specimens. In *S. schall* and *S. serratus*, the posterior blocking process of the large specimens has a wavy edge, while in *S. serratus*, it is curved in young individuals and straight in larger specimens.

Key words: Ostariophysi, fins, anatomy, growth and differentiation, taxonomic identification

1. Introduction

Catfish species are considered an important group in freshwater and brackish water environments. They constitute a significant proportion of the inland fisheries of several countries, and therefore, several catfish species have been reared. Several species are also significant for the aquarium industry and represent a substantial sector in the world aquarium trade (Teugels 1996).

Catfish species are broadly spread and occur on all continents. Among the different families of catfish, Ariidae and Plotosidae are the only marine taxa, while others are all freshwater fish (Roxo et al. 2014). The skeletal system of catfish is distinguished by joint-locking pectoral- and dorsal fin spines. The shared features of these fin spines among the different species of catfish may hint at their early

phylogenetic origin (Fine et al. 1997; Sullivan et al. 2006; Lundberg et al. 2014).

The wahrindi, *Synodontis schall* (Bloch & Schneider, 1801) is a freshwater species that inhabits the benthopelagic region (Riede 2004). It is found mainly in Africa and chiefly in the river basins of West Africa (Gosse 1986). It is also reported in the Nile River basin downstream of Murchison Falls, including Lake Albert (Bailey 1994; Seegers 2008); Lake Turkana (Seegers et al. 2003; Seegers 2008); and the Ethiopian lakes Abaya and Chew Bahir (Seegers 2008). Individuals of this species reach maturity at 120 – 170 mm in total length, with a maximum standard length of 370 mm (Paugy & Roberts 2003). The maximum reported weight of this species is 500.00 g (Ita 1984.), and the maximum recorded age is 12 years (Paugy & Roberts 2003). This omnivorous species feeds on insect nymphs, larvae, eggs and detritus (Willoughby 1974). It also feeds on fish, bivalves in the Sudd and snails in Gezira irrigation canals. Individuals of this species are oviparous (Breder & Rosen 1966), and breeding happens during the flood season (Bailey 1994).

Synodontis serratus Rüppell, 1829 is a freshwater species that inhabits the benthopelagic region. This species lives in tropical areas and is well distributed in Africa, mainly in the Nile River basin (Poll 1971). Individuals of this species reach a maximum total length of 395 mm (Gosse 1986). The females of this species are oviparous (Breder & Rosen 1966) and form a distinct pairing during breeding (Breder & Rosen 1966).

The golden Nile catfish *Chrysichthys auratus* (Geoffroy Saint-Hilaire, 1809) is a freshwater species that sometimes enters brackish water exhibiting potamodromous behaviour (Riede 2004). It is distributed in different regions of Africa. It is reported from most of the West African hydrographic basins, except in the coastal areas between Gambia and Liberia, where it is replaced by *Chrysichthys maurus* (Risch 1992, 2003). It is recorded from southern Liberia to Cabinda (Angola) (Risch 2003) and is widespread throughout Lower Guinea (Geerinckx et al. 2007). It has also been reported from the Chad (Risch 1986, 2003) and Nile (Risch 1986; Boulenger 1911; Lévêque et al. 1991; Hardman 2008) basins. Individuals of this species reach maturity at 110 mm in total length, its maximum total length (Ofori-Danson et al. 2002). This species usually occurs over soft, slightly muddy substrates or substrates with heavy layers of leafy detritus in deep, relatively quiet waters (Burgess 1989). It feeds on molluscs and small crustaceans (Branchiopods, Copepods, Ostracoda), which it digs from the substrate (Laleye 1995), and on insects (Bailey 1994) and fish (Bailey 1994; Seegers 2008).

From an anatomical point of view, the catfish spine embodies a link between the lepidotrichia and the spines of acanthopterygian fishes. The difference occurs in how these constituents are combined into a single assembly (Reed 1924). The lepidotrichia, which supports the growth of the spine, first looks like an expansion of the basement membrane as in the occurrence of soft rays designated by Harrison (Harrison 1893; Goodrich 1904).

