A confirmed record of the European catfish Silurus glanis L., 1758 (Actinopterygii: Siluriformes: Siluridae) from the southern marshes of Iraq, with a new anatomical set of characters to separate S. glanis and S. triostegus

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A confirmed record of the European catfish *Silurus glanis* L., 1758 (Actinopterygii: Siluriformes: Siluridae) from the southern marshes of Iraq, with a new anatomical set of characters to separate *S. glanis* and *S. triostegus*

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Abstract

Investigations conducted in the southern Iraq freshwater systems allowed the authors to collect the European catfish, *Silurus glanis* L., 1758. These are the first confirmed records of *S. glanis* from the freshwater systems in Lower Mesopotamia, based on 13 adult specimens, each 325–525 mm in total length. Furthermore, a new set of anatomical characters of *S. glanis and S. triostegus* from Chibayish marsh area, south of Iraq, was examined to reveal similarities and differences between the two *Silurus* species. In addition to the traditional separation of the two species of *Silurus* by number of barbels, these two species can now be recognised based on a new set of morphological and osteological features.

Keywords: Asian catfish, Iraq, marshes, osteology, morphology, anatomy

Zusammenfassung

Untersuchungen in südirakischen Fließgewässern führten zu Aufsammlungen des Europäischen Welses, *Silurus glanis* L., 1758. Dies sind die ersten bestätigten Nachweise von *S. glanis* aus Fließgewässern im Unteren Mesopotamien, basierend auf 13 adulten Exemplaren, mit Körperlängen von 325–525 mm. Weiterhin wurde ein neues Set anatomischer Merkmale bei *S. glanis and S. triostegus* aus der Chibayish Region, Südirak, untersucht, um Ähnlichkeiten und Unterschiede zwischen den beiden Welsarten aufzudecken. Zusätzlich zur traditionellen Trennung der beiden Arten mittels der Anzahl an Barteln können beide Arten nun anhand eines neuen Sets an morphologischen und osteologischen Merkmalen unterschieden werden.

Contents

1 Introduction

Members of the family Siluridae are freshwater catfishes that are distributed in Europe and Asia. They can be diagnosed by the lack of adipose fin and dorsal spine and the presence of a very long anal fin (KOTELLAT & FREYHOF 2007). Among the several genera belonging to this family is the well-known genus *Silurus*. It contains about 19 nominal species that are broadly distributed throughout Eurasia (KOBAYAKAWA 1989, TELCEAN & CUPŞA 2009).

Up to now the genus *Silurus* in Iraq has been represented by one species, *Silurus triostegus* Heckel 1843, which is widely distributed in inland waters throughout the country (COAD 2010, JAWAD & AL-JANABI 2016, JAWAD et al. 2017). It has also been found in other parts of the Tigris and Euphrates drainages (KURU 1979, ÜNLÜ & BOZKURT 1996, COAD & HOLCIK 2000).

With its large size, the European catfish, *Silurus glanis*, is considered the largest freshwater fish species in the world (ALP et al. 2011). This species is found to be a good contestant in fish farms as a supplementary species, which will bring revenue more quickly than other fish species like sturgeons (MUSCALU et al. 2010).

S. glanis and *S. triostegus* have shown morphological similarities that might cause a degree of uncertainty in the identification between these two species. Therefore, several morphological studies have been conducted on comparing *S. glanis* with other silurid species (HAIG 1952, CERNY 1988, KOBAYAKAWA 1989, COAD & HOLCIK 2000). Additionally, external morphological characters of

S. triostegus have been repeatedly investigated (Heckel 1843, Kobayakawa 1989, Ünlü & Bozkurt 1996, Coad & Holcik 2000). All the results of studies on both species of *Silurus* have revealed that there are morphological variations due to different environments.

Recently, Ünlü et al. (2012) published on the anatomical differences between *S. glanis* and *S. triostegus* in order to provide differentiating characters for the identification of these two species. In the present study, the work of Ünlü et al. (2012) has been used as a base method to separate these two species.

It has been previously documented that the European catfish *S. glanis* is not present in the inland waters of Iraq (Coad 2014, Froese & Pauly 2020), but, anecdotal reports of *S. glanis* in an unspecified locality in Iraq exist. Until the present study no specimens of *S. glanis* have been scientifically documented from the freshwater systems of Iraq (Ciepielewski et al. 2001, Coad 2010).

The aim of the present study is: (1) to describe specimens of *S. glanis* collected from the southern marshes of Iraq; (2) to document and confirm the presence of a sustainable population of the European catfish in these inland freshwater habitats, and (3) to provide an additional set of anatomical characters to separate the two species of the genus *Silurus*, *S. glanis* and *S. triostegus*.

Acknowledgements

We are grateful to Heok Hee Ng, Lee Kong Chian Natural History Museum, National University of Singapore for the confirmation of the identity of *Silurus glanis*. We also would like to thank the reviewer for improving the English of the manuscript. This research did not receive any specific funding. The authors declare that they have no conflict of interest. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. The authors confirm that their study meets the ethical guidelines and adhere to the legal requirements of the study country.

Figure 1. General view of the Chibayish marsh near Al- Fuhud Village, Thiqar, Iraq. Courtesy of Hussein Raqi, Iraq.

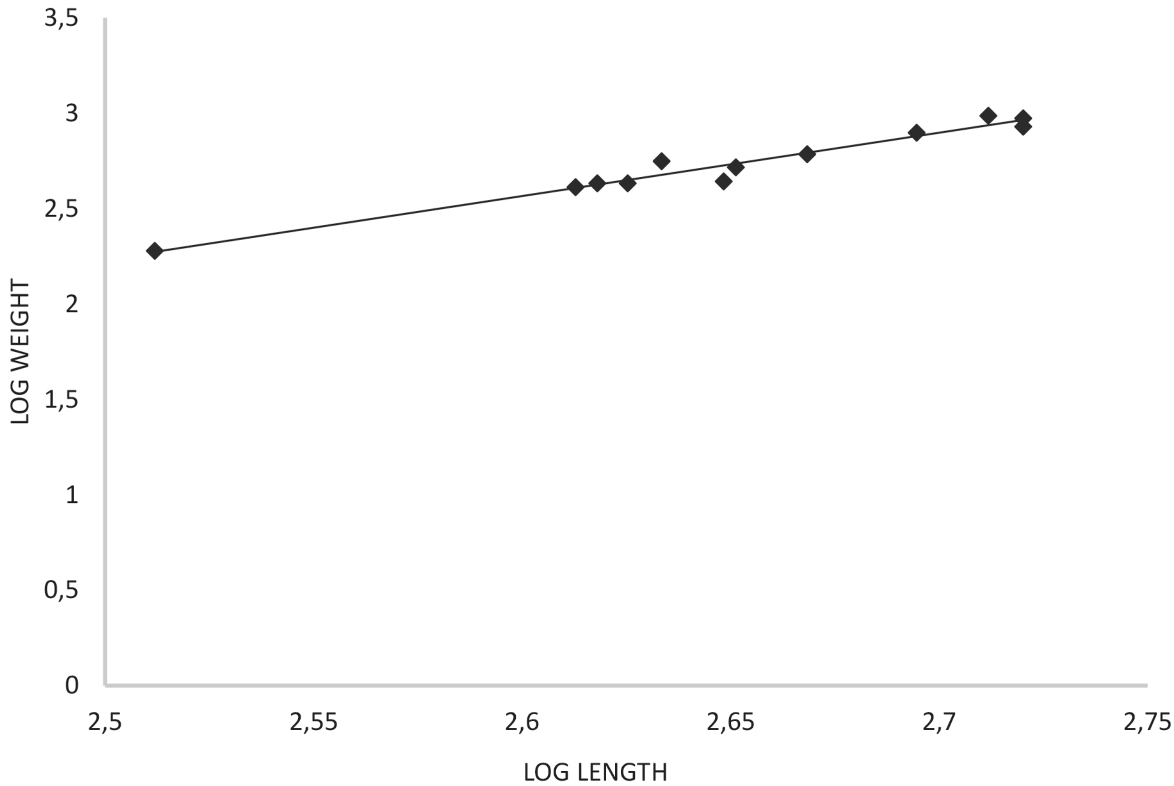


Figure 2. Length-Weight relationship of *Silurus glanis* collected from Chibayish marsh, south of Iraq.

2 Material and methods

A total of 14 adult specimens of *S. glanis*, ranging from 325 to 525 mm in total length (TL), were collected during the period July – August 2018. The specimens were captured from the Chibayish marsh located 10 Km northwest of Basrah City, 47°05 00.9″ E, 30°58´24.4″ N, using cast nets (Fig. 1). All the available specimens were immediately examined, photographed, and identified according to Ünlü et al. (2012) and Coad (2014). A total of 37 specimens of the Asian catfish *S. triostegus,* ranging from 200 to 500 mm in total length (TL), were collected from the same area for comparison. Morphometric and meristic characters were taken following Ünlü et al. (2012) and measurements recorded to the nearest millimetre (mm) using a digital calliper (see Table 1). Skulls, cheek bones and pectoral fin spines of both species were prepared after boiling the fish specimens. The specimens of *S. glanis* were deposited in the fish collection of the Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, Basrah, Iraq. Taxonomic status of the species follows Fricke (2020). The mean values calculated for each morphological parameter were evaluated using Student's t-tests and a significance level of 95% probability. The length-weight relationship for specimens of *S. glanis* was presented as W = a TLb, and also transformed into its logarithmic expression: log W = log (a) + b log (TL) to assess other potential values (Sparre et al. 1989, Froese 2006). The coefficient of determination (R^2) was used as an indicator of the quality of the linear regression (Scherrer 1984). The values of Kn were estimated adapting the formula of Le Cren (1951) as, Kn = TW/aLb where TW = observed weight (g), aLb = calculated weight obtained from the length-weight relationship.

