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Dragonflies and damselflies in Cross River State, Nigeria (Odonata)

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Abstract

This report presents the results of a 17-day Odonata expedition to Cross River State, southeast Nigeria. The rainforest and highland habitats of this state and adjacent parts of Cameroon are thought to support the highest diversity of Odonata in Africa, with a particularly high share of threatened and range-restricted species. Nevertheless, field surveys in this region have been very scarce in recent decades, and knowledge from the Nigerian territory lags behind that from Western Cameroon. Yet, a growing interest in Odonata among Nigerian eco-

logists is now creating opportunities for increased survey effort in this region. A collaboration between Nigerian and Dutch students resulted in an extensive exploration of freshwater habitats across Cross River State during the dry season in January-February 2022.

This team visited four locations in Cross River State, exploring diverse running waters and occasionally stagnant waters both in legally protected forests and in adjacent human-influenced landscapes. Three locations fell into the lowland rainforest zone in the Cross River National Park – Oban Section (Aking & Ekang) and Afi River Forest Reserve (Buanchor), while the fourth represents the highland habitats of the Obudu Plateau (1200-1700 m a.s.l.). Sampling emphasis was on rare and little-known Odonata, and special attention was paid to specimen collection and in-situ photography.

The survey recorded 138 taxa, of which (preceding DNA-barcoding) 123 could be identified to species level, confirming the exceptional Odonata diversity of this region. These species represent twelve new national records for Nigeria, and three species new to science: a *Tetrathemis* species from Aking resembling the West African *T. godiardi*, and *Atoconeura* and *Neodythemis* species from the Obudu Plateau. 11 species were photographed in the field for the first time, including range-restricted species such as *Allocnemis vicki, Neurolestes nigeriensis, Umma purpurea* and *U. mesumbei*. Furthermore, extensive photographic material provided further insight in the extraordinary colour transformations of *Africocypha lacuselephantum* and *A. centripunctata* males and females.

The highest local species diversity was observed at streams in the lowland sites of Aking and Ekang, while sites with limited disturbance at Buanchor and the Obudu Plateau also had a relatively high species diversity. High diversities of Zygoptera, notably Calopterygidae and Platycnemididae, were recorded at forested streams, while sites with some human disturbance were richest in Libellulidae. Specialized relict species were recorded in small seepage-fed streams at Aking (*Neurolestes trinervis, Pentaphlebia stahli* and *Stenocnemis pachystigma*) as well as at the edge of the Obudu plateau at 1200 m a.s.l. (*P. stahli* and *S. pachystigma*). Well-preserved highland streams on the Obudu plateau supported a small but distinct assemblage of specialized species including *A. vicki, N. nigeriensis* and *Nubiolestes diotima*. It was in this habitat that *Pentaphlebia gamblesi* was collected in 1973. We could not find adults of this little-known species, which was a major target of the expedition, but collected larvae of *Pentaphlebia* spec. at two sites.

As the mystery surrounding *P. gamblesi* persists, many other promising areas remain unexplored, and an even greater species diversity (notably of Gomphidae and species of ephemeral waters) is expected during the rainy season, the scope for further exploration of Cross River State's Odonata remains. Widespread habitat degradation, especially on the Obudu plateau, increases the urgency of further research and conservation efforts in this region.

Keywords: Nigeria, Odonata, Cross River National Park, Obudu plateau, Afi River Forest Reserve, *Pentaphlebia*, grazing effects, colour patterns in Chlorocyphidae.

Introduction

Cross River State is located in the far southeast of Nigeria, bordering Cameroon to the east and the Atlantic Ocean to the south. It has a wet tropical climate with high annual rainfall and a marked rainy season during the northern hemisphere summer, supporting trop-

ical rainforest as the dominant natural habitat (Jimoh et al., 2012). The Cross River forests connect to the forests of Western Cameroon. Together, the forests between the Cross River and Cameroon's Sanaga River form one of the largest contiguous blocks in West Africa, supporting an extraordinary biodiversity and endemism (Cronin et al., 2014; Oates et al., 2004). Cross River State forms the western edge of the Lower Guinean forests extending through Cameroon, Gabon and Congo-Brazzaville, and forms a connection to the West African forests. Consequently, there are few places in western Africa that support a comparable richness of species and natural habitats. Much of the remaining forested area falls within the Cross River National Park.

While Cross River State is mostly at a lower altitude, the highlands of Western Cameroon, formed by volcanic activity along the Cameroon line, are West Africa's most extensive and highest montane region (Cronin et al., 2014). These highlands extend to the west into Nigeria in the form of the Obudu plateau, which reaches 1700 m in altitude. Situated in the north of Cross River State, this plateau marks the boundary of the rainforest belt and the drier habitats further north, while its southern escarpment has montane cloud forests that are notably cooler and wetter than the adjacent lowland rainforests (Parr, 1977). Smaller and lower hill ranges in other parts of Cross River include the Afi Mountains and Oban Hills, both reaching over 1000 m a.s.l. These highlands support a large variation in elevation and climatic conditions and form one of Africa's most important centres of endemism (Bergl et al., 2007; Dijkstra & Vick, 2004; Oates et al., 2004). Situated at the heart of Africa's current rainforest zone, during dry periods these highlands also formed one of the continent's primary refuges of rainforest habitat that strongly influenced its biodiversity.

The ecoregion formed by the Lower Guinea forests and Western Cameroon Highlands is known to host Africa's highest Odonata diversity, one of its highest concentrations of range-restricted species, and due to its relatively poor coverage in scientific literature, also one of its highest research and conservation priorities (Dijkstra & Vick, 2004; Dijkstra et al., 2011). Of particular interest is the diversity of strict rainforest groups such as Calopterygidae and *Allocnemis*, and the presence of a few relict genera such as *Nubiolestes, Neurolestes, Stenocnemis* and *Pentaphlebia*. As the freshwater habitats in this region face numerous threats, notably deforestation and overexploitation of water sources, many of its unique species are likely facing decline, especially in Nigeria (Dijkstra & Vick, 2004; Ekpah et al., 2020). Indeed, the Western Cameroon Highlands host the highest concentration of (near-) threatened species in Africa (Dijkstra et al., 2011).

Although several odonatologists have explored this region over the last centuries, many of these publications date from before 1950 and the vast majority refer to locations in Western Cameroon. Gambles (1959, 1967), Pinhey (1961a,b, 1974) and most recently Vick (1996, 1999) and Dijkstra et al. (2015) described recent additions to the Odonata of Western Cameroon. The Odonata of Cross River State have been explored on only a few occasions. Odonata records from this region published since 1950 are from Gambles (1970, 1975) and Parr (1977), both describing new species from the Obudu plateau: *Neurolestes nigeriensis* (Gambles, 1970), *Africocypha centripunctata* (Gambles, 1975) and *Pentaphlebia gamblesi* (Parr, 1977). More recently, surveys in Cross River State were published by Ekpah et al. (2020) and Akindele et al. (2021), recording several species already known from Cameroon for the first time in Nigeria.

Despite these investigations, the dragonfly diversity of Cross River State is still remarkably poorly known. Since its forests form a natural extension of the forests of western Cameroon, a considerable similarity of the Odonata of both regions can be expected, but numerous species described from Western Cameroon remain unrecorded in Cross River State. Moreover, unknown species may lurk unseen in its forests. This is illustrated in particular by the enigmatic *Pentaphlebia gamblesi*, which has not been recorded since its description from a single male specimen by Parr (1977). The richness and uniqueness of Cross River State's dragonfly and damselfly fauna, combined with the rapid degradation of natural habitats, create an urgent need for further investigation of this region. A promising perspective to address this need arises from the increasing interest of Nigerian odonatologists in this region, as is reflected by recent publications.

Emergence of this study

In October 2020, Nigeria odonatologist Ojonugwa Ekpah sent an open invitation to Dutch entomologists to participate in a survey to Cross River State. Two students, Jan van Leeuwen and Rick Buesink, both passionate about Odonata, learned of this project and applied to join. Odonatologist KD Dijkstra quickly became involved in the process of fundraising. To optimise returns from the project, the group decided to form a reciprocal collaboration between Dutch and Nigerian students: students took the lead in jointly setting up the project, guided by both Dutch (KD Dijkstra, Reinier de Vries) and Nigerian (Sylvester Ogbogu, Kehinde Kemabonta and Babasola Adu) expertise. The aim of this collaboration was not just to organise the survey efficiently, but also to develop a higher learning output and a basis for fruitful cooperation in the future. Nigerian students involved were Ojonugwa Ekpah, Bibitayo Ayobami Owolabi, Isaac Erhomosele Ehikhamele and Abiodun Matthew Adedapo.

After months of preparation and online meetings, the team was ready to start their journey in January 2021. Unfortunately, a new Covid-19 lockdown was announced in The Netherlands and travel advice to almost every part of the world was negative. As a result, the entire trip was pushed forward a whole year, to January 2022. The Dutch team members arrived in Nigeria on January 2022 to meet the Nigerian team members in Lagos, Nigeria's biggest city. The team travelled to Cross River State via Calabar and conducted dragonfly surveys during 17 days from January 20th to February 6th, visiting four villages and multiple sites in their surroundings. The sites were chosen so that they covered a variety of conditions in terms of elevation (100-1600 m a.s.l.), habitat (small-scale cultivation to primary rainforest) and water bodies (different substrates and rates of flow). After the field survey, a full-day workshop on Odonata was given at the University of Lagos with students from several Nigerian universities participating. This report presents the results of the survey in Cross River State.

Materials & Methods

Field methods

Dragonflies and damselflies were recorded, identified and photographed in the field from the 20th of January until the 6th of February 2022. With small groups of team members, surveys along streams and roads were conducted at each site. Fieldwork lasted mainly from 10 a.m. to 4 p.m., when the sun was highest. As the sampling period fell in the dry season,

weather conditions were favourable for Odonata activity on all sampling days. As species identification generally required examination of handheld features, flying, resting or sunbathing individuals were caught in the field. All team members used long, wide insect nets optimal for dragonfly catching. At all sites, we tried to sample the odonate diversity at all available water bodies. Local guides generally informed us of, and guided us to, potential streams and pools. Species identification utilised Dijkstra (2016) and Dijkstra & Clausnitzer (2014), but primarily was by consultation with team member KD Dijkstra. Observations were recorded on the platform Observation.org by team members, thereby registering the precise coordinates of records and specimens.

Specimen collection and preservation

If identification in the field was uncertain or difficult, or if specimens were important for other reasons (e.g. representing rare, unexpected or little-known species), specimens were collected. Specimens were preserved by immersing them in acetone overnight and carefully placing them in glassine envelopes. For selected specimens a detached leg was preserved in 100% ethanol for DNA extraction. We aimed to take pictures of as many species as possible, preferably before collecting them (in situ) or otherwise before preservation to show their natural coloration.

Collected specimens were labelled and are currently stored in the collection of the Naturalis Biodiversity Center in Leiden, The Netherlands. Further examination of interesting individuals was done using a stereo-microscope and relevant literature. DNA samples are still being processed, but DNA-barcodes will become available on BOLD after sequencing.

Although not our main focus, it has to be noted that larvae were collected with small water nets from several streams as well, particularly those expected to be inhabited by *Pentaphlebia* species. The specimens were collected and identified (mostly to family- or genus-level) by B. Adu and A.M. Adedapo, both members of the expedition team. Rearing the specimens was not possible because of time-constraints and highly specific environmental demands of most species. Therefore we decided to only photograph and collect the specimen. A few larvae were photographed in the field or sampled for DNA-barcoding.

Study sites

The expedition was carried out in four different parts of Cross River State (hereafter: locations) where the team stayed for several days each. Two locations were in the lowland Oban Hills Division of Cross River National Park, near Aking (location 1) and Ekang (location 2). Next, we sampled the forest and the so-called “farm-bush” (i.e. the secondary growth derived from forest that follows slash-and-burn agriculture; typically a mosaic of bushes and small agricultural fields) around the Afi River Forest Reserve near Buanchor (location 3). Finally, we sampled the montane habitats around the (former) cattle ranch and resort on the Obudu Plateau (location 4), which borders the Okwangwo Division of Cross River National Park. Figure 1 shows these four locations in Cross River State.