The significance of the morphology of the dorsal spines of catfish species is apparent from identifying both extant and fossilised specimens, as most of the catfish fossils have dorsal spines, which are strong and fossilised well. Their shape has been used to differentiate families or genera (Gayet & Van Neer 1990; Greenwood 1959) but not species.

Consequently, the taxonomic value of variation in fin spine structure is essential for understanding the sonic behaviour of different catfish based on variances in their spine morphology. The taxonomic significance of spine morphology in catfish has long been known. The building of spines has been valuable for recognising and distinguishing between catfish species and even some higher groups (Gayet & Van Neer 1990; Rodiles-Hernández et al. 2010; Egge & Simon 2011).

The present study provides a standard morphological description for the dorsal fin spine of three catfish species collected from the Nile River and Lake Nasser in Egypt, *Synodontis schall, Synodontis serratus,* and *Chrysichthys auratus*. This will help anatomists compare the structure of this spine with other catfish species living in the Nile River.

2. Materials and methods

The specimens of *Synodontis schall* (n = 40), *Synodontis serratus* (n = 20), and *Chrysichthys auratus*

(n = 30) for this study were collected from the Nile River at Asyut City and Lake Nasser on 10 November 2017, about 319 and 900 Km south of the capital Cairo respectively (Fig. 1). Catfish specimens of all species represent 30% and 25% of each catch observed at the Nile River station at Asyut City and Lake Nasser, respectively. The species examined were *Chrysichthys auratus* (Geoffroy Saint-Hilaire 1809) (180-370 mm in total length), Family: Claroteidae; *Synodontis schall* (Bloch & Schneider 1801) (200-400 mm in total length) and *Synodontis serratus* Rüppell, 1829, (200 - 600 mm in total length), Family: Mochokidae. Ninety fish specimens were used in this study and separated into groups according to their total length as follows: *Chrysichthys auratus* (3 groups, ten specimens each, GI 100 – 200 mm TL, GII 201 – 300 mm TL; 301 -400 mm TL); *Synodontis schall* (4 groups, ten specimens each, GI 200 – 250, GII 251 – 300, GIII 301 – 350, GIV 351 – 400 mm TL) and *Synodontis serratus* (2 groups, ten specimens each, GI 200 – 400 mm TL, GII 401 -600 mm TL). The size of the specimen is taken as a measure of the age (Fine et al. 1997; Fine et al. 2012). All specimens were collected fresh at a depth range of 3-7 m. Since this study is a preliminary, the sex of each specimen was not determined and left for a future comprehensive study. Individuals of *S. serratus* and *S. schall* were collected from Lake Nasser using trammel netting. Specimens of *C. auratus* were obtained from both the Nile River and the Lake Nasser localities using a long line. The skeletons of fish specimens were prepared by boiling the fish, followed by the maceration of soft tissues. The cleaned bones were dried at room temperature. Images of the dorsal fin spines of different species were photographed. The lateral, anterior, and posterior surfaces of the dorsal fin spine had their images recorded and documented for surface morphology patterns using the methods of Kaatz et al. (2010) and Vanscoy et al. (2015). In the description of dorsal fin spine anatomy, the spines are erected at a right angle to the longitudinal axis of the fish, with the fin spread in the vertical plane and the spine tip pointed dorsally. The indicator terms are dorsal, ventral, anterior and posterior are related to the edges of the spine in its erect position. For each dorsal fin spine, the following characters were taken following Pinton et al. (2006): size and shape of the median foramen, the shape of the articular head, shape, depth, and arrangement of the striations on the lateral sides, the ornamentations on the crest (smooth or tubercles), distribution, size and shape of tubercles and curvature of the spine. The following ratios were measured: the ratio of the width of the articular head to the width of the spine at its base and the ratio of the width of the median foramen at its base to the width of the anterior head in the anterior view. The average angle (A') made by the lateral border of each wing (A' = (A1 + A2)/2) of the articular head with the corresponding lateral edge in the anterior view was also recorded. Measurements were taken after high-resolution photographs were imported and magnified in Microsoft PowerPoint for increased accuracy. Differences in length were statistically analysed using ANOVA with Statistica (Version 6.0).

