

Scale-stacking in the live-bearer *Belonesox belizanus* (Poeciliidae)

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(Received 20 November 2012, Accepted 3 July 2013)

An incidence of scale-stacking was found in a museum collection of *Belonesox belizanus* (Poeciliidae) from the Río Tesechocán, Veracruz, México. This phenomenon is thought to be unique to lepidophagous East African cichlids, although no studies have addressed the behaviour in any detail. This finding in *B. belizanus*, the first in Cyprinodontiformes, indicates *Belonesox* is able to manipulate scales into stacks in the buccal cavity.

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Key words: Central America; life history; México; pike killifish; scale-eating; trophic strategy.

Belonesox belizanus Kner 1860 is the largest live-bearing toothcarp (Poeciliidae) reaching >200 mm total length (L_T) (Lucinda, 2003). It occurs along the Atlantic Ocean Slope from México to Northern Costa Rica and invasive populations occur in southern Florida (Page & Burr, 1991, 2011). *Belonesox* is monotypic and sister to *Gambusia* (Hrbek *et al.*, 2007), a diverse genus of primarily insectivorous species. Unlike all other poeciliids and most cyprinodontiforms, *B. belizanus* is primarily piscivorous and possesses a unique jaw morphology, including a dorsally rotating premaxilla that is used to produce an enlarged gape, thereby facilitating the ingestion of larger prey items (Turner & Snelson, 1984; Greven & Brenner, 2008; Ferry-Graham *et al.*, 2009).

While examining morphological variation in museum specimens across the range of *B. belizanus*, stacked scales were observed in the buccal cavities of several specimens from a population from the Río Tesechocán (part of the Río Papaloapan system), Veracruz, México. The museum lot under inspection (Field Museum of Natural History, Chicago, IL; lot FMNH 4686) was collected by S.E. Meek in 1903 and the specimens are in fairly good condition given their age. The phenomenon of scale-stacking is previously known only in obligate lepidophagous cichlids from East Africa (Liem & Stewart, 1976; Konings, 1998). Although lepidophagy has evolved multiple times within fishes, scale-stacking has only been documented in two species of African cichlids, *Perissodus microlepis* Boulenger 1898 (Liem & Stewart, 1976)

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and *Plecodus multidentatus* Poll 1952 (Konings, 1998); thus the existence of stacked scales in the buccal cavity of *B. belizanus* is particularly interesting. Scale-stacking behaviour consists of several scales manipulated in the jaws and stacked, *i.e.* one on top of the other, in the buccal cavity. Once stacked, the scales are swallowed as a packet, which is believed to more efficiently fill a short digestive tract (Liem & Stewart, 1976; Konings, 1998). Dissection of these two cichlid species has shown packets of neatly stacked scales. No other scale-stacking behaviour has been documented in cichlids (Fryer *et al.*, 1955; Nshombo, 1994). It has yet to be determined if this behaviour has been overlooked in other species or simply does not exist. The presence of stacked scales in the Río Tesehocán population of *B. belizanus* indicates that further investigation of this issue is needed.

Twelve of the 15 specimens from the Río Tesehocán lot (56.8–91.7 mm, standard length, L_S) were found to have a large number of scales in their mouths, with 10 specimens each containing one stack of several (3–12) scales in the posterior portion of the buccal cavity, neatly stacked atop each other and centred over the tongue (Fig. 1). To further examine this phenomenon in *B. belizanus*, additional specimens from throughout the range, encompassing 54 lots with 403 total individuals, were examined for the presence of scales in the buccal cavity. In 28 of the 54 museum lots from across the range of *B. belizanus*, scales were observed wedged between teeth; however, no evidence of scale-stacking was found in these specimens.

In addition, to assess the likelihood of lepidophagy, gut content analysis was performed on specimens containing scale-stacks. The entire gut was cut longitudinally so that content could be evaluated under a dissecting microscope. No identifiable scales were observed in the gut of any specimens; however, no other identifiable material was found in the gut as well. The lack of evidence of stacked scales in the gut may be the result of the fish being collected before actual consumption, or that consumed scales were digested and unidentifiable due to the ability of *B. belizanus* to quickly digest materials. Unfortunately, the pace of digestion in *B. belizanus* has never been examined. Because of its propensity to consume the prey tail-first (E. Marchio, pers. obs.), it would be interesting to see how its digestive ability compares to the more common head-first consumption of other piscivores. It is also possible that this population of *B. belizanus* never intended to ingest the scales, but stacked them in order to expel them from the oral cavity. This activity has never been documented in *B. belizanus*.

