Odonatologica 30(1): 29-38 *March 1, 2001*

THE ODONATA OF BIOKO, REPUBLIC OF EQUATORIAL GUINEA, WITH THE DESCRIPTION OF FAN-SHAPED SETAE ON EARLY INSTAR LIBELLULIDAE LARVAE

S.J. BROOKS and K.A. JACKSON
Department of Entomology, The Natural History Museum, Cromwell Road, London, SW7 5BD, United Kingdom

Received July 7, 2000 / Reviewed and Accepted August 31, 2000

A checklist of 48 spp. recorded from the island of Bioko (3°30'N 8°40'E), based on historical records compiled by Dr Elliot Pinhey and augmented by a collection made in March-April 1999, is presented, together with notes on the distribution of the spp. on the island. The Odonata fauna apparently comprises 2 elements, an upland fauna which includes 6 spp. that only occur above 500 m, and a lowland fauna of 17 spp., none of which occurs above 500 m. A further 13 spp. have been found in both lowland and upland sites. There are insufficient published data on the remaining 13 spp. to assign them to either of these faunistic elements. In addition, unique fan-shaped setae on the dorsum of the head, thorax and abdomen of early instar libellulid larvae are described. These setae are thought to be mechano-receptors that are held above the sediment to detect the presence of prey and current flow while the larva remains buried.

INTRODUCTION

Bioko is a small west African island situated about 40 km off the coast of Cameroon in the Gulf of Guinea (3°30'N 8°40'E). The island was formerly known as Fernando Póo and now forms part of the Republic of Equatorial Guinea, together with Río Muni on the mainland and the more southerly island of Annobón. Bioko covers an area of about 2000 km^2 and is about 72 km North-to-South and 35 km West-to-East. There are three volcanoes, Basilé (3011 m) in the North, and Calder de Luba (2261 m) and Biao (2001 m) in the South. Most of the human population lives in the littoral lowlands below 500 m in the North of the island. Here much of the forest is secondary, or has been replaced by cocoa plantations and other agricultural crops. Above 500 m and in the South, which is largely inaccessible except by foot, are extensive tracts of primary tropical rain forest. Bioko is one of the wettest places on earth. Annual rainfall, which can exceed 14 m (DE TERAN, 1962) is seasonal, mostly falling between July and November. There are 247 rivers and streams on the island, of which about 58% flow during the dry season (McCALL et al.,1998). Because the island is so steep, most of these rivers are fast flowing even in the coastal lowlands. Average annual coastal temperatures are about 25°C.

Bioko supports a rich biota with some endemic species. The island has a significant level of species endemism, running at about 1-3% in those groups so far studied, including birds, reptiles, amphibians and fish (JONES, 1994). Part of the island has been designated as a UNESCO World Heritage Conservation Site. The dragonflies of Bioko have been relatively well-studied, and the fauna was most recently reviewed by PINHEY (1971; 1974), although he never actually visited the island himself. PINHEY (1974) listed 42 species with provisional records for an additional four species. These records were based mainly on collections made by W. Hartwig, who lived on the island from 1957-1963, and from two expeditions to Bioko, one in 1900-1902 by Leonardo Fea (MARTIN, 1908) and the other by W.H.T. Tams in 1932 (LONGFIELD, 1936). Of the 42 species recorded, six were described from the island and thought to be endemic. However, recent taxonomic revisions and further collections from the African mainland have shown that in fact none of the Biokoan odonate species is restricted to the island (VICK, 1999). The only endemic taxon now recognised is *Chlorocypha cancellata insulana*, a subspecies of *C. cancellata* which is widespread in equatorial Africa southwards to Zaire (PINHEY, 1974).