Figure 1

Location of sampling stations

3. Results

In all species, the dorsal spine is an elongate, compressed, tapered, slightly arched, osseous structure, bearing a series of retrorse dentations along the anterior and posterior surfaces and has a sharp sagittate tip. The retrorse, anterior dentations are most pronounced in the upper third of the spine and gradually alter in form until they appear as a series of distinct notches on the basal third of the spine. The anterolateral surfaces of the dorsal spine are marked by numerous short, irregular, shallow, anastomosing, longitudinal furrows. Located along the posterior margin of the spine, a shallow groove gradually deepens and broadens toward the base of the spine. Lying within this groove are posterior dentations, which, at about the level of the junctions of the basal and middle thirds of the spine, gradually increase in size and then abruptly terminate near the inferior margin of the distal opening of the central canal. The posterior surface of the sagittate tip, superior to the

first posterior dentation, is flattened and set at an angle which contains the distal opening of the central canal of the spine. The rear spine gradually broadens to the basal third and then abruptly expands into the triangular-like articulation. The proximal opening of the central canal is located at the upper apex of the triangular base. Inserting a fine wire through the proximal opening of the central canal indicates that the canal extends throughout the entire spine length, and the wire can be removed from the distal opening. Immediately beneath the proximal opening of the central canal is a median foramen, which receives the ring-like articulation of the second interneural spine. The articulating portion of the dorsal spine's base comprises three condyles, a large median, and a small lateral condyle on either side.

The median foramen is small and rounded in shape (Figs. 2, 3). In *C. auratus*, this foramen is not surrounded by ridges, but in *S. schall* and *S. serratus*, the foramen is surrounded by high ridges from the dorsal side only. In individuals of *S. Schall* smaller than 230 mm, the median foramen is large but smaller in individuals greater than 310 mm TL. On the other hand, the median foramen in *S. serratus* is larger in individuals of 400- and 500-mm TL. The ridges are coarse in large specimens of *S. serratus* (between 400- and 500-mm TL).

The shape of the articular head is triangular in all species. It comprises three parts, two wings, usually rounded edges, and a broad middle section. In *C. auratus*, the central part is similar in width to the wings and is level with them. In *S. schall*, the middle part is broader than the wings and longer than the wings in individuals of 220 mm TL, shorter than the wings in individuals of 230 mm TL and straight in individuals of 310 – 350 mm TL. The left-wing in *S. schall* is triangular, while the right is rounded. A groove is usually present, which separates the wings from the middle part. In young individuals of *C. auratus* (180 mm TL), the groove is shallow and becomes deeper in large specimens (> 260 mm TL). This is also the case for *S. schall,* as young individuals (220, 230 mm TL) showed a shallow groove, while large specimens are furnished with deep grooves. In *S. serratus*, a deep groove separates the wings, and the middle part is present.

In *C. auratus*, the sides of the spine are smooth, with no striations. In contrast, in *S. schall,* shallow striations are present in young individuals (230 – 250 mm TL) that become deeper in prominent individuals (400 – 500 mm TL); the striations decrease in number toward the spine tip. In *S. serratus*, shallow striations are present in young individuals and become more pronounced and irregular and fall towards the end in more prominent individuals.

