Journal of Fish Biology (2007) **71,** 279–283
doi:10.1111/j.1095-8649.2007.01473.x, available online at http://www.blackwell-synergy.com

The air-breathing behaviour of *Brevimyrus niger* (Osteoglossomorpha, Mormyridae)

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(Received 2 May 2006, Accepted 6 February 2007)

Brevimyrus niger is reported to breathe atmospheric air, confirming previous documentation of air breathing in this species. Air is taken up by rising to the water surface and gulping, or permanently resting just below the surface, depending on the environmental conditions.

Key words: elephantfishes; Osteoglossomorpha; weakly electric fish.

The Mormyridae consists of 201 weakly electric fishes endemic to Africa (Nelson, 2006). They belong to the Osteoglossomorpha among which air-breathing behaviour is known from several families. All genera of the Osteoglossidae are able to breathe atmospheric air utilizing their swimbladder as a respiratory organ, *i.e*. *Heterotis niloticus* (Cuvier) (Lüling, 1977), *Arapaima gigas* (Schinz) (Lüling, 1964, 1977). Similarly, *Pantodon buchholzi* Peters (Schwarz, 1969), which is the only member of the Pantodontidae, and the members of the Notopteridae (Graham, 1997) are air-breathers. A close relative to the mormyrids, *Gymnarchus niloticus* Cuvier, the only member of the Gymnarchidae, is also well known to breathe air (Hyrtl, 1856; Bertyl, 1958). In the remaining two families within the Osteoglossomorpha air breathing has never been reported from the Hiodontidae (Graham, 1997) and only for a single species, *Brevimyrus niger* (Günther), within the Mormyridae (Benech & Lek, 1981; Bigorne, 2003). Benech & Lek (1981) described the air-breathing behaviour, but their results have not been cited in studies on air-breathing fishes (Graham, 1997) or the behaviour of mormyrids (Moller, 1995). During fieldwork in Benin, Burkina Faso and Sudan, and associated photographic analysis of live specimens, observations have been made which confirm that *B. niger* has the ability to breathe

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air. Four different sets of observations have been made, and are discussed below.

In a rainforest fragment in southern Benin (7°30′40″ N; 2°5′32″ E) fish were caught in traps for a species survey during three nights in May 2005. *Brevimyrus niger* ($n = 46$) always died in completely submerged traps, as did most of the *Xenomystus nigri* (Günther) ($n = 43$, of which only three stayed alive), an air-breathing notopterid. Another mormyrid, *Brienomyrus longianalis* (Boulenger), however, usually survived ($n = 17$, of which only three died). It seemed that *B. niger*, like *X. nigri*, was drowned in the traps.

In the savannah region of West Africa (*e.g.* in the Upper Volta system), in small sun-exposed residual ponds, *B. niger* is often found in large schools of similar sized specimens. *Brevimyrus niger* was the only mormyrid to be found in these hot and shallow ponds during a cumulated 12 month period of fieldwork between October 2003 and May 2005. It was found together with several species of air-breathing fishes, such as *Polypterus senegalus* Cuvier, *Polypterus endlicheri* Heckel, *Clarias gariepinus* (Burchell) and *Ctenopoma petherici* Günther. Non air-breathing fishes such the cichlids *Hemichromis bimaculatus* Gill and *Oreochromis niloticus* (L.), and annual killifish, *Pronothobranchius kiyawensis* Ahl and *Fundulosoma thierry* Ahl (Wildekamp & van der Zee, 2003), however, were also found. This finding, by itself, only indicates that *B. niger* is adapted to survive in low oxygen environments, but does not necessarily attest air-breathing capability. Other observations noted here and by Benech & Lek (1981), however, indicate the likelihood of air breathing in these conditions.

In the Pendjari National Park, northern Benin, the fish community of a desiccating pool of *c.* 30 m in diameter and only 0·5 m depth was studied at the end of April 2005. At this time, which is the end of the dry season in this region, the water temperature exceeded 41° C in this pool during noon. With the exception of a single *H. bimaculatus*, only air breathers like *C. gariepinus* and *Parachanna obscura* (Günther) and again many *B. niger* have been found. Due to high sediment loads of the pool it was impossible to see fish swimming very far below the surface, but fish have been observed swimming continuously, in schools, immediately below the surface with their mouths open. Using a 1 × 1 m umbrella net these fish have been collected and identified as *B. niger* (64–92 mm standard length, L_S, only 16 collected and measured, although several more were present). It has not been possible, however, to ascertain whether the fish were air breathing or using the uppermost water layer, which contains some oxygen *via* diffusion, as known for many tropical fishes (Kramer & McClure, 1982). This behaviour of skimming the surface with the mouth agape is observed in other species which are not known to breathe air and are only very rarely reported to swallow atmospheric air.