We were in Bioko to conduct an environmental impact assessment on behalf of the World Health Organisation African Programme for Onchocerciasis Control (WHO/APOC). The visit was made between 23 March and 9 April 1999 and, although it was relatively short, we were able to collect Odonata from many more sites than had been visited by previous Odonata collectors to the island. The purpose of this paper is to update the checklist of Odonata recorded from Bioko and to provide a more detailed account of the distribution of Odonata around the island than has been possible before. In addition, we take this opportunity to describe some extraordinary fan-shaped structures that we found on the dorsum of early instar libellulid larvae collected during our fieldwork.

METHODS

Adult dragonflies were sampled using a standard butterfly net. Adult dragonflies can be difficult and time-consuming to collect so, in order to optimise species representation, up to six specimens of each taxon recognisably different in the field were collected at each sampling locality. Special efforts were made to sample pairs in tandem so that females could be associated with males. Samples collected in this manner are not quantitative but give a good indication of the distribution of adult Odonata (BROOKS, 1989). Odonata larvae were sampled from fast-flowing rivers by standard kick-sampling (ENVIRONMENT AGENCY, 1997). At each sampling station 20 ten--second subsamples were taken across the stream channel. Slow-flowing sections and standing water were sampled by sweeping amongst vegetation. Samples were collected using a 250 µm mesh net and were sorted within a few hours of collection so specimens were alive and very small larvae were easy to locate as they moved around the sorting tray.

To estimate the distribution of Odonata on Bioko a total of 17 localities was sampled mostly in the northern half of the island (Fig. 1). Most of the sites sampled had similar physical characteristics, being relatively fast-flowing streams dominated by riffle sections, below 500 m in altitude. Samples were taken from both open, sunny sections and tree-shaded reaches. Odonata were also sampled from slow-flowing and standing water sites, but these were few on the island because of the steep topography. One site at about 600 m, and two at about 1500 m were also sampled to provide an indication of the influence of altitude on dragonfly distribution, but few high altitude sites were accessible.

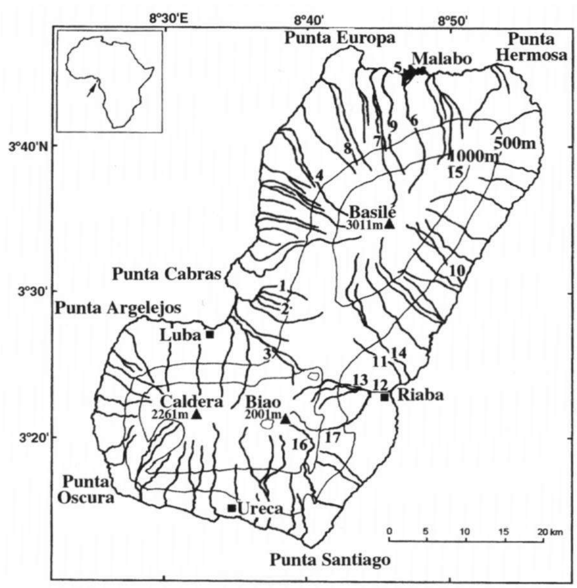

Fig. 1. The island of Bioko, Equatorial Guinea, showing major rivers and towns, and the three volcanic peaks. The numbers indicate the sampling localities: (1) Rio Edda; – (2) Rio Lada; – (3) Rio Musola (this river was sampled throughout its length from upstream of Musola village to the river mouth; – (4) Rio Apú; – (5) Malabo; – (6) Rio Matadores; – (7) Rio Sampaca; – (8) Rio Tiberones-Uruabella; – (9) Rio Timbabé; – (10) Rio Cope; – (11) Rio Garcia; – (12) Riaba Reservoir; – (13) Rio Ruma; – (14) Rio Sabo; – (15) Basilé; – (16) Rio Iladyi; – (17) Rio Teo.

Adult Odonata were identified using an unpublished key to the Odonata of Cameroon (VICK, 1996) and identifications were confirmed by reference to the Odonata collections at The Natural History Museum, London. Odonata larvae were identified to family or genus with reference to DEJOUX et al. (1981), ASKEW (1988) and CHELMICK (1998).

