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AN ANNOTATED LIST OF ODONATA COLLECTED IN GHANA IN 1997, A CHECKLIST OF GHANA ODONATA, AND COMMENTS ON WEST AFRICAN ODONATE BIODIVERSITY AND BIOGEOGRAPHY

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Collections were made at 8 localities in southern Ghana during the summer of 1997. Three regions were sampled: coastal savanna, wooded savanna, and rainforest. 71 spp. were collected, 24 of which are new for the country, bringing the Ghana list to 123 spp. A list of spp. known from the country is included. *Trithemis dejouxi* Pinhey, 1978, is raised to specific rank. Individual variation in *Phaon iridipennis* and *Palpopleura lucia* is quantified. West African Odonata biodiversity and biogeography are discussed.

INTRODUCTION

To date, only four studies have focused specifically on the dragonflies of Ghana (KARSCH, 1893; NEVILLE, 1960; MARSHALL & GAMBLES, 1977; D'ANDREA & CARFI, 1994). Little has been published about the biology of the species occurring there, and no list of species known from the country has been compiled. From these papers and others, especially PINHEY (1962a), 99 species of Odonata have been recorded in Ghana to date.

The landscape of Ghana varies from wet forest to dry savanna due to a sharp rainfall gradient. The southern portion of the country is covered by wet, semi-moist and semi-dry forests, while farther north, in central Ghana, forest gives way to the tall grasses, short shrubs, and scattered trees of the savanna (SAYER et al., 1992). Terrestrial organisms exhibit a diversity gradient along this habitat gradient, but to date no one has done a systematic survey of aquatic organisms along it. The

research presented here began as an attempt to determine whether a similar diversity gradient occurred in Odonata. The original intent was to test the hypothesis that two changes in biodiversity will occur along the gradient as it changes from wet forest to savanna woodland, the first a decline in species richness of Odonata and the second a shift in species composition. Due to field conditions, only two sites along the gradient could be sampled very well, but two previous studies (NEVILLE, 1960; MARSHALL & GAMBLES, 1977) fall at different places along the gradient and allow further comparisons.

The gradient from wet to dry in Ghana occurs from south to north, with increased distance from the coast, but it also occurs from west to east. Ghana is one of the easternmost countries in the West African forest belt, and, moving from west to east, the climate becomes drier and drier until the Dahomey Gap is reached in Togo and Benin. The Dahomey Gap, where the dry savanna extends all the way to the coast and there is no wet forest, represents a well-known climatic barrier in West Africa (SAYER et al., 1992). This gap has biogeographic significance, because for many terrestrial wet-forest species it represents a barrier of inhospitable habitat. This causes some species to occur on only one side of the gap. The present collections also contribute to an attempt to understand the significance of that barrier for Odonata.

METHODS

Field work was conducted by the first author at three sites in Ghana from June to August 1997. The first site was near Pantan, a small village in the southern coastal savanna, approximately 10 miles north of Accra. Specimens were collected 2-6 June at a small stream and several small ponds in the area (see below for habitat descriptions). The second site was Bui National Park, a Guinea savanna/semi-dry forest mosaic in the western part of the central region. Specimens were collected 19 June-24 July from the Djapoli, a medium-sized stream, and the Black Volta River, a large river. The third site was Kakum National Park, a dense rainforest site in the southwestern section of Ghana. Specimens were collected 26-27 August at two small streams in dense forest.

Identifications were made using published literature, the unpublished keys of VICK (1997), and comparisons with material in the second author's collection. All specimens have been deposited in that collection. Notes on eye color in life, ecology, and behavior are included for some species.

COLLECTION LOCALITIES

GREATER ACCRA REGION, PANTAN, 5°42' N, 0°12' W

- (Oya) Oyarefa coastal savanna pond, 0.5-1 m deep 30 m wide pond, 1-2 m mud surrounding, then 1 m tall grass, sparse trees and shrubs.
- (Dak) Dakobi stream, 1-2 m wide coastal savanna stream near road, marshy in places, 1 m tall grass bordering, sparse trees and shrubs.
- (Pan) Pantan coastal savanna pond, 30 m wide pond, surrounded by 1-2 m tall grass, 1 m deep water, then sparse trees and shrubs.

  (a) Dawa, an open coastal savanna area, 1-2 m tall grass, near road.

CENTRAL REGION, SHAI HILLS GAME PRODUCTION RESERVE, 5°52' N, 0°4' E

- (Sha) open coastal savanna area with 0.5-1 m tall grass, more trees on nearby steep rocky hills, short grass near small stream.

BRONG AHAFO REGION, BUI NATIONAL PARK, 8°20' N, 2°19' W

- (Dja) Djapoli stream, 3-4 m wide stream with rocky/sandy bed, alternating pools and trickles, 0.05-0.30 m deep water, bordered by 1-2 m tall grass and large trees.
  (a) Bui Camp, small farm lands surrounding village, 0.5-1 m tall grass with exposed areas of soil and rock, no water nearby.
  (Vol) Black Volta River, 50-70 m wide river, water 13-15 m deep, bordered by very dense shrubs and trees.

CENTRAL REGION, KAKUM NATIONAL PARK, 5°22' N, 1°22' W

- (Kak1) small rainforest stream, meandering 0.5-1 m wide trickle with sandy soil/small rock bed through dense rainforest, sun shining through only in limited areas of thinned canopy.
- (Kak2) rainforest stream, slow flowing 1 m wide stream, sandy soil/pebble rock bed with areas of solid rock causing waterfalls/small pools, through dense rainforest, sun shining through only in limited areas of thinned canopy.