At each location, different water bodies reachable from the team’s camp were surveyed. These are here referred to as sampling sites; they are summarized in Table 1 and described in detail below.

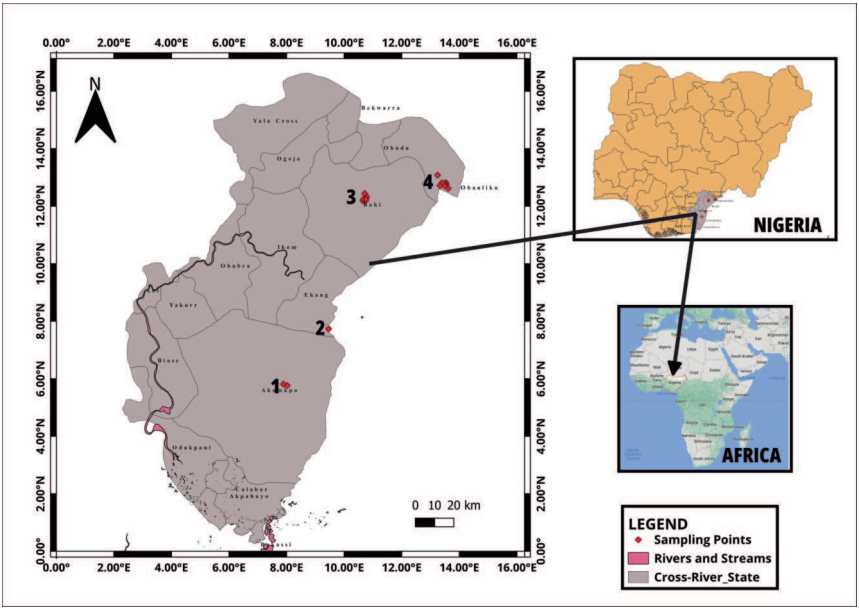

Figure 1: Map of Cross River State in Southeast Nigeria showing the four locations visited during this expedition (see Table 1 and descriptions below).

Locations 1 & 2: Cross River National Park, Oban Hills Division, Aking and Ekang

The Oban division of the Cross River National Park (CRNP) covers an area of roughly 3000 km² of primary lowland forest, the largest intact block in Nigeria. To the east, it shares a boundary with Korup National Park in Cameroon. The terrain is rugged and the elevation rises from near sea level in the river valleys to over 1000 m a.s.l. in the Oban Hills. Annual rainfall is estimated to range between 2500 and 3000 mm.

The economy in the Oban division is largely agrarian, although hunting, trapping, and collection of forest products are important for subsistence and to some extent for trade. The Oban division is inhabited predominantly by the Ejagham tribe with a few Ibibio, Efiks, Calabaris, and Igbos. The following are the villages where this study was carried out: Aking/Osomba, Ifumkpa, Ekuri, Esang, and Ekang. Aking lies next to one of the highest hill ranges in the area, with steep slopes and fast-flowing rocky rivers, while Ekang lies in lowland forest with slow-flowing sandy rivers at 100 m a.s.l. The park is under the control of the Federal Government of Nigeria.

Site 1. Ikpang river

The Ikpang River is a clear and moderately fast-flowing river with a substrate of sandy detritus, rocks and pebbles (Figure 2A). The forest canopy is almost nowhere completely closed and does not provide very much shade. It is adjacent to the Aking office of the CRNP on the Ikot Offiong-Ekang road at about 150 m a.s.l. The sampling area near the bridge is moderately disturbed where residents fetch water and bathe. The river is

Table 1: Short descriptions of the locations (1-4) and sampling sites (1-9b) visited during this expedition. More extensive and illustrated descriptions are given in the text. CRNP = Cross River National Park

Site	Site name	Habitat description
Location 1: Cross River National Park - Oban Hills Division, Aking		
1	Ikpang river	Larger river, rather fast-flowing with rocky substrate, in "farm-bush" habitat.
2	Manko river	Larger river with small side-streams, fast-flowing with rapids and rocky substrates, in primary forest habitat.
Location 2: Cross River National Park - Oban Hills Division, Ekang		
3	Acham river	Large river, slow-flowing with bedrock and gravel substrates, in open "farm-bush" habitat.
4	Atemayip river	Small stream, slow-flowing to stagnant with sandy and organic substrates, in secondary forest & "farm-bush" habitat.
Location 3: Afi River Forest Reserve		
5a	Buanchor, rice fields	Extensively managed or abandoned rice-fields, in open "farm-bush" habitat.
5b	Buanchor, "farm-bush"	Small streams, rather slow-flowing with sandy & organic substrates, in "farm-bush" habitat.
5c	Buanchor, Magbe river	Small river, fast-flowing with rapids and rocky substrate, in degraded secondary forest habitat on Afi mountain slope.
6a	Drill Ranch Reserve, Bano river	Larger river, rather fast-flowing and degraded by landslide debris, in secondary forest habitat.
6b	Drill Ranch Reserve, muddy stream	Small stream, stagnant with seepage and muddy & organic substrates, in primary forest habitat.
6c	Drill Ranch reserve, Cataract stream	Small streams, rather fast-flowing with rocky & organic substrates, in primary forest habitat at the mountain base.
6d	Drill Ranch reserve, Cataract stream (low)	Larger stream, slow-flowing with sandy substrate, primary forest habitat.
Location 4: Obudu Plateau		
7a	Obudu Cattle Ranch, Becheve Forest Reserve	Small streams, rather slow-flowing with sandy & organic substrate, in primary montane forest habitat.
7b	Obudu Cattle Ranch, Grotto Pool Reserve	Small river, fast-flowing with rocky and sandy substrates, in secondary montane forest habitat.
7c	Obudu Cattle Ranch, Emba Forest Reserve	Small streams, rather fast-flowing with rocky & sandy substrates, in secondary montane forest habitat.
8a	Avase River	Larger river, fast-flowing with rocky substrate, in deforested habitat with secondary riparian vegetation.
8b	Lower Emba river	Small stream, fast-flowing with rocky substrate, in degraded secondary riparian vegetation.
8c	Afundu I River near Igaga Falls	Larger river, fast-flowing with rapids and rocky substrate, in deforested habitat with secondary riparian vegetation.
9a	CRNP - Okwangwo Section, Afundu II river	Larger river, rather fast-flowing with rocky substrate, in primary forest habitat.
9b	CRNP - Okwangwo Section, Anape river	Small stream, rather slow-flowing with sandy & organic substrate, in dense primary montane forest habitat.

surrounded by “farm-bush” and some of the riparian vegetation was being cleared at the time of sampling.

Site 2. Manko river

The Manko River is a fast-flowing, shaded river with rocky substrate, rapids and a waterfall. The river flows down from hills that reach1014 m a.s.l. Few observers have entered the interior of this block for extended stays (Oates et al., 2002). Sampling was conducted at 200-250 m a.s.l. along the main course of the Manko River (Figure 2C) as well as small seepage streams running down from the hills with a substrate mostly of bedrock (Figure 2D). The surrounding habitat is closed-canopy primary rainforest.

Site 3. Acham river

The Acham river is the major source of water for the Ekang community. The river is open and slow-flowing with gravel and rocky substrates and exposed gravel banks (Figure 3A). The banks are overhung by trees and bushes or have a narrow strip of riparian vegetation in “farm-bush” habitat.

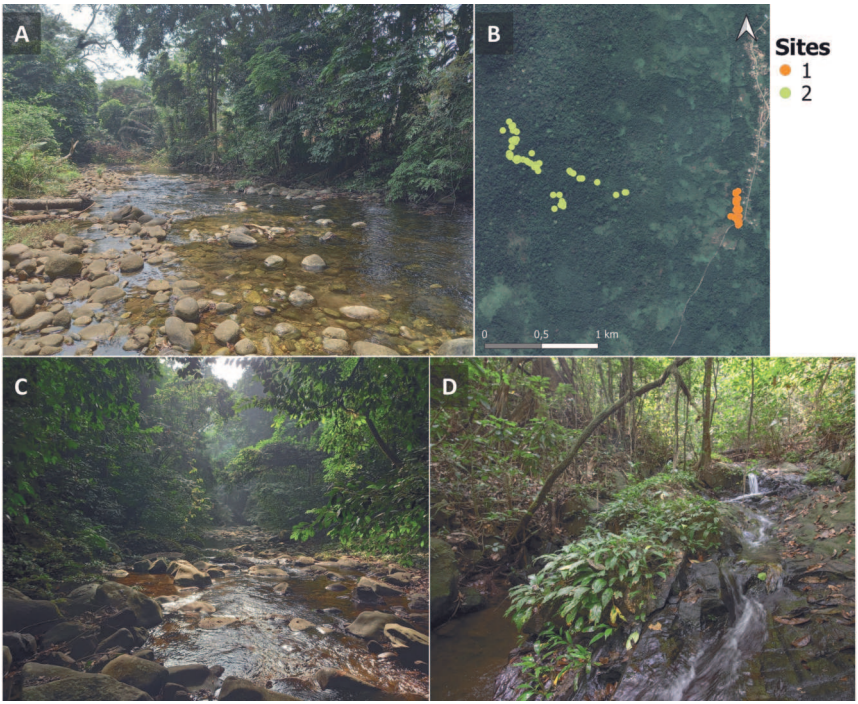

Figure 2: Sampling sites near Aking in Cross River National Park - Oban Hills Division (location 1). The satellite image (B) shows the distribution of Odonata records at sites 1 (Ikpang river) and 2 (Manko river). The “farm-bush” around the Ikpang river and primary forest around the Manko River are visible on the satellite imagery. Other photographs show the Ikpang river (A) and Manko river’s main channel (C) and one of its tributaries (D).

Site 4. Atemayip river

The Atemayip river is a small slow-flowing stream with stagnant parts in the dry season. It has a sandy substrate with deposits of detritus and some bedrock (Figure 3C-D). The stream runs through former clearings and plantations and partly through well-developed secondary forest.

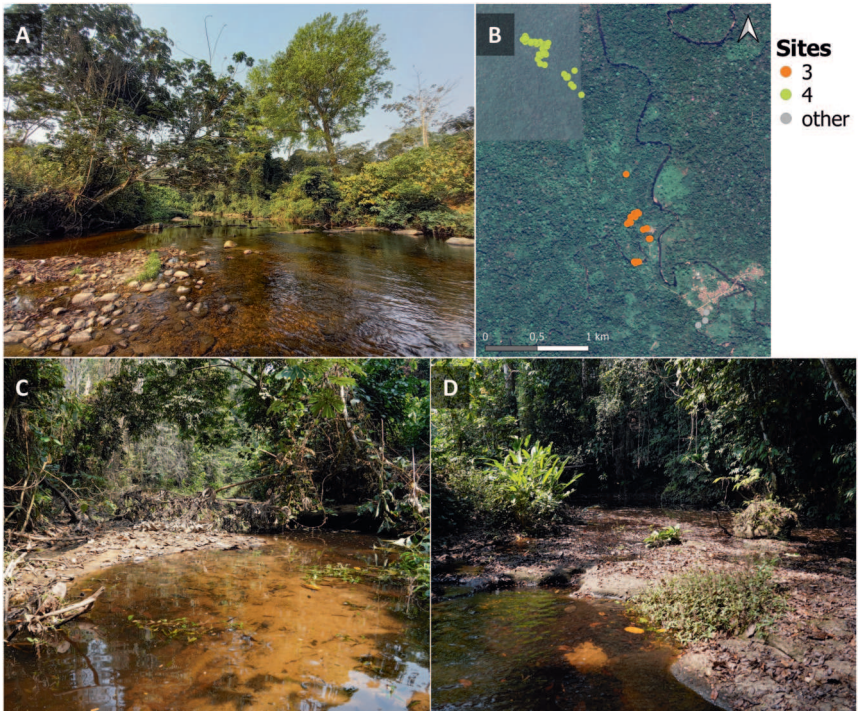

Figure 3: Sampling sites near Ekang in Cross River National Park - Oban Hills Division (location 2).The satellite image (B) shows the distribution of Odonata records at sites 3 (Acham river) and 2 (Atemayip river), as well as three additional records at the river next to Ekang village that was not extensively surveyed (lower-right on the map). Other photographs show the Acham river (A) and the Atemayip river with sandy substrates (C) and more rocky and organic-rich parts in tall secondary forest (D).