CHECKLIST OF ODONATA RECORDED FROM BIOKO

Approximately 260 adult specimens were collected, representing 24 species. A list of these and their distribution, together with a list of all the Odonata recorded from the island in the past, is presented below. In addition, 47 larvae were collected. These were identified as Protoneuridae, *Pseudagrion, Chlorocypha, Sapho, Paragomphus*, Tetratheminae and *Orthetrum.* We also collected 10 specimens of early instar libellulid larvae from Rio Musola upstream of Musola village.

Numbers refer to localities marked on map (Fig. 1). Records from PINHEY (1974) are indicated with ^{P}, other records are from the present study. Species marked * were not previously recorded from Bioko.

Protoneuridae	Localities
Chlorocnemis nigripes Selys, 1886	3; 7; 8[P]; 15
**Elattoneura balli* Kimmins, 1938	2; 3; 4; 6; 7; 10; 11; 13; 14; 15
Coenagrionidae	
Agriocnemis maclachlani Selys, 1877	3[P]; 6; 14
Ceriagrion glabrum (Burmeister, 1839)	6;12[P]; 16[P]
Enallagma buchholzi Pinhey, 1971	16[P]
Pseudagrion angelicum Fraser, 1947	12[P]
Pseudagrion epiphonematicum Karsch, 1891	no locality cited[P]
Pseudagrion kersteni (Gerstaecker, 1869)	no locality cited[P]
Pseudagrion melanicterum Selys, 1876	3; 4; 6; 7 ; 8; 9; 10; 11; 13; 14; 15; 16
**Pseudagrion serrulatum* Karsch, 1839	16; 17
Pseudagrion sjostedti Förster, 1906	12[P]
Chlorocyphidae	
Africocypha lacuselephantum (Karsch, 1899)	16[P]
Chlorocypha cancellata (Selys, 1879)	2; 3; 4; 9; 10; 13; 14; 16[P]
Chlorocypha curta (Hagen, 1853)	no locality cited[P]
**Chlorocypha cyanifrons* (Selys, 1873)	15
**Chlorocypha rubida* (Hagen, 1853)	3; 4; 6
Calopterygidae	
Sapho orichalcea McLachlan, 1869	3; 4; 7; 15
Umma longistigma (Selys, 1869)	4
Umma mesostigma (Selys, 1879)	8[P]; 15; 16; 17
Umma purpurea Pinhey, 1961	8[P]
Gomphidae	
Paragomphus abnormis Karsch, 1890	16[P]
Paragomphus sp. indet. (larva)	3; 4; 13
Aeshnidae	
Acanthagyna cylindrata (Karsch, 1891)	5
Anax imperator Leach, 1815	3; 12[P]; 13
Hemianax ephippiger (Burmeister, 1839)	no locality cited[P]
Corduliidae	
Macromia aeneothorax (Nunney, 1895)	16[P]; 17
Libellulidae	
Acisoma trifidum Kirby, 1889	3[P]; 12[P]
Allorhizucha klingi Karsch, 1890	3; 4; 14; 15; 16[P]
Brachythemis leucosticta (Burmeister, 1839)	no locality cited[P]
Chalcostephia flavifrons Kirby, 1889	no locality cited[P]
Crocothemis erythraea (Brullé, 1832)	no locality cited[P]
Diplacodes lefebvrei (Rambur, 1842)	12[P]
Hadrothemis camarensis (Kirby, 1889)	5[P]
Orthetrum africanum (Selys, 1887)	5[P]
Orthetrum austeni (Kirby, 1900)	12; 16[P]
Orthetrum chrysostigma (Burmeister, 1839)	no locality cited[P]
Orthetrum guineense Ris 1910	no locality cited[P]
Orthetrum julia Kirby, 1900	3; 4; 6; 7; 8; 9;10; 11; 12; 14; 15; 16[P]; 17
Palpopleura lucia (Drury, 1773)	3[P]; 5[P]; 8; 12; 16[P]
Pantala flavescens (Fabricius, 1798)	12
Thermochoria equivocata Kirby, 1889	no locality cited[P]
**Tholymis tillarga* (Fabricius, 1798)	12