3 Results

3.1 *Silurus glanis* in the south of Iraq

The specimens of *S. glanis* collected from the Chibayish marsh, southern Iraq have the following set of characters: body elongated, naked, with depressed head; caudal fin rounded to truncate, absence of adipose fin; anal fin almost touching caudal; large mouth with lower jaw noticeably longer than the upper jaw and meeting in antero-dorsal position; teeth are curved in both jaws; presence of 3 pairs of barbels, one maxillary and two mandibular, with maxillary barbels longer than head; pectoral fin spine finely serrated on its inner surface and smooth on its outer surface in males only; lateral mesethmoid long; eye small; one patch of vomerine teeth; brownish colour dominated most parts of the body, with variable pale-yellowish patches distributed anterior-posteriorly, mandibles with large brown spots, ventral side of head and abdomen white. Morphometric and meristic characters are given in Table 1 and 2.

Table 1. Morphometric data of the specimens of *S. triostegus* (n = 37) and *S. glanis* (n = 14) in the Chibayish marshes, south of Iraq. Min: minimum; Max: maximum; S.D.: standard deviation. Significant differences are indicated by asterisks (P<0.05).

Morphometric characters	Present study		Ünlü et al. (2012)	
	Silurus triostegus	*Silurus glanis*	*Silurus triostegus*	*Silurus glanis*
	Mean ± S.D. (Min. – Max.)		Mean ± S.D. (Min. – Max.)	
Total length (TL)	356 ± 2.9 (200 – 500)	439 ± 2.6 (325 – 525)	374.44 ± 219.30 (127.0–1040.0)	324.0 ± 47.8 (250.0–405.0)
Standard length (SL)	240 ± 2.0 (180 – 490)	394 ± 1.8 (290 – 480)	344.11 ± 214.81 (121.0–1030.0)	297.0 ± 44.2 (228.0–370.0)
Head length (HL)	105 ± 1.9 (102 – 110)	96.6 ± 1.7 (68.9 – 119)	71.25 ± 43.01 (27.0–205.0)	70.0 ± 9.56 (56.0–93.0)
Eye diameter (ED)	32 ± 0.9 (30 – 35)	10.6 ± 0.7 (7.37 – 12.1)	5.76 ± 2.19 (3.0–12.0)	6.5±0.7 (5.2–8.0)
Body depth (BD)	46 ± 1.9 (41 – 52)	69.6 ± 1.6 (45.6 – 80)	60.91 ± 42.03 (20.0–203.0)	65.0 ± 12.3 (41.0–87.0)
Interorbital length (IO)	37.03±21.02 (14.0 – 76.0)	35 ± 19.1 (14.0 – 56.0)	37.03 ± 21.02 (14.0–100.0)	30.0 ± 4.5 (23.0–40.0)
Predorsal fin length (PrD)	95.56±55.72 (39.3 – 97.0)	112.9 ± 42.7 (86.7 – 143.8)	95.56 ± 55.72 (39.3–260.0)	91.0±9.9 (68.0–106.0)
Caudal peduncle depth (CPD)	23 ± 2.2 (7.0 – 42.2)	35.3 ± 2.3 (11.7 – 20.9)	16.55 ± 10.77 (6.0–50.0)	14.1 ± 1.3 (12.0–16.0)
1st Mandibular barbel length (fMBL)	29.25 ± 12.79 (14.0 – 45.0)	27.4 ± 11.2 (14.0 – 41.0)	29.25 ± 12.79 (14.0–65.0)	35.0 ± 5.4 (27.0–46.0)
2nd Mandibular barbel length (sMBL)	38.91 ± 14.73 (19.0 – 48.0)	27.8 ± 12.3 (18.0 – 38.2)	38.91 ± 14.73 (19.0–78.0)	16.0 ± 3.0 (12.0–18.0)
Maxillary barbel length (MaxBL)	123.05 ± 47.78 (38.0 – 102.0)	64.2 ± 34.2 (37.9 – 94.3)	123.05 ± 47.78 (38.0–225.0)	75.0 ± 9.4 (62.0–98.0)
TL/SL	1.14±0.03 (1.11 – 1.19)	1.10 ± 0.01 (1.12 – 1.09)	1.10 ± 0.04 (1.0–1.1)	1.1±0.0 (1.1–1.1)
SL/HL*	3.09 ± 0.15 (1.78 – 4.46)	4.32 ± 0.13 (4.21 – 4.25)	4.80 ± 0.17 (4.5–5.1)	4.2 ± 0.2 (4.0–4.6)
SL/BD*	6.67 ± 0.45 (4.39 – 9.42)	12.6 ± 0.35 (6.36 – 6.74)	5.76 ± 0.47 (5.1–6.7)	4.4 ± 0.5 (3.9–5.6)
HL/ED	3.42 ± 2.24 (3.40 – 3.49)	9.35 ± 2.2 (9.35 – 9.39)	11.73 ± 2.38 (9.0–17.1)	10.8 ± 1.1 (9.7–13.3)
HL/ MaxBL*	1.78 ± 0.11 (1.10 – 2. 68)	1.55 ± 0.10 (1.82 – 1.94)	0.56 ± 0.13 (0.4–0.9)	0.9 ± 0.1 (0.8–1.0)
HL/ fMBL*	7.65 ± 0.52 (7.28 – 7.9)	4.87 ± 0.43 (4.87 – 4.95)	2.36 ± 0.55 (1.9–3.8)	1.9 ± 0.2 (1.7–2.3)
HL/ sMBL*	5.6 ± 0.33 (5.37 – 6.23)	3.65 ± 0.31 (3.83 – 3.93)	1.76 ± 0.43 (1.4–3.2)	4.3 ± 0.4 (4.1–4.8)
MaxBL/ fMBL*	2.89 ± 0.63 (2.71 – 2.86)	2.63 ± 0.42 (2.71 – 2.84)	4.25 ± 0.74 (2.7–5.7)	2.2 ± 0.2 (1.9–2.5)
HL/IO*	7.34 ± 0.07 (7.28 – 7.78)	4.92 ± 0.05 (4.91 – 4.98)	1.91 ± 0.09 (1.8–2.1)	2.0 ± 0.1 (2.1–2.4)
SL/CPD	25.6 ± 1.64 (25.7 – 25.9)	24.67 ± 1.43 (24.78 – 24.97)	21.06 ± 1.75 (17.3–25.0)	20.6 ± 1.3 (20.9–24.6)

Table 2. Meristic data on the specimens of *S. triostegus* (n = 37) and *S. glanis* (n = 37) in the Chibayish marshes, south of Iraq.

Meristic characters	Present study		Ünlü et al. (2012)	
	Silurus triostegus	*Silurus glanis*	*Silurus triostegus*	*Silurus glanis*
Anal fin	I–83–93	80–86	I–83–93	81–86
Caudal fin	17	16–17	17	16–17
Pectoral fin	16–17	I–12–14	15–17	I–12–14
Pelvic fin	I–12	I–9–10	I–11–12	I–9–10
Branchiostegal rays	15	15	15	14–15
Gill rakers	13	15	12–13	12–16
Number of vertebrae	18 + 54 = 72	16 + 52 = 68	(18)19+(54)55(56) = (72)73(74)	(16)17+(52)53 = (69)70

Total length-weight calculation shows the parameters: $a = 0.003$; $b = 3.3199$; $R^2 = 0.9615$ (Fig. 2) Kn = 0.6475.

The examination of the gonads revealed that there were 4 males and 10 females in the post spawning stage, where the gonads were in a spent case.

3.2 Comparison between *S. glanis* and *S. triostegus* based on an additional set of anatomical characters

Morphological characters

The body colouration of the *S. glanis* in Iraq can be of variable degrees of dark brown, dark mottled with white patches and dark brown mottled with yellow patches (Fig. 3). Ventral side of head and abdomen are usually white and all fins are dark. The mandibles are mainly white with varying degree of dark spot pigmentation (Fig. 4).

The position of the eye in relation to the anterior end of the upper jaw also varies between *S. glanis* and *S. triostegus*. An imaginary line (a–b) passing through the anterior tip of the upper jaw is also passing well above the orbit in *S. glanis*, while it passes through the lower 1/3 of the eye in the case of *S. triostegus* (Fig. 5a–d).

The European and the Asian catfish species also showed to be different in number of morphometric ratios such as SL / BD, HL / MaxBL, HL / fMBL, HL / sMBL, MaxBL / fMBL and HL / IO.

The shape of the caudal fin in *S. glanis* is truncated. The upper and lower edges are rounded. On the other hand, the caudal fin in *S. triostegus* is rounded (Fig. 5c–d).

Usually in *S. glanis* there are 3 pairs of barbels present (Fig. 6a–b) and in *S. triostegus* there are only 2 pairs of barbels present (Fig. 6c–d). However, three specimens of *S. glanis* were bearing a total of five barbels, with two specimens each having two barbels on their left side and three barbels on their right side (Fig. 6e).