Location 3: Afi River Forest Reserve

The Afi River Forest Reserve comprises another set of forest blocks of over 100km² in the north-eastern part of Cross River State. The reserve is sandwiched between the Afi Mountain Wildlife Sanctuary in the west and the Okwangwo division of the Cross River National Park in the east. It mostly includes lowland forests lying at around 150 m a.s.l., while the Afi Mountains also harbour some montane forest patches reaching 1200 m a.s.l. Large parts of the Afi Mountains' slopes, however, are degraded by clearing, bushfires and erosion. Sampling occurred around Buanchor village, which lies at the foot of the Afi mountains

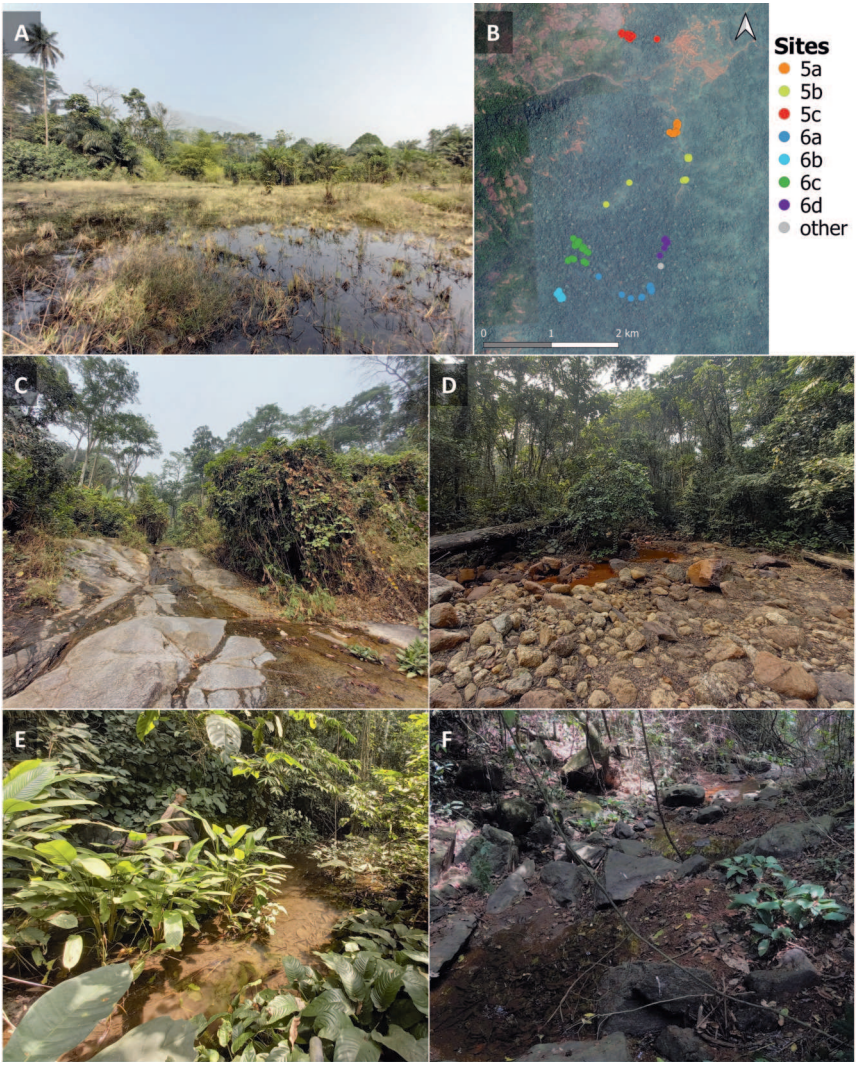

Figure 4: Sampling sites at the Afi River Forest Reserve (location 3). The satellite image (B) shows the distribution of Odonata records at the seven sites that were surveyed at this location; around Buanchor (rice fields 5a, "farm-bush" 5b and the Magbe river 5c) and in the Drill Ranch Reserve (Bano river 6a, muddy stream 6b and the Cataract stream upper part 6c and lower part 6d). The satellite imagery shows the Afi Mountains (left), Buanchor village (upper right) with surrounding "farm-bush" and the forested Drill Ranch reserve. Other photographs show the rice fields (A) and the Magbe river (C) in the Buanchor area, and the degraded Bano river (D), the muddy stream (E) and the Cataract stream (upper part) (F) in the Drill Ranch reserve.

and next to the Drill Ranch primate sanctuary (part of Afi River Forest Reserve). Different habitats could be reached on foot from Buanchor; streams in the Forest Reserve, streams and swampy rice fields in the "farm-bush" habitat around Buanchor, and the Magbe Stream running down from the Afi Mountains.

Site 5a Buanchor, rice fields

An area of swampy ponds in open "farm-bush" used intermittently for rice cultivation (Figure 4A). The substrate is mainly muddy and silty.

Site 5b. Buanchor, "farm-bush"

The area is dominated by banana plantations mixed with secondary forest remnants. Logging for local construction is common. Several small, moderately fast-flowing streams with sandy and silty substrate run through this area, while dragonflies were also observed foraging away from water in plantations and cultivated areas.

Site 5c. Buanchor, Magbe river

The Magbe Mountain rises above the town of Buanchor. A partly shaded stream flows down the mountain, with a mostly organic substrate downstream, becoming rocky upstream (Figure 4C). The mountain slopes are covered with secondary forest and secondary growth after degradation by large-scale bushfires; these slopes remain very prone to erosion. Dumping of refuse and sewage was observed at the foot of the mountain, but further upstream the water is clear.

Site 6a. Drill Ranch reserve, Bano river

The Bano River is the main stream on the Drill Ranch reserve but one of the most impacted aquatic habitats in the Afi Forest Reserve, having suffered severely from a landslide along its course (Figure 4D). Rocky debris covers the entire riverbed and the water is permanently muddy. The river is partially shaded by the remaining taller riparian forest. The river flows close to the Drill Ranch, around a former canopy walkway and continues further to the nearby villages.

Site 6b. Drill Ranch reserve, muddy stream to River Bano

A number of streamlets run into the River Bano around the Drill Ranch. One of them is a well-shaded tributary with mostly organic substrate and extensive vegetation under a closed forest canopy (Figure 4E). It contains clear seepage water but is mostly stagnant in the dry season.

Site 6c. Drill Ranch reserve, Cataract stream (upper part)

The Cataract Stream is a moderately fast-flowing tributary near the Drill Ranch with a rocky substrate and deposits of detritus. The first sections are slow-flowing with a mainly organic substrate, but the upstream parts have some rapids with a rocky substrate, although flow velocity is low in the dry season (Figure 4F). It runs through primary forest with a dense canopy.

Site 6d. Drill Ranch reserve, Cataract stream (lower part)

The downstream section of the Cataract Stream has a more sandy substrate with banks of coarse sand and organic deposits. It has a lower flow velocity and dense canopy cover. Only a short section of this stream near the road was visited.

Location 4: Obudu Plateau

The Obudu region of Cross River State includes the Obudu Plateau, an extension of the Western Cameroon Highlands that reaches 1700 m a.s.l. Its natural habitats are made up of a combination of tropical rainforests in the surrounding lowlands and montane forests on the plateau. Air temperatures were as low as 17°C on the plateau in January. Around Obudu Cattle Ranch lie several remnants of montane forest, but the surrounding high-altitude habitat is mostly severely degraded by forest clearing and subsequent overgrazing. Only narrow riparian vegetation remains in these areas. Larger areas of undisturbed forest are found on the southern slope of the Obudu plateau that is part of the Okwangwo section of Cross River National Park.

Site 7a. Obudu Cattle Ranch, Becheve Forest Reserve

This is a nature park that borders the reception area of the Obudu Mountain Resort at 1570-1600 m a.s.l. The forest reserve protects a remnant of montane cloud forest containing several networks of streamlets with slow to moderate flow velocities. All are shaded (Figure 5A-B), except where trees have fallen (Figure 5C). The substrate comprises a combination of mainly sand and silt downstream with pebbles and some portion of bedrock upstream. The forest has both a dense canopy and understorey, with many climbing plants.

Site 7b. Obudu Cattle Ranch, Grotto Pool Reserve

The forest patch downstream of the Becheve Forest Reserve at 1550 m a.s.l. contains a single larger and rather fast-flowing stream (Figure 5E), which flows under the bridge at the main entrance to the Ranch. The substrate comprises sandy and silty portions midstream and downstream, interrupted by rocky substrates towards the artificial Grotto Pool. The stream is mostly shaded, except for areas altered by human activity. Natural vegetation is confined to a relatively broad band of riparian vegetation that cattle cannot enter. Compared to the Becheve Reserve, the vegetation in the Grotto section is more disturbed but denser and more shaded.

Site 7c. Obudu Cattle Ranch, Emba Forest Reserve

The Emba reserve, situated southwest of the Becheve and Grotto reserves at about 1550 m a.s.l., contains a small stream with a moderate rate of flow and some rapids (Figure 5F). Substrates are mainly pebbles with sandy and detritus deposits and some rocky parts. The reserve is moderately disturbed by cattle entering in low numbers and has some small sunny clearings around the stream. It contains well-developed secondary forest habitat.

Site 8a. Avase river

The Avase river is one of the largest water systems on the Obudu Plateau and lies downstream of the Grotto section at about 1450 m a.s.l. The substrate is a combination of sand, cobbles and boulders and the stretch is largely unshaded (Figure 6G). The river is bordered by narrow strips of bushy riparian vegetation surrounded by bare grassy hills. Erosion and eutrophication by cattle dung may affect the stream.

Site 8b. lower Emba river

The lower Emba River downstream of Emba reserve contains higher levels of habitat alteration, mainly from the action of cattle grazing. The stream is rather fast-flowing and has sandy and rocky substrates. The valley is mainly unshaded and contains pollutants such as cow dung and remnants of burnt vegetation (Figure 6H).