**Trapezostigma basilaris* (Palisot de Beauvois, 1805)	12
Trithemis aconita Lieftinck, 1969	1; 3; 4; 6; 7; 8; 9; 11; 14
Trithemis arteriosa (Burmeister, 1839)	no locality cited[P]
Trithemis dichroa Karsch, 1893	3[P]; 7; 9; 16[P]
Trithemis furva Karsch, 1899	5[P]
Trithemis hartwigi Pinhey, 1970	16[P]
Trithemis nuptialis Karsch, 1894	no locality cited[P]

DESCRIPTION OF FAN-SHAPED SETAE IN EARLY INSTAR LIBELLULIDAE LARVAE

The early instar libellulid larvae were found to have extraordinary fan-shaped setae, mounted on tubercles and arranged in pairs on the dorsum of the head, thorax and abdomen (Figs 2a-c). These setae are absent from later instar libellulid larvae.

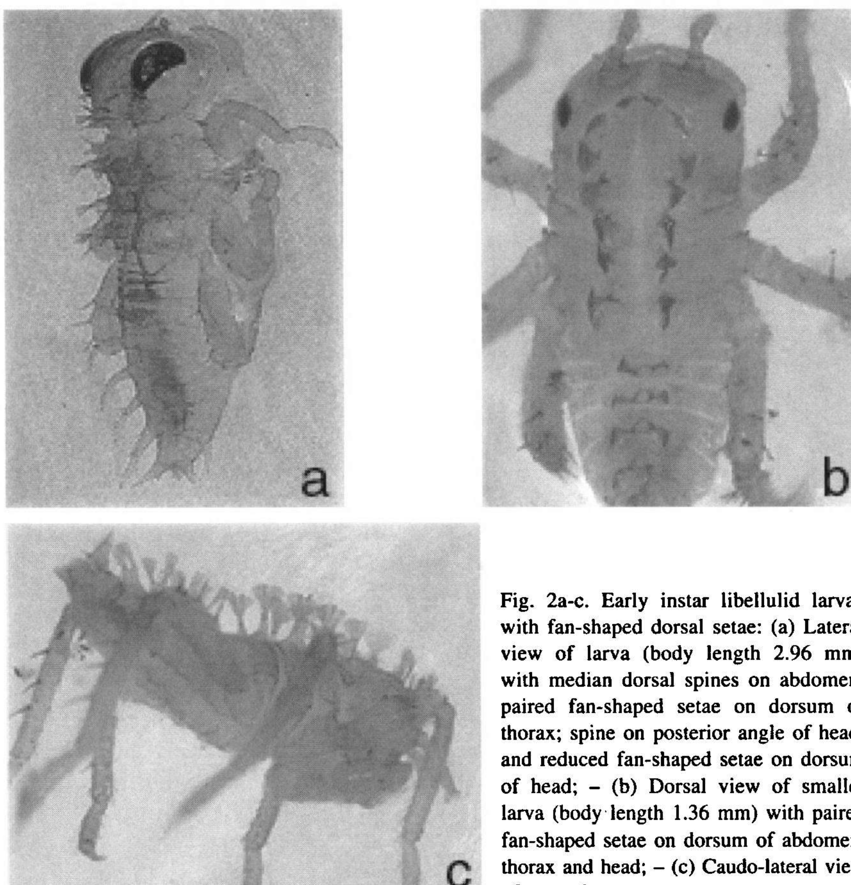

Fig. 2a-c. Early instar libellulid larvae with fan-shaped dorsal setae: (a) Lateral view of larva (body length 2.96 mm) with median dorsal spines on abdomen; paired fan-shaped setae on dorsum of thorax; spine on posterior angle of head; and reduced fan-shaped setae on dorsum of head; – (b) Dorsal view of smaller larva (body length 1.36 mm) with paired fan-shaped setae on dorsum of abdomen, thorax and head; – (c) Caudo-lateral view of same larva.