Inside the mouth, the mesethmoid bone area is wider in *S. glanis* than in *S. triostegus*. Also, there is only one vomerine teeth patch present in *S. glanis,* whereas there are two slightly separated patches present in *S. triostegus*. In the upper jaw of *S. glanis*, the most posterior row of teeth is narrow and long, but only few lateral teeth can reach the anterior edge of the vomerine teeth plate (Fig. 7a, b). In *S. triostegus*, these teeth are broad and short, but reaching the anterior edge of the vomerine teeth patch from both the median and the lateral sides (Fig. 8a–b). The area posterior to the lower teeth patch is highly pigmented in *S. glanis*, while pigmentation is very trivial in *S. triostegus*. In addition, there are some small black pigments on the tongue of the former species, while such pigmentations are absent from the tongue of the latter species. The posterior row of the teeth on the lower jaw in *S. glanis* is long, slender, arranged in more or less a uniform line, and individual teeth are noticeably separated from each other by a slight distance. In *S. triostegus*, the numerous teeth located in the posterior edge of the lower jaw are short, with broad base, and they are crowded unevenly. Teeth on the posterior right lateral end of the lower jaw of *S. glanis* are many, short, with short or without spine and irregularly arranged, while they are few, stubby ending with short spine and grouped in small patches in *S. triostegus* (Fig. 8c–d).

Osteological characters

Individuals of *S. glanis* and *S. triostegus* show differences in a set of osteological characters of hypobranchial apparatus and skull.

The infrapharyngobranchial plate (IPB) of *S. glanis* is slightly bean-shaped, with long, medially curved and pointed teeth confined to the anterior and lateral side of the plate. Teeth in the posterior lateral region are very small and blunt. The IPB of *S. triostegus* has an oblong shape with a broad posterior lateral edge. Teeth of IPB are mainly small and slightly curved. Longer and irregular teeth are confined to the anterior lateral side of the IPB (Fig. 9a–d).

The 5th ceratobranchial arch (CBA) in *S. glanis* has an elongated shape, with broad anterior end tapering toward

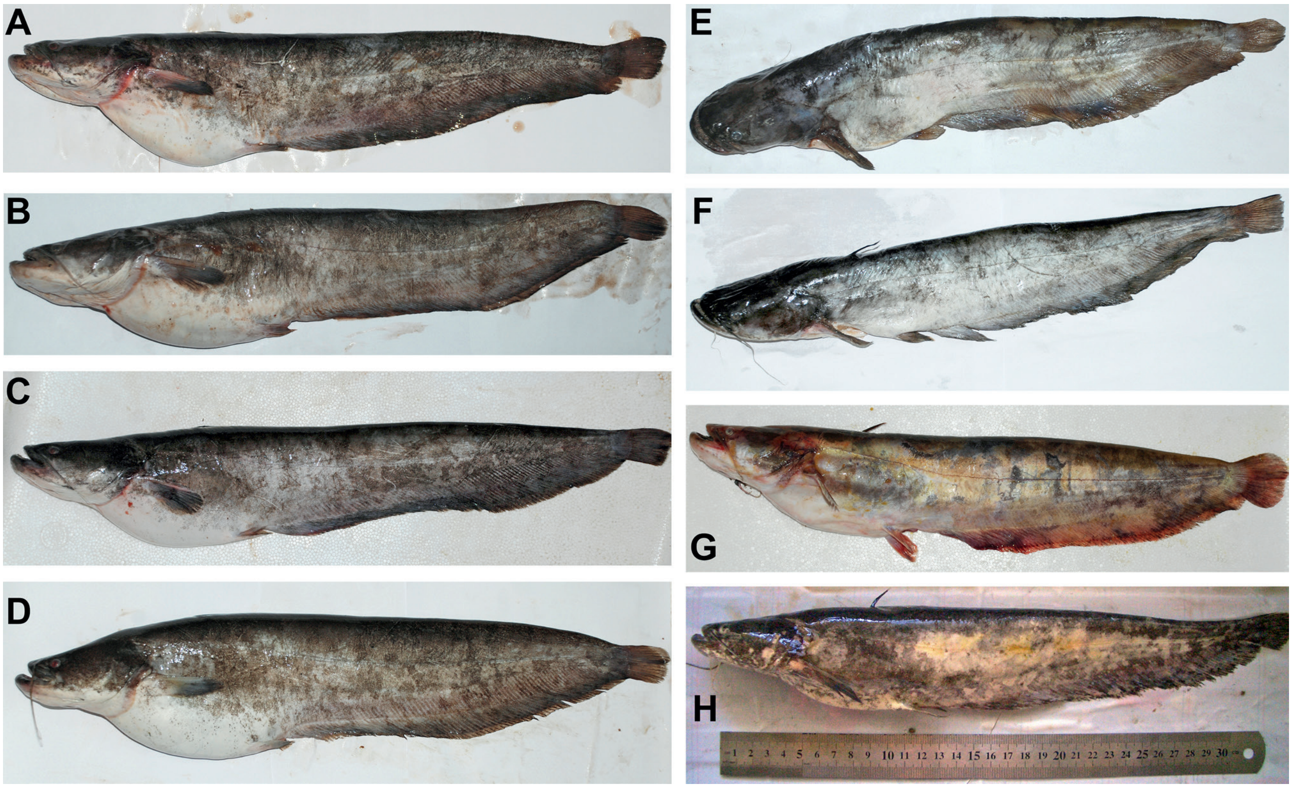


Figure 3. Colour forms of *Silurus glanis* collected from Chibayish marsh, south of Iraq.

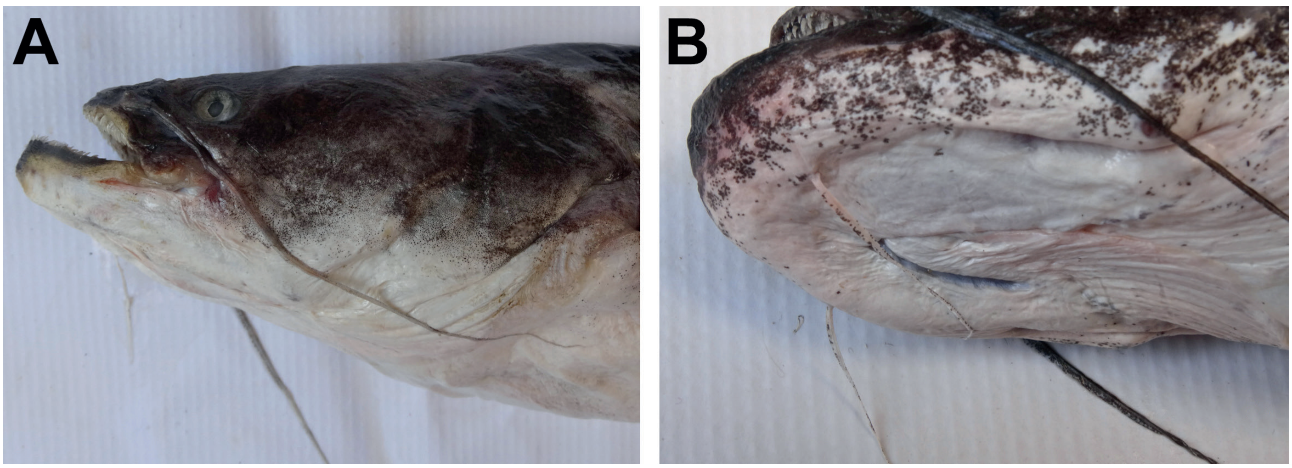


Figure 4. Head showing the ventral side of mandible of A. *Silurus glanis* with no pigmentation; B. *Silurus triostegus* with heavy pigmentation.

