

## Can an eel be a flatfish? Observations on enigmatic asymmetrical heterenchelyids from the Guinea coast of West Africa

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Morphological asymmetry is described in the heterenchelyid mud eel *Pythonichthys cf. macrurus* from inshore coastal waters of Guinea, West Africa. The intensity of asymmetry differs between two examined specimens, with the more extreme case exhibiting strong asymmetry in both external and internal features, including unilateral depigmentation, reductive degeneration and embedding of a blind-side eye, skewed jaws with reduced dentition and tooth loss. The extent and nature of asymmetry suggests that this individual probably lived primarily on its left lateral side, not unlike sinistral pleuronectiform flatfishes.

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Heterenchelyidae (Anguilliformes:Teleostei), a small family of so-called mud eels, contains two genera, *Panturichthys* Pellegrin 1913 (four species) and *Pythonichthys* Poey 1868 (four species)(Smith *et al.*, 2012). These fishes are rarely caught and remain largely understudied, resulting in very little information regarding their ecology or role in marine ecosystems. Heterenchelyids, however, share a number of traits that are purportedly linked to their infaunal lifestyle, including a series of specializations in external morphology, osteology and myology thought to facilitate predatory–evasive head-first burrowing into the substratum (Eagderi & Adriaens, 2010). The Ichthyology Department at the American Museum of Natural History (AMNH) received a collection of fishes trawled from the Guinea coast of West Africa during November of 2015 that included two eel specimens, one of which [AMNH 265399, female, total length ( $L_T$ ) 312 mm] was markedly asymmetrical in external appearance (Fig. 1). The second specimen (AMNH 265398, female,  $L_T$  373 mm), collected some 10 km to the east, although less modified, also exhibited strongly asymmetrical pigmentation patterning (Fig. 2). Apart from asymmetry, the heterenchelyid identification key of Smith

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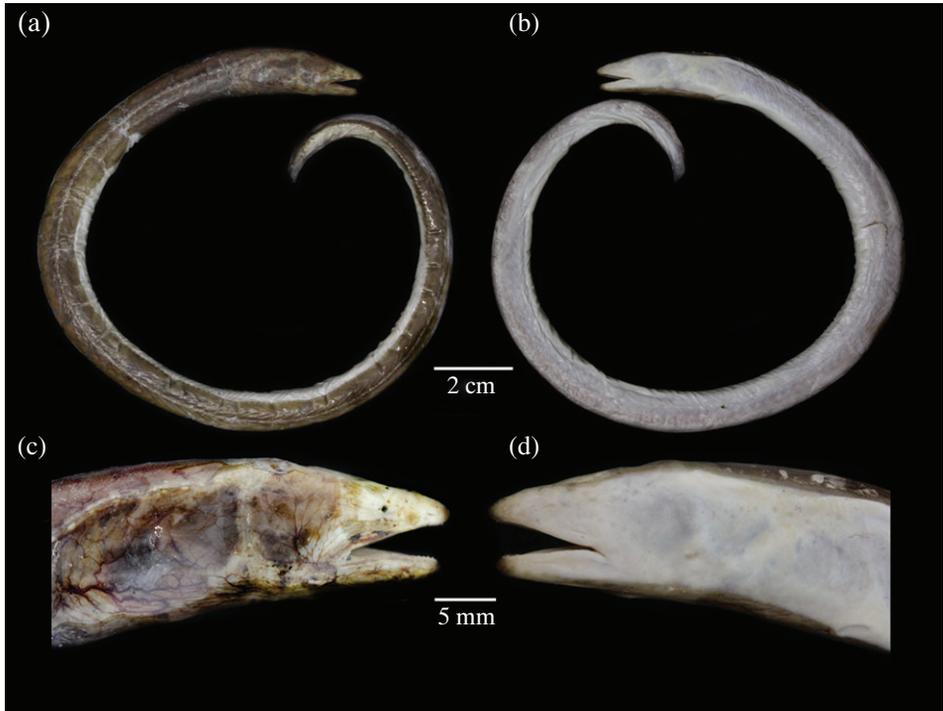


FIG. 1. *Pythonichthys cf. macrurus* (specimen AMNH 265399) displaying asymmetrical morphologies: (a) right lateral view; (b) left lateral view; (c) right lateral head profile; (d) left lateral head profile.

*et al.* (2012) indicates that the Guinean eels fall well within the known geographical and morphological–meristic range of *Pythonichthys macrurus* (Regan 1912). As no record of asymmetry in this, or any other heterenchelyid species has previously been reported and in the absence of genetic resources to compare the Guinean specimens with other *Pythonichthys* species, the taxonomic uncertainty is acknowledged herein. This manuscript presents a brief description of the unique morphological irregularities present in the asymmetric heterenchelyids recently collected from the Guinea coastal region, designating them as *P. cf. macrurus*.