Based on the arrangement of the fan-shaped setae, the larvae could be placed in four groups. On the heads of the two largest larvae (head width 0.79-1.18 mm; body length 1.61-2.96 mm) were a single spiniform seta on a prominent tubercle at the posterior angle, four pairs of postero-dorsal fan-shaped setae, and two pairs of robust, narrow antero-dorsal setae. They also had large, recurved mid-dorsal spines on abdominal segments 5-9 and a vestigial mid-dorsal spine on segment 4. One intermediate-sized larva (head width 0.54 mm; body length 1.64 mm) had six pairs of fan-shaped setae on the head (four pairs posteriorly and two pairs anteriorly) and paired sub-dorsal fan-shaped setae on abdominal segments 6-9. All three large larvae had a large lateral spine on abdominal segment 9 and short, slender setae on the mid-dorsal spines. Six small larvae (head width 0.45-0.46 mm; body length 0.93-1.36 mm) each had four pairs of fan-shaped setae on the head (two pairs posteriorly and two pairs anteriorly), paired sub-dorsal fan-shaped setae on abdominal segments 6-9, and a small narrow seta positioned mid-dorsally on segment 10. No fan-shaped setae were present on the smallest larva (head width 0.43 mm; body length 0.93 mm). All the larvae, with the exception of the smallest, had a pair of sub-dorsal fan-shaped setae on each thoracic segment. All the larvae had 3-5 robust spines on the dorsum of the femora, and the six smaller larvae also had a similar number of spines in a row on the dorsum of the mid- and hind-tibiae.

The fan-shaped setae (Figs 3a-b) (macrotrichia) had a finely crenellated apical margin and shallow corrugations on the surface. They appeared to be hollow internally but this cavity was sealed and did not extend into the body of the larva. They were attached to a tubercle rising from the body surface by a 'ball-and-socket' joint.

DISCUSSION

SETATION OF EARLY INSTAR LIBELLULID LARVAE

We were unable to identify the early instar libellulid larvae to genus- or species-level; however, *Allorhizucha klingi, Orthetrum julia* and *Trithemis aconita* were the only libellulids recorded as adults from the Rio Musola where the larvae were collected. The three largest larvae differed morphologically from the six small larvae which suggests that they may have belonged to different taxa.

However, it is also possible that the larvae represented different developmental stages of the same taxon. The fan-shaped setae appear to be unique, suggesting a taxonomic affinity between the specimens, although adaptive convergence could also account for this similarity. The distribution of the setae on the head of all the larvae is similar. The two pairs of narrow anterior head setae in the largest larvae were in the same position as the two anterior pairs of fan-shaped setae in the intermediate-sized larva. This suggests they were homologous but have become reduced in size, perhaps because functionally they are no longer important. Fan--shaped setae have never been recorded in any late-instar Odonata larvae which implies that at some stage in the larval development they are lost. If all the larvae are of the same taxon, the abdominal fan--shaped setae, which are only present on the smallest class of larvae, must be replaced by long spines in the larger larvae. There is a circular area between the base of the abdominal fan--shaped setae from which the mid-dorsal spines may develop in later instars.