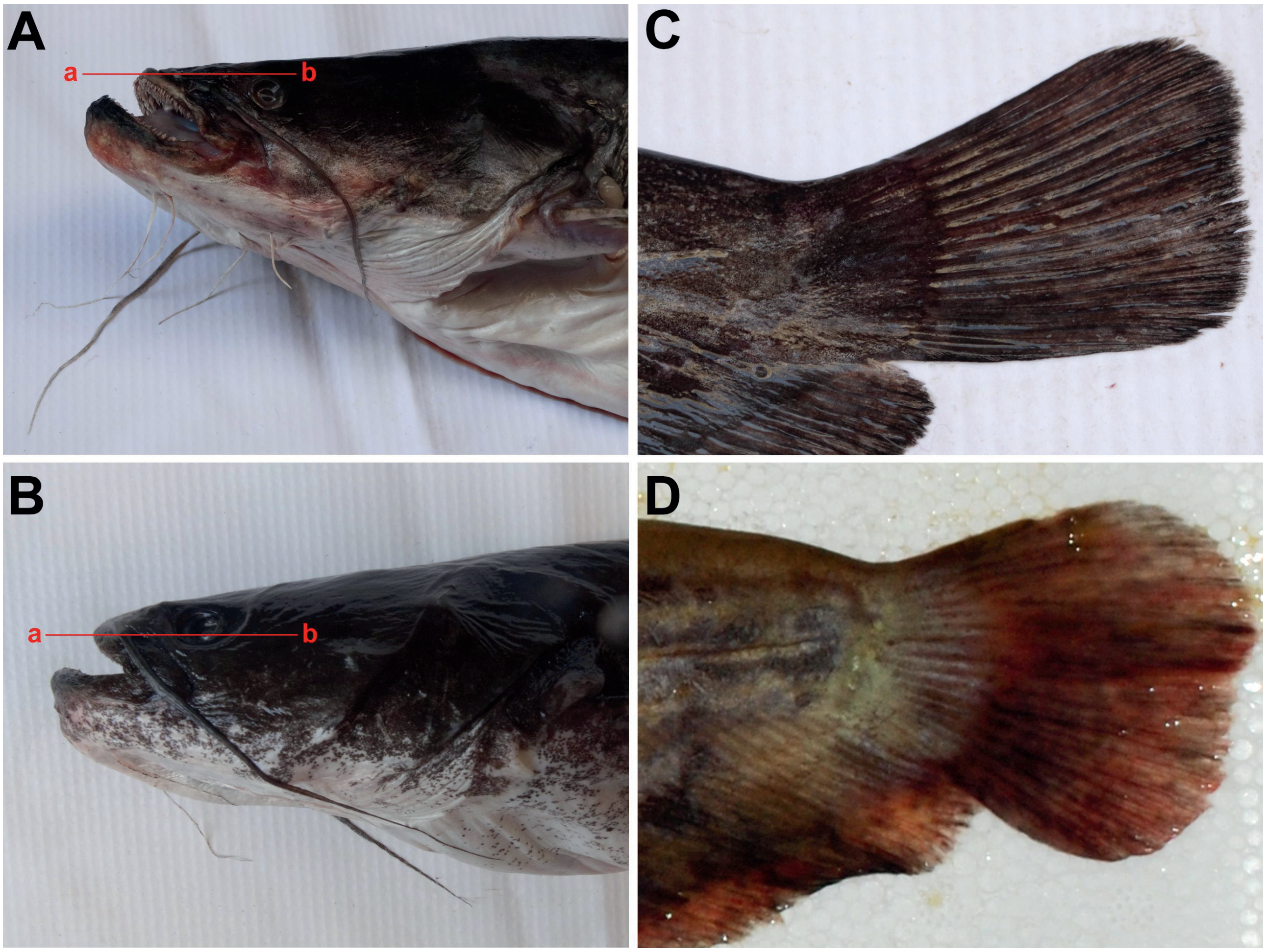


Figure 5. Imaginary line passing through the snout of A, *Silurus glanis*; B, *Silurus triostegus*; caudal fin of C, *Silurus glanis*; D, *Silurus triostegus*.

the posterior lateral side and slightly curved median side. The longer and straighter teeth are located anteriorly, while the small crowded teeth are confined to the posterior and lateral sides. In *S. triostegus*, the CBA has an elongated shape, with straight median and deeply indented lateral sides. Teeth are mainly short, with a small patch of long and straight teeth, which are restricted to the anterior lateral side.

Sexual dimorphisms

Male and females of both *Silurus* species showed some osteological differences that can be summarised in the following comparison.

Male vs female cheek bones of *S. glanis*

The three cheek bones, namely, opercular (OP), interopercular (IO) bone, and preopercular bones (PO), show variations between male and female individuals (Fig. 9e–f)

In females of *S. glanis*, OP has a straight anterior edge and is slightly curved forward; anterior articulated facet broad and directed upward; curved dorsal side; serrated, and texture with braided ridges and grooves on posterior edge. IO has a straight anterior edge; undulated anterior ventral side; anterior articulated facet, with undulation. The PO is narrow, with long neck and irregularly serrated anterior articulated facet; long, narrow and pointed dorsal end; long, broad, with obvious elongated ridge expanding ventrally; thick, curved upward posterior edge forming a trough at its ventral end.

In males of *S. glanis,* OP straight with anterior edge curved backward; articulated facet narrow and directed forward; smooth, posterior dorsal edge undulated; straight dorsal side. The IO has the anterior edge forwardly curved; smooth anterior ventral side; broad, with short neck and smooth, articulated face; ventral part is short, broadly pointed dorsal part; short, broad, smooth, with pointed

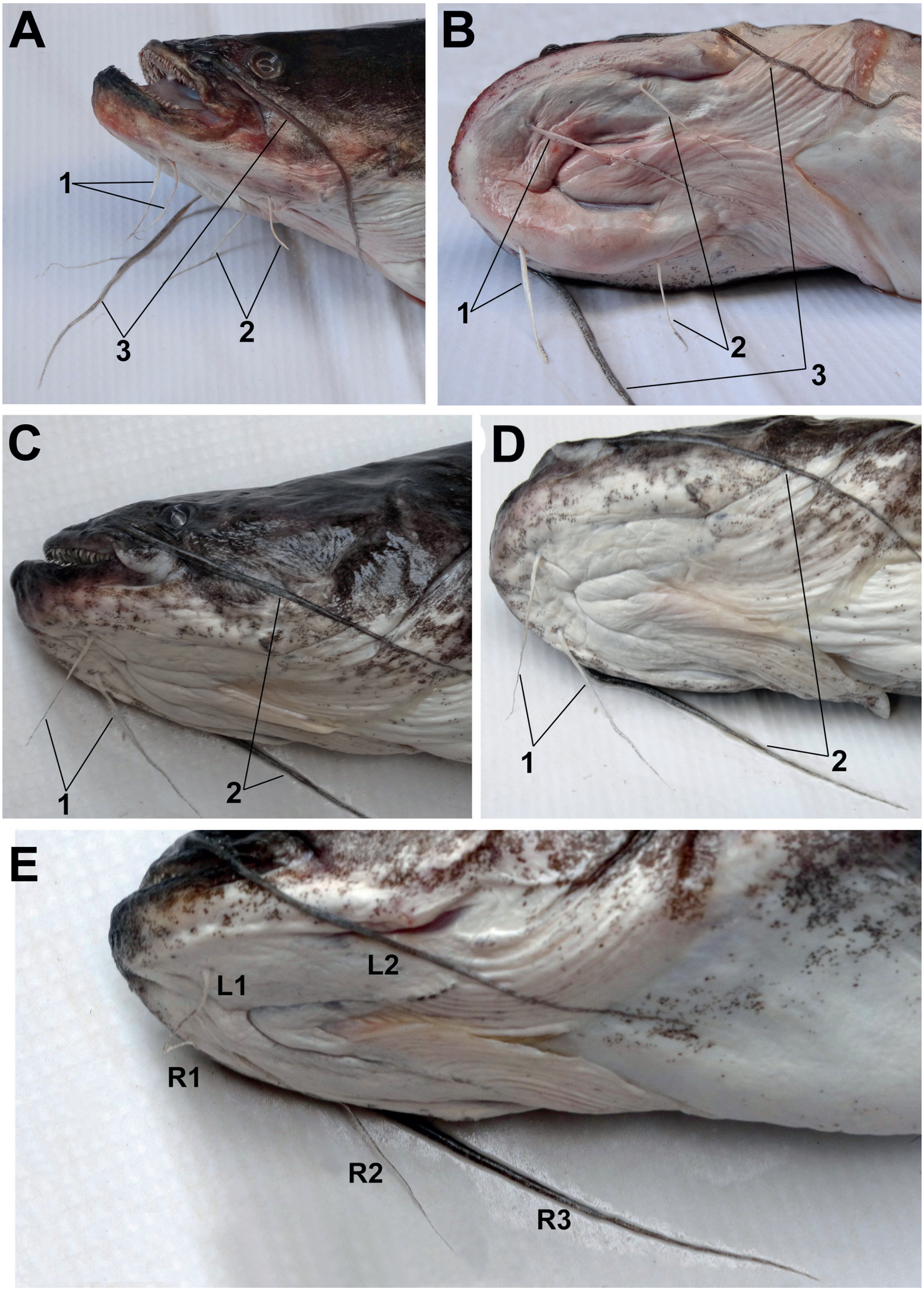
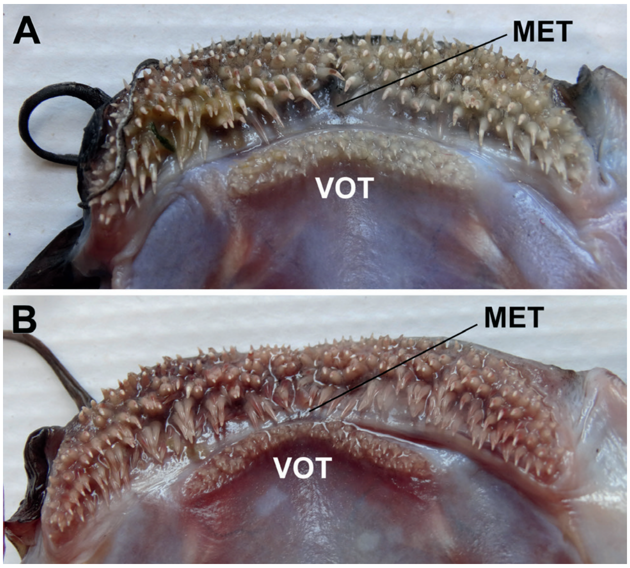


Figure 6. Head of *Silurus glanis* showing 3 pairs of barbels. A, lateral view; B, ventral view. Head of *Silurus triostegus* showing 2 pairs of barbels. C, lateroventral view; D, ventral view. Head of *Silurus glanis* showing 2 barbels on left side and 3 barbels on right side. E, lateroventral view.



ventral edge; posterior side is poorly developed, curved inward and with smooth ventral edge (Figs 10a–b).

Male vs female cheek bones of *S. triostegus*

The cheek bones of females and males of *S. triostegus* are different in many aspects from those of *S. glanis*.

In the females of *S. triostegus*, the OP has straight anterior side; anterior articulated facet with large and rounded dorsal process; slightly curved anterior dorsal edge, with serration confined to the posterior end; concave dorsal side. The IO is straight, with long pointed dorsal edge; slightly undulated anterior ventral side. The PO has well-developed anterior articulated facet, produced, with obvious neck and irregular anterior edge that sepa-

Figure 7. Roof of the anterior part of the mouth of A, *Silurus glanis*; B, *Silurus triostegus*. MET, mesethmoid bone; VOT, vomerine teeth.