As stated, scale-stacking could be a means of mass removal of the scales from the oral cavity. *Belonesox belizanus* teeth can be depressed 45° posteriolaterally (Greven & Brenner, 2008). This could allow the fish to push scales back onto the tongue where they are stacked. The teeth of *B. belizanus*, however, resist anterior depression potentially making mass removal of scales from the mouth difficult. Additionally, mass scale removal has never been documented in any species. It seems unlikely that a fish would manipulate nutritious and digestible material in order to simply expel it from the oral cavity. Scales are an excellent source of carbohydrates and minerals, such as calcium and phosphorous, and may be eaten in order to supplement a diet lacking in these nutrients (Nico & de Morales, 1994). Fishes are not considered to be fully lepidophagous unless scales are found in the stomach without the presence of bones or flesh (Peterson & McIntyre, 1997). With the evidence gathered here, it is evident that *B. belizanus* is not fully lepidophagous but some are capable of manoeuvring and manipulating scales into stacks (Fig. 1),

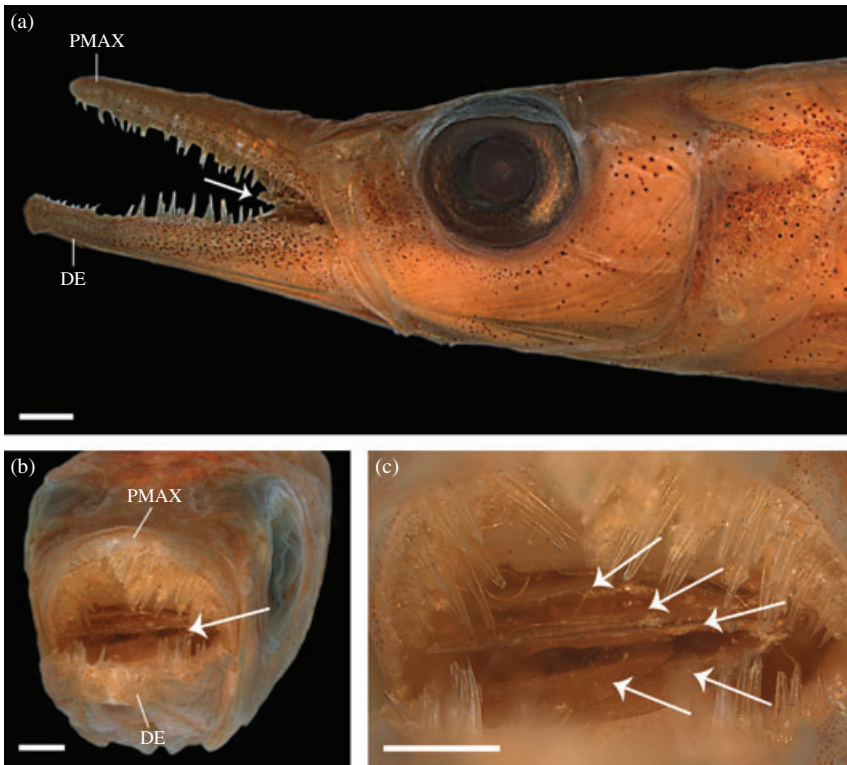


FIG. 1. *Belonesox belizanus*, FMNH 4686, 62 mm standard length (L_S) individual from the Río Tesehocacán, Veracruz, México. (a) Lateral view. \Rightarrow , the location of stacked scales in the buccal cavity. Scale bar = 2.5 mm. (b) Anterior view of the jaws. \Rightarrow , the location of stacked scales. Scale bar = 2.5 mm. (c) Anterior view close-up clearly showing five scales stacked atop each other (\Rightarrow). Scale bar = 1.25 mm. DE, dentary; PMAX, premaxilla.

a phenomenon not previously documented in any poeciliid or cyprinodontiform species. Further study is required in order to increase sample sizes and fully quantify gut contents in modern Río Tesehocacán populations of *B. belizanus*.

These observations show that *B. belizanus* are as unique as their morphology predicts and because *B. belizanus* is so widely distributed and scale-stacks were only observed in one population, this interesting observation warrants further study. It further suggests that a more detailed investigation into the feeding behaviours of lepidophagous species is needed to better understand this interesting life-history strategy.

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