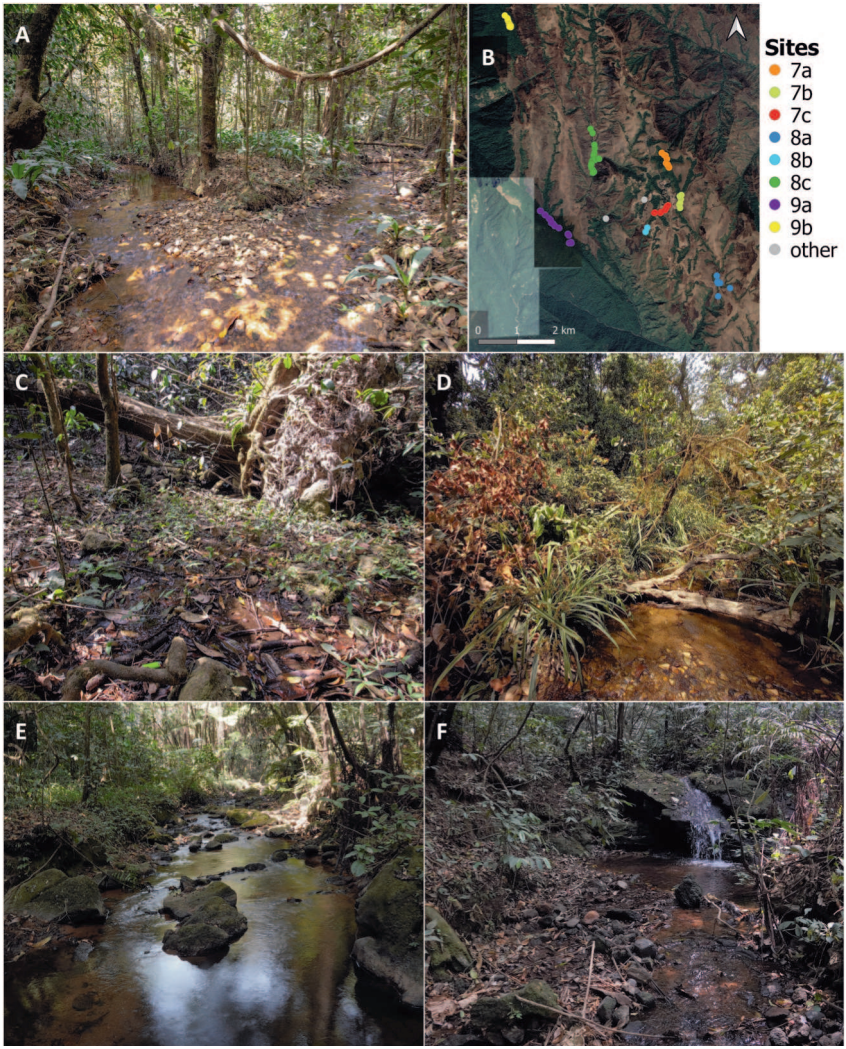

Figure 5: Sampling sites at the Obudu plateau (location 4). The satellite image (B) shows the distribution of Odonata records at the eight sites that were surveyed at this location; protected areas near Obudu Cattle Ranch (Becheve Forest Reserve 7a, Grotto Pool Reserve 7b and Emba Forest Reserve 7c), degraded rivers in the deforested areas (Avase river 8a, lower Emba river 8b and the Afundu I river 8c) and the Okwangwo section of Cross River National Park (Afundu II river 9a and the Anape river 9b). Two records outside of these sites are indicated in grey on Panel B. Other photographs show the Becheve Forest Reserve with shaded streams (A), seepage areas (C) and sunny clearings (D), the Grotto Pool Reserve (E) and the Emba Forest Reserve (F), all being montane forest habitats (see also Figure 6).

Figure 6: Photographs of the rivers in deforested areas at the Obudu plateau (site 8a-c) showing the Avase river (G), lower Emba river (H), and the Afundu I river (I) with the Igaga waterfalls (J). The last two photographs are of primary forest sites in the Okwangwo section of Cross River National Park (site 9a-b) showing the Afundu II river (K) and the Anape river (L). See also Figure 5, (B).

Site 8c. Afundu I river near Igaga Waterfall

The Afundu catchment lies west of Obudu Cattle Ranch, beyond the Becheve community, and consists as two tributaries (Afundu I and Afundu II) separated by a high ridge. The Igaga Waterfall is located in Afundu I River at about 1200 m a.s.l. The stream above this waterfall has a rather sparse riparian corridor (Figure 6I). The river substrate is mainly rocky and sandy with several rapids and is apparently cleaner than the Cataract and Emba channels. Sunny bedrock and seasonal ponds occur at the Igaga Waterfall (Figure 6J). There is evidence of bushfires in this section, which has reduced the riparian corridor. Grazing intensity is lower here than in the Cataract and lower Emba sections, but the steeper slopes are prone to soil erosion.

Site 9a. Cross River National Park - Okwangwo section, Afundu II river

Afundu II River is located more distantly from the Becheve community and lies between Afundu I River and the Berekete community. It forms the edge of the Okwangwo section of Cross River National Park. This river is more shaded and runs through denser primary forest, supporting very tall deciduous trees, epiphytes and other undergrowth (Figure 6K). At an elevation of 1150-1200 m a.s.l., this forest has more similarities to the Manko river forest near Aking (site 2) rather than to the montane forests on top of the Obudu Plateau. The river has several rocky sections with rapids, interrupted by sandy portions with large pebbles.

Site 9b. Cross River National Park - Okwangwo section, Anape river

The Anape River is one of the larger stretches of river in Obudu, fed by several streams in valleys, some of which flow through the border region of the Okwangwo Division of CRNP. The sampled tributary stream lies at high altitude (1700 m a.s.l.) and runs through dense montane forest and is therefore shaded except for small natural clearings. It is rather slow-flowing with sandy and detritus substrates, as well as rocky parts (Figure 6L).

Results

Recorded species

Over 1200 individual Odonata were observed and identified during this study, representing 138 taxa of which 123 could be identified to species, while 14 could only be assigned to the genus level so far (pending DNA-barcoding results). Most species were observed as adults, but unidentified *Paragomphus, Diastatomma, Notogomphus, Phyllomacromia* and *Zygonyx* species were recorded only as larvae. A complete list of the observed, photographed and collected species per sampling site is presented in table 2. Taxonomy follows that of Dijkstra (2016). The table also provides the recorded species richness per site and family.

Of these 123 species recorded, 12 represent new national records for Nigeria, and three represent species new to science (Dijkstra et al. in prep). Moreover, 88 species were photographed, mostly in situ or sometimes handheld, including 11 species of which no photographs of living individuals were available online. The photographed species are indicated in Table 2 (third column; rec. 'P'), with those photographed alive for the first time highlighted in bold. Photos are available in Appendix 1 to hopefully facilitate future identification.

We collected a total of 445 specimens representing 103 species; unrepresented species are indicated in Table 2 (third column; rec. '()'). All Odonata records and specimens collected during this study are organised as Excel table. This can be obtained on request from the authors. The specimens are stored at the Naturalis Biodiversity Center, Leiden, The Netherlands. 7 species are new to the Naturalis collection that is one of the most complete African Odonata collections worldwide. 97 DNA samples were taken from 56 species to help with identification or to clarify taxonomic problems.

Discussion

This expedition confirmed our expectations of an exceptionally high Odonata diversity in Nigeria's Cross River State, including multiple range-restricted species and habitat specialists (see also Dijkstra & Vick, 2014). Not only did we record little-known species occurring only in this part of Africa, but also three species new to science. This highlights that much remains to be discovered about the Odonata fauna of the Gulf of Guinea lowland forests and highlands.

We targeted four locations in differing habitats spread across Cross River State, and the contrasting aquatic habitats that were present at each location were explored by a large team. The 138 taxa recorded are therefore thought to represent an important part of the state's Odonata diversity. It is nevertheless certain that more species await discovery in this region. Our results were affected by the dry conditions encountered, with smaller streams often reduced or even dried out. Genera such as *Lestes, Agriocnemis, Ceriagrion* and *Hadrothemis* were therefore remarkably scarce. Species inhabiting ephemeral waters were rarely observed and gomphids were underrepresented, with only few observations of freshly emerged individuals. This is largely because our expedition fell in the dry season, which was most pronounced in the more northern locations of Afi River Forest Reserve and the Obudu plateau. We therefore recommend undertaking future explorations in a different season. Nevertheless, one must keep in mind that travelling and sampling conditions may become notably more difficult. For example, one of us (A.M. Adedapo) experienced daily showers and barely one hour of sunshine per day at the Obudu Plateau in June.

Furthermore, many unexplored but promising areas remain in Cross River State. For instance, large areas of primary forest occur in the northern part of the state in the Okwangwo

Table 2: Overview of the taxa recorded per location (1-4) and sampling site (1-9b). The third row from above gives the recorded species richness per sampling site. Next, the table indicates for each site which species were recorded with an "X". Species are listed in taxonomic order following Dijkstra (2016), with the species richness per family given in brackets (excluding 'spec.' entries unless these represent a new genus). Taxa for which only larvae were recorded are written in italic. The column 'Rec.' gives some details on the observations: a "P" indicates that the species was photographed (88 in total), a P in bold indicates that the species was photographed alive for the first time (11 in total), while brackets indicate that the species was not collected during this expedition (32 taxa; leaving 102 collected taxa); *only recorded at a transit location.

Location		1		2		3							4							
Site		1	2	3	4	5a	5b	5c	6a	6b	6c	6d	7a	7b	7c	8a	8b	8c	9a	9b
Species	Species richness	36	41	24	37	27	10	16	14	14	26	8	9	9	13	9	4	30	18	10
	Rec.																			
Synlestidae																				
Nubiolestes diotima (Schmidt, 1943)	P												X		X					X
Lestidae																				
Lestes ochraceus Selys, 1862	P					X														
Argiolestidae																				
Neurolestes nigeriensis (Gambles, 1970)	**P**												X	X	X					X
Neurolestes trinervis Selys, 1885	P		X																	
Calopterygidae																				
Phaon camerunensis Sjöstedt, 1900	P	X	X		X															
Phaon iridipennis (Burmeister, 1839)	P							X	X	X			X						X	
Sapho orichalcea McLachlan, 1869	P	X	X		X		X	X			X								X	
Umma longistigma (Selys, 1869)	P	X	X		X		X	X				X								
Umma mesostigma (Selys, 1879)	P		X							X	X									
Umma mesumbei Vick, 1996	**P**																		X	X
Umma purpurea Pinhey, 1961	**P**		X		X															
Umma spec. Kirby, 1890		X						X												
Chlorocyphidae																				
Africocypha centripunctata (Gambles, 1975)	P												X	X	X		X	X	X	X
Africocypha lacuselephantum (Karsch, 1899)	P		X					X											X	X
Chlorocypha cancellata (Selys, 1879)	P	X	X	X																
Chlorocypha curta (Hagen in Selys, 1853)	P	X		X					X							X	X	X	X	
Chlorocypha cyanifrons (Selys, 1873)	P		X		X		X		X	X	X	X								
Chlorocypha glauca (Selys, 1879)	P			X	X							X								
Chlorocypha selysi (Karsch, 1899)	P							X			X									
Platycypha rufitibia (Pinhey, 1961)	P	X		X																
Pentaphlebiidae																				
Pentaphlebia stahli Förster, 1909	P		X																X	
Pentaphlebia spec. *Förster, 1909*	P																	X	X	

	Location	1		2		3							4							
	Site	1	2	3	4	5a	5b	5c	6a	6b	6c	6d	7a	7b	7c	8a	8b	8c	9a	9b
Platycnemididae																				
Allocnemis contraria (Schmidt, 1951)	P		X					X	X		X									
Allocnemis interrupta (Legrand, 1984)	P		X				X			X										
Allocnemis nigripes (Selys, 1886)	P		X					X		X	X									
Allocnemis vicki Dijkstra & Schütte, 2015	**P**												X	X	X					X
Allocnemis spec. Selys, 1863			X							X										
Mesocnemis singularis Karsch, 1891		X		X																
Stenocnemis pachystigma (Selys, 1886)	P		X					X											X	
Elattoneura acuta Kimmins, 1938	P	X																		
Elattoneura balli Kimmins, 1938	P		X		X						X	X								
Elattoneura nigra Kimmins, 1938				X	X															
Elattoneura pruinosa (Selys, 1886)	P	X	X		X			X			X							X	X	
Elattoneura vittata (Selys, 1886)	P				X		X			X	X	X								
Copera rufipes (Selys, 1886)										X										
Copera sikassoensis (Martin, 1912)	P	X			X	X														
Coenagrionidae																				
Aciagrion gracile (Sjöstedt, 1909)	( )														X					
Aciagrion spec. Selys, 1891															X					
Africallagma subtile (Ris, 1921)						X			X										X	X
Ceriagrion glabrum (Burmeister, 1839)						X						X								
Ceriagrion suave Ris, 1921	P		X						X											
Ceriagrion spec. Selys, 1876																		X		
Pseudagrion epiphonematicum Karsch, 1891	P		X							X	X									
Pseudagrion hemicolon Karsch, 1899	P									X										
Pseudagrion kersteni (Gerstäcker, 1869)	P					X			X							X		X		
Pseudagrion melanicterum Selys, 1876	P	X	X		X						X	X				X		X	X	
Pseudagrion serrulatum Karsch, 1894		X																		
Pseudagrion glaucescens Selys, 1876															X					
Pseudagrion hamoni Fraser, 1955	P	X		X		X														
Pseudagrion sjoestedti Förster, 1906	P	X		X	X															