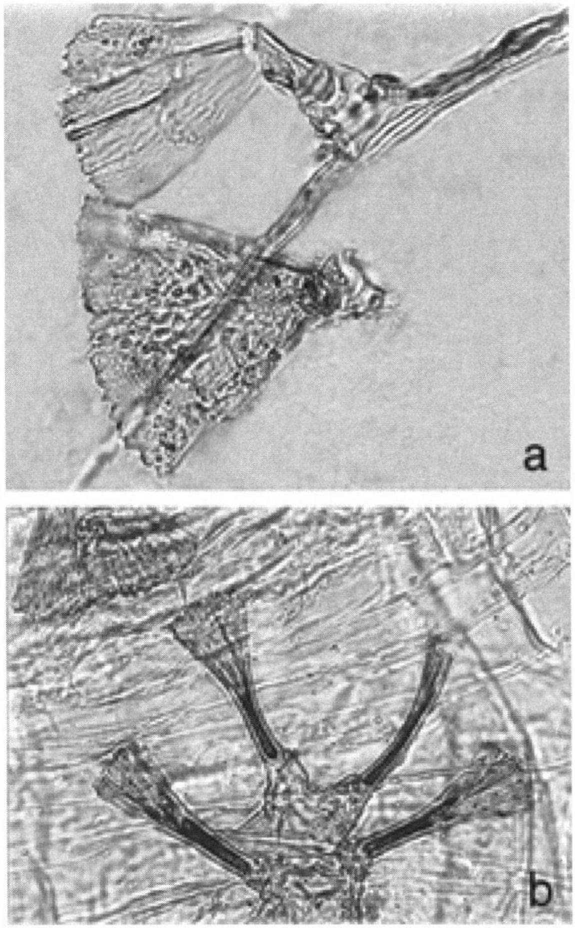

Fig. 3a-b. Early instar libellulid larva: (a) Fan-shaped setae on dorsum of head; – (b) Paired fan-shaped setae on dorsum of abdominal segments 6 and 7.

Specialised setae, restricted to early instar odonate larvae, have been described from a number of Odonata families including Coenagrionidae, Libellulidae, Gomphidae and Corduliidae (see CORBET, 1999, for a review). These setae are generally considered to be mechano-receptors that aid the larva to detect prey. In most cases these setae are spiniform, but in *Cordulegaster insignis*, which lives in flowing water, the setae are flattened, stiff and fan-shaped (VERSCHUREN, 1989). In *C. insignis* these modified setae are located only on those anterior parts of the body that are exposed to the water when the larva is resting, partly buried in the sediment. Although the modified setae of *C. insignis* are very much smaller and more numerous than those described in this paper, they are similar in shape and this suggests that they may have a similar function. Unfortunately, we did not observe the microhabitat occupied by the early instar libellulid larvae, but perhaps they lie buried just below the surface of the sediment with the tall fan-shaped setae protruding above the substrate to detect the movements of prey and current flow. Later instar larvae may migrate from this habitat and use visual stimuli to detect prey and so no longer have need of these modified setae.

DISTRIBUTION OF ODONATA IN BIOKO

Of the 42 species previously recorded from Bioko, 19 were found during this study, together with an additional six species which had not been listed previously. Relatively little of the island had been surveyed for dragonflies in the past and PINHEY (1974) lists species collected from just six localities: Malabo (as Santa Isabel), Finca Frauendorf (close to Basupú and Rio Tiburones-Uruabela), Luba (as San Carlos), Rio Musola, Moca, and Riaba (as Parador Concepcion). During this study all these localities were visited, as well as additional sites. Unfortunately, there was no time to visit the southern part of the island since this was not accessible by road. Much of the forest in the South is still pristine and for this reason it is possible that other species of Odonata may occur there but not elsewhere on Bioko.

These results beg two questions. Why were so many of the previously recorded species not rediscovered during the present study? Why were so many (24%) of the dragonflies collected during this study recorded for the first time? The answers to both questions are probably the marked seasonality of some Odonata species.

