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First Report of the Larva of a Vulnerable Damselfly in Nigeria, With Some Ecological Notes: A Case for Umbrella Species Conservation Approach

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Abstract

Background and Research: Lack of information on the distribution of threatened aquatic species impedes their conservation, thus predisposing them to extinction risk before being reported. Hence, this study reports in Nigeria, for the first time, the occurrence and habitat specificity of the larva of *Pentaplebia stahli* (Zygoptera: Pentaplebiidae) a vulnerable damselfly.

Methods: Samples of *P. stahli* were collected in July and December 2020 from a rural stream situated at the Ekor Waterfalls in the Cross River State of Nigeria and very close to the Nigeria–Cameroon border. Some water quality parameters were also measured in each sampling period.

Results: A total of 27 larvae of *P. stahli* and 1 teneral adult emerging from its exuvia were recorded in the two sampling periods. The habitat was a forested stream characterized by rapids, falls, and dark rock substrata. Water flows at a fast rate of 1 m in 3 or 4 seconds, thus characterizing a rifle and headwater stream. Dissolved oxygen concentration was between 8.05 and 8.09 mg/L, while dissolved oxygen saturation was ~98%. Biological oxygen demand was between 1.04 and 1.08 mg/L, while pH ranged from 7.28 and 7.56.

Conclusion: The stream could be described as having high ecological integrity as evidenced in its optimum range of values for the investigated water parameters and the presence of a threatened species.

Implications for Conservation: Based on habitat specificity, *P. stahli* is considered an umbrella species required for conserving other co-occurring species in the tropical stream and its riparian forest.

Keywords

Nigeria–Cameroon border, odonata, riparian forest, threatened species, waterfall

Introduction

Damselflies are suitable environmental indicators for water quality assessment (Jacob et al., 2017). It is against this background that these insects have been used as indicators for biomonitoring studies in many tropical African countries, including Nigeria and Cameroon. Among such biomonitoring studies are the works of Vick (2003) on the odonata of Cameroon's Takamanda Forest Reserve, Adu et al. (2015) on the odonate fauna of Iloyin Forest Reserve of Nigeria, and Adu et al. (2016) on the odonate fauna of Kribi Forest and

Campo Ma'am National Park of Southern Cameroon. Other related studies of odonata in the Afrotropics include

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Clausnitzer and Dijkstra (2005) in Ethiopia and Dijkstra and Clausnitzer (2014) in Eastern Africa from Sudan to Zimbabwe.

Pentaplebiidae is one of the least diverse damselfly families in the suborder Zygoptera (Order: *Odonata*). Members of this family were initially placed in the relict family Amphipterygidae. Currently, Pentaplebiidae is one of the few families endemic to the Afrotropical region (Dijkstra & Clausnitzer 2014). It is a monotypic family as it has only one genus, *Pentaplebia*. *Pentaplebia stahli* was the first described species in the family/genus, and it was reported in the Southwest Province of Cameroon (e.g. Förster, 1909; Vick, 1998). It is currently listed as Vulnerable on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List (Clausnitzer & Dijkstra, 2018).

Although the occurrence of *P. stahli* had been confirmed in Cameroon, its recently documented occurrence in Nigeria at the Cross River National Park (Ojonugwa et al., 2020) was based on adult specimens, and larvae (aquatic larval forms) have not been documented for Nigeria. Therefore, this report aims to present the first confirmed occurrence and habitat specificity of the larva of *P. stahli* within the Nigerian territory. The report also underscores habitat conservation

and knowledge of geographical distribution as precursors for the conservation of rare and threatened species.

