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Temporal and spatial distribution of young *Brachyplatystoma* spp. (Siluriformes: Pimelodidae) along the rapids stretch of the Madeira River (Brazil) before the construction of two hydroelectric dams

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Monthly (April 2009 to May 2010) bottom-trawl sampling for *Brachyplatystoma* species along the rapids stretch of the Madeira River in Brazil revealed that *Brachyplatystoma rousseauxii* larvae and juveniles were present in low abundances in all areas and during all hydrological periods. The presence of larvae and juveniles throughout the hydrological cycle suggests asynchronous spawning in the headwaters of the Madeira River.

Key words: dourada catfish; hydrological cycle; natural barriers; young-of-the-year.

The giant Pimelodid catfishes of the genus *Brachyplatystoma* inhabit the main channel of large Amazonian rivers (Lundberg & Akama, 2005). These heavily exploited migratory species are among the most important commercial fishes of the Amazon Basin (Barthem & Goulding, 1997, 2007; Petrere *et al.*, 2004). *Brachyplatystoma rousseauxii* (Castelnau 1855) has an exceptional life cycle. Adults reproduce in the headwaters of

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the main turbid water rivers in the pre-Andean portion of Ecuador, Peru, Colombia and Bolivia (García-Vásquez *et al.*, 2009; Vam Damme *et al.*, 2011; Agudelo *et al.*, 2013) and the larvae and juveniles drift thousands of km downstream to the Amazon Estuary, where they are resident for two years and then start migrating back towards the headwaters (Barthem & Goulding, 1997, 2007). During this migration, the fish grow and initiate their gonadal maturation, which is completed close to the headwaters (Barthem *et al.*, 1991; Barthem & Goulding, 1997; Alonso, 2002; García-Vásquez *et al.*, 2009).

Brachyplatystoma spp. are considered heavily or overexploited in Brazil, Colombia and Peru, where they are caught by driftnet and bottom longline fishing (Petrere *et al.*, 2004; García-Vásquez *et al.*, 2009; Agudelo *et al.*, 2013). The upper Madeira Basin represents the last area of the Amazon Basin where these species are considered to still be weakly exploited (Vam Damme *et al.*, 2011). This refuge, however, is now threatened by the construction of at least two hydroelectric power plants in the Brazilian part of the Madeira River, which might disrupt natural upstream breeding movements of these catfishes and the downstream drifting of their larvae and juveniles.

The aim of this study was to assess the spatial and temporal variation in the natural abundance of larvae and juveniles of *Brachyplatystoma* spp. along the rapids stretch of the Madeira River prior to the construction of the reservoirs of the Jirau and Santo Antonio power plants.

The Madeira River begins at the confluence of the Mamoré and Beni Rivers on the border between Brazil and Bolivia. The abrupt elevation change in the transition from the Brazilian central highlands to the Amazon lowlands results in a series of rapids, where the steepest waterfalls are situated in a 300 km river stretch between the cities of Guajará-Mirim and Porto Velho in the State of Rondônia, Brazil, where this study was conducted (Fig. 1). This section of river includes 19 major rapids, two of which, the Jirau and Teotônio Waterfalls, have abrupt falls (Cella-Ribeiro *et al.*, 2013). In this region, the river channel is between 350 and 1500 m wide, 3–33 m deep and water velocity is up to $2{\cdot}5\ \mathrm{m\,s^{-1}}$ in rapids and waterfalls. Three areas were sampled during this study: (A) upstream Jirau Waterfall, (B) between the Jirau and Teotônio Waterfalls and (C) downstream of the Santo Antonio Waterfall (Fig. 1). In each area, samples were collected from five stations, resulting in a total of 15 fixed sampling stations where fish populations were sampled monthly between April 2009 and May 2010 resulting in 210 samples (three areas × five stations × 14 months). Sampling was conducted using a 3 m long × 1 m wide bottom trawl that was hauled behind a boat, as described by López-Rojas *et al.* (1984). The net had a 5 mm mesh bag that was lined with 1 mm mesh netting. A 10 min trawl haul was performed at each sampling station at depths between 5 and 25 m according to the seasonal variation in the water level of the Madeira River.

Most of the sampled *Brachyplatystoma* spp. larvae and juveniles were already dead when pulled out of the water. The few individuals collected alive were euthanized with an overdose of anaesthetic (eugenol or clove oil) and subsequently fixed in a solution of 10% formalin. Fishes were transported to the Ichthyology and Fishing laboratory of the Universidade Federal de Rondônia (UNIR) for sorting, identification and measurement (standard length, L_S, mm). The developmental stage of each individual was determined based on morphological characteristics and pigmentation, according to Nakatani *et al.* (2001) and Leite *et al.* (2007). Voucher specimens were deposited in the UFRO-I fish collection (Universidade Federal de Rondônia, Porto Velho, Brazil).