The family with the lowest representation of previously recorded species in the present collection were Libellulidae. Twenty-one libellulid species had been recorded from the island in the past, but only seven of these were found this time, plus a further two species that had not been found on Bioko before. The probable explanation is that most of the libellulid species recorded from Bioko breed in standing water. Very few standing water sites were available for breeding odonates in Bioko during late-March and early-April 1999. The largest of these was the reservoir on Rio Ruma above Riaba, which was constructed after PINHEY's, (1974) account was published. We found six libellulid species at this site in 1999, including *Trapezostigma basilaris* and *Tholymis tillarga* which had not been recorded from the island before, although PINHEY (1974) predicted that eventually they would be discovered. We collected most of the other libellulids by pools and slow-flowing sections of rivers elsewhere on the island. The only exceptions were *Orthetrum julia* which was ubiquitous and *Allorhizucha klingi* which was restricted to fast--flowing riffle sections of certain streams.

During the beginning of April 1999 rain became more frequent, filling numerous puddles and pools on roads and tracks. These rapidly attracted territorial male libellulids. It seems likely that during the rainy season the abundance and diversity of libellulids on Bioko increases as the number of standing water biotopes increases. Such temporary biotopes probably do not support these species year round on Bioko, suggesting that many of the libellulids spend the dry season on mainland Africa and migrate to the island during the rainy season.

The streams close to the type locality of *Paragomphus moka* (= *P. abnormis*) were visited but no adults of the species were seen. However, the species was previously recorded between November and February (PINHEY, 1974) suggesting that adults may be seasonal in occurrence. More puzzling was the failure to find *Africocypha lacuselephantum* during this study since we visited the upper reaches of Rio Iladyi, and it was here that Hartwig collected large numbers on 11 March 1963 (PINHEY, 1974).

The failure of previous collectors to find *Elattoneura balli* is surprising since we found the species to be abundant and almost ubiquitous on the island's lowland streams. The species is fairly cryptic, being slender, dark coloured and generally flies in deep shade but, nevertheless, was not difficult to collect. Perhaps the species has colonised the island since the last intensive dragonfly collections were made in the early 1960s. Similarly, *Chlorocypha rubida* was common on several streams including Rio Musola which was one of Hartwig's collecting localities, but he failed to find it.

Since most of the lowland rivers were physically fairly uniform they each supported a similar dragonfly fauna. However, there was some evidence of biotope segregation since *Ceriagrion glabrum, Agriocnemis maclachlani, Palpopleura lucia, Trithemis dichroa* and *Anax imperator* were restricted to pooled and slow-flowing biotopes. *Chlorocnemis nigripes* and *Elattoneura balli* (both Protoneuridae) were most common in the shaded stretches of streams.

The two streams sampled above 1500 m near Moca supported an impoverished suite of species including *Umma mesostigma, Pseudagrion serrulatum* and *Macromia lieftincki* that were not found at any of the sites sampled below 500 m. *Enallagma buchholzi, Africocypha lacuselephantum* and *Trithemis hartwigi*, which were not recorded during the present study, may also be restricted to the highlands around Moca (PINHEY, 1974). *Paragomphus abnormis* has only certainly been recorded on Bioko from Moca (as *P. moka* by PINHEY, 1974), but in this study larvae of an unidentified species of *Paragomphus* were found in three streams below 500 m, so the species may be more widespread on the island. PINHEY (1974) recorded *Trithemis dichroa, Chlorocypha cancellata* and *Allorhizucha klingi* from streams around Moca but all three species were collected on lowland streams during this study. *Umma mesostigma* occurred at the high altitude sites, and also at Basilé, a site at intermediate altitude (600 m). This was the only locality at which *Chlorocypha cyanifrons* was found.

These results indicate that elements of the dragonfly fauna of Bioko occupy two distinct altitudinal zones. Six species were restricted to localities above 500 m, 17 species occur only at sites below 500 m and 13 species were found at all altitudes. All the Odonata species known from Bioko also occur on the African mainland in Cameroon (VICK, 1996; 1999). However, other odonate species may be awaiting discovery in the southern part of the island.