	Location	1		2		3							4							
	Site	1	2	3	4	5a	5b	5c	6a	6b	6c	6d	7a	7b	7c	8a	8b	8c	9a	9b
Aeshnidae																				
Afroaeschna scotias (Pinhey, 1952)	( )													X						
Anax chloromelas Ris, 1911	( )		X																	
Anax congoliath Fraser, 1953	( )				X															
Anax imperator Leach in Brewster, 1815						X														
Gynacantha cylindrata Karsch, 1891	P		X								X									
Gynacantha bullata Karsch, 1891	(P)										X									
Gynacantha nigeriensis (Gambles, 1956)	P																			
Heliaeschna fuliginosa Karsch, 1893	P	X	X							X	X									
Gomphidae																				
Diastatomma gamblesi Legrand, 1992	**P**						X													
Diastatomma spec. in Burmeister, 1839			X																	
Ictinogomphus fraseri Kimmins, 1958	P			X	X															
Lestinogomphus spec. Martin, 1911					X															
Microgomphus spec. Selys, 1858		X			X					X										
Notogomphus spec. Selys, 1858	(P)														X			X		
Paragomphus serrulatus ([Karsch], 1898)	( )			X																
Paragomphus spec. Cowley, 1934	(P)				X															
Paragomphus spec. Cowley, 1934	P													X				X		
Libyogomphus tenaculatus Fraser, 1926	P	X	X								X							X		
Macromiidae																				
Phyllomacromia caneri (Gauthier, 1987)	**P**										X									
Phyllomacromia hervei (Legrand, 1980)					X															
Phyllomacromia lieftincki (Fraser, 1954)	**P**												X		X				X	X
Phyllomacromia melania (Selys, 1871)	P						X				X									
Phyllomacromia spec. Selys, 1878	( )												X	X	X					
Libellulidae																				
Acisoma inflatum Selys, 1882		X		X		X														
Acisoma trifidum Kirby, 1889	( )	X			X	X														
Aethriamanta rezia Kirby, 1889	(P)					X														

	Location	1		2		3							4							
	Site	1	2	3	4	5a	5b	5c	6a	6b	6c	6d	7a	7b	7c	8a	8b	8c	9a	9b
Atoconeura sp. nov. Karsch, 1899	**P**												X	X	X					
Bradinopyga strachani (Kirby, 1900)	( )																	X		
Chalcostephia flavifrons Kirby, 1889			X			X			X		X									
Crocothemis divisa [Karsch], 1898																		X		
Crocothemis erythraea (Brullé, 1832)	( )	X		X		X												X		
Crocothemis sanguinolenta (Burmeister, 1839)		X						X										X		
Cyanothemis simpsoni Ris, 1915	P		X	X																
Diplacodes lefebvrii (Rambur, 1842)	P					X										X		X		
Eleuthemis buettikoferi Ris, 1910	P	X		X																
Hadrothemis camarensis (Kirby, 1889)	P		X		X						X									
Hadrothemis coacta (Karsch, 1891)	(P)				X				X		X								X	
Hadrothemis infesta (Karsch, 1891)	(P)										X									
Hemistigma albipunctum (Rambur, 1842)	P					X	X	X											X	
Malgassophlebia bispina Fraser, 1958	P				X						X									
Neodythemis cf. gorillae	**P**														X			X		X
Neodythemis klingi (Karsch, 1890)	P		X		X		X	X			X								X	
Neodythemis preussi (Karsch, 1891)	P	X					X													
Notiothemis robertsi Fraser, 1944	P	X	X		X				X	X										
Olpogastra lugubris (Karsch, 1895)	P		X	X																
Orthetrum abbotti Calvert, 1892	P					X										X		X		
Orthetrum africanum (Selys, 1887)	P		X		X				X											
Orthetrum angustiventre (Rambur, 1842)								X												
Orthetrum austeni (Kirby, 1900)						X					X									
Orthetrum brachiale (Palisot de Beauvois, 1817)			X								X									
Orthetrum camerunense Gambles, 1959	P															X	X	X		
Orthetrum chrysostigma (Burmeister, 1839)		X		X		X		X										X		
Orthetrum guineense Ris, 1910	P															X		X		
Orthetrum hintzi Schmidt, 1951	P			X		X														
Orthetrum julia Kirby, 1900		X	X		X					X			X		X				X	X
Orthetrum microstigma Ris, 1911	( )	X			X															
Orthetrum saegeri Pinhey, 1966																		X		

Location		1		2		3							4							
	Site	**1**	**2**	**3**	**4**	**5a**	**5b**	**5c**	**6a**	**6b**	**6c**	**6d**	**7a**	**7b**	**7c**	**8a**	**8b**	**8c**	**9a**	**9b**
Orthetrum stemmale (Burmeister, 1839)	( )	X		X		X														
Orthetrum trinacria (Selys, 1841)	( )					X														
Palpopleura lucia (Drury, 1773)	( )	X	X		X	X														
Palpopleura portia (Drury, 1773)	( )	X			X				X								X	X	X	
Palpopleura spec. Rambur, 1842	( )															X				
Pantala flavescens (Fabricius, 1798)	( )					X														
Rhyothemis fenestrina (Rambur, 1842)	(P)					X														
Rhyothemis semihyalina (Desjardins, 1835)	( )					X														
Tetrathemis camerunensis (Sjöstedt, 1900)					X															
Tetrathemis sp. nov. Brauer, 1868	**P**		X																	
Tholymis tillarga (Fabricius, 1798)	P		X						X											
Tramea basilaris (Palisot de Beauvois, 1817)	(P)					X														
Tramea limbata (Desjardins, 1835)	(P)					X														
Trithemis arteriosa (Burmeister, 1839)	P	X		X	X													X		
Trithemis imitata Pinhey, 1961				X																
Trithemis kalula Kirby, 1900	P																	X		
Trithemis aconita Lieftinck, 1969	P	X	X	X								X						X		
Trithemis basitincta Ris, 1912	P				X															
Trithemis legrandi Dijkstra, Kipping & Mézière, 2015			X																	
Trithemis dichroa Karsch, 1893	P	X		X												X		X		
Trithemis furva Karsch, 1899	P													X						
Trithemis pruinata Karsch, 1899	P				X				X									X		
Trithemis grouti Pinhey, 1961	P				X															
Trithemis kirbyi Selys, 1891	( )	X		X																
Trithemis spec. Brauer, 1868	( )																	X		
Urothemis assignata (Selys, 1872)	( )					X														
Zygonyx flavicosta (Sjöstedt, 1900)	P	X	X	X	X													X		
Zygonyx natalensis (Martin, 1900)	P							X										X		
Zygonyx speciosus (Karsch, 1891)	**P**				X						X									
Zygonyx spec. in Hagen, 1867	( )		X																	
Zygonyx spec. in Hagen, *1867*	( )													X						

Location	1		2			3							4								
Site	1	2	3	4	5a	5b	5c	6a	6b	6c	6d	7a	7b	7c	8a	8b	8c	9a	9b	(P)
Zyxomma atlanticum Selys, 1889*																				

section of Cross River National Park and the Mbe Mountains. This area includes elevation ranges of 500-1000 m a.s.l. that are hard to reach. Moreover, the highlands of the Obudu plateau extend further north than the sites that we surveyed, and even more extensive highlands (although with a drier climate) occur further north in Nigeria. These areas, as well as the fact that there still remain species that are known from neighbouring countries but not from Nigeria, provide a scope for further exploration of Nigeria's dragonfly fauna.

Sampled locations and notable records

Lowland locations

A high species diversity was recorded at Aking in the Oban Hills Division of Cross River National Park. Both sampling sites there were larger rivers with intermediate flow velocities and a relatively high diversity of both river substrates (pebbles and rocky bottoms with sandy and organic deposits) and surrounding habitats. The Ikpang river (site 1, see Table 1 & figure 2) has a moderate level of disturbance with half-open habitats, which is reflected in the richness of genera like *Pseudagrion, Orthetrum* and other Libellulidae. *Elattoneura acuta* and *Pseudagrion serrulatum* were only recorded at this site and the latter, as well as *Libyogomphus tenaculatus*, represented a first record for Nigeria. Species richness was even higher at the Manko river (2) (41 species), a site where two full sampling days were spent. A notable diversity of Zygoptera species was recorded here, including the highest richness of Calopterygidae and Platycnemididae of all sampling sites. *Umma purpurea, Africocypha lacuselephantum* and *Libyogomphus tenaculatus* were specialties of the main river channel (Figure 2C), whereas a distinct set of species was present on the small side streams (Figure 2D). These included specialist relicts such as *Pentaphlebia stahli*, *Stenocnemis pachystigma* and *Neurolestes trinervis*; the latter we recorded only at this site. *Allocnemis interrupta*, caught at one side stream, was a new national record and previously only known from Gabon. Of the species recorded at the main stream, *Trithemis legrandi* and *Tetrathemis* sp. nov. were only recorded at this site during our survey. *T. legrandi* was previously known only from Cameroon and Gabon. Our *Tetrathemis* specimens differ sufficiently from the West African *T. godiardi* to represent an undescribed but probably closely related species (Dijkstra et al., in prep.) (see Appendix 1, page 50).

Both sampling sites at Ekang represent slow-flowing waters at low altitude with extensive sandy substrates. The Acham river (3) is the largest river visited during the survey and species typical of larger rivers, such as *Platycypha rufitibia, Mesocnemis singularis, Paragomphus serrulatus* and *Trithemis imitata* were recorded only here or on the Ikpang river (1). By contrast, the Atemayip river is a small, largely stagnant stream with both moderately disturbed parts adjoining cultivation (Figure 3C), and relatively undisturbed parts in secondary forest habitat (Figure 3D). This variation resulted in a high species richness (37 species). This stream supported high numbers of *Trithemis* species and *Chlorocypha glauca* at sunny places, and a few specialists such as *Umma purpurea*

in the forested part. This was the only site where *Anax congoliath, Lestinogomphus* spec., *Phyllomacromia hervei, Tetrathemis camerunensis* and *Trithemis basitincta* were recorded. *Elattoneura nigra* and *Ictinogomphus fraseri* were also recorded only at Ekang, but at both rivers. Both *T. basitincta* and *I. fraseri* represent the first national records, while *C. glauca* was discovered in Nigeria only very recently (A.M. Adedapo, unpublished).

The sites at Buanchor represent contrasting aquatic habitats in a human-altered but varied "farm-bush" landscape. At the abandoned rice fields (5a), almost no Zygoptera were observed but instead a high number of Anisoptera species, predominantly Libellulidae. Most of these were associated with swampy stagnant water, a habitat not found at any of the other sites sampled in this study, and many were therefore recorded only here, including both *Rhyothemis* and *Tramea* species. The small streams in the Buanchor "farm-bush" (5b) had rather low numbers of species but a few specialties such as *Allocnemis interrupta*, *Phyllomacromia melania* and *Diastatomma gamblesi*. The latter was only recorded at this site and previously not known east of Togo, and therefore rather a surprising new national record. The Magbe river (5c) differs strongly from the other sites around Buanchor, being a fast-flowing river running down the Afi Mountains, albeit through strongly degraded forest. It nevertheless supported good populations of *Africocypha lacuselephantum* and *Chlorocypha selysi*, as well as *Stenocnemis pachystigma*. *Orthetrum angustiventre* was only recorded at this site.