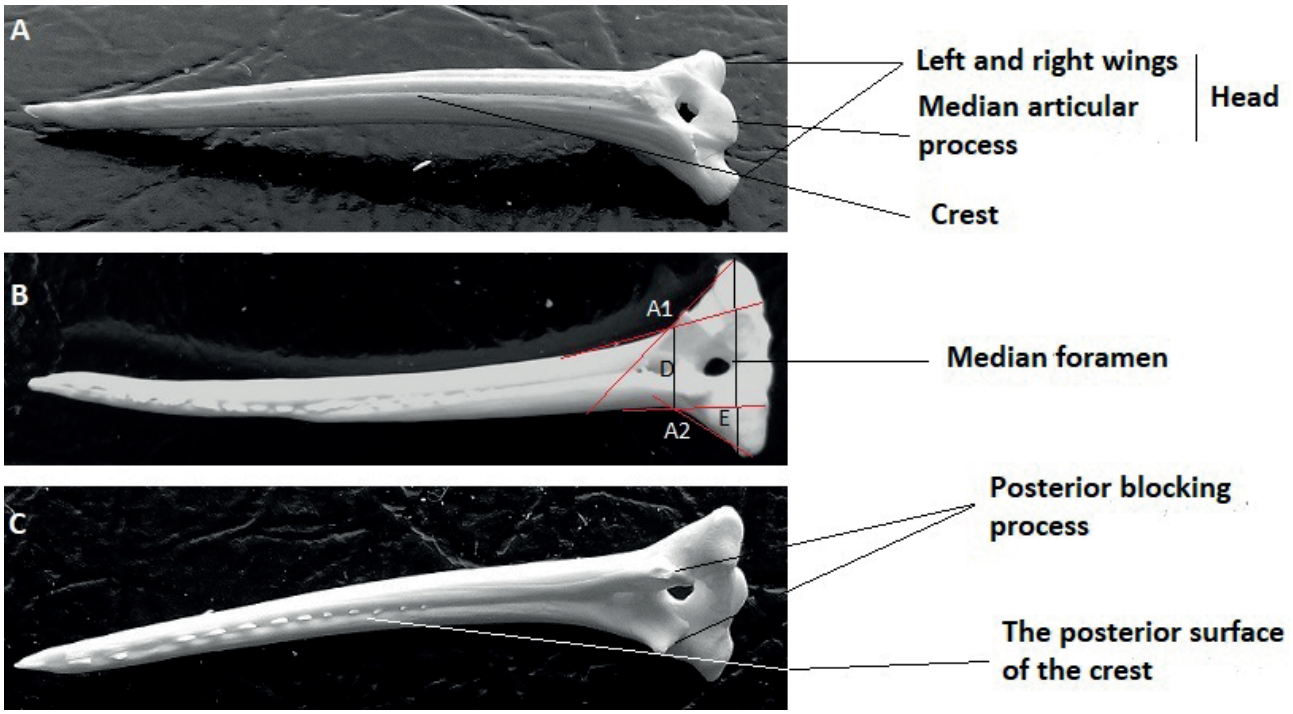

Figure 2

Dorsal fin spine of *Chrysichthys auratus*, 270 mm TL, **A.** anterior view; **B.** posterior view; **C.** spine elevated to show ventral side.

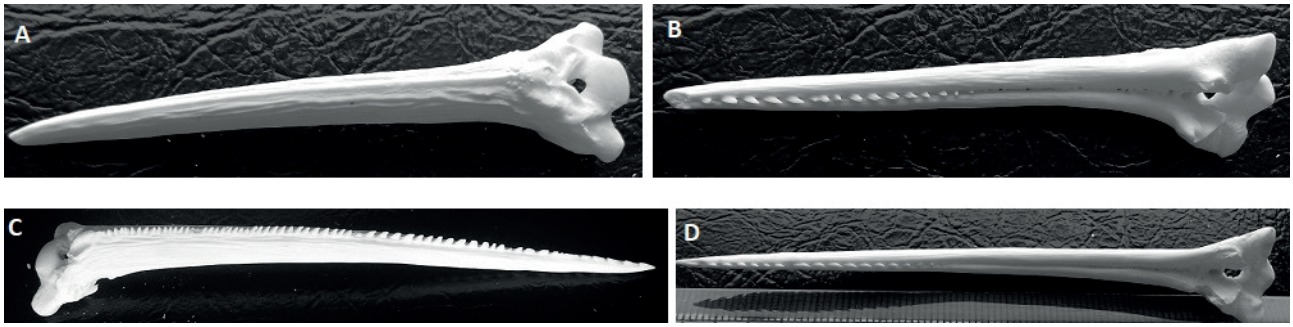

Figure 3

Dorsal fin spine of *Synodontis schall*, 400 mm TL; **A.** anterior view; **B.** spine elevated to show ventral side. Dorsal fin spine of *Synodontis serratus*, 400 mm TL, **C.** anterior view; **D.** posterior view.