ANNOTATED LIST OF SPECIES COLLECTED

After the species names are the localities and the number of each sex collected. The code for locality refers to the list of collecting localities above. The asterisked species are new for Ghana. The collections are summarized in Table I, which is also a complete list of the Odonata known to occur in Ghana.

CHLOROCYPHIDAE

(1) *Chlorocypha curta* (Hagen, 1853). Dja (8♂, 8♀). – This species apparently favors more open streams than the following two species, which were found together at Kakum.

(2) *Chlorocypha glauca* (Selys, 1879). Kak2 (2♂).

(3) *Chlorocypha selysi* (Karsch, 1899). Kak1 (6♂), Kak2 (1♂).

CALOPTERYGIDAE

(4) *Phaon iridipennis* (Burmeister, 1839). Oya (2♂), Dak (3♂), Dja (26♂, 10 ♀), Vol (2♂), Kak1 (2♂), Kak2 (1♂). – This species, widespread across Africa, was collected at nearly every site visited. Common perching places included rocks in the stream bed, vines on the walls of the stream bed, and in 1-2 m grass bordering the stream. Oviposition took place in the stems of a 20 cm tall plant next to a slow-flowing 1.5 m wide stream at Djapoli. Many individuals were observed feeding by making short (5-20 cm) flights, capturing small flying insects, and landing on the original perch for consumption of the prey. The intensity of the green thoracic markings varied greatly in both males and females, not apparently correlated with age, and some specimens had a light blue pruinosity on the ventral surface of the thorax. PINHEY (1961a, 1961b) discussed briefly the variation in the relative size

and color of the thorax and the size and presence of the pterostigma in this species. Thus we analyzed the substantial series from Ghana collected for this study. Variation in size was not especially noteworthy (Fig. 1), except for a single male from Djapoli stream that fell well below the range of the others, with a hind wing length of 32.3 mm. This male is duller than most of the other specimens, and its cerci and epiproct are relatively short, but otherwise it appears identical to the rest of the series. With the exception of the especially small male, the range in hind wing length of 34.4--37.2 mm in males (N = 35) and 37.2-39.6 mm in females (N = 10) seems not especially large. PINHEY (1951, 1961a) gives the range for males as 37-40 mm, implying distinctly larger animals in southern and eastern Africa than those from Ghana, and indeed 5 males in the Paulson collection from Kenya and Zimbabwe ranged from 37.9-39.0 mm. Figure 1 does show that pterostigma length is quite variable in males. The polymorphism apparent (pterostigma vs no pterostigma) is surely not a real polymorphism but instead represents continuous variation in size, because the smallest pterostigma possible corresponds to the length of the cells at that point on the wing. Two of the males with the smallest pterostigmas also have relatively little pigmentation in the cell that would be considered the pterostigma, and that cell is not very well differentiated from adjacent cells. Males that lack a pterostigma merely lack pigment in any cell.

(5) *Sapho bicolor* Selys, 1853. Kak1 (1♂), Kak2 (seen).

(6) *Sapho ciliata* (Fabricius, 1781). Kak2 (5♂, 1♀). – This species was more

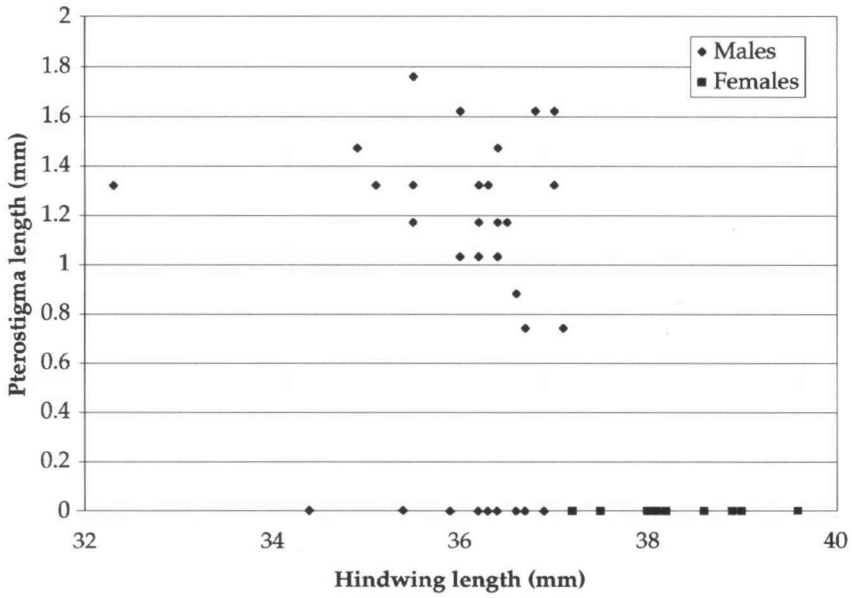

Fig. 1. Hindwing and pterostigma length of *Phaon iridipennis* from Ghana.

common than *S. bicolor* and was found at the larger of the two streams in the wet forest at Kakum. All specimens collected were perched 1-1.5 m over the stream.

(7) *Umma cincta* (Hagen *in* Selys, 1853). Kak1 (1♀), Kak2 (2♂). – Observed both under the shade of the canopy and in sun under gaps in the canopy.

PROTONEURIDAE

(8) *Chlorocnemis elongata* Hagen *in* Selys, 1853. Kak1 (6♂, 1♀). – Males have wings suffused with yellow, and the only female collected has clear wings.

(9) * *Elattoneura nigra* Kimmins, 1938. Dja (8♂, 7♀). – Nearest previous records Côte d'Ivoire to the West and Nigeria to the East. Five pairs were collected in tandem, one over a 5 cm deep trickle and one over a 2 m wide stream.