Methods

Study Area and Collection of Larvae and Field Data

Mature larvae of the *P. stahli* were collected from Ekor Waterfall, near Abia Village in the Etung Local Government Area of Cross River State, Nigeria ($05^{\circ}56.876'N$, $008^{\circ}54.690'E$, 91 a.m.s.l.). The waterfall is situated very close to the Nigeria–Cameroon border (Figure 1). Field collection of larvae was done twice (i.e., July 2020 and December 2020) to ascertain the occurrence of the species in both the rainy and dry seasons of the year. The basic physico-chemical water parameters (i.e., water temperature, dissolved oxygen, dissolved oxygen saturation, pH, electrical conductivity, and total dissolved solids) were measured *in-situ* using a Multi 3630 IDS digital meter (WTW/Xylem, Germany). Larvae clinging to rocky substrata and organic debris were detached and preserved in specimen bottles containing 70% alcohol, pending laboratory identification. A total of 10 specimens were collected for laboratory

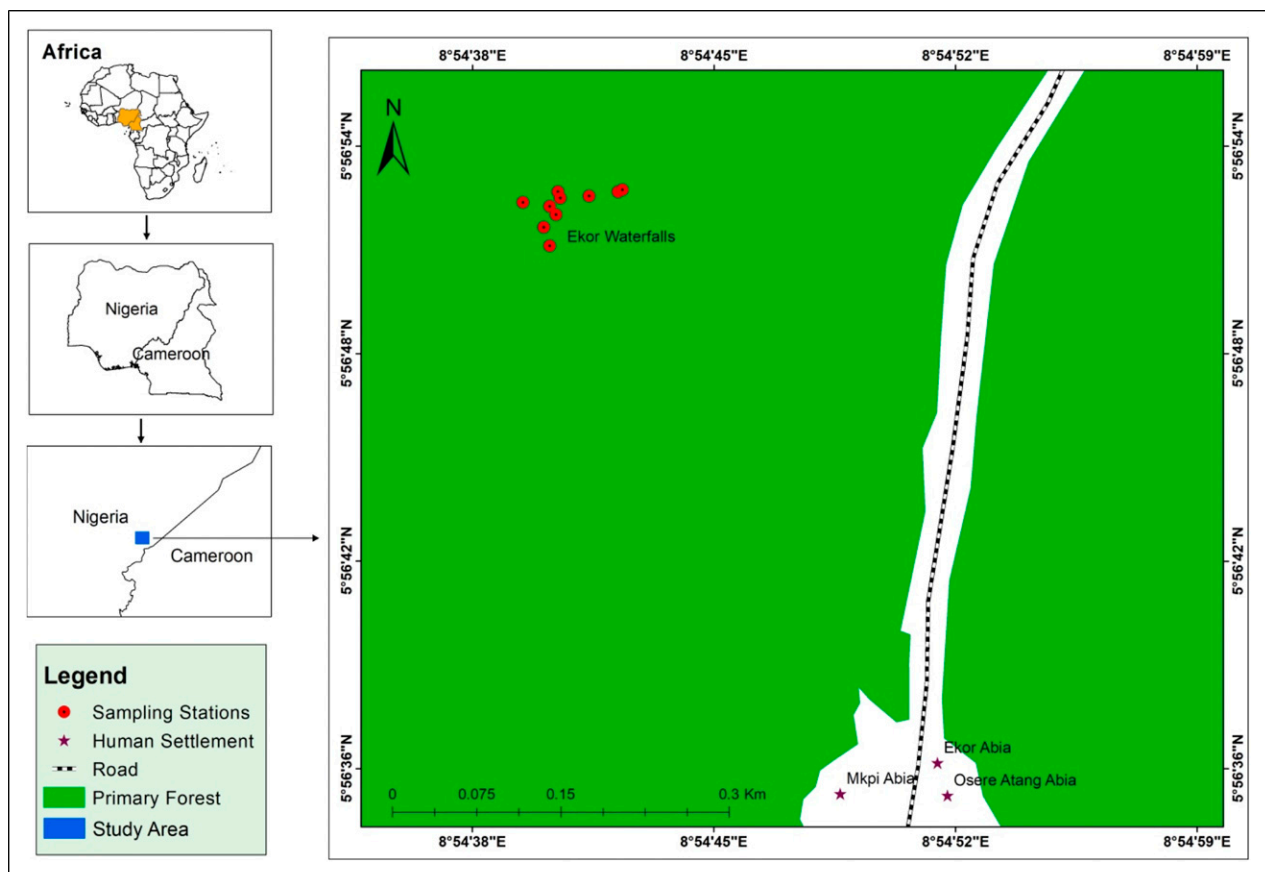


Figure 1. Image showing the location of Ekor Waterfalls and the sampling stations (Inset: Maps of Africa, Nigeria, Cameroon, and the Nigeria–Cameroon border, showing the location of the study area).