The crest of the spine is usually provided with ornamentations. In *C. auratus,* it is smooth, with no features. *Synodontis schall* and young individuals (220 mm TL) have small tubercles, while in specimens of 230 mm TL, the tubercles are replaced by a longitudinal keel traversing the length of the spine. Tubercles disappear in the more prominent individuals (400 – 500 mm TL), and the surface becomes irregular. Small *S. serratus* (220- and 230-mm TL) have a shallow groove supplied with curved dentations, which become more prominent toward the tip. The groove is deeper in larger specimens (400 -500 mm TL); the dentations become larger and curve downward. Large dentations are located near the tip of the spine.

The ratio of the articular head's width to the spine's width at its base ranges from 1.10 in *S. schall* and 2.65 in *C. auratus*. The percentage of the width of the median foramen to the width of the articular head ranges from 0.05 in *S. serratus* to 0.15 in *C. auratus*. The largest range for the average angle made by the lateral border of each wing of the articular head with the corresponding lateral border in ventral view was observed in *S. serratus* (114° - 137.7°), and the smallest occurred in *S. schall* (122° - 138°).

The posterior surface of the median crest has no grooves, but small tubercles are present in small individuals of *C. auratus* (180 mm TL). The grooves become deeper, and tubercles are more prominent in large specimens of this species (> 260 mm TL). In *S. serratus* and small individuals (250-330 mm TL), irregular pores occur along the length of the median crest. In larger specimens (> 400 mm TL), dentations curve down and become more prominent toward the spine tip.

In three species (*C. auratus*, *S. schall*, *S. serratus*), the posterior process is poorly developed and directed laterally in young individuals and well produced and directed posteriorly in older specimens. In *S. schall* and *S. serratus*, the posterior blocking process of the large specimens has a wavy edge, while in *S. serratus*, it is curved in young individuals and straight in larger specimens.

Regarding the effect of pollution on the morphology of the dorsal fin spine in the localities from which species were collected, no abnormalities were recorded in any species examined.

4. Discussion

The general morphology of the spine of the dorsal fin of the three catfish species examined in this study agrees with the description given by Alexander (1966). Most catfish have large spines in their dorsal fin. Similar spines occur in quite a variety of other fish, for instance, *Gasterosteus* (Gasterosteiformes) and *Triacanthus* (Perciformes) (Alexander 1966). The principal function of these spines is protection. A fish with erect spines is more difficult for a predator to swallow, and the predator cannot swallow them without suffering pain or injury (Fine et al. 2011; Shine et al. 2021). Hoogland et al. (1956) have shown that two predacious fish, *Percu* and *Esox,* learn not to attack *Gusterosteus* after a few experiences with its spines (Hoogland et al. 1956). The possible protective importance of spines seems excellent, as nearly all fish-eating fish swallow their prey whole.

Some spine-bearing catfish are too large, when adult, to be in danger of predation by other fish, but the spines must protect them while young. Some catfish have evolved poison glands associated with their spines (Bhimachar 1944; Norman & Greenwood 1963; Fine & Ladich 2003; Bosher et al. 2006).

The size and type of ornamentations found on the surface of the dorsal fin spine are variable due to the size of the fish and the species.

Changes in the surface morphology and structure of the spine were noticed in individuals from both

the families examined, Claroteidae and Mochokidae. Considerable variations were also seen in the morphology of the dorsal fin spine within a small range of fish size for different individuals of the three species. The rapid growth of the dorsal spine prepares it as a weapon essential for the fish's survival (Alexander 1966). The Claroteidae and Mochokidae are considered venomous (Fine & Ladich 2003), and both individuals depend on the spines of their dorsal and pectoral fins to be used as weapons. Therefore, they need rapid growth of these spines in a short time, but there are also growth changes in the dorsal fin spines of these species. The present results showed that the growth period of the dorsal spine for *S. schall* and *S. serratus* is rapid. The spine gained its full weaponry status in a shorter period than those individuals of *C. auratus*.