(10) *Isomecocnemis subnodalis* (Selys, 1886). Kak1 (1♀). – The specimen collected was a teneral, and the specific identification is not certain, but *subnodalis* is the only species known from Ghana to date.

(11) *Prodasineura villiersi* Fraser, 1948. Kak1 (9♂, 2♀), Kak2 (3♂). – This species is known from only Ghana and the Côte d'Ivoire.

PLATYCNEMIDIDAE

(12) * *Mesocnemis robusta* (Selys, 1886). Vol (5♂). – This record extends the known range of this species, previously known from Nigeria to Sudan, and is the first record West of the Dahomey Gap. Specimens collected were found less than 1 m over the Black Volta River, where vegetation hung down from the bank.

(13) * *Mesocnemis singularis* (Karsch, 1891). Vol (6♂). – Nearest records from Côte d'Ivoire to the West and Togo to the East. Specimens were collected only from the Black Volta River, where the species coexisted in apparent equal numbers with *M. robusta*. Both species of the genus were colored similarly in life, heavily pruinose.

(14) * *Platycnemis guttifera* (Selys, 1886). Kak1 (1♂). – This record extends the known range of this species, previously known from Guinea to Côte d'Ivoire, slightly to the East.

(15) *Platycnemis sikassoensis* (Martin, 1912). Dja (6♂, 6♀). During copulation the male opened its wings, then closed them when straightening the abdomen afterwards. Three pairs were collected in tandem.

COENAGRIONIDAE

(16) * *Aciagrion hamoni* Fraser, 1955. Dja (2♂). – Nearest records from Côte d'Ivoire to the West and the Republic of Congo to the Southeast. One male collected at dusk in an open area with 0.5 m tall grass, some bare soil, and trees 10-15 m apart. PINHEY (1972) described the only male of this species heretofore reported,

and the two specimens collected in Ghana match his description quite well.

(17) *Agriocnemis zerafica* Le Roi, 1915. Oya (1♂, 3♀), Dak (1♂, 2♀).

(18) * *Ceriagrion bakeri* Fraser, 1941. Dja (1♂). – Nearest previous records Côte d'Ivoire to the West and Togo to the East.

(19) *Ceriagrion glabrum* (Burmeister, 1839). Dak (8♂, 3♀), Pan (8♂, 7♀), Dja (4♂, 1♀). – Five tandem pairs were collected, one of them during oviposition.

(20) * *Ischnura senegalensis* (Rambur, 1842). Oya (1♂, 1♀). – We could find no records closer than Guinea to the West and Nigeria to the East. Although this species is one of the more ubiquitous odonates of Africa (PINHEY, 1962a), it is clearly not widespread and common in Ghana, as we recorded it only from a coastal pond, and neither NEVILLE (1960) nor MARSHALL & GAMBLES (1977) found it at their study sites. It may be generally rare in the West African forest region, as it was not reported from the relatively well-sampled Nimba Mountains in Guinea and Côte d'Ivoire (LEGRAND, 1983; 1985), or at Korhogo (LINDLEY, 1974), Lamto (LEGRAND, 1982), or Taï (LEGRAND & COUTURIER, 1985) in the Côte d'Ivoire.

(21) * *Pseudagrion epiphonematicum* Karsch, 1899. Kak1 (4♂). – First record between Guinea to the West and Nigeria to the East. This species is restricted to West Africa.

(22) *Pseudagrion glaucescens* Selys, 1876. Dak (3♂). – Recorded only from a slow-moving coastal stream.

(23) *Pseudagrion hamoni* Fraser, 1955. Dak (21♂, 11♀), Dja (20♂, 12♀). – The thorax of the specimens collected was green dorsally and pruinose blue ventrally. The eyes of males are black dorsally and red ventrally, those of females brown dorsally and green ventrally. The species emerged abundantly from Djapoli; eight tenerals were preserved. Pairs oviposited in tandem in the stream.

(24) *Pseudagrion kersteni* (Gerstaecker, 1869). Dak (1♂), Dja (9♂, 2♀). – The eyes are black dorsally and green ventrally in life.

(25) *Pseudagrion melanicterum* Selys, 1876. Dja (21♂, 6♀), Kak1 (6♂), Kak2 (8♂, 2♀).

(26) * *Pseudagrion nubicum* Selys, 1876. Oya (1♂), Dak (1♂). – Known from Côte d'Ivoire to the West and Nigeria to the East.

(27) *Pseudagrion sjostedti* Förster, 1906. Dja (6♂, 1♀), Vol (4♂, 1♀).

(28) *Pseudagrion sublacteum* (Karsch, 1893). Dak (2♂), Dja (1♂, 1♀).

AESHNIDAE

(29) * *Anax ephippiger* (Burmeister, 1839). Pan (1♂). – Known from Côte d'Ivoire to the West and Nigeria to the East. Recorded only from the coastal area.

(30) * *Gynacantha cylindrata* Karsch, 1891. Dja (2♀). – Known from Côte d'Ivoire to the West and Benin to the East. This species was collected at dusk flying over an area of bare soil 40 m from the stream.

(31) *Gynacantha manderica* Grünberg, 1902. Dja (1♂, 1♀). – This species was collected at dusk.

GOMPHIDAE

(32) * *Crenigomphus renei* Fraser, 1936. Dja (1♂). – Known from Côte d'Ivoire to the West and Nigeria to the East.