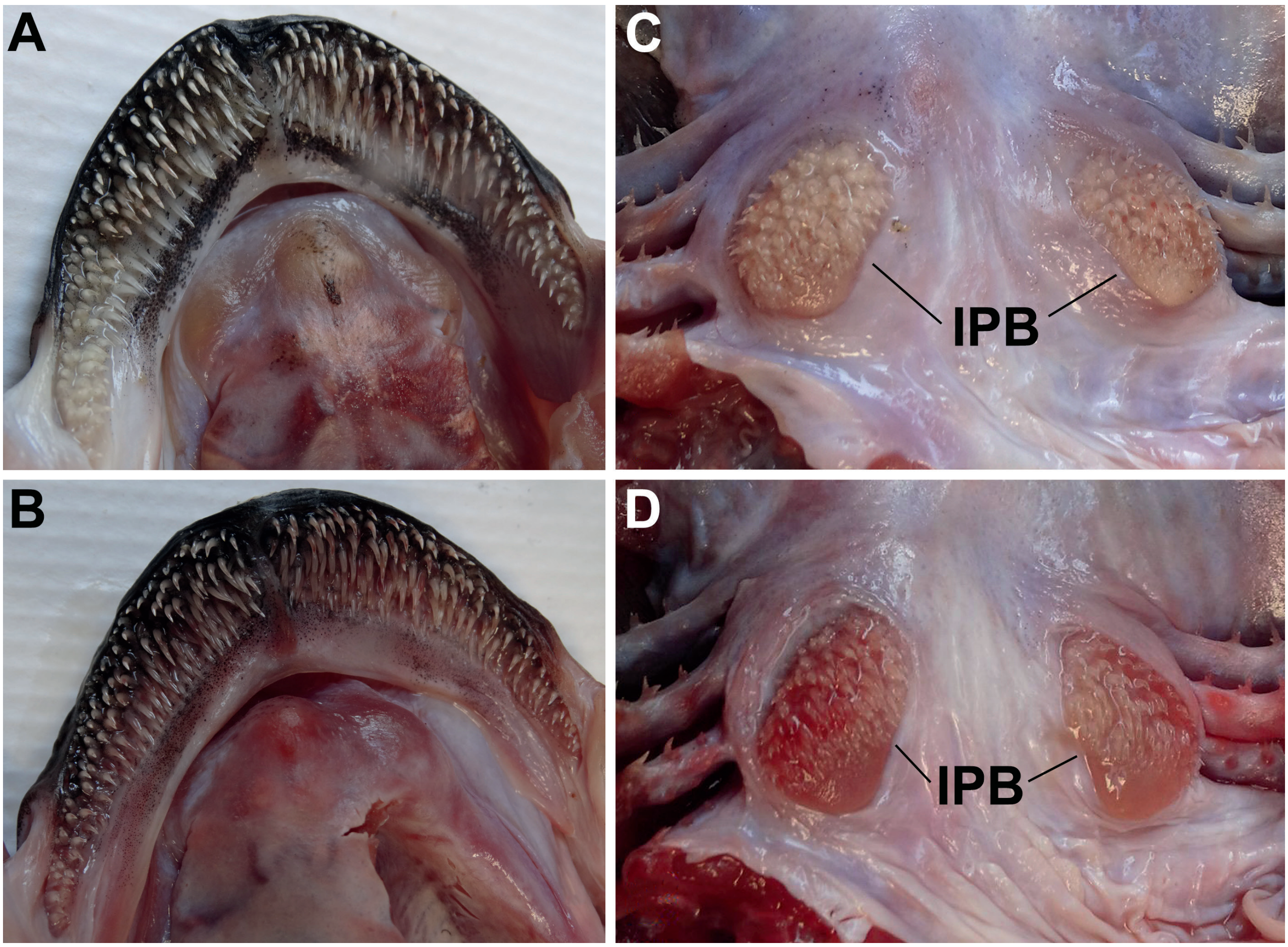


Figure 8. Inner lower jaw showing pigmentation posterior to teeth plate of lower jaw of A, *Silurus glanis*; B. *Silurus triostegus*. Infrapharyngobranchial plate (IPB) of C, A. *Silurus glanis*; D. *Silurus triostegus*.

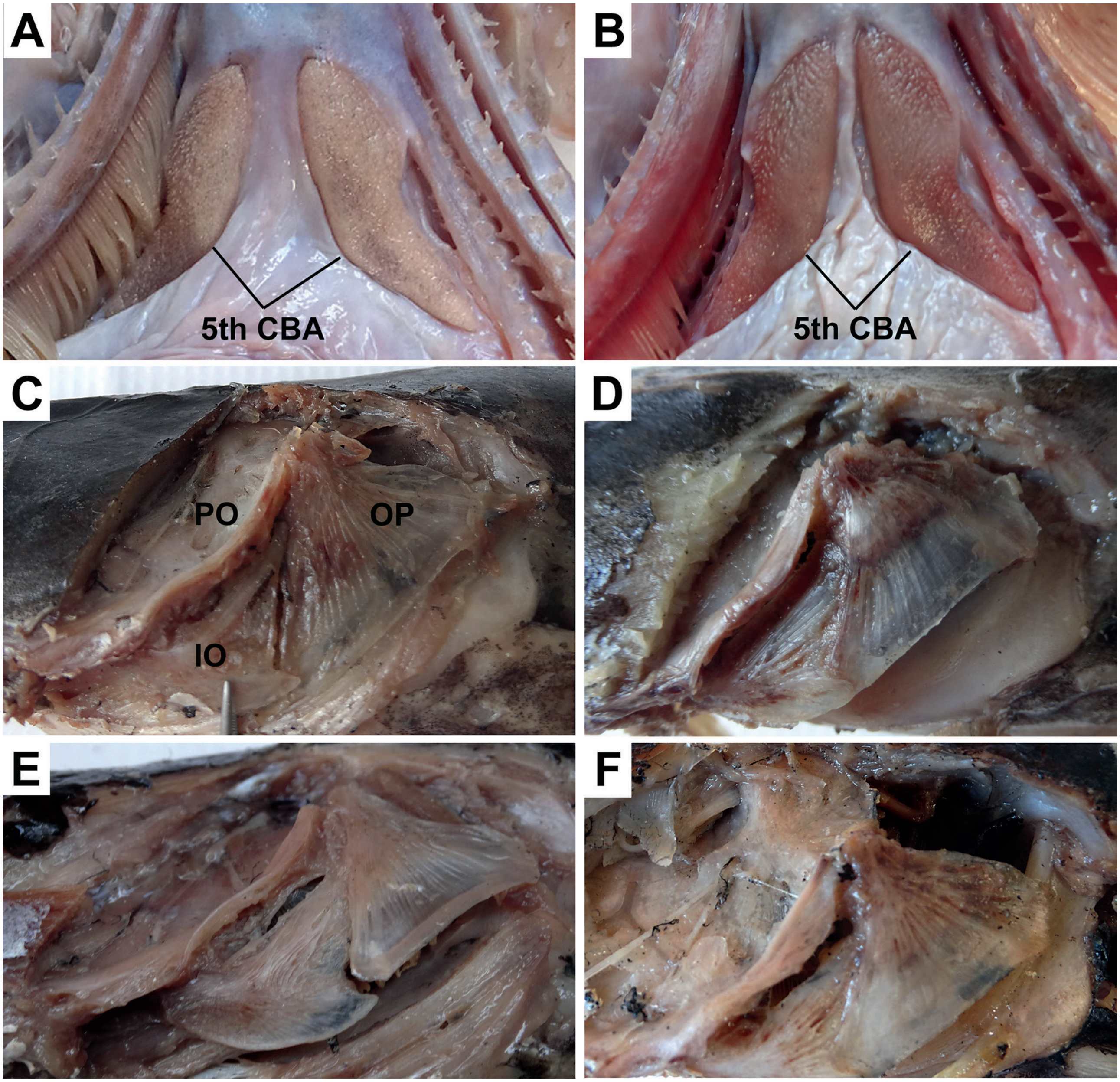


Figure 9. The 5th ceratobranchial arch of A, *Silurus glanis*; B, *Silurus triostegus*. Cheek bones (in situ) of *Silurus glanis*, C, female; D, male. *Silurus triostegus*, E, female; F, male. CBA, ceratobranchial arch; IO, interoperculum; OP, operculum; PO, preoperculum.

rates it from the dorsal side; long, dorsal part broad and curved forwardly; ventral part long, broad, with finally pointed ventral edge and the presence of a well-developed ridge; thick, curved upward on posterior side and backward on ventral side.

In males of *S. triostegus*, the OP is straight, with a sharp edge; posterior dorsal side small and with truncated articulated facet; straight, smooth along the whole posterior edge; convex dorsal side. The IO has a short dorsal part, smooth anterior ventral side; anterior articular facet not produced, absence of neck, continuous with dorsal side of bone. The PO is short, broad and straight dorsal part; ventral part short, broad, with broadly pointed ventral edge and smooth surface; smooth and not upraised posterior side (Figs 10a–d).

Skull differences in both sexes

In dorsal view, the anterior edge of mesethmoid (MET) in both sexes of *S. glanis* is wide spanning at an angle of 110°, with the presence of small process in the middle and absence of ridges on the posterior part. In *S. triostegus,* MET deeply curved, narrow, absence of process, with a wide spanning at angle of 95°, and the presence of ridges on the posterior part. Ridges are absent in female individuals (Fig. 11 a, b).

In the males of *S. glanis*, the anterior fontanel (AF) is wide and oval; in the females narrow and of elongated shape. The posterior fontanel (PF) is narrow and nearly closed in males, and completely closed in females.

In males of *S. triostegus*, AF is narrow and with elongated slit, in females wide and with oval opening. In both females and males, the PF is a nearly closed slit (Fig. 11c–d).

In females of *S. glanis*, the vomerine teeth plate is broad and oval, but narrow and elongated in males. In both females and males of *S. triostegus*, it is broad and oval in shape. The lateral sides of the anterior end of the vomer bone (VO) in female *S. glanis* are straight and forming an angle with the remaining part of the vomer bone extending backward. In the males, the lateral sides of the anterior end of the vomer are smoothly joining the posterior extension of the vomer. A similar connection was observed in females and males of *S. triostegus* (Fig. 12a, b).