The shape of the dorsal fin spine differs between *S. schall* and *S. serratus* in five respects: these are the shape of the articular head, the shape of the ornamentations on the crest, the average angle made by the lateral border of each wing of the articular head with the corresponding lateral border in ventral view, the posterior surface of the median crest, and the posterior blocking processes. The dorsal spine of these two species showed similarity in only two characteristics: the shape and size of the median foramen and the presence or absence of striations on the lateral sides of the spine, along with their shape and size. Slight differences in the morphology of the dorsal spine of *S. schall* and *S. serratus* were observed in only two characters: these are the ratio of the width of the articular head to the width of the spine at its base and the ratio of the width of the median foramen to the width of the articular head (Tables 1, 2 and 3).

In the dorsal spine growth of the species *S. serratus*, the following characteristics were noted to be conservative in the smaller and more prominent individuals: the shape of the articular head, the shape of the ornamentations on the crest, and the shape of the posterior blocking processes. On the other hand, in the shape of the dorsal fin spine of *S. schall*, the following characteristics were noted to be conservative: the shape of the articular head, the ratio of the width of the median foramen to the width of the articular head, the shape of the posterior surface of the median crest, and the shape of the posterior blocking processes. The conservative morphological characters of the dorsal spine of *S. schall* and *S. serratus* can be used as diagnostic features for those two species (Tables 1, 2 and 3).

Wide variations in the morphology of the dorsal spines of claroteid and mochokid individuals were investigated. These differences are represented in the following set of characters: the shape and size of the median foramen, the shape of the articular head, the shape of the ornamentations on the crest, the ratio of the width of the articular head to the width of the spine at its base, the ratio of the width of the median foramen to the width of the articular head, the average angle made by the lateral border of each wing of the articular head with the corresponding lateral border in ventral view, and the shape of the posterior surface of the median crest. Gayet & Van Neer (1990) also observed such differences in the morphology of the dorsal spine of some African silurid fish species and Pinton et al. (2006) on some species of the genus *Synodontis*.

Table 1

Features of the dorsal-fin spine of *Synodontis serratus* collected from Lake Nasser, Egypt

Characters	200 – 400 mm TL, n = 10	401 – 600 mm TL, n = 10
Median foramen, shape and size	Small, rounded, with dorsal edge	Large, rounded, with course ridges dorsally
Shape of the articular head	Triangular in shape, with the middle part has rounded lower edge, higher than the wings which have rounded edges and well-separated from the middle part.	Triangular in shape, with middle part broad, rounded and larger than wings. Rounded wings, well-separated from the middle part
Presence or absence of striations on the lateral sides of the spine, their shape and size	Presence of a shallow striations traversing over most of the length of the spine and diminish towards the tip.	Deep and irregular striations diminish towards the tip of the spine
Ornamentations on crest	Presence of an irregular ridges along the length of the crest	Presence of an irregular dentations getting larger towards the tip of the spine and irregularly separated
Ratio of width of the articular head/width of the spine at its base	1.82	2.65
Ratio of the width of the median foramen/width of the articular head	0.15	0.05
Average angle made by the lateral border of each wing of the articular head with the corresponding lateral border in ventral view	114°	137.7°
Posterior surface of the median crest	Presence of an irregular pores along the length of the median crest.	Presence of curved down dentations getting larger towards the tip of the spine
Posterior blocking processes	Well-developed, broad, with curved posterior edge directed posteriorly	Well-developed, with straight edge directed posteriorly

Table 2

Features of the dorsal-fin spine of *Chrysichthys auratus* collected from Lake Nasser, Egypt