(33) * *Gomphidia madi* Pinhey, 1961. Dja (1♂), Vol (2♂, 1♀). – This West African species was previously known only from Côte d'Ivoire, Nigeria, and Uganda.

(34) *Ictinogomphus ferox* (Rambur, 1842). Dak (1♂).

(35) *Lestinogomphus africanus* (Fraser, 1926). Vol (1♂). – Collected 20 m from a large river in 1 m tall grass.

(36) * *Paragomphus genei* (Selys, 1841). Dja (2♂), Vol (1♀). – Known from Côte d'Ivoire to the West and Nigeria to the East, as well as much more extensively on the continent. The eyes are green dorsally and light blue ventrally.

(37) * *Paragomphus nigroviridis* (Cammaerts, 1969). Kak2 (1♂). – Known from Côte d'Ivoire to the West and Cameroon and Zaire to the East, it appears to be a species of wet forest, unlike the previous species, which is distributed widely over Africa.

CORDULIIDAE

(38) *Phyllomacromia bifasciata* Martin, 1912. Dja (1♂).

(39) * *Phyllomacromia pseudafricana* Pinhey, 1961. Dja (1♂). – Known from Côte d'Ivoire to the West and Nigeria to the East and fairly widespread throughout West Africa.

(40) * *Phyllomacromia* sp. Dja (1♀). – This female has not been identified, but it is surely not any of the species known from the country, including the two species listed above as well as *P. melania* (Selys), and *P. sophia* (Selys). It does not appear to fit in either the *picta* or *sophia* groups as defined by GAMBLES (1979). It is a small (abdomen 38.6 mm, hindwing 36.5 mm) species with three conspicuous stripes on each side of the thorax. The face is brown, with a small yellow spot at each end of the postclypeus, the frons metallic blue-violet above. The abdomen is mostly black, with the following yellow markings: large square lateral marks and pair of transversely oriented middorsal spots on 1; fine yellow rings at bases and paired dorsal spots at middles of segments 3 to 6, becoming smaller to rear; and a conspicuous yellow band on the basal third of segment 7. The vulvar laminae are small (0.7 mm), narrow, and pointed.

LIBELLULIDAE

(41) *Acisoma panorpoides* Rambur, 1842. Dak (2♂, 1♀), Pan (1♀).

(42) * *Aethriamanta rezia* Kirby, 1889. Dak (1♂). – Recorded only from the coastal area. Known from Côte d'Ivoire to the West and Nigeria to the East.

(43) * *Brachythemis lacustris* (Kirby, 1889). Vol (5♂, 8♀). – Known from Côte d'Ivoire to the West and Nigeria to the East. Recorded only from a large river. This species was found in high populations among the small shrubs that grew on islands near the bank of the river.

(44) *Brachythemis leucosticta* (Burmeister, 1839). Oya (7♂, 2♀), Dak (2♂), Vol (1♂). – Recorded from the coastal area and on a large river.

(45) *Bradinopyga strachani* (Kirby, 1900). Sha (2♂, 1♀). This genus is usually associated with rocky areas, and the Shai Hills have abundant rock outcrops.

(46) *Chalcostephia flavifrons* Kirby, 1889. Dak (4♂), Pan (3♂).

(47) *Crocothemis divisa* Baumann, 1898. Dja-a (2), Sha (1♂). – As with the species of *Bradinopyga*, this species is typically associated with rocky areas, and both localities where it was taken had exposed rocks.

(48) *Crocothemis erythraea* (Brullé, 1832). Dak (1♀). – Recorded only from the coastal area. This species is very widespread and common throughout Africa, and it is surprising that it was nowhere common at the sites visited during this study in Ghana. Unlike *Ischnura senegalensis*, it has been found at a number of West African forest sites.

(49) * *Eothemis zygoptera* Ris, 1909. Kak1 (2♂). – Recorded only from wet forest. Known from Côte d'Ivoire to the West and Nigeria to the East.

(50) *Hemistigma albipuncta* (Rambur, 1842). Dak (3♂), Pan (2♀).

(51) * *Nesciothemis pujoli* Pinhey, 1971. Dak (6♂), Pan (1♀). – This species was described from two males from the Central African Republic (PINHEY, 1971) and has not been discussed subsequently. Our specimens match Pinhey's description quite well and differ from a series of male *N. farinosa* (Förster, 1898) examined (2 from Kenya, 1 from Malawi, 4 from Zimbabwe, 2 from South Africa). The difference in the hamules is readily apparent in the shape of the outer hamule, broader and less deeply indented in *pujoli*, narrower and with a deep longitudinal groove on the outer surface in *farinosa*. Although Pinhey noted that *pujoli* differed from *farinosa* in being darkly pruinose, we suspect this might have been an artifact of preservation, as the Ghana specimens as preserved show a shade of light blue pruinosity identical to that of *farinosa*. The extent of abdominal pruinosity may furnish another species difference: the six *pujoli* males are pruinose to the tip of segment 3 or extreme base of 4; two Kenya *farinosa* are pruinose to the tip or just short of the tip of 4; and two Zimbabwe and one Malawi *farinosa* are pruinose to the tip of 5. PINHEY (1951) stated that the basal 4-6 segments of male *farinosa* became pruinose, but there is no indication of the geographic source of the specimens from which he came to this conclusion. In addition, the male *pujoli* have entirely black labia, while the labia of the male *farinosa* examined are pale (the two from Kenya have black on the median edges of the palpi). The labrum and legs of *pujoli* are entirely black, unlike those of *N. minor* Gambles, 1966, a similar

but smaller species. The single female *Nesciothemis* was taken at a different locality from the males but is associated with them because of her size, wing venation, and general appearance. She appears to be quite mature, dark all over with light pruinosity on the thorax and three basal abdominal segments. Unlike the males, her entire face and labium are light brown, as are the outer surfaces of her femora and tibiae. The foliations on abdominal segment 8 are shaped as in *farinosa* and are pale with dark borders. As the two species are superficially very similar, it would be of interest to re-examine all specimens of "*farinosa*" from West Africa, where it is considered widespread (PINHEY, 1962a).