Figure 2. (a) Image of a larva of *P. stahli* swimming back to a suitable microhabitat after its return to the wild; (b) image of a teneral adult of *P. stahli* after emerging from its exuvia; (c) dorsal view; (d) ventral view; (e) and late instar larva showing the extension of the wing pads to the 9th abdominal segment.

identification in July 2020, while only one specimen was collected out of the 17 that were observed in the field in December 2020. Other specimens were returned to the wild (see Figure 2a) since it is a vulnerable species.

Laboratory Analysis

Identification of the specimens was carried out under a VZE/VZF SERIES Trinocular Zoom Stereo Microscope (China), and the photomicrographs of the different parts of the body taken. To ascertain the species-level identification of the specimens, the morphological features of the specimen were compared with those recorded for the

nymph of *P. stahli* in the Southwest Province of Cameroon (Vick, 1998). The specimens (larvae) were also compared with the exuviae of the emerging teneral adults (Figure 2b) and some of the exuviae found at the rocky bank of the stream.

Results

Morphological Description

General appearance: The morphometric details (i.e., total body length, head length, thorax length, abdomen length, and cerci length) of both early and late instar larval stages of the

damsel fly are shown in Table 1. The body is slender, dark brown, and somewhat dorso-ventrally flattened (Figures 2c and d).

Head: A pair of antennae with seven segments, the scape is short and slightly cylindrical, the pedicel is cylindrical

Table 1. Morphometry of Early and Late Instar Larvae of *Pentaplebia stahli* in Ekor Waterfalls, Abia, Cross River State, Nigeria.

Length	Stage of Development	Range (mm)	Mean (mm)
Total body	Early instar larvae	6.10–6.80	6.47
	Final instar larvae	15.30–15.70	15.53
Head	Early instar larvae	1.50–1.90	1.63
	Final instar larvae	3.45–3.55	3.50
Thorax	Early instar larvae	2.10–2.80	2.38
	Final instar larvae	5.30–5.55	5.43
Abdomen	Early instar larvae	2.50–3.20	2.73
	Final instar larvae	6.40–6.60	6.46
Cerci	Early instar larvae	2.50–2.90	2.93
	Final instar larvae	7.10–7.50	7.26

and biggest of the antennal segments, antennal segments 3 and 4 sometimes appear fused but are distinct segments, and distal segments are slender and decreasing in length. Antennal length in the late instar larva is approximately 1.3 mm. A row of setae is at the anterior portion of the head, between scapes of antennae. Eyes are large, and there is a postocular lobe with a rounded lateral margin (Figure 3a). Three ocelli are present on the central dorsal part of the head. Prementum subquadrate in shape, and the anterior region of prementum is only indented medially. The labial palp has one moveable hook, one intermediate hook, and one end hook (Figure 3b).

Thorax: There are two pairs of divergent wing pads: one pair attached to the mesothorax and the other pair attached in the same manner to the metathorax. Wing pads extend to abdominal segments 4 or 5 in penultimate instar larva but up to the 9th abdominal segment in final or ultimate instar larva (Figures 2c and e). Legs increase progressively in length with the forelegs being the shortest (10.5 mm average), followed by mid legs (12.5 mm), and the hind legs (14 mm). The femora are flattened dorso-ventrally, tibiae triquetral. Femora and tibiae of all legs are positioned laterally with short rows of