Neighbouring the Afi River Forest Reserve near Buanchor, the Drill Ranch sanctuary supports a remnant of primary rainforest with several smaller streams. The Bano river (6a) is the largest of these, but its course was severely degraded by a deluge of rocks and debris brought down by landslides upstream (Figure 4D). It still supported species typical of disturbed habitats such as *Chlorocypha curta and Palpopleura portia*. The tributaries of this river were still in good condition. One of these, a small muddy seepage stream (6b) supported high numbers of *Heliaeschna fuliginosa* and several Zygoptera species, including *Allocnemis interrupta* and our only records of *Copera rufipes and Pseudagrion hemicolon*, of which *C. rufipes* was a new national record. Two adjacent streams at the foothills of the Afi Mountains (6c) known as the 'Cataract stream' supported both slow-flowing and faster flowing rocky parts, although their water level was low during our visit. This transition yielded a relatively high species diversity at these streams with several Anisoptera species characteristic of running water, notably *Phyllomacromia caneri, P. hervei* and *Zygonyx speciosus. P. caneri, Gynacantha bullata* and *Hadrothemis infesta* were only recorded at this site and *P. caneri* also represents a new species for Nigeria. Finally, a few species were recorded at the slow-flowing downstream part of the same Cataract stream (6d), of which *Chlorocypha glauca* is most notable.

Obudu Plateau

This plateau was extensively explored because of its diverse habitats where highland specialists can be found. The streams support a lower species diversity than the lowland sites explored on this trip, probably because of a variety of factors like a lower ecosystem productivity and lower water temperatures, but many specialists occur where montane forest habitat remains. A strong contrast exists between the small forest reserves near Obudu Cattle Ranch and their severely degraded surroundings. The largest and best-pre-

served area near the village is the Becheve Forest Reserve (7a), which is also the source of the Avase river. Seepage areas in the reserve (Figure 5C) with gravel or muddy substrates supported *Allocnemis vicki and Neurolestes nigeriensis*. These seepages give rise to several small streams with mostly gravel substrates and a rather fast flow. Shaded parts of these streams (Figure 5A) support the enigmatic *Nubiolestes diotima and Phyllomacromia lieftincki*, while sunny spots typically held *Africocypha centripunctata*. Where gaps in the forest cover created larger sunny spots (Figure 5D), we encountered an *Atoconeura* that combines features of several known species, but also has some unique characters too, and clearly represents a new species (Dijkstra et al., in prep.) (for pictures see Appendix 1, page 46).

Downstream of Becheve Forest Reserve, the stream running through Grotto Pool reserve (7b) (Figure 5E) is bigger and its narrow forested habitat consists of secondary forest that is denser than Becheve's. *A. centripunctata* and *A. vicki* were present on this part of the stream as well, and at this site the new species of *Atoconeura* was recorded first. Seepage areas adjacent to the streambed supported *N. nigeriensis*. The Emba Forest Reserve (7c) (Figure 5F) drains to the Afundu river catchment and represents a rather large but moderately disturbed forest patch where cattle and goats enter in low numbers. This reserve again supported *N. diotima, N. nigeriensis, A. centripunctata, A. vicki* and *P. lieftincki* in similar habitats as described from the Becheve Forest Reserve. Slightly increased disturbance has created small grassy sunny open patches along the stream in the higher part of the reserve. *A. vicki* and the new *Atoconeura* were present here as well as a *Neodythemis* species that recalls the Albertine Rift endemics *N. munyaga* and *N. nyungwe* (Dijkstra et al., in prep.) (see Appendix 1, page 48). This is probably what Robert Gambles called *N. gorillae* on his visits to the Obudu plateau, but Elliot Pinhey's holotype of this species from nearby Cameroon pertains to *N. afra*. Furthermore, grassy patches of the Emba stream provided the only records of *Aciagrion gracile* and *Pseudagrion glaucescens* on this trip.

Downstream of these reserves lie extensive areas of pastureland that were once forested, but are now degrading under heavy grazing pressure. Through this landscape flow the more degraded streams of the Obudu plateau. Although usually a narrow band of permanent riparian vegetation is left, the streams suffer from the eutrophication and erosion of the adjacent pasturelands and are themselves also frequently disturbed by livestock. The highland specialists encountered in the plateau's forest reserves were generally absent at these sites, although *Africocypha centripunctata* appears to be tolerant to disturbance as it was recorded at nearly every sampling site on the plateau. Instead, these streams supported species typical of more open habitats, such as *Chlorocypha curta* and *Palpopleura portia*, and including *Orthetrum camerunense, O. guineense* and *Trithemis dichroa* that during this trip were only recorded at Obudu's degraded streams. The Avase river (8a) (Figure 6G) downstream of Grotto Pool Reserve flows through the most heavily grazed areas and was the only site where *A. centripunctata* was absent, whereas the lower part of the Emba stream (8b) (Figure 6H) also experiences heavy disturbance and held only very few species, in stark contrast to the adjacent Emba reserve.

A considerably higher species richness was found at the Afundu I river (8c), which has clearer water and more diverse habitats, including very rocky parts, local seepages and sandy substrates, and more developed riparian vegetation than at sites 8a and 8b. Moreover, it pas-

ses through a less intensively grazed and more recently deforested valley. Its rocky substrate and lower altitude make this river most comparable to the Afundu II river (see below). *A. centripunctata* occurred here in good numbers, while also the new *Neodythemis* was found at a side-stream and *Pentaphlebia* nymphs were collected in the main river. At the Igaga waterfall there lies an area of exposed bedrock and temporary rocky pools (Figure 6J), that supported a particularly high diversity of *Orthetrum* and *Trithemis* species. *O. saegeri* and *T. kalula* were only recorded at this waterfall, although in different habitats (respectively a grassy seepage and a rockpool).

The western edge of the Obudu plateau marks the border of both the Okwangwo division of Cross River National Park and the remaining pristine forest. The rocky Afundu II river (9a), a large tributary of the Afundu river, flows through rather tall forest at 1200 m a.s.l. that has similarities to the habitat of the Manko river in the Oban Hills (site 2), despite lying at a considerably higher elevation (Figure 6K). This is reflected by the presence of species such as *Sapho orichalcea*, *Africocypha lacuselephantum*, *Pentaphlebia stahli*, *Stenocnemis pachystigma* and *Neodythemis klingi*. A good diversity of Calopterygidae was found here including the little-known *Umma mesumbei*, previously known only from Cameroon. With few exceptions, Calopterygidae prefer more shaded streams through natural forest and disappear when habitats open up. The family was absent at the Afundu I river, for instance. *Pentaphlebia stahli* similarly appears to be confined to smaller fast-flowing streams and seepage in undisturbed rainforest, although *Pentaphlebia* larvae were also collected from the Afundu I river. Upstream of the Afundu I valley, the high-altitude Anape river (9b) (Figure 6L) runs through pristine forest where a rather complete community of specialized highland and forest species was present, including *Nubiolestes diotima, Neurolestes nigeriensis, Umma mesumbei, Allocnemis vicki, Phyllomacromia lieftincki* and the new *Neodythemis* species. Both *Africocypha centripunctata* and *A. lacuselephantum* occurred along this river, which lies at the upper boundary of the known elevation range of the latter species (0-1600 m a.s.l.).

Species of interest

Striking colour patterns in Chlorocyphidae

The extravagant *Africocypha lacuselephantum* and only slightly less spectacular *A. centripunctata* were often encountered, allowing us to document their unusual colour transformations photographically, as presented in Appendix 1 (see pages 36 and 37). The colour variation in *Chlorocypha* has confused their taxonomy in the past (Dijkstra et al., 2014). Both face blackening and abdominal change in colour were previously noted by Pinhey (1967) as a natural process of maturation in certain species, notably those of the genus *Africocypha*. Colour variation has been described for *Africocypha* before (Dijkstra et al., 2015; Gambles, 1975; Pinhey, 1971), but its function and cause (e.g. genetic or developmental) remain unknown (Dijkstra et al., 2015). In both species, abdomen colour seems to change form from bright blue to white, then yellow-orange, and finally bright red. Anyhow, none of these transitions were observed in the field in the same individuals.

During this trip we recorded males of *A. centripunctata* with orange and red on all abdominal segments simultaneously, and blue males were observed but unfortunately not photographed. In males of *A. lacuselephantum* multi-coloured abdomens (one colour per segment) were

observed, rather than a gradual transitioning like *A. centripunctata*. Descriptions of female *A. lacuselephantum* are rare (Pinhey, 1967, 1971; Ekpah et al., 2020), but our photographs of correspond to similar descriptions: *A. lacuselephantum* females show blue to green lateral stripes on the abdomen and a blue dorsal pattern. Female descriptions of *A. centripunctata* are lacking completely in published literature. In *A. centripunctata* females a wide range of colour patterns was found, similar to other *Africocypha* males; some specimens had a bright yellowish coloration on the head and thorax, while others were dull brown, and facial colour varied from yellowish green to pale blue. Abdomens had pale blue spots in some individuals but white to yellow and orange spots in others

Besides these striking species, unusual phenotypes of *Chlorocypha cyanifrons* (see Appendix 1, pages 38/39) and *C. selysi* (with a yellow abdomen tip; see Appendix 1, page 39) were observed. We observed wide variation in blue coloration on the face, frons, vertex and epistome of *Chlorocypha cyanifrons* at the Atemayip river in Ekang (see Appendix 1, pages 38/39), ranging from extensive blue to almost entirely black coloration resembling *Chlorocypha rubida*. Although black individuals are sometimes described as 'melanic examples' (Pinhey, 1967), no clear description of this patterning is present in literature.

Taxonomic insights

Both *Neodythemis gorillae* and *Zygonyx ikomae* were described by Pinhey (1960) as new species from the Cameroon-Nigeria border region, but later synonymized with respectively *N. afra* and *Z. natalensis* (Dijkstra & Vick, 2006; Dijkstra, 2007). Our observations of *Zygonyx* from habitats assumed to be similar to the type locality of *Z. ikomae* shed some light on this 'dark relative of *Z. natalensis*' as described by Pinhey. Our specimens were very dark, with less pruinosity than is typical elsewhere in Africa, but did not differ from *Z. natalensis* otherwise. Pinhey writes that dark and pruinose individuals were found together, just as we did. This supports the conclusion that '*Z. ikomae*' refers to a dark individuals of *Z. natalensis* and not to a separate species.

The Natural History Museum in London possesses a single female specimen identified by Robert Gambles as *Neodythemis gorillae*, which he collected from Obudu on 25 March 1971. That species, which was described from lowland forest in adjacent Cameroon, however, is a synonym of *N. afra* (Dijkstra & Vick, 2006). We obtained additional *Neodythemis* specimens from the Obudu plateau, including males, which show substantial differences with *N. afra* and pertain to an undescribed species nearer to *N. nyungwe* Dijkstra & Vick, 2006 from Rwanda and especially *N. munyaga* Dijkstra & Vick, 2006 from Uganda.

Pentaphlebia gamblesi, the main subject of the expedition to the Obudu Plateau, has not been recorded since the male holotype was collected in July 1973 by Mike Parr at the Grotto Pool (Parr, 1977). Recently a larva of *Pentaphlebia* spp. was collected in December 2021 in the Afundu I river near Igaga waterfall (pers. comm. E. Akindele & A.M. Adedapo), corresponding to our site 8c where we found larvae again. We furthermore recorded larvae of *Pentaphlebia* spp. and remarkably also a male *Pentaphlebia stahli* at the Afundu II river (site 9a) – the latter at a seepage aside of the main riverbed. This was a first record of this species from the Obudu Plateau, suggesting a possible sympatry between the two *Pentaphlebia* species. They are not altitudinally separated as *P. stahli* also occurs at yet higher altitude in Cameroon, and a phenological asynchrony of both species also seems unlikely

because *P. gamblesi* was collected in July and adults of *P. stahli* have been seen in July as well (Vick, 1998). Yet the Afundu II river valley differs in atmospheric conditions and vegetation from the higher parts of the Obudu plateau, being more typical of tropical rainforest than montane vegetation. Moreover, *P. stahli* prefers small fast-flowing shaded streams (Akindele et al., 2021; this publication) whereas *P. gamblesi* might prefer larger, sunnier water bodies as in its type locality. It is therefore possible that the larvae that we found in such habitat on the Obudu plateau might belong to this *P. gamblesi*. Comparison of larval morphology and genetics might help clarify this, and shed light on the status of this iconic and critically endangered damselfly.