(52) * *Olpogastra fuelleborni* Ris, 1912. Vol (1♂, 1♀). – This record extends the known range of this species, previously known from Nigeria to South Africa and Kenya, and is the first record West of the Dahomey Gap. Recorded only from a large river. The eyes were green in life. The female collected was a teneral, perched 2 m above the water.

(53) *Olpogastra lugubris* Karsch, 1895. Dak (1♂, 1♀), Vol (7♂, 1♀). – Recorded from the coastal area and a large river. A mating pair perched 0.5 m above the water on a branch approximately 15 m from the bank of the river.

(54) *Orthetrum brachiale* (P. de Beauvois, 1805). Pan-a (1♂).

(55) *Orthetrum chrysostigma* (Burmeister, 1839). Dak (3♂), Pan (1♂), Sha (6♂), Dja (1♂, 3♀).

(56) *Orthetrum hintzi* Schmidt, 1951. Pan (1♂).

(57) *Orthetrum julia* Kirby, 1900. Dja (2♂, 2♀), Kak2 (1♂). – One of the females collected was ovipositing, guarded by a male.

(58) *Orthetrum stemmale* (Burmeister, 1839). Dak (1♂), Pan (1♂), Dja (12♂, 12♀), Vol (1♂). – The eyes of this species are blue in life. One pair was collected in tandem. Another pair was collected while mating in 1 m tall grass. Seven females were collected while ovipositing at Djapoli. All oviposition occurred by the female dipping the tip of her abdomen into small trickles and pools. This is the species listed previously in West African publications as *O. brachiale kalai* Longfield, 1936 (PINHEY, 1979).

(59) *Palpopleura deceptor* (Calvert, 1899). Sha (1♂).

(60) *Palpopleura lucia* (Drury, 1773). Dak (10♂, 3♀), Pan (3♂, 6♀), Sha (6♂, 4♀), Dja (13♂, 6♀), Vol (1♂). – This common and very widespread species was collected at every site except the wet forest. Two females were observed ovipositing at Djapoli while the male hovered over the female. Of the 33 males collected, only two from Djapoli were of the form *portia*, with much reduced wing markings. The situation with these two forms remains one of the more puzzling cases of polymorphism in the Odonata. Both types apparently occur throughout the range of the species, yet at some localities, only one of them is reported. Differences between the forms in extent of wing markings, although long known, have not been quantified, and we attempted that by examining 58 male specimens in the Paulson collection from Sierra Leone (2), Liberia (1), Côte d'Ivoire (1), Ghana (35),

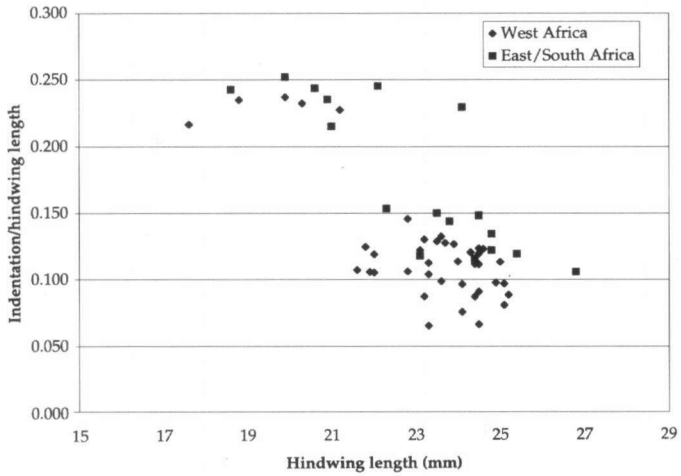

Fig. 2. Size and wing markings of *Palpopleura lucia* from Africa.

Congo (2), Uganda (1), Kenya (3), Malawi (1), Zambia (1), Zimbabwe (10), and South Africa (1). The black coloration in the hind wing is typically widest distal to the nodus and narrowest at or just proximal to the nodus. The width of the black was measured at both of these points, and the difference between them (the "indentation") was taken as a measure of the extent of the black. This was then expressed as a proportion of the hind wing length, to take the dragonfly's size into account. These measurements are shown in Figure 2. It can be seen that the specimens are distributed bimodally, corresponding to the forms *lucia* (indentation/hind wing < 0.2) and *portia* (indentation/hind wing > 0.2). Two points are apparent here. (1) The two forms overlap in size, although *portia* averages smaller, as usually described (PINHEY, 1951). (2) West African specimens of *lucia* have wings more extensively marked with black, on the average, than those from East and South Africa; PINHEY (1961a) noted that the black extended farther out the wing in West African specimens. Although the specimens examined here clearly fall into two distinct groups based on wing markings, intermediates are known (PINHEY 1984), and the erection of *portia* to specific status by GAMBLES et al. (1998) is premature, with no new information about the biology of the two forms.

(61) *Pantala flavescens* (Fabricius, 1798). Dak (2♂, 2♀), Pan (1♂), Sha (3♂, 4♀), Dja (2♂, 4♀), Vol (1♂). – This very widespread species was observed flying in large numbers over an open area at Shai hills. One pair was collected while copulating 15 m from the stream at Djapoli.