ACKNOWLEDGEMENTS

We take this opportunity to thank Mr GRAHAM VICK (Basingstoke, UK) and Mr DAVID CHELMICK (Haywards Heath, UK) for allowing us to refer to their unpublished keys to the Odonata fauna of Cameroon and for sharing their knowledge of the Odonata of this region. Our fieldwork on Bioko was funded by World Health Organisation African Programme for Onchocerciasis Control (WHO/APOC) and we thank Dr A. SÉKÉTÉLI (WHO/APOC) and NOTF for permission to publish this note. We also thank Dr ROLF MEYER (OCP, Kara, Togo), Dr JORDI MAS (University of Barcelona, Spain) and Dr ANACLETO SIMA (Ministry of Health, Malabo, Bioko) whose local knowledge of Bioko made the field work possible. In addition, we thank Mr MICHAEL WHITEHEAD (Oxford Brookes University, UK) for assistance in sorting the macro-invertebrate samples and Ms EDITH KAPINOS for carrying out a literature survey.

REFERENCES

ASKEW, R.R., 1988. *The dragonflies of Europe*. Harley Books, Colchester.

BROOKS, S.J., 1989. Odonata collected from Guanacaste National Park, Costa Rica, July 1988. *Notul. odonatol.* 3: 49-52.

CHELMICK, D.G., 1998. *The dragonflies of Cameroon. An identification key to the larvae.* – [Unpublished].

CORBET, P.S., 1999. *Dragonflies. Behaviour and ecology of Odonata.* Harley Books, Colchester.

DEJOUX, C., J.M. ELOUARD, P. FORGE & J.L. MASLIN, 1981. *Catalogue iconographique des insectes aquatiques de Côte d'Ivoire.* ORSTOM. – [Unpublished].

DE TERAN, M., 1962. *Sintesis geographica de Fernando Póo.* Instituto de Estudios Africanos, Consejo Superior de Investigaciónes Cientificas, Madrid.

ENVIRONMENT AGENCY, 1997. *Procedures for collecting and analysing macro-invertebrate samples.* Environment Agency, Bristol.

JONES, P.J., 1994. Biodiversity in the Gulf of Guinea: an overview. *Biodiv. Conserv.* 3: 772-784.

LONGFIELD, C., 1936. Studies on African Odonata, with synonymy, and descriptions of new species and subspecies. *Trans R. ent. Soc. Lond.* 85: 467-498.

MARTIN, R., 1908. Voyage de Feu Leonardo Fea dans l'Afrique Occidentale. Odonates. *Annali Mus. civ. Stor. nat. Giacomo Doria* 3: 649-667.

McCALL, P.J., R.A. CHEKE, M.D. WILSON, R.J. POST, P.K. FLOOK, R. MANK, A. SIMA & J. MAS, 1998. Distribution of the Simulium damnosum complex on Bioko island, Equatorial Guinea, and the potential for onchocerciasis control by vector eradication. *Med. vet. Ent.* 12: 267-275.

PINHEY, E.C.G., 1971. Odonata of Fernando Po Island and of neighbouring Cameroons Territory. *J. ent. Soc. sth Afr.* 34: 215-230.

PINHEY, E.C.G., 1974. Odonata of the northwest Cameroons and particularly of the islands stretching southwards from the Guinea Gulf. *Zool. Beitr.* 25: 179-212.

VERSCHUREN, D., 1989. Revision of the larvae of West-Palaearctic Cordulegaster Leach, 1815 (Odonata, Cordulegasteridae), with a key to the considered taxa and a discussion on their affinity. *Bull. Annls Soc. r. ent. Belg.* 125: 5-35.

VICK, G.S., 1996. *Dragonflies of Cameroon. A guide to identification.* – [Unpublished].

VICK, G.S., 1999. A checklist of the Odonata of the South-West Province of Cameroon, with the description of Phyllogomphus corbetae spec. nov. (Anisoptera: Gomphidae). *Odonatologica* 28: 219-256.