The lateral edge of the frontal bone (FR) is curved in females of *S. glanis* and straight in males. In both sexes of *S. triostegus*, the lateral edges of the frontal bone (FR) are straight. The prootic bone (PRO) in the females of *S. glanis* is short and broad, but long and narrow in males. The latter condition is also present in both sexes of *S. triostegus*.

Differences in the pectoral fin spine

The pectoral fin spine in both sexes of *S. glanis* and *S. triostegus* is different in shape and in the form of the small spines they carry.

Females of *S. glanis* carry fine, closely arranged spines on the anterior side of the shaft. Medium-sized, widely separated spines are found on the posterior side of the shaft, the shaft itself is straight, with short and broad dorsal articular process, absence of neck, ventral articular process is elongated and directed posterolateral, dorsal and ventral surface of shaft textured with fine, braided ridges and groves (Fig. 13 a).

In males of *S. glanis*, the anterior side of shaft is smooth, with presence of long and variably arranged barbs on the posterior side of the shaft, shaft curved distally, dorsal articular process narrow, long, with neck, the ventral articular process straight and with neck, dorsal and ventral surface of shaft smooth (Fig. 13b).

Females of *S. triostegus* with shaft curved at proximal end and directed posteriorly toward the distal end, articular end large, disc-shaped, with dorsal articular process larger than ventral articular process, shaft surface not smooth (Fig 13c).

Males of *S. triostegus* with fine spines distributed on the distal half of the anterior side of the shaft, presence of long, variably arranged barbs on the posterior side of the shaft, broad, slightly curved shaft, with straight distally, articular end small, disc-shaped, with the ventral articular process poorly developed, surface of shaft smooth (Fig. 13d).

Females of *S. triostegus* and *S. glanis* exhibit the identical shape and arrangement of spines on both anterior and posterior sides of the shaft.

4 Discussion

Regarding the body length and stages of maturity of gonads in the 14 individuals of *S. glanis* collected in the present study, it may be justified to assume that this species has established a sustainable population in the Chibayish marshes in southern Iraq. Al-Sayab (1988) stated that egg laying in the Asian catfish in south of Iraq occurs between June and July. This may be the same period for the European catfish *S. glanis* in the same environment. If this is the case, then the spent case of the gonads denotes a post spawning status. On the other hand, the individuals of *S. glanis* collected from the Chibayish marsh seem to have good well-being condition with a Kn value of 0.6475.

With the already known characteristics of and the above- mentioned additional set of new characteristics, it is possible to separate *S. glanis* and *S. triostegus.* So we can confirm that the specimens collected from Chibayish marsh indeed belong to *S. glanis*.

Silurus glanis is found in the upper Mesopotamian reaches in Turkey (Kuru 1979, Ünlü & Bozkurt 1996, Coad & Holcik 2000, Ünlü et al. 2012) and in the eastern Tigris River drainages in Iran (Coad 2010, 2014). There are two possible explanations for the presence of *S. glanis* in the Chibayish marsh, south of Iraq. The first possibility would be that fish individuals might have entered the Iraqi freshwater system by descending Euphrates River from Turkish waters. This possibility may be unlikely as no individuals were collected from the northern and middle portions of Iraq. On the other hand, the topography of the southern reaches of the Tigris River provides the opportunity for fish to move freely between the freshwater system of Iraq and Iran through the southern marsh areas located in southern Mesopotamia.

The slight variation in the morphometric and meristic characters between the results of the present study and those obtained for *S. glanis* by Ünlü et al. (2012) may be due to the differences in the environmental factors such as water temperature. Variations in morphology are less noticeable at intra-specific level, whereas phenotypic variation is less obvious under genetic control and more subject to environmental effects (Clayton 1981). Differ-

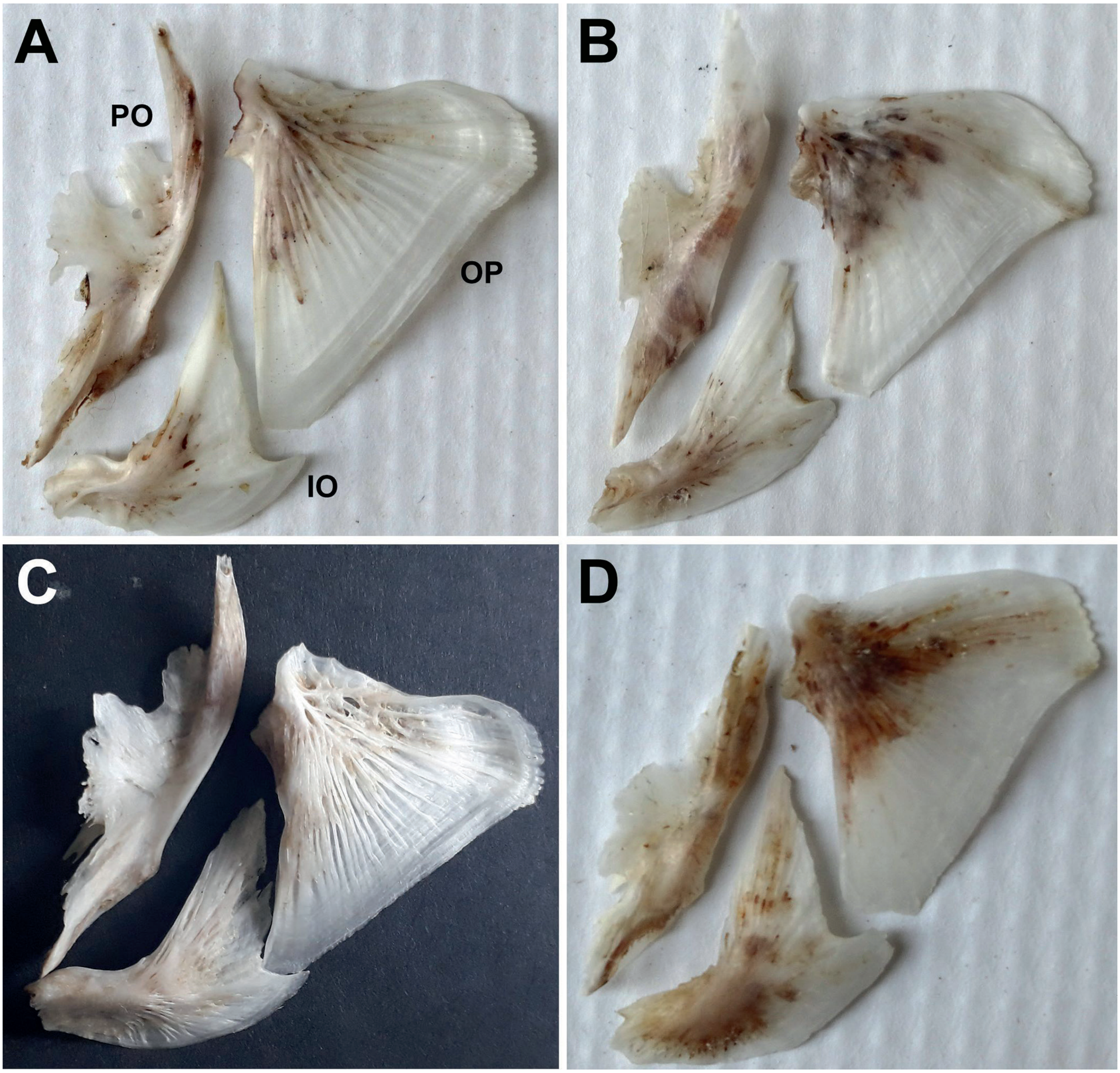


Figure 10. Cheek bones (extracted) of *Silurus glanis*, A, female; B, male. *Silurus triostegus*, C, female; D, male. OP, operculum; IO, interoperculum; PO, preoperculum.

ences in the morphology of fish permit adaptations to environmental alteration by modification of their physiology and behaviour to environmental conditions, which leads to changes in morphology, reproduction and survival (Stearns 1983, Meyer 1987). Jawad & Al-Janabi (2016) showed that *S. triostegus* was larger in the Tigris River at Mosul City and smaller in downstream populations from the Shatt al-Arab River. In the populations of the Tigris River at Baghdad City, the size of fishes was intermediate. They attributed these differences to water temperature as it varies between 8 to 18 ℃ in northern, 15 to 25 ℃ in central Iraq and 20 to 40 ℃ in southern Iraq (Al-Sanjari & Al-Tamimi 2009, Al-Noor et al. 2013).