(62) *Tholymis tillarga* (Fabricius, 1798). Dja (3♂, 2♀). – The eyes of this species are red dorsally and blue ventrally in life. Four of the specimens were collected in low flight at dusk near the stream.

(63) *Tramea basilaris* (P. de Beauvois, 1805). Sha (1♀).

(64) *Trithemis aconita* Lieftinck, 1969. Dja (20♂, 5♀).

(65) *Trithemis annulata* (P. de Beauvois, 1805). Dak (4♂).

(66) *Trithemis arteriosa* (Burmeister, 1839). Dak (9♂), Pan (1♂, 1♀), Dja (18♂, 2♀).

(67) * *Trithemis dejouxi* Pinhey, 1978, new status. Dja (2♂). – Known from Côte d'Ivoire to the West and Nigeria, Central African Republic, and Ethiopia to the East. PINHEY (1978) described this form as *Trithemis donaldsoni dejouxi* (type locality Bouar, Central African Republic), considering it a subspecies of *T. donaldsoni* (Calvert, 1899; type locality Ethiopia). Although we did not examine the type of *dejouxi*, we assume the Ghana specimens belong to that taxon, as they are much like *donaldsoni* but have a suffusion of brown across the middle of both fore and hind wings, as PINHEY (1978) described for *dejouxi*. What we are calling *dejouxi* differs structurally from the widespread East and South African *donaldsoni*, as typified by specimens from Zimbabwe, in having the hamules more sharply curved and the anterior lamina much less deeply bifid. These differences appear sufficient to raise *T. dejouxi* to specific rank. In addition, our 2 mature males of *dejouxi* have the median half of each lobe of the labium black and the abdomen entirely black below, while 4 mature males of *donaldsoni* examined have the labium entirely pale and pale spots beneath segments 2-8. It will be interesting to examine specimens of this group from other equatorial African countries from which *donaldsoni* is recorded (including Congo; PINHEY, 1978). Specimens from Nigeria were said to have faint patches of color on the hind wings (PINHEY, 1978), while those from western Ethiopia also had colored wings and were considered *dejouxi* by PINHEY (1981b). The ranges of the two taxa approach one another in Ethiopia (PINHEY, 1981b).

(68) *Trithemis dichroa* Karsch, 1893. Dak (1♂), Dja (1♂).

(69) *Trithemis grouti* Pinhey, 1961. Dak (1♂). – We follow GAMBLES et. al. (1998) in using this name for the species previously called *T. atra* Pinhey, 1961. This species is probably restricted to West Africa.

(70) * *Trithemis kirbyi* (Selys, 1891). Dja (5♂, 2♀). – Known from Côte d'Ivoire to the West and Benin to the East, it is surprising this abundant species had not been taken in Ghana.

(71) *Zygonyx torrida* (Kirby, 1889). Dja (4♂). – The eyes of this species are black dorsally and blue ventrally.

DISCUSSION

This collection adds significantly to the known Odonata fauna of Ghana. With 24 new species records (one of which is still unidentified), the known dragonfly fauna for the country is increased by 24%, to 123 species. These new records also include the first records of 9 genera for Ghana (*Elattoneura*, *Mesocnemis*, *Aciagrion*, *Crenigomphus*, *Gomphidia*, *Paragomphus*, *Aethriamanta*, *Eothemis*, *Nesciothemis*),

Table I

A list of the Odonata of Ghana, with records from the present collection, Mole (MARSHALL & GAMBLES, 1977), Kumasi (NEVILLE, 1960), and other localities

Species	Localities						Species	Localities					
	Kakum	Pantan	Bui	Mole	Kumasi	other		Kakum	Pantan	Bui	Mole	Kumasi	other
CHLOROCYPHIDAE							*melanicterum*	X		X		X	5
Chlorocypha curta			X			5	*Pseudagrion nubicum*		X				
Chlorocypha dispar					X	5,7	*Pseudagrion sjostedti*			X			7
Chlorocypha glauca	X				X	6,7	*Pseudagrion sublacteum*	X		X	X		5
Chlorocypha luminosa						5	*Pseudagrion sudanicum*				X		
Chlorocypha selysi	X				X	5	AESHNIDAE						
CALOPTERYGIDAE							*Anax ephippiger*		X				
Phaon iridipennis	X	X	X	X	X	5	*Anax speratus*						5
Sapho bicolor	X				X	1,7,8	*Anax tristis*				X		7
Sapho ciliata	X				X	5,7,8	*Gynacantha bullata*						1
Umma cincta	X					5,7	*Gynacantha cylindrata*			X			
LESTIDAE							*Gynacantha manderica*			X	X		
Lestes dissimulans				X			*Gynacantha sextans*				X		
Lestes ochraceus				X			*Gynacantha vesiculata*				X		1
PROTONEURIDAE							*Heliaeschna lanceolata*					X	
Chlorocnemis elongata	X				X	1,5,9	GOMPHIDAE						
Chlorocnemis flavipennis						5	*Crenigomphus renei*			X			
Elattoneura nigra			X				*Diastatomma multilineata*						8
Isomecocnemis subnodalis	X					1,5	*Diastatomma soror*						1
							Diastatomma tricolor						5
Prodasineura villiersi	X				X		*Gomphidia madi*			X			
PLATYCNEMIDIDAE							*Ictinogomphus ferox*		X		X		
Mesocnemis robusta			X				*Lestinogomphus africanus*			X	X		
Mesocnemis singularis			X				*Onychogomphus supinus*						X
Platycnemis congolensis					X		*Paragomphus genei*			X			
Platycnemis guttifera	X						*Paragomphus nigroviridis*	X					
Platycnemis sikassoensis				X	X		CORDULIIDAE						
Stenocnemis pachystigma						7	*Neophya rutherfordi*						7
COENAGRIONIDAE							*Phyllomacromia bifasciata*			X			2,7
Aciagrion hamoni			X				*Phyllomacromia melania*						4
Agriocnemis maclachlani						1	*Phyllomacromia pseudafricana*				X		
Agriocnemis zerafica		X				12	*Phyllomacromia sophia*						5,7
Ceriagrion bakeri			X				*Phyllomacromia* sp.			X			
Ceriagrion glabrum		X	X	X	X	3	LIBELLULIDAE						
Ceriagrion ignitum						7	*Acisoma panorpoides*		X		X	X	
Ceriagrion moorei				X		7	*Acisoma trifidum*					X	
Ceriagrion platystigma					X		*Aethriamanta rezia*		X				
Ceriagrion suave				X	X		*Allorrhizucha klingi*					X	1,5,8
Enallagma deserti						1	*Brachythemis lacustris*			X			
Enallagma glaucum				X			*Brachythemis leucosticta*		X	X	X	X	1,3
Ischnura senegalensis		X					*Bradinopyga strachani*		X		X		
Pseudagrion epiphonematicum	X						*Chalcostephia flavifrons*			X		X	X
							Crocothemis divisa		X	X	X		
Pseudagrion glaucescens			X		X		*Crocothemis erythraea*		X		X		5
Pseudagrion hamoni		X	X	X			*Cyanothemis simpsoni*						7
Pseudagrion kersteni		X	X			5	*Diplacodes lefebvrei*				X		
Pseudagrion							*Eothemis zygoptera*	X					