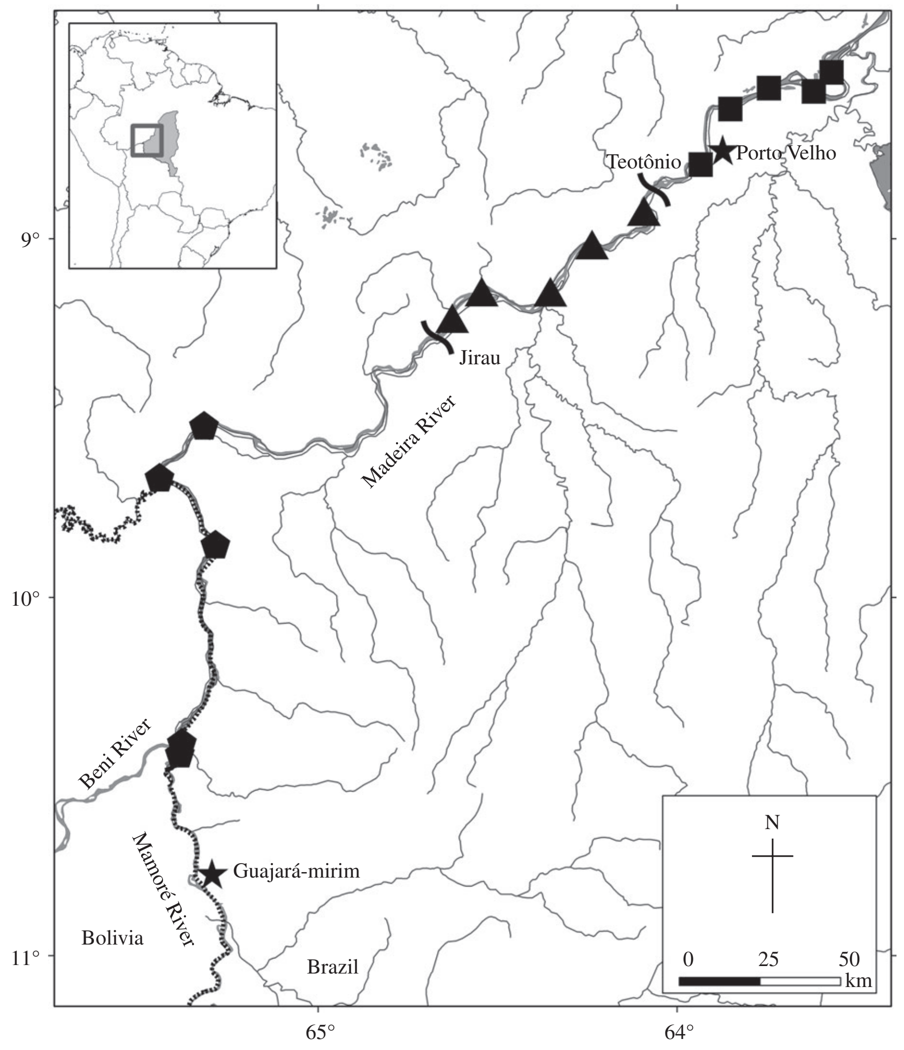

FIG. 1. Map of the study areas: A (⬟), B (▲) and C (■) (⋯⋯, political boundaries; ⟍, waterfalls).

A total of 80 *B. rousseauxii* and 58 of other *Brachyplatystoma* species were collected. Forty four specimens (three juveniles and 41 larvae) were too small or damaged for species identification. The remaining 14 specimens were *Brachyplatystoma filamentosum* (Lichtenstein 1819) ($n = 1$), *Brachyplatystoma capapretum* Lundberg & Akama 2005 ($n = 8$) and *Brachyplatystoma platynemum* Boulenger 1898 ($n = 5$). Juveniles were more abundant than larvae for all species in all samples. No specimens (larvae or juveniles) of *B. capapretum* and *B. filamentosum* were collected upstream of the Jirau Waterfall (area A), and no larvae or juveniles of *B. platynemum* were observed in the samples taken between Jirau and Teotônio Waterfalls (area B). Below the rapids stretch (area C), almost all sampled individuals were juveniles.

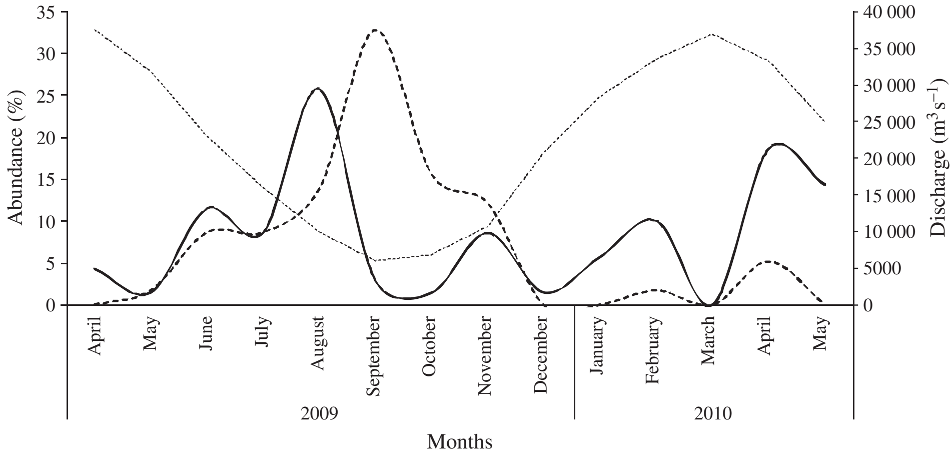

Fig. 2. Relative abundance of each *Brachyplatystoma* species per sampling month, all sampling stations pooled (------, unidentified *Brachyplatystoma* spp.; ——, *Brachyplatystoma rousseauxii*; ...., discharge $m^3 s^{-1}$).

Brachyplatystoma spp. larvae and juveniles were collected throughout the hydrological cycle, but mostly between June and November (dry season) (Fig. 2). There was, however, no difference in the abundance (ANOVA, d.f. = 2,437, $P > 0{\cdot}05$) and L_S (ANOVA, d.f. = 0,187, $P > 0{\cdot}05$) of larvae and juveniles of *B. rousseauxii* among the three sampling areas (Table I). Similarly, no significant temporal difference in the abundance of *B. rousseauxii* (grouping larvae + juveniles) was detected between the flood and dry periods (*t*-test, d.f. = 11, $P > 0{\cdot}05$; Table II).

During the 14 months of the study, the bottom-trawl sampling of the Madeira River resulted in very low overall abundances of larvae and juvenile fishes compared with other studies in the Amazon and Orinoco Basins (López-Rojas *et al.*, 1984; Cox-Fernandes *et al.*, 2004; Thomé-Souza & Chao, 2004). As the same sampling protocol and gear yielded larger abundances in these studies, the low abundances observed in the Madeira can be considered as a robust result. This is further emphasized by the fact that sampling effort was increased by doubling the duration of trawl transects and reducing mesh size in this study. Such results are consistent with the low overall fish abundance observed along the rapids stretch of the Madeira River (Torrente-Vilara *et al.*, 2011).

The increased abundance of *Brachyplatystoma* spp. (including *B. rousseauxii*) late larvae and juveniles during the autumn and dry season may suggest that these species use the periods of lower water flow of the Madeira River for the downstream drifting and migration of young individuals towards the Amazon Estuary. Downstream drifting during the low water season may constitute a strategy to minimize the chances of juveniles being diverted to the floodplains in the intermediate portions of the basin and not reaching the Amazon Estuary, as hypothesized by García-Vásquez *et al.* (2009).

Brachyplatystoma rousseauxii is a typical periodic spawner (Winemiller & Rose, 1992), characterized by its large size, long generation time, long lifespan, the production of large numbers of small eggs and a breeding cycle synchronized with the hydrological periodicity (García-Vásquez *et al.*, 2009). In tropical rivers with

TABLE I. Standard length (L_S) range (mean ± S.D.) of the specimens of *Brachyplatystoma* species captured in the three sampling areas (A, upstream from the Jirau Waterfall; B, between the Jirau and Teotônio Waterfalls; C, downstream from the Teotônio Waterfall) along the Madeira River on Brazilian territory. *n*, number of individuals in each area (values in parentheses show the abundance of larvae and of juveniles in the samples; *, one damaged; **, three damaged; ***, five damaged; ****, six damaged)

	Area A		Area B		Area C	
Species	*n*	L_S (mm)	*n*	L_S (mm)	*n*	L_S (mm)
Brachyplatystoma capapretum	2* (0:1)	17·2	5 (2:3)	11·4–20·8 (15·5 ± 3·8)	1 (1:0)	16·3
Brachyplatystoma filamentosum	0		1 (1:0)	8·7	0	
Brachyplatystoma platynemum	3 (0:3)	14·2–53·6 (40·3 ± 22·6)	1 (0:1)	19·8	1* (0:0)	
Brachyplatystoma rousseauxii	13 (3:10)	11·9–22·6 (16·7 ± 4·3)	40** (9:28)	8·7–25·1 (17·5 ± 3·6)	27 (0:27)	9·1–25·3 (17·0 ± 3·8)
Unidentified *Brachyplatystoma* spp.	6 (3:3)	7·2–13·3 (10·8 ± 2·3)	19**** (13:0)	7·8–11·1 (9·5 ± 0·8)	19*** (14:0)	8·2–12·8 (10·5 ± 1·2)
All species pooled	24 (6:17)	7·2–53·6 (18·3 ± 11·8)	66 (34:32)	7·8–25·1 (15·3 ± 4·7)	48 (21:27)	8·2–25·3 (15·0 ± 4·4)

TABLE II. Relative abundance of each *Brachyplatystoma* species per sampling month, all sampling stations pooled (values in parenthesis indicate the abundance of larvae and juveniles, respectively)

	2009									2010				
Species	April	May	June	July	August	September	October	November	December	January	February	March	April	May
B. capapretum		1 (1:0)	2 (2:0)			2 (1:1)	1 (0:1)						2 (0:2)	
B. filamentosum							1 (1:0)							
B. platynemum			1 (0:1)		2 (1:1)	2 (0:2)								
B. rousseauxii	3 (1:2)	1 (0:1)	8 (1:7)	6 (2:4)	18 (6:12)	2 (1:1)	1 (0:1)	6 (0:6)	1 (0:1)	4 (0:4)	7 (2:5)		13 (1:12)	10 (1:9)
Unidentified *Brachyplatystoma* spp.			2 (1:1)	5 (5:0)	6 (6:0)	15 (15:0)	7 (7:0)	7 (7:0)			1 (0:1)		1 (0:1)	

predictable seasonal flow fluctuations, however, spawning of periodic species is usually restricted to a short period (a few months) during the rising waters (Tedesco & Hugueny, 2006). According to Agudelo *et al.* (2000, 2013) and García-Vásquez *et al.* (2009), *B. rousseauxii* and its congeners have relatively long breeding seasons (>5 months) in the headwaters of the Amazon River (Colombian and Peruvian Amazon). The occurrence of larvae and juveniles of *B. rousseauxii* in the rapids stretch throughout the year suggests that *B. rousseauxii* spawn at slightly different times in the rivers that compose the headwaters of the Madeira River in Bolivia and Peru, resulting in more than one peak of late larvae and juveniles crossing the rapids stretch in the Brazilian portion of the basin. This is consistent with observations of previous studies in the upper Madeira. Maximum larval densities occur during the period of highest flow between October and December in the upper Madre de Dios (Cañas & Pine, 2011; Cañas & Waylen, 2012). In the upper Mamoré River, *B. rousseauxii* spawns between February and May (Vam Damme *et al.*, 2011), whereas in the upper Beni River females with ripe gonads were observed from October to May (F. Carvajal & F. Duponchelle, unpubl. data). Therefore, the existence of different breeding periods corroborates molecular data on the presence of distinct populations of *B. rousseauxii* in different parts of the Madeira River basin (Carvajal-Vallejos *et al.*, 2014).

Another striking result of this study is the low abundance of larvae and juveniles collected, despite the considerable sampling effort, for such highly fecund species (García-Vásquez *et al.*, 2009). It is possible that a large proportion of the larvae that hatched in the Bolivian and Peruvian portions of the basin might be retained in the extensive flooded area of the Bolivian Amazon, thus resulting in the very low abundances in the Brazilian portion of the Madeira River. This contradicts, however, the standing hypothesis that the Amazon Estuary is essential for the completion of the *B. rousseauxii* life cycle. Small specimens (<1 kg) of these species are, however, very rarely observed in this portion of the basin (Carvajal-Vallejos *et al.*, 2014) and it is therefore unlikely that a large proportion of the larvae hatched in the Upper Madeira River were finding growth areas above the rapids. An alternative explanation is that only a small fraction of the *B. rousseauxii* larvae hatched in the upper Madeira survive long enough to reach the rapids stretch of the river, and ultimately the Amazon Estuary. If this holds true, it highlights the fragility of the life cycle of this species, and how it may depend on a small number of juveniles reaching the estuary, at least from the Madeira River basin. It also further stresses the question of how the downstream movements of such a low number of juveniles will be affected by the dams in the Madeira River. The presence of the dams may also impair the upstream migration of pre-adults, further reducing the production of larvae in the headwaters. While a fish pass was built at the Santo Antonio hydroelectric power plant, its efficiency to allow the upstream movements of *Brachyplatystoma* spp. has not been tested. Monitoring the relative abundances of a long-term data of *Brachyplatystoma* juveniles is therefore essential to evaluate the long-term effects of the dams on *Brachyplatystoma* species in the Madeira River basin.

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