Similarly, meristic characters such as the fin ray count and the number of vertebrae are fixed early during larval growth. These characters are affected by environmental factors, especially temperature (Täning 1952). It has been shown that the lower the temperature is in early life

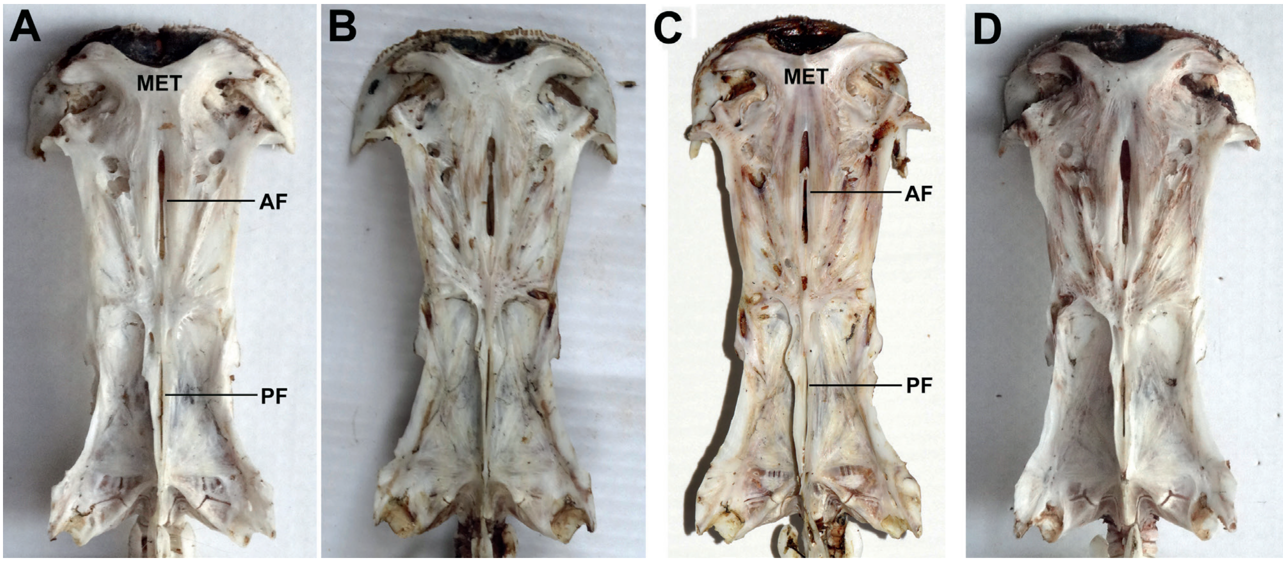


Figure 11. Dorsal side of the skull of *Silurus glanis*, A, female, B, male. AF, anterior fontanel; Dorsal side of the skull of Silurus triostegus, C, female, D, male. AF, anterior fontanel; PF, posterior fontanel, MET, mesethmoid bone.

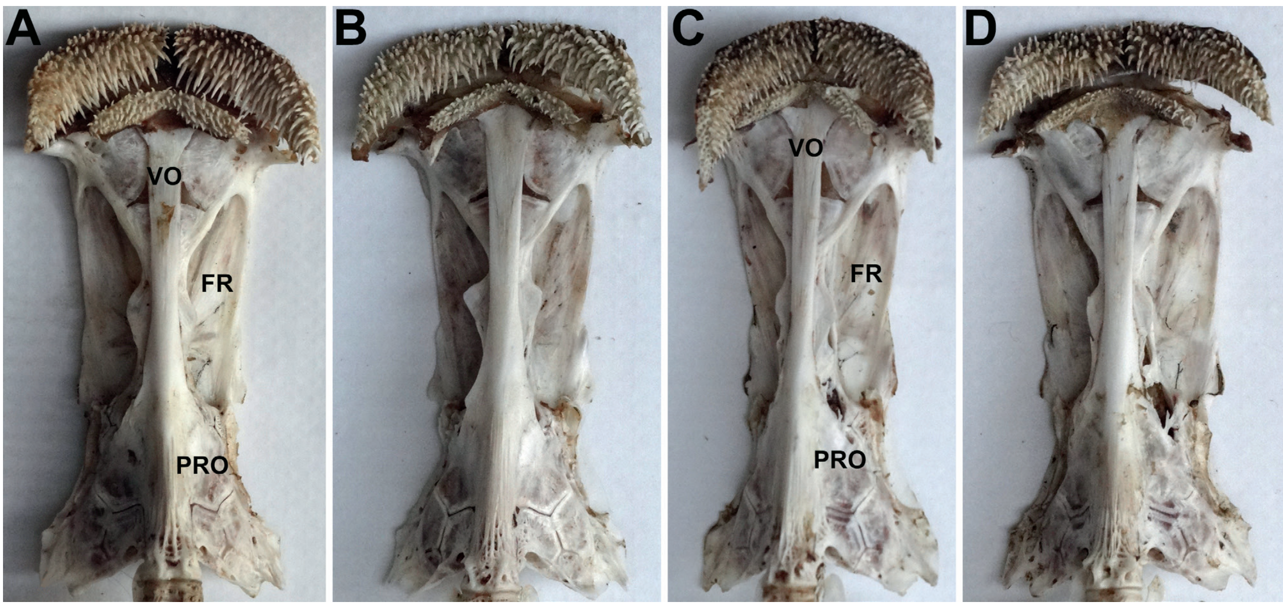


Figure 12. Ventral side of the skull of *Silurus glanis*, A, female, B, male. Ventral side of the skull of *Silurus triostegus*, C, female, D, male. FR, frontal bone; PRO, prootic bone, VO, vomer bone.

stages, the larger the number of vertebrae (Templeman & Pitt 1961). Jawad et al. (2017) have observed variations in meristic counts among the 16 populations of *S. triostegus* distributed in the Tigris, Euphrates, and Shatt al-Arab Rivers in Iraq. They suggested that such differences might be due to the environmental or genetic factors, or both.

The morphological similarities between *S. glanis* and its congener *S. triostegus* occurring in the inland water of Iraq in many instances hindered the identification process of both species. Several workers studied the general diagnostic characters of both species separately (Kottelat & Freyhof 2007; Coad & Holcik 2000, Coad 2010, 2014).

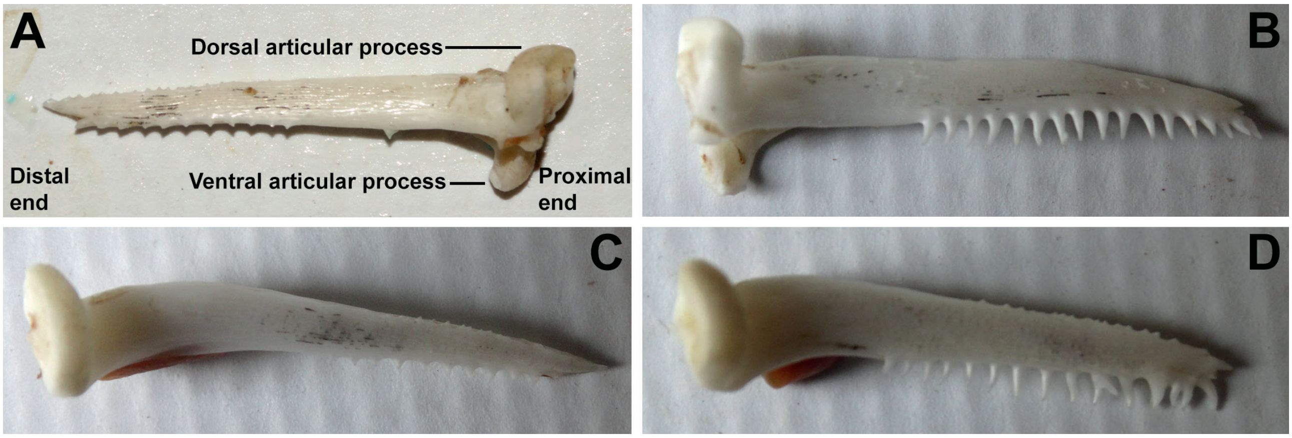


Figure 13. Pectoral spine of A, B, *Silurus glanis*; C, D, *Silurus triostegus*.

COAD (2010) mentioned some differences between the two species, but recently ÜNLÜ et al. (2012) added some more characters.

In this study, we were able to notify additional differences regarding osteological and other morphological characters. Also, differences in sexes of both *S. glanis* and *S. triostegus* were also given to provide a more complete picture regarding the characteristics of *S. glanis* and at the same time adding more taxonomic features to separate these two species.

The colour pattern shown in the *S. glanis* individuals collected from the freshwater system of Iran by COAD (2014) is completely different from the colour shades obtained in the present study. In addition, there is only one colour form in the Iranian specimens of *S. glanis*. Such variation in colouration of the same species could be related to the environment. MORRONGIELLO et al. (2010) and KELLEY et al. (2012) have shown that the colour patterns of a species or population are often correlated with the composition or luminance of light in the local habitat.

The differences observed in the morphometric characters between the two species were also noted by ÜNLÜ et al. (2012). They reported on differences in the morphometric ratios (SL/HL and SL/BD) between the two species. These results were supported by those obtained by KOBAYAKAWA (1989) and COAD (2010). As mentioned above, variabilities in morphometrics of the body size may be due to the alterations in environmental parameters such as water temperature.

However, KOBAYAKAWA (1989) argued that the number of mandibular barbels was not a valid benchmark for distinguishing these two taxa, as the number of barbels vary between 4 and 6. Individuals with a single pair of barbels were also found in *S. triostegus* specimens from Turkey and Iraq (ÜNLÜ & BOZKURT 1996, COAD 2010). Such variation in the number of barbels other than the standard number was also observed in both species by COAD (2010). HAIG (1952) suggested that some barbels are reabsorbed during ontogenetic development.

A similar width of the mesethmoid area like in *S. glanis* was also observed in another *Silurus* species, *S. aristotelis,* by KOBAYAKAWA (1989). On the other hand, a narrow mesethmoid area similar to that of *S. triostegus* is also present in *S. grahami* and *S. mento* (KOBAYAKAWA 1989).

Using morphometric distances between fish body parts for identification is not uncommon practice. FISHER & BIANCHI (1984) have mentioned the use of this technique to separate some species of the genus *Thryssa* (Engraulidae) and CLEMENTS et al. (2000) have used it to identify the triplefin species *Grahamina signata*. In the present study, this technique has been proven a good taxonomic criterion to separate *S. glanis* and *S. triostegus*.