Few heterenchelyids are available in museum collections, therefore non-destructive methods were employed for examinations of specimen morphologies. External anatomy was examined in all comparative materials, while osteology was compared for *P. macrurus* and *P. cf. macrurus* specimens based on whole-body x-rays and micro-computed tomography (mCT) scans of cranial and branchial regions. In order to visualize the ocular globes, one specimen (AMNH 265399) was also incubated in 1% aqueous phosphotungstic acid (PTA) for 10 days prior to scanning.

As in other heterenchelyids, the Guinean eels lack pectoral fins and both median fins are fully embedded under flesh, but their external appearance featured several notable differences when compared with other *Pythonichthys* specimens. The Guinean eels exhibit strong countershading, with areas of heavy pigmentation (medium to dark brown in colour) contrasted by other completely unpigmented and creamy-white areas. In AMNH 265399, the entire left lateral side lacks pigmentation, creating a blind side



FIG. 2. *Pythonichthys cf. macrurus* (AMNH 265398) showing asymmetrical pigmentation on body and left lateral head profile.

(Fig. 1). In AMNH 265398, white unpigmented skin occurs on the ventral surface over the middle one third of the body, but is found on the left side approaching the head and on the right side approaching the caudal region (Fig. 2). Discoloration is not an artefact of preservation, as images of specimens taken directly after capture showed identical pigmentation patterning. Other accounts and the authors' own observations of heterenchelyids, suggest muted, if any, countershading (Rosenblatt & Rubinoff, 1972; Eagderi & Adriaens, 2010; Smith *et al.*, 2012). As in all heterenchelyids, lateral-line pores are absent (Rosenblatt & Rubinoff, 1972). Unlike the condition in other specimens, however, embedded lateral-line canal ossicles in Guinean specimens are clearly visible externally in pigmented regions [Fig. 1(a), (c)], but less so in unpigmented regions [Fig. 1(b), (d)]. Finally, the blind side of AMNH 265399 lacks an externally visible eye and nostril openings, while present, are greatly reduced in size.

Examination of x-rays and CT scans revealed additional, internal asymmetry in AMNH 265399, relative to other specimens. On the blind side, a greatly diminished ocular globe, consisting of an isolated lens, is visible deeply embedded in the tissues of the head (Fig. 3). In addition to a structural reduction, the blind-side eye is recessed beneath a thick layer of flesh that covers the entire side of the head, resulting in a unique example of unilateral cryptophthalmia (*sensu* Schobert *et al.*, 2012). The fourth and fifth infraorbitals on the blind side are moderately crowded in comparison to those on the right, leading to a closer association with the neurocranium and a reduction in size of the fifth element. Finally, the most striking differences are evident in the asymmetry of the lower jaws and their dentition. Curvature of the left side dentary is markedly reduced, such that the mouth lies flat on the blind side of the body (Fig. 4). The right dentary appears unmodified and bears 22–23 apically recurved, conical teeth, uniformly arrayed along an outer row [Fig. 4(b)]. In contrast, outer row dentition on the left dentary is reduced to 8–9 irregularly arrayed recurved unicuspid teeth anteriorly on the jaw, while posteriorly teeth are mostly missing or, if present, are weakly developed [Fig. 4(a)].

Morphological asymmetry is a pervasive phenomenon among pleuronectiform flatfishes and oral jaw asymmetry has also been documented in scale-eating cichlids of the genus *Perissodus* Boulenger 1898 (Stewart & Albertson, 2010; Raffini *et al.*, 2016), but has never before been reported for any other fish taxon. Given the small sample size

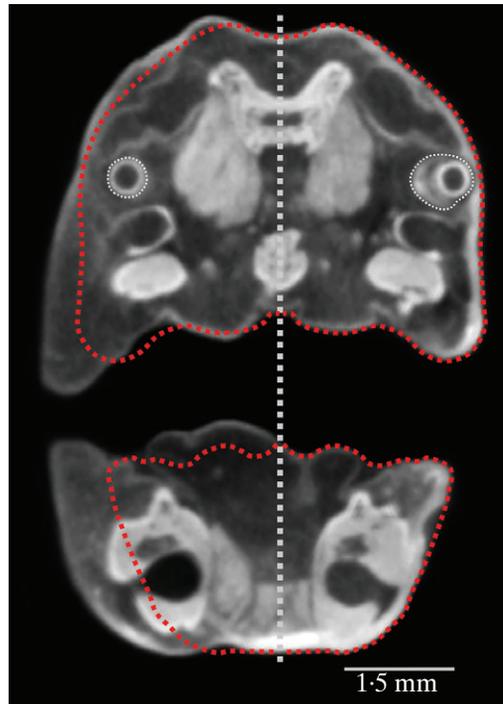


FIG. 3. Transverse cross-section from a micro-computed tomography (CT) scan of *Pythonichthys cf. macrurus* (AMNH 265399) after treatment with 1% aqueous phosphotungstic acid (PTA). A line (.....) around the right side is reflected onto the left side to emphasize the degree of asymmetry. Note the thickened flesh on the left (blind) side of the head. The eyes are delineated (---) with a full optic orb visible on the right and a deeply embedded lens on the left. |, Anatomical median line.