Characters	100 – 200 mm TL, n = 10	201 – 300 mm TL, n = 10	301 – 400 mm TL, n = 10
Median foramen, shape and size	Small, rounded, with no edges	Large, rounded, with high edges	Large, oval, with high edges
Shape of the articular head	Triangular in shape. The middle part is narrow and levelled with the wings, which are separated from the middle part by shallow grooves	Triangular in shape, with middle part is levelled with the wings. No grooves	Triangular in shape. Broad middle part, with edges and deep grooves separating it from the wings. The middle part is higher than the wings
Presence or absence of striations on the lateral sides of the spine, their shape and size	No striations are present on the sides of the spine		Deep striations present towards the posterior edge of the spine and shallow anteriorly. Diminish towards the tip of the spine.
Ornamentations on crest	Smooth, no ornamentations	Mainly smooth, with slight irregularities in the surface near the head	Presence of a few tubercles irregularly arranged near the articular head and smooth on the remaining surface of the crest. They are variable in size.
Ratio of width of the articular head/width of the spine at its base	1.46	2.0	1.74
Ratio of the width of the median foramen/ width of the articular head	0.15	0.13	0.14
Average angle made by the lateral border of each wing of the articular head with the corresponding lateral border in ventral view	119°	101.5°	109°
Posterior surface of the median crest	No grooves. Tubercles are small	Presence of shallow grooves and tubercles getting larger towards the tip of the spine	Presence of deep grooves, tubercles getting larger towards the tip of the spine
Posterior blocking processes	Poorly developed directed posteriorly	Well-developed, pointed directed laterally	Broad, well-developed, posteriorly directed.

Table 3

Features of the dorsal-fin spine of *Synodontis schall* collected from Lake Nasser, Egypt

Characters	200 – 250 mm TL, n = 10	251 - 300 mm TL, n = 10	301 - 350 mm TL, n = 10	351 – 400 mm TL, n = 10
Median foramen, shape and size	Small, rounded, with high edges at dorsal side	Large, elongated dorsal ventrally, with ridges at the dorsal side	Small, rounded, with low edges	Large, rounded, with high edges
Shape of the articular head	Triangular in shape. The middle part broad and wider than the wings. Rounded edged wings, with notch at their lateral base	Triangular in shape. The middle part with rounded edges and shorter than the wings. The left wing with triangular left head and rounded right head.	Triangular in shape. The middle part broad. The wings with rounded edges. Presence of deep groove separating middle part and the wings.	Triangular in shape. The middle part broad levelled with wings. Presence of a deep groove separating wings and the middle part.
Presence or absence of striations on the lateral sides of the spine, their shape and size	Presence of a shallow striations diminish towards the tip of the spine		Presence of a deep striations at the lateral sides decrease in number towards the tip of the spine.	Presence of a deep curved striations decrease in number towards the tip of the spine.
Ornamentations on crest	Presence of a small sized tubercles confined to the anterior base of the spine	Smooth, with longitudinal keel traversing over the length of the spine	Smooth, with slight irregularities near the articular head.	Irregular surface, with no tubercles.
Ratio of width of the articular head/width of the spine at its base	1.7	1.14	1.9	2.3
Ratio of the width of the median foramen/width of the articular head	0.1	0.08	0.29	0.27
Average angle made by the lateral border of each wing of the articular head with the corresponding lateral border in ventral view	134°	122°	127.5°	138°
Posterior surface of the median crest	Presence of a shallow groove, with curved dentations getting larger towards the tip of the spine	Presence of a deep groove, with long and curved dentations getting longer towards the tip of the spine. Regularly spaced.	Presence of a deep groove, with large and dentations curved downward. Large dentations located near the tip of the spine.	
Posterior blocking processes	Broad, not produced directed posteriorly	Broad, not produced, with wavy edge directed posteriorly.	Broad, not produced and directed posteriorly.	

During the present work, it was possible to distinguish two groups of characters of the dorsal fins spines features: (1) exclusive characters that clearly define a taxonomic group (genus or species); (2) characters that are shared by several genera, but that may be useful to define certain species within a genus. These features are, therefore, valid for the taxonomic identification of the catfish species investigated, but they need to be checked for indicating any phylogenetic signals.

Conflicts of interest

The authors reveal no conflicts of interest, and no fund was obtained to perform this work.

Author contributions

LAJ contributed to ideas, data analysis and manuscript preparation. MMSF contributed to collecting fish samples, osteological preparation, and imaging. JMP contributed to the data analysis.

Ethical approval and consent to participate

The fish material was obtained from a commercial catch. Therefore, no ethical approval is needed.

Human and animal ethics

N/A

Consent for publication

All authors of this manuscript agreed to submit it for publication in Oceanological & Hydrobiological Studies.

Availability of supporting data

There are no supporting data to make available.

Competing interests

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