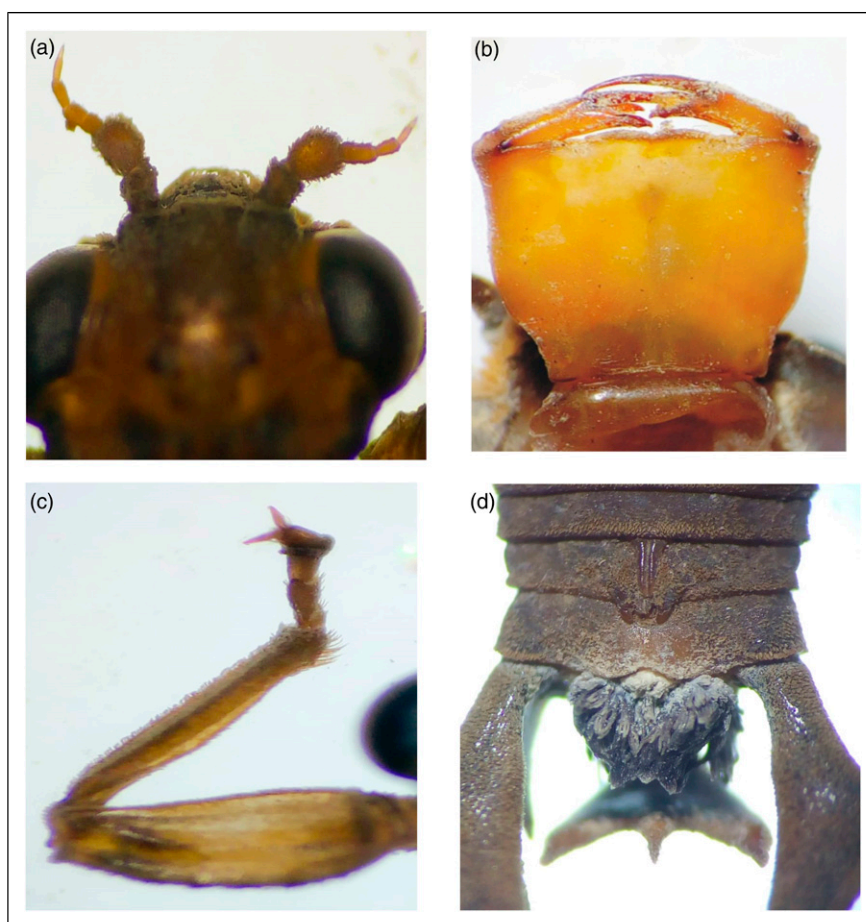


Figure 3. (a) Head region of the larva of *P. stahli* showing antennal segments and rows of setae in between the scapes of the antennae; (b) prementum and labrum; (c) description of the leg; and (d) description of the pyramid.



Figure 4. (a) Field images showing one of the waterfalls; and (b) rapids at Ekor Waterfalls, Abia Village, Etung Local Government Area of Cross River State, Nigeria.

setae. Tibiae of forelegs apically (close to tarsus) have longer tufts of setae. There are three tarsal segments, the longest ending with a pair of divergent tarsal claws (Figure 3c).

Abdomen: Generally slender than the thorax, abdominal segments are generally parallel in width. There are backward-pointing bladelike mid-dorsal spines on the abdomen; spines increase in size progressively from segment 1 to 9 and vestigially in segment 10 (Figures 2e and 3d). Segment 9 is slightly convergent, while segment 10 is slightly divergent; tufts of anal gills are attached to segment 10 (Figure 3d). Pronounced cerci measure up to 7.5 mm in mature larvae with a row of long lateral spines with short, spiny tips; cerci strongly evaginate proximally to the paraprocts and epiproct (Figures 2 c and d). Anal gills are numerous and brush-like.

Habitat Description

The habitat of *P. stahli* larva in this study was shaded, perennial, and free-flowing with many water cascades (Figure 4). It was surrounded with about 85% forest cover. The stream has an expansive riparian corridor with no evidence of human habitation, farming, and deforestation within the vicinity of the waterfall (Figure 1). There was also no evidence of water abstraction and waste dumping in or around the stream except for some few plastic containers sighted at the waterfall. The stream's substrata were mainly rocky with plant debris from the riparian forest. The rocks were very dark and volcanic (Figures 2b and 4a and b). The penultimate and ultimate larval instar which need exposed rocks for support in preparation for emergence were mostly found clinging to the rocks from where the adults emerged from the exuviae (Figure 2b). Flow velocity measured was 0.33 m/s and 0.25 m/s during the July and December sampling periods, respectively. Water temperature was 24.71°C and 24.69°C in July and December sampling periods, respectively; pH

recorded was 7.28 and 7.56; dissolved oxygen recorded was 8.09 mg/L and 8.05 mg/L; and dissolved oxygen saturation recorded was 98.26% and 97.69%, respectively. Biological oxygen demand recorded was 1.04 mg/L and 1.48 mg/L in both sampling periods, respectively, while electrical conductivity recorded was 48.14 μ S/cm and 81.41 μ S/cm, and total dissolved solids recorded was 32.2 mg/L and 54.5 mg/L, respectively.