Threats to Cross River States' Odonata species

Although substantial parts of Cross River States' forests are formally protected, habitat quality was severely degraded at several sites visited. The lowland habitats around Aking and Ekang seem least under pressure, as this area is sparsely populated and extensive forest blocks remain in the Oban section of Cross River National Park. Small-scale subsistence farming occurs around the villages and could be observed expanding into the forests at both Aking and Ekang, while large-scale palm oil plantations are being developed just south of Aking. The rivers that we sampled in the small-scale "farm-bush" habitats in this area are moderately disturbed but still support a high Odonata diversity. Expansion of large-scale agriculture such as palm oil would however threaten these habitats.

The "farm-bush" around Buanchor also supports rather rich Odonata communities including specialist species, but habitat degradation here was considerably more widespread. Human activities including waste dumping have degraded habitat quality of the streams adjacent to Buanchor village (Figure 7A), while forest clearing continues further away from the village (Bassey & Okeke, 2013; Sunday, 2021; own observations). This is causing the forest block around the Drill Ranch to become increasingly isolated. Moreover, extensive forest loss is occurring on the steep slopes of the Afi Mountains. In the Magbe River catchment above Buanchor village, slash-and-burn activities have caused wildfires that destroyed the forest cover over an elevation range of nearly 1000 meters – almost from the base to the top of the mountain range. This steep slope is now covered by low vegetation with only a few remaining trees (Figure 7B), leaving it highly vulnerable to soil erosion and landslides. This could potentially severely affect the Magbe river as well as Buanchor village. The devastating effects of erosion and landslides to stream habitats in particular could be seen at the Bano River (Figure 4D). Despite running through protected forest habitat, the course of this river is severely impacted by debris originating from landslides that occurred kilometres away on the mountain slopes in 2012 (Bassey & Okeke, 2013). The forested habitats on the stream banks are re-establishing, but only a few Odonata species tolerant to high disturbance levels now inhabit this river.

The most severe habitat degradation was encountered in the unique highland habitats of the Obudu plateau. The high-altitude valleys here historically supported extensive montane forests, but widespread forest clearing and burning have pushed back the tree cover to narrow strips along the streams (Figure 7C, showing the Afundu I river catchment). We observed fires in some of the remaining forest patches on every day of our visit (Figure 7E). The reserves that still support montane forest and an Odonata community with highland

Figure 7: Photographs of habitat degradation encountered at the sampling sites. Human disturbance (A) and former forest destroyed by fire on the Afi Mountains' slopes (B), both near Buanchor (location 3). Deforestation strongly affected the Afundu I river catchment (C) and approaches the still pristine valley of the Afundu II river (D), Obudu plateau (location 4). Fire continues to affect remaining natural habitats and secondary vegetation (E; here near the lower Emba river - site 8b). Forest cover loss, burning and overgrazing drive soil erosion and may ultimately result in barren slopes that fail to support a rich biodiversity as well as the needs of the local community (F; here near the Afundu I river - site 8c).

specialists (sites 7a-c and 9b) are nowadays small and fragmented. In their surroundings, deforested land is cultivated only for a few years and is then transferred to pasture as the soil degrades, where frequent burning and overgrazing cause runoff of nutrients and sediments to the streams. Resultantly, water quality of the streams in these valleys is likely deteriorating and disturbance by cattle can be frequent (Figure 6H). Our results show that although minor disturbances are tolerated by most highland specialist species and might even create new micro-habitats (e.g. at site 7b), impoverished species communities without specialist species remain at severely degraded sites (8a-b). The large Afundu I valley (site 8c) was deforested rather recently and still supports a high species richness, but it now mainly supports widespread species of low conservation value. The Afundu II catchment by contrast represents one of the last forested margins on the Obudu plateau, situated at the fringe of its steep western slope (Figure 7D).

As habitat degradation continues on the Obudu plateau, it is clear that its highland habitats and their specialist Odonata are under immediate threat. This is especially concerning given that species such as *Allocnemis vicki* and *Neurolestes nigeriensis*, classified as endangered and critically endangered respectively, are only known from this plateau in Nigeria and very few locations in Cameroon. This likely applies also to *Pentaphlebia gamblesi* (critically endangered) and the two new species mentioned in this report, that are still only known from the Obudu plateau. *Africocypha centripunctata* is also classified as endangered but appears much more tolerant to habitat degradation. The local human population itself is also at risk of losing ecosystem services it depends on if soil degradation and erosion continue, especially in the steeper valleys such as the Afundu I valley (Figure 7C & 7F). Therefore, both for the communities and the natural habitats of the Obudu plateau, halting further deforestation and habitat degradation is desperately needed. This requires the development of more sustainable land-use practices and habitat restoration efforts, in parallel with improved education and socio-economic perspective for the local community, before the last montane forests are lost.

Conclusion

This expedition was the first focused survey of Odonata in Cross River National Park. A wide variety of habitats was visited, ranging from pristine forest streams in lowland and highland forests to larger rivers and swampy rice-fields. Yet, taking seasonal limitations and remaining unexplored natural habitats and elevations into consideration, the current list may represent only about half of the fauna present. Surveys outside the dry season and larval work are therefore needed. Nevertheless, the 123 species recorded during this survey demonstrate the outstanding Odonata richness of this region, while twelve new country records, including three species new to science, reflect how much remains to be discovered. The collected specimens support further taxonomic work on the Odonata of this region. In addition to physical specimens, 88 species were photographed, 11 of them for the first time. Moreover, this expedition did not only result in valuable new data, but also provided the foundation for future collaboration between European and Nigerian entomologists.

From a conservation perspective, contrasts in both biodiversity and threats to Odonata habitats were observed between pristine and disturbed habitats and between the lowland

sites at Aking, Ekang and Buanchor and the highlands of the Obudu Plateau. While species richness was highest at the lowland locations, including at some sites where limited disturbance occurred, high diversities of specialists, Calopterygidae and Platycnemididae were found in undisturbed forest streams. These were not yet as much under pressure as the montane habitats of the Obudu Plateau. Large parts of this plateau are already severely degraded, while further burning, deforestation and overgrazing were observed on our visit. Only a few well-preserved streams remain inside patchy and fragmented forest reserves. The unique species of these habitats are under immediate threat, and even the survival of *Pentaphlebia gamblesi*, which was observed here 50 years ago, remains uncertain. Future fieldwork must provide more insight into these species, and conservation action to preserve and restore their unique habitats is especially urgent.

Notes on specimen collection

Specimens are available for examination in Naturalis Biodiversity Center in Leiden, The Netherlands, which houses the most complete collection of African Odonata, largely assembled by KD Dijkstra. This study added several important specimens and seven new species to the collection. A complete list of voucher specimens is available from the authors upon request.

Although ample taxonomic expertise is now available in the country, a central collection of Nigerian Odonata does not yet exist. This could nonetheless be a huge boon to the country's odonatology, streamlining taxonomic insights from this hugely diverse region.

Specimens were collected under supervision of park rangers in Cross River National Park. Export permission was provided by the Federal Ministry of Agriculture and rural Development, Nigeria (Gifmis Code for Veterinary Export, 1000174430). Collection material was imported with permission of Naturalis Biodiversity Centre in Leiden, the Netherlands, and specimens are available here for further examination.

Acknowledgements

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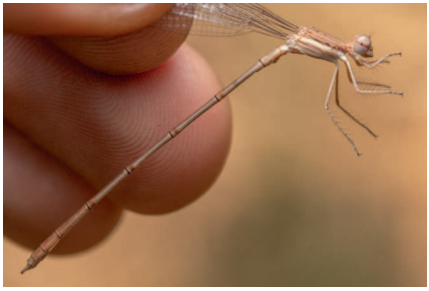
Appendix I: Odonata photographs

SYNLESTIDAE

Nubiolestes diotima **(Schmidt, 1943), ♂**

LESTIDAE



Lestes ochraceus **(Selys, 1862), ♂**

ARGIOLESTIDAE

Neurolestes nigeriensis **(Gambles, 1970), from left to right: ♀, ♂, ♂, ♂**

***Neurolestes trinervis* (Selys, 1885) ♂**

CALOPTERYGIDAE

***Phaon camerunensis* (Sjöstedt, 1900) ♂**

***Phaon iridipennis* (Burmeister, 1839) ♂**

***Sapho orichalcea* (McLachlan, 1869) ♀,♂**

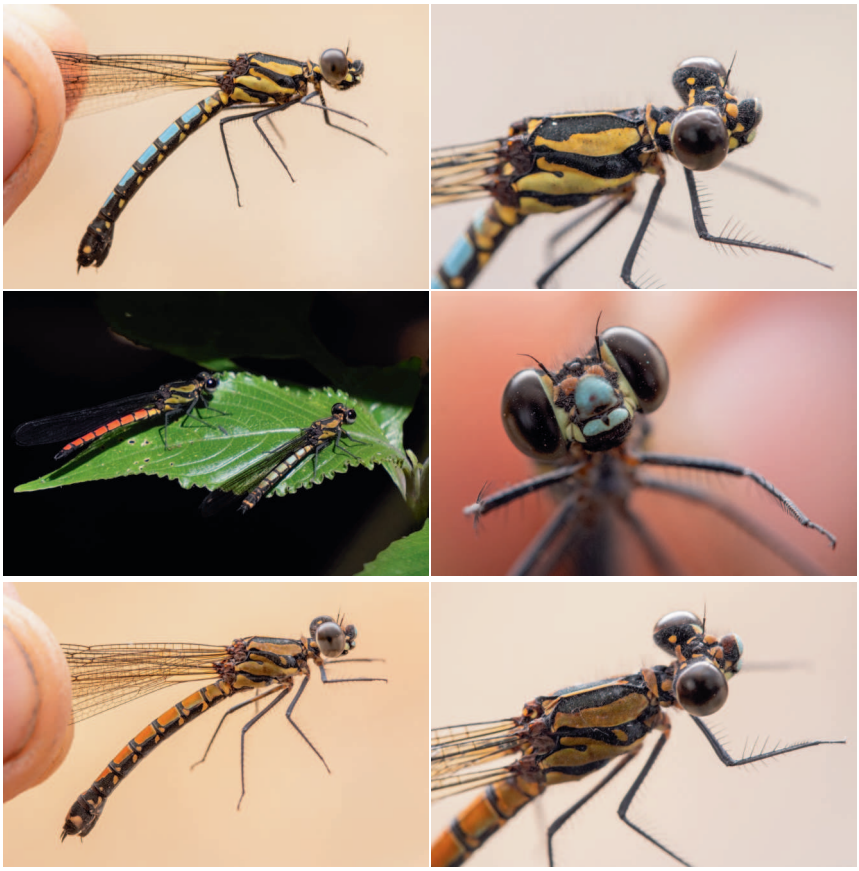
***Umma longistigma* (Selys, 1869) ♀,♂**

***Umma mesostigma* (Selys, 1879) ♂**

***Umma purpurea* (Pinhey, 1961) ♀, ♂**

***Umma mesumbei* (Vick, 1996)♂**

CHLOROCYPHIDAE



***Africocypha centripunctata* (Gambles, 1975)** ♀, ♀, ♂+♀, ♀, ♀,♀, ♂, ♂

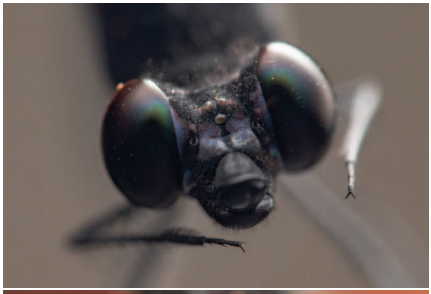
Color variation displayed by *A. centripunctata*. Note that the female abdomen exhibits a remarkable transition from bright blue (first row) to pale whitish (second row, left) to orange (third row), while the thorax color develops from yellow to brown. The observed males showed abdomen color variation from yellow-orange to red (fourth row), while blue coloration was observed but not photographed.