The present study showed that the anterior side of the shaft of the pectoral fin spine is smooth only in the male individuals of *S. glanis*. This new finding affects the present known diagnostic character of *S. glanis* that the anterior side of the pectoral fin spine is smooth (ÜNLÜ et al. 2012, COAD 2014). The two species of the genus *Silurus* examined in the present study can be easily separated based on the characters of the pectoral spine. Differences between species of catfishes were also detected by other workers such as VASCOY et al. (2015) in the tribe Brachyplatystomini and VALLONE (2017) in Argentine Siluriformes. The occurrence of pectoral spines is an appropriate character in the diagnosis of Siluriformes. Numerous catfish fossils are only recognized by their spines, nevertheless, descriptions and illustrations of spines (both fossil and extant) of Siluriformes are scarce (ARRATIA 2003). The taxonomic importance of the presence of denticles in the pectoral spine of some catfish species such as *Corydoras paleatus* is evidence of the similarity between Loricariidae and Callichthydae (BISBAL & GÓMEZ 1986). As with other studies (Vallone 2017), the two catfish species in this study showed no relationship between fish size and the shape and the sizes of the pectoral spine. This result was also observed by other authors (Marzolf 1955; Sendra & Freire 1981; Bisbal & Gómez 1986). This is significant for the systematic interpretation of this group.

5 References

Al-Noor, T. A., Arslan, L. K. & Abd Ali, L. J. (2013): Studying the effects of Industrial Wastes on Tigris water in Al-Great City-Baghdad-Iraq. – Advances in Physics Theories and Applications **25**: 48–57.

Alp, A., Kara, C., Uckardes, F., Carol, J. & Garcia-Berthou, E. (2011): Age and growth of the European catfish (Silurus glanis) in a Turkish Reservoir and comparison with introduced populations. – Reviews in Fish Biology and Fisheries **21**: 283–294.

Al-Sanjari, M. N. & Al-Tamimi, M. A. (2009): Interpretation of Water Quality parameters for Tigris River within Mosul City by Using Principal Components Analysis. – Tikrit Journal of Pure Science **14**: 1–6.

Al-Sayab, A. A. (1988): Ecology and biology of Asian catfish, *Silurus triostegus* Heckel, 1843 in Hammar marsh, South Iraq. Thesis, Basrah University, Basrah, Iraq [In Arabic]).

Arratia, G. (2003): Catfish head skeleton: An overview. – In: Kapoor, A.S., Arratia, G., Chardon, M. & Diogo, R. (eds): Catfishes, pp. 3–46; Science Publishers, Inc., Enfield, NH, USA.

Bisbal, G. A. & Gómez, S. E. (1986): Morfología comparada de la espina pectoral de algunos Siluriformes Bonaerenses (Argentina). – Physis, Secc. B, **44** (107): 81–93.

Cerny, J. (1988): Osteology of the sheatfish (*Silurus glanis* Linnaeus, 1758). – Prace Ustavu Rybarstva a Hydrobiologie **6**: 181–209.

Ciepielewski, W., Martyniak, A. & Szczerbowski, J. A. (2001): Ichthyofauna in the Dokan and Derbendikhan reservoirs. – Archives of Polish Fisheries **9**, Supplement **1**: 157–170.

Clayton, J. W. (1981): The stock concept and the uncoupling of organismal and molecular evolution. – Canadian Journal of Fisheries and Aquatic Sciences **38**: 1515–1522.

Clements, K. D., Jawad, L. A. & Stewart, A. L. (2000): The New Zealand triplefin *Grahamina signata* (Teleostei; Tripterygiidae): a junior synonym of *G. gymnota* from Tasmania. – Journal of the Royal Society of New Zealand **30**: 373–383.

Coad, B. W. (2010): Freshwater fishes of Iraq. Pensoft Series Faunistica No. 93, 274 pp. Pensoft Publishers, Moscow.

Coad, B. W. (2014): Review of the freshwater catfishes of Iran (Order Siluriformes). – Iranian Journal of Ichthyology **1**: 218–257.

Coad, B. W. & Holcik, J. (2000): On *Silurus* species from Iran (Actinopterygii: Siluridae). – Folia Zoologica **49**: 139–148.

Fischer, W. & Bianchi, G. (eds) (1984): FAO species identification sheets for fishery purposes. Western Indian Ocean (Fishing Area 51). – FAO, Rome, vols 1–5.

Fricke, R. (ed.) (2020): Eschmeyer`s catalog of fishes. References. Online version, accessed December 2020. http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp

Froese, R. (2006): Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. – Journal of Applied Ichthyology **22**: 241–253.

Froese, R. & Pauly, D. (Eds) (2020): FishBase. World Wide Web electronic publication. Available at: www.fishbase.se, version 12/2020 (accessed December 2020).

Haig, J. (1952): Studies on the classification of the catfishes of the Oriental and Palaearctic family Siluridae. – Records of the Indian Museum **48**: 59–116.

Heckel, J. J. (1843): Abbildungen und Beschreibungen der Fische Syriens: Nebst einer neuen Classification und Characteristik sämmtlicher Gattungen der Cyprinen. Stuttgart.

Jawad, L. A. & Al-Janabi, M. I. (2016): Morphometric characteristics of catfish *Silurus triostegus* Heckel, 1843 from the Tigris and Shatt al-Arab Rivers, Iraq. – Croatian Journal of Fisheries, Ribarstvo **74**: 179–185.

Jawad, L. A., Ligas, A. & Al-Janabi, M. I. (2017): Meristic character variability among populations of *Silurus triostegus* Heckel, 1843 from the Euphrates, Tigris, and Shatt al-Arab Rivers, Iraq. – Archives of Polish Fisheries **25**: 21–31.

Kelley, J. L., Phillips, B., Cummins, G. H. & Shand, J. (2012): Changes in the visual environment affect colour signal brightness and shoaling behaviour in a freshwater fish. – Animal Behaviour **83**: 783–791.

Kobayakawa, M. (1989): Systematic revision of the catfish genus *Silurus*, with description of a new species from Thailand and Burma. – Japanese Journal of Ichthyology **36**: 155–186.

Kottelat, M. & Freyhof, J. (2007): Handbook of European freshwater fishes. Publications Kottelat, Cornol & Freyhof, Berlin. 646 pp.

Kuru, M. (1979): The freshwater of South-Eastern Turkey-2 (Euphrates-Tigris System). – Hacettepe Bulletin of Natural Sciences and Engineering **7**: 105–114.

Le Cren, E. D. (1951): Length-weight relationship and seasonal cycle in gonad weight and condition of perch (*Perca fluviatilis*). – Journal of Animal Ecology **20**: 201–219.

Marzolf, R. G. (1955): Use of pectoral spines and vertebrae for determining age and rate of growth of the channel catfish. – Journal of Wildlife Management **19**: 243–249.

Meyer, A. (1987): Phenotypic plasticity and heterochrony in *Cichlasoma managuense* (Pisces, Cichlidae) and their implication for speciation in cichlid fishes. – Evolution **41**: 1357–1369.

Morrongiello, J. R., Bond, N. R., Crook, D. A. & Wong, B. B. M. (2010): Nuptial coloration varies with ambient light environment in a freshwater fish. Journal of Evolutionary Biology **23**: 2718–2725.

Muscalu, R., Muscalu, C., Nagy, M., Bura, M. & Szelei, Z. T. (2010): Studies on wells catfish (*Silurus glanis*) development during cold season as an auxiliary species in sturgeon recirculated aquaculture systems. – AACL Bioflux **3**: 362–366.

Scherrer, B. (1984): Biostatistique. Gaëtan Morin, Québec, Canada.

Sendra, E. D. & Freire, L. R. (1981): Un método para la corrección de mediciones de las marcas periódicas de crecimiento en radios de peces. – Limnobios **2** (4): 233–238.

Sparre, P., Ursin, E. & Venema, S. C. (1989): Introduction to tropical fish stock assessment. Part 1. Manual, FAO. – Fish. Tech. Rep., 1989, vol. **306:** 337pp.

Stearns, S. C. (1983): A natural experiment in life-history evolution: field data on the introduction of Mosquitofish (*Gambusia affinis*) to Hawaii. – Evolution **37**: 601–617.

Täning, Å. V. (1952): Experimental study of meristic characters in fishes. – Biological Review **27**: 169–193.

Telcean, I. C. & Cupşa, D. (2009): The backwaters and drainage canals as natural refuges for the lowland rivers' fishfauna (Someş, Crişuri, and Mureş Rivers – north-western Romania). – Biharean Biologist **3**: 37–44.

Templeman, W. & Pitt, T. K. (1961): Vertebral numbers of redfish, *Sebastes marinus* (L.), in the North-West Atlantic, 1947.–1954. – ICES Rapp. Proc.-Verb. **150**: 56–89.

Ünlü, E. & Bozkurt, R. (1996): Notes on the catfish, Silurus triostegus (Siluridae) from the Euphrates River in Turkey. – Cybium **20**: 315–317.

Ünlü, E., Değer, D. & Çiçek, T. (2012): Comparison of morphological and anatomical characters in two catfish species, *Silurus triostegus* Heckel, 1843 and *Silurus glanis* L., 1758 (Siluridae, Siluriformes). – North-Western Journal of Zoology **8**: 119–124.

Vallone, E. R. (2017): Comparative morphology of the pectoral spine of some Argentine Siluriforms. – Scientia Interfluvius, Paraná **8**: 13–30.

Vanscoy, T., Lundberg, J. G., Luckenbill, K. R. (2015): Bony ornamentation of the catfish pectoral-fin spine: comparative and developmental anatomy, with an example of fin-spine diversity using the Tribe Brachyplatystomini (Siluriformes, Pimelodidae). – Proceedings of the Academy of Natural Science of Philadelphia **164**: 177–212.

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