Table I, continued

Species	Localities						Species	Localities					
	Kakum	Pantan	Bui	Mole	Kumasi	other		Kakum	Pantan	Bui	Mole	Kumasi	other
Hadrothemis camarensis					X	1,7,8	*Philonomon luminans*						1,5
Hadrothemis coacta					X	7,8	*Tetrathemis bifida*						8
Hadrothemis infesta					X	8	*Tetrathemis camerunensis*					X	7,8
Hemistigma albipuncta		X		X		3,5	*Tetrathemis godiardi*						7
Lokia incongruens						5	*Thermochoria equivocata*						X
Nesciothemis pujoli		X					*Tholymis tillarga*			X	X		3
Olpogastra fuelleborni			X				*Tramea basilaris*		X		X		
Olpogastra lugubris		X	X	X			*Tramea continentalis*					X	
Orthetrum abbotti				X			*Trithemis aconita*			X	X		11
Orthetrum angustiventre				X			*Trithemis annulata*		X			X	
Orthetrum brachiale		X		X			*Trithemis arteriosa*		X	X	X	X	5
Orthetrum chrysostigma		X	X	X		5	*Trithemis basitincta*						7
Orthetrum guineense				X			*Trithemis dejouxi*			X			
Orthetrum hintzi		X				7	*Trithemis dichroa*			X	X		5
Orthetrum julia	X				X	7,10	*Trithemis grouti*		X		X		
Orthetrum machadoi						7	*Trithemis kirbyi*			X			
Orthetrum microstigma						10	*Trithemis nuptialis*					X	7
Orthetrum monardi				X		7	*Urothemis assignata*				X		3
Orthetrum stemmale		X	X	X		7,8,10	*Urothemis edwardsi*				X		3
Palpopleura deceptor		X		X			*Zygonyx torrida*			X	X		5
Palpopleura lucia		X	X	X	X	3,5							
Pantala flavescens		X	X	X	X	5	TOTAL SPECIES	*15*	*32*	*39*	*46*	*32*	

REFERENCES: (1) D'ANDREA & CARFI, 1994; – (2) FRASER, 1928; – (3) FREMPONG & NIJJHAR, 1973; – (4) GAMBLES, 1979; – (5) KARSCH, 1893; – (6) LIEFTINCK, 1973; – (7) PINHEY, 1962a; – (8) PINHEY, 1962b; – (9) PINHEY, 1969; – (10) PINHEY, 1970a; – (11) PINHEY, 1970b; – (12) PINHEY, 1974.

an increase by 19% to a total of 56 genera. The new records come from Bui (15), Pantan (5), and Kakum (4), indicating all parts of the country have been inadequately sampled. The new records from Kakum stem from only two partial days there, and that rainforest region would very much repay more intensive collecting.

A current species list for Ghana is presented in Table 1, with records from this study as well as those from Mole (MARSHALL & GAMBLES, 1977) and Kumasi (NEVILLE, 1960). All other published records of Odonata from Ghana are listed as well, including those of KARSCH (1893); the title of that paper refers to Togo, but the area sampled is now included in Ghana (K.D.B. Dijkstra, pers. comm.). We have not included a few species listed in the literature from Ghana (*Enallagma pseudelongatum* Longfield, 1936 [FREMPONG & NIJJHAR, 1973], *Pseudagrion thenartum* Fraser 1955 [NEVILLE, 1960], and *Trithemis pluvialis* Förster, 1906 [NEVILLE, 1960]) based on the lack of additional records from West Africa and the potential for misidentification.

DRAGONFLY COMMUNITIES

The 3 streams that were sampled differed in their adult odonate communities in some predictable ways. The rainforest streams at Kakum had 2 chlorocyphids, 4 calopterygids, and 3 protoneurids, while the more open stream (Djapoli) at Bui had one representative of each family, and the still more open stream (Dakobi) at Pantan had only *Phaon iridipennis*, the only species of this group in common to all 3 sites.