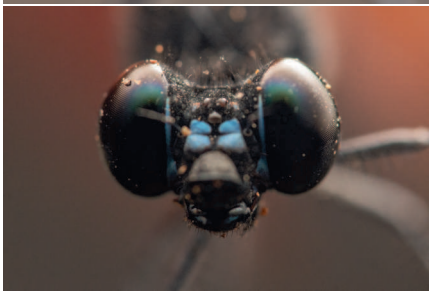
***Africocypha lacuselephantum* (Karsch, 1899)** ♀, ♂, ♂, ♂

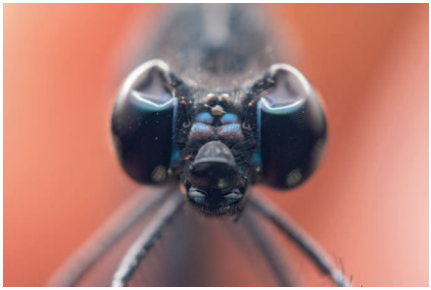
Color variation displayed by *A. lacuselephantum*. The observed females displayed all-encompassing blue coloration (first row, left). In males, the five median abdominal segments change color one segment at the time, starting at the tail-end and ending in the middle (segment 6) from blue (first row, right) to pale whitish, yellow, orange and finally red (middle & bottom) to eventually become entirely red (Pinhey, 1967). The thorax darkens gradually.

***Chlorocypha cancellata* (Selys, 1879) ♂**

***Chlorocypha curta* (Hagen in Selys, 1853) ♂**







***Chlorocypha cyanifrons* (Selys, 1873) all ♂**

Extensive variation in facial coloration was observed in *C. cyanifrons* at the Atemayip river, Ekang (site 4). While *C. cyanifrons* usually is bright blue from eye to eye, in these specimens the blue was reduced to various degrees. In extreme cases only a narrow purple-blue line alongside the eyes was left.

***Chlorocypha glauca* (Selys, 1879) ♂**

***Chlorocypha selysi* (Karsch, 1899) ♂**

***Platycypha rufitibia* (Pinhey, 1961) ♂**

PENTAPHLEBIIDAE

***Pentaphlebia* spec.**

***Pentaphlebia stahli* (Förster, 1909) ♂**

PLATYCNEMIDIDAE

Allocnemis contraria **(Schmidt, 1951)** ♂

Allocnemis nigripes **(Selys, 1886)** ♂

Allocnemis interrupta **(Legrand, 1984)** ♂, ♂

Allocnemis vicki **(Dijkstra & Schütte, 2015)** ♂, ♂

Stenocnemis pachystigma **(Selys, 1886)** ♂

Elattoneura acuta **(Kimmins, 1938)** ♂

***Elattoneura balli* (Kimmins, 1938) ♂**

***Elattoneura pruinosa* (Selys, 1886) ♂**

***Elattoneura vittata* (Selys, 1886) ♂**

***Copera sikassoensis* (Martin, 1912) ♂**

COENAGRIONIDAE

***Ceriagrion suave* (Ris, 1921) ♂**

***Pseudagrion epiphonematicum* (Karsch, 1891) ♂**

***Pseudagrion hemicolon* (Karsch, 1899) ♂**

***Pseudagrion kersteni* (Gerstäcker, 1869) ♂**

***Pseudagrion melanicterum* (Selys, 1876) ♂**

***Pseudagrion hamoni* (Fraser, 1955) ♂**

***Pseudagrion sjoestedti* (Förster, 1906) ♂, ♂+♀**

AESHNIDAE

***Gynacantha cylindrata* (Karsch, 1891) ♂**

***Gynacantha bullata* (Karsch, 1891) ♂**

***Gynacantha nigeriensis* (Gambles, 1956)**
♀

***Heliaeschna fuliginosa* (Karsch, 1893)** ♀, ♂

GOMPHIDAE

***Diastatomma gamblesi* (Legrand, 1992)** ♂

***Ictinogomphus fraseri* (Kimmins, 1958)** ♂

***Lestinogomphus* spec.** ♀

***Microgomphus* spec.** ♀

***Libyogomphus tenaculatus* (Fraser, 1926) ♂**

MACROMIIDAE

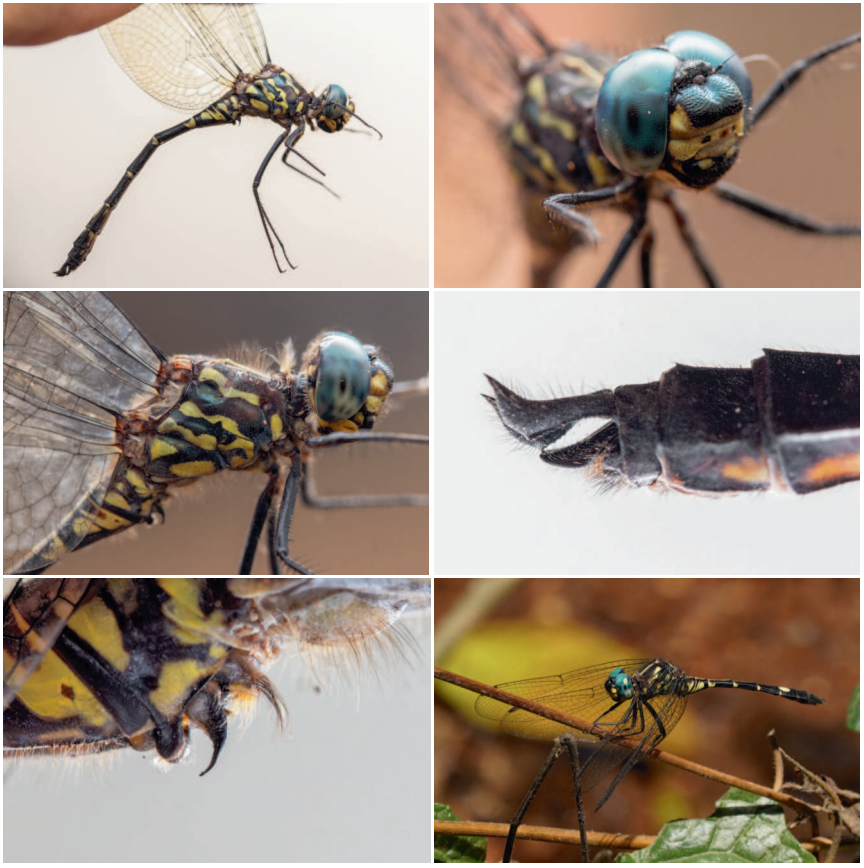
***Phyllomacromia caneri* (Gauthier, 1987) ♂**

***Phyllomacromia melania* (Selys, 1871) ♂**

***Phyllomacromia lieftincki* (Fraser, 1954) ♂, ♂**

LIBELLULIDAE

***Aethriamanta rezia* (Kirby, 1889) ♂**



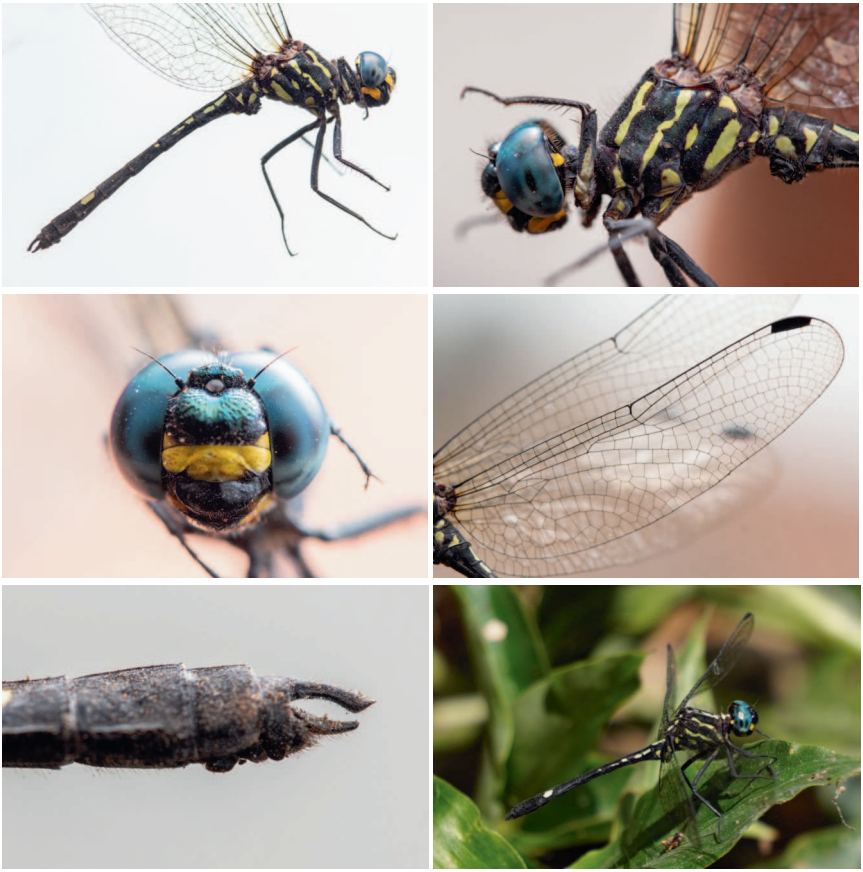
***Atoconeura* sp. nov. , ♂**

***Eleuthemis buettikoferi* (Ris, 1910) ♂**

***Hadrothemis camarensis* (Kirby, 1889) ♂**

***Malgassophlebia bispina* (Fraser, 1958) ♀**

***Hemistigma albipunctum* (Rambur, 1842) ♂**



***Neodythemis* sp. nov. ♂**

***Neodythemis klingi* (Karsch, 1890) ♀**

***Neodythemis preussi* (Karsch, 1891) ♀**

***Notiothemis robertsi* (Fraser, 1944) ♂**

***Olpogastra lugubris* (Karsch, 1895) ♂**

***Orthetrum abbotti* (Calvert, 1892) ♂**

***Orthetrum africanum* (Selys, 1887) ♂**

***Orthetrum guineense* (Ris, 1910) ♂**

***Orthetrum hintzi* (Schmidt, 1951) ♂**

***Orthetrum camerunense* (Gambles, 1959) ♀, ♂, ♂**

***Rhyothemis fenestrina* (Rambur, 1842) ♂** ***Tetrathemis* sp. nov., ♂**

Trithemis arteriosa **(Burmeister, 1839) ♂**

Trithemis kalula **(Kirby, 1900) ♂**

Trithemis aconita **(Lieftinck, 1969) ♂**

Trithemis legrandi **(Dijkstra, Kipping & Mezière, 2015) ♀**

Trithemis dichroa **(Karsch, 1893) ♂**

Trithemis pruinata **(Karsch, 1899) ♂**

Trithemis grouti **(Pinhey, 1961) ♂**

***Zygonyx flavicosta* (Sjöstedt, 1900) ♂**

***Zygonyx natalensis* (Martin, 1900) ♂**

***Zygonyx speciosus* (Karsch, 1891) ♀**

***Zyxomma atlanticum* (Selys, 1889) ♂**

Photographer: Rick Buesink (*L. tenaculatus, P. lieftincki* (2nd), T. kalula), Reinier de Vries (*U. purpurea* (1st), *U. mesumbei* (1st), *A. centripunctata* (3rd, 8th), *A. vicki* (2nd), *P. sjoestedti* (2nd), *Atoconeura* sp. nov. (6th), *Neodythemis* sp. nov. (6th, 7th), *O. guineense, O. camerunense* (1st, 3rd)), Jan van Leeuwen (all other photos).

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