In January 2006, the air-breathing behaviour of two specimens of *B. niger* could be observed repeatedly in an aquarium. The specimens measured *c.* 60 mm L_S and were caught in the White Nile at Kosti, Sudan (13°10′21″ N; 32°40′23″ E). The behaviour was documented five times by filming with a Nikon Coolpix 4500 camera (Fig. 1): the fish approached the surface [Fig. 1(a), (b)] and started to release five to seven air bubbles over a period of *c.* 0·5 s [Fig. 1(c)–(h)]. Next it swam to the surface [Fig. 1(i), (j)] and ingested air [Fig. 1(k)]. After a short break of *c.* 0·2–0·4 s [Fig. 1(l), (m)] it ingested air for a second time

FIG. 1. Air breathing in *Brevimyrus niger*. (a), (b) approaching the surface, (c)–(h) releasing used air through gill opening, (i)–(k) reaching the surface and breathing first time, (l), (m) resting below the surface, (n) breathing a second time and (o) submerging. Air bubbles are indicated by white arrows. Numbers in right corner indicate time in seconds.

[Fig. 1(n)]. Upon submerging a few small air bubbles commonly leaked from the gill slits [Fig. 1(o)]. Each fish repeated this behaviour more or less every 90 s, each time ingesting air two times with a short interval of *c.* 0·4 s in-between.

In conclusion, field observations and photographic documentation of *B. niger* confirm the report of Benech & Lek (1981) and indicate the air-breathing capability within the Mormyridae. Benech & Lek (1981) did not, however, report the typical two-fold air-gulping during breathing behaviour. Air breathing has not yet been reported from any other species of mormyrid, although several

species are kept for the aquaria trade or are under close observation in scientific institutions working on the electro-communication and electro-orientation of this family. Thus, air breathing is probably not widely distributed within the Mormyridae and may be restricted to *B. niger*. If oxygen concentrations in the water are high it seems unnecessary for *B. niger* to breathe atmospheric air. Exceptions are given by stressful situations which may also elicit air-breathing behaviour (Benech & Lek, 1981). At low oxygen concentrations, as in the aquarium used for photography, the fish breathe air intermittently, and if virtually no oxygen is present, they stay continuously on the surface, as described. Under certain circumstances *B. niger* will even drown although oxygen concentrations still allow related species to survive. Thus *B. niger* appears to be a facultative air-breather in most circumstances, but it may be forced to breath air under some naturally occurring conditions. Similar observations have been made in *Amia calva* L. in which air breathing is almost negligible at temperatures of 10° C, but is inevitable at temperatures of 27° C (Johansen *et al.*, 1970).

The organ used for air breathing has not been identified thus far. The observation that some small bubbles leak from the gill slits may indicate that air is stored somewhere in the branchial chamber. On the other hand, the observation that they ingest air twice when approaching the surface may indicate that the air has to be swallowed to fill an air-breathing organ with more volume than the orobranchial cavity. All other air-breathing osteoglossomorphs breathe by use of the gas bladder, which has often large development of its gas exchange surface, *e.g.* in *Arapaima gigas* (Lüling), *Pantodon buchholzi* (Poll & Nysten) or *Gymnarchus niloticus* (Hyrtl). Dissections made as a part of this study did not reveal a similarly large development of the gas exchange surface of the bladder in *B. niger*. Additional experiments involving manipulation of oxygen levels in aquarium tanks are required to specify under which conditions the air-breathing behaviour of *B. niger* is obligatory or facultative. Only two specimens, however, have been available for study thus far. Both show air-breathing behaviour as described above at low oxygen concentrations (20% oxygen saturation at 26° C) and do not show such behaviour during usual aquarium conditions (80–100% oxygen saturation at 26° C). Nevertheless, statistically reliable analyses have not been possible with this small sample size.

P. Lalèyè, B. Sinsin and A. El-Din helped with receiving research permits and V. von Vietinghoff and K. Conway assisted in fieldwork. K. Conway made helpful comments on the manuscript and R. Mayden supported the fieldwork in the Republic of Sudan. This study was partly funded by the German Federal Ministry of Education and Research (BMBF), W07 BIOTA-West Africa, FZ01L0017.

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