currently available, it is unclear how prevalent the condition is and to what extent it is expressed across populations of *P. macrurus*–*P. cf. macrurus* in the eastern Atlantic Ocean generally. Regardless, while all heterenchelyids possess reduced eyes (Eagderi & Adriaens, 2010), and there is no apparent eye migration in the specimens examined here, in many respects the asymmetry exhibited by the Guinean eels (particularly AMNH 265399) mirrors aspects found in numerous pleuronectiform flatfishes. For instance, the presence of one flattened unpigmented side and a more convex pigmented side is a characteristic of those benthic fishes. Further, the asymmetrical lower jaw, loss of teeth and reduced blind side laterosensory system are also common features of many pleuronectiforms (Chapleau, 1993; Cooper & Chapleau, 1998). While based on limited samples, the morphological variations described here suggest a potentially novel insight on heterenchelyid ecological diversity and strongly indicate that these individuals are not active head-first burrowers, but more likely sit-and-wait ambush predators, lying with a lateral side in contact with the sediment surface.

Comparative materials include:

*Pythonichthys cf. macrurus*: AMNH 265398, 1 ex., Guinea coast, offshore trawl, 9.21666° N; 13.3577° W–9.22589° N; 13.36555° W, depth 10.4–11 m, EI-15-XI-CF09.

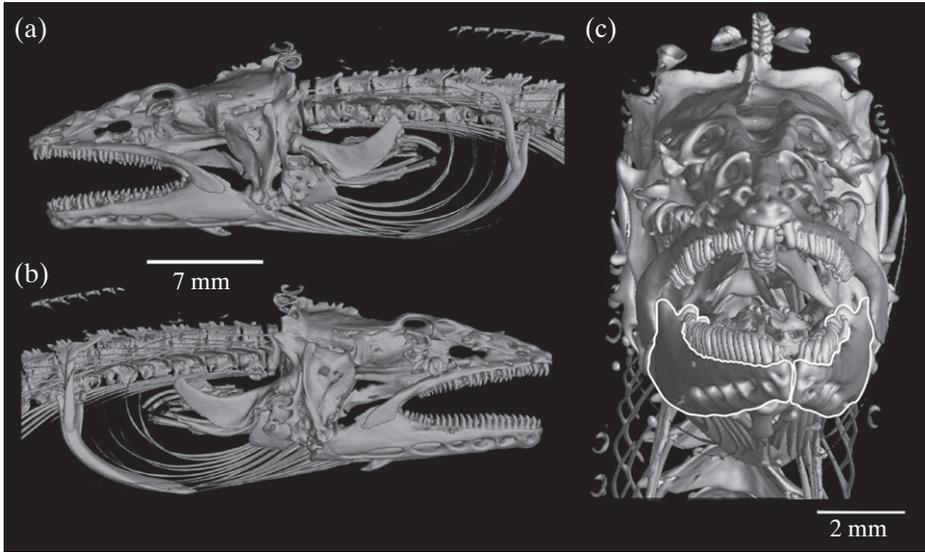


FIG. 4. Micro-computed tomography (CT) scans of *Pythonichthys cf. macrurus* (AMNH 265399): (a) left lateral view; (b) right lateral view; (c) frontal view with contralateral dentaries outlined (—) to emphasize asymmetry.

*Pythonichthys cf. macrurus*: AMNH 265399, 1 ex., Guinea coast, offshore trawl, 9.14381° N; 13.31205° W–9.15119° N; 13.3177° W, depth 10.1–10.9 m, EI-15-XI-CF11.

*Pythonichthys macrurus*: USNM (National Museum of Natural History, Smithsonian Institution, Washington, D.C.) 311225, 1 ex., Dahomey: Au Large Cotonou, Benin, 273612, F. Paraijo.

*Pythonichthys micropthalmus* (Regan 1912): AMNH 17142, 1 ex., off mouth of Congo River at Banana, Democratic Republic of Congo, H. Lang and J.P. Chapin.

*Panturichthys mauritanicus* (Pellegrin 1913): AMNH 73239, 2 ex., off Mauritania, H. Genthe *et al.*

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