Several genera are sufficiently speciose, and their habitat preferences have been sufficiently poorly described, that it is of interest to examine their distribution among the collections made. Of the 8 species of *Pseudagrion* collected, more occurred at the two more open streams (5 at Bui, 5 at Pantan, and 2 at Kakum). *P. glaucescens* and *nubicum* were found only at Pantan, *sjostedti* only at Bui, and *epiphonematicum* only at Kakum. Three species (*hamoni*, *kersteni*, and *sublacteum*) occurred at both Bui and Pantan, and *melanicterum* occurred at both Bui and Kakum. *P. epiphonematicum* and *melanicterum* seem to be characteristic West African forest-stream species, while all the other species collected range much more widely in sub-Saharan Africa.

Orthetrum also appears to be more characteristic of open areas in Ghana. Of the 5 species collected, 4 were taken at Pantan, 3 at Bui, and one at Kakum. *O. brachiale* and *O. hintzi* were found only at Pantan, *O. chrysostigma* and *stemmale* occurred at both Bui and Pantan, and *O. julia* occurred at Kakum and Bui. Again, the dark subspecies *O. j. julia*, the only member of the genus collected at Kakum, is a characteristic West African form, and all the other species are very widespread.

Trithemis was entirely characteristic of open areas. Of the 7 species collected, 3 occurred at Pantan and 4 at Bui, while none was taken at Kakum. Interestingly, only the very widespread and abundant *arteriosa* occurred at both Pantan and Bui; *dejouxi*, *dichroa*, and *kirbyi* were found only at Bui and *annulata* and *grouti* only at Pantan. In this genus, the most narrowly distributed species, *dejouxi* and *grouti*, occurred away from the rainforest environment. This genus seems especially heat tolerant; the second author saw males of four species in the open at a Zimbabwe stream on an extremely hot (>40° C) day when males of four species of four other anisopteran genera were sheltering in the shade of a large bridge.

It must be kept in mind that the sampling at Kakum was brief, and that area will doubtless be found to support populations of additional species of these genera, perhaps increasing the similarity of its fauna to the other sites. Alternatively, more species restricted to that rainforest region will surely be discovered there. Sampling of additional habitats would doubtless expand the lists of species at each locality.

BIODIVERSITY AND BIOGEOGRAPHY

In this study, we attempt to analyze how species richness and species composition change along a habitat gradient. The change from wet forested areas to drier savanna woodland areas would logically be accompanied by a decline in the total number of Odonata species, due to the dependence of members of the order on water for their life history. Species diversity would be affected in two ways by this habitat change; not only would the number of species decline, but also the composition of species would change. Those species that occur in drier areas are likely to be different than those occurring in wet environments. Different species will be better adapted to live in slightly different habitats along the gradient, some more adapted for dry savanna and some more successful in wet rainforest. For example, a species living in the savanna might be adapted to survive the greater seasonality of wetlands that occurs in drier regions by having larvae that develop rapidly in temporary pools and adults that can avoid overheating in the hot sun of the open plains. This would be different from a species living in a rainforest, where larvae might develop in small permanent streams and the adults live in cool shady areas under the canopy. If this idea is applied to many species and variations throughout the changing habitat, the result should be a turnover in species composition.

To test these hypotheses, species lists were compiled for ten moderately-well to well-studied sites in Ghana and nearby Côte d'Ivoire and Guinea, arbitrarily chosen by their having species lists of more than 30 species. These sites were divided into forest sites (Simandou in Guinea, Monts Nimba in Guinea/Côte d'Ivoire, and Taï, Lamto, and Abidjan in Côte d'Ivoire) and savanna sites (Korhogo in Côte d'Ivoire and Mole, Bui, Kumasi, and Pantan in Ghana). See Table II for details, including references. The sites are not perfectly comparable, as some of them represent samples from much larger areas than others, and they differ substantially in the amount of time spent surveying them, but it is instructive to see what can be learned from

Table II

West African localities at least moderately well-sampled for Odonata

Country	Region	Year	Months	Season	Species	Reference
FOREST			*forest site mean 59.6*			
Guinea	Simandou	1984	Jan	dry	33	LEGRAND & GIRARD, 1992
Guinea/Côte d'Ivoire	Nimba	several	all year	both	90	LEGRAND, 1983, 1985, 1992, 1993
Côte d'Ivoire	Taï	several	all year	both	51	LEGRAND & COUTURIER, 1985
Côte d'Ivoire	Lamto	several	all year	both	75	LEGRAND, 1982, 1991
Côte d'Ivoire	Abidjan	1941, 1946	?	?	49	FRASER, 1947
SAVANNA			*savanna site mean 49.2*			
Côte d'Ivoire	Korhogo	1967, 1972	Dec-Apr	dry	92	LINDLEY, 1974
Ghana	Mole	1974, 1975	Jul-Aug	wet	46	MARSHALL & GAMBLES, 1977
Ghana	Bui	1997	Jun-Jul	wet	41	this paper
Ghana	Kumasi	1958	Aug-Sep	dry	34	NEVILLE, 1960
Ghana	Pantan	1997	Jun	wet	33	this paper

Table III
Similarity between the Odonata fauna of Ghana and that of other African countries

Country	Species	% in Ghana
Guinea	150	0.43
Côte d'Ivoire	175	0.47
Ghana	123	1.00
Nigeria	238	0.42
Cameroon	204	0.40
Kenya	187	0.31
Botswana	111	0.24
Zimbabwe	155	0.26
Mozambique	126	0.28
South Africa	161	0.22

comparing them.

The expected decline