Discussion

Until recently, it was suggested that the geographical distribution of *P. stahli* extended from Southwestern Cameroon to Southeastern Nigeria, even though there was no empirical data to confirm its occurrence in the latter region (Dijkstra, 2021). However, a recent study of the odonate fauna of the Cross River National Park (CRNP) confirmed the occurrence of *P. stahli* in Nigeria (Ojonugwa et al., 2020) based on adult specimens. Nonetheless, the current study reports the larva and habitat specificity of *P. stahli* for the first time in Nigeria, and it confirms the report of Ojonugwa et al. (2020). With two reports of *P. stahli* in two different locations of the Cross River State of Nigeria, the extension of the geographical distribution of the species to the Southeastern part of Nigeria is confirmed. Furthermore, its occurrence in a sedentary larval form as reported in this study points to the fact that the species is not migratory, but also resident in Nigeria. The sedentary nature of odonata larvae is one of the reasons why they are suitable for site-specific studies since they reflect the ecological condition overtime (Basset et al., 2004). Thus, the preponderance of *P. stahli* larvae in Ekor Waterfall at two different seasons (July—wet season and December—dry season) in the year indicates that the species is well adapted to the habitat along the Nigeria–Cameroon border.

The habitat requirements of *P. stahli* as reported in Dijkstra (2021) are the same as in Ekor Waterfalls. The species was

recorded in a forested stream characterized by rapids, falls, and rock substrata. This suggests that it is imperative to conserve the riparian forest, as well as the geological condition, natural stream channel morphology, and physico-chemical water quality of the stream at Ekor Waterfalls. Riparian forests are regarded as an important reserve for biodiversity sustenance, especially for rare species that alternate their existence between freshwater and terrestrial ecosystems (Hylander et al., 2004). They shade streams and regulate the water temperature and also provide food and organic substrates for macroinvertebrate colonization (Hussain & Pandit, 2012). The basic water parameters of the stream (e.g., pH < 8.5; EC < 100 μ S/cm; DO \sim 8.00 mg/L; DO saturation \sim 100%) also indicate a good water quality. For instance, DO in unpolluted fresh waters typically ranges from 15 mg/L at 0°C to 8 mg/L at 25°C (Chapman & Kimstach, 2006). The stream is well saturated with oxygen and the water quality parameters generally established that the stream is of high ecological integrity (Chapman & Kimstach, 2006). Given the foregoing, the specificity of the *P. stahli* habitat in Ekor waterfall must be conserved to protect the species.

Habitat conservation has been well established in the literature as a precursor for the conservation of threatened species (e.g., Casazza et al., 2016). The presence of plastic litter (especially bottles) at the site underscores the urgency of a habitat conservation strategy for the area. The plastics were evidence of human activities which may include recreation. This accentuates the need for concerned authorities (state and/or federal government) to urgently initiate management strategies for the conservation of the habitat and its threatened species. The management of the waterfall is currently a community-based (Abia Village) initiative, as both the Federal Government of Nigeria and the Cross River State Government are yet to designate it as a protected area.

Implications for Conservation

Effective conservation of *P. stahli* requires large areas and specific habitat types. Habitat requirements qualify this Vulnerable damselfly as a potential umbrella species and conservation focus for the Ekor Waterfall. Conservationists (e.g., Caro, 2003; Mills, 2013) suggest that the protection of umbrella species could protect other species (otherwise known as co-beneficiary species) in particular ecosystems. More studies are required to take an inventory of the biodiversity of aquatic animals at Ekor Waterfall. The ensuing database could then provide useful hints for formulating and implementing species and habitat conservation policies for the site. Also, future studies should consider a DNA barcoding of the species. This becomes imperative to delineate the *P. stahli* from its congeners (*Pentaplebia gamblesi* and *Pentaplebia mangana*) which have been reported in Nigeria

(Parr, 1977) and Gabon/Congo-Brazzaville (Dijkstra et al., 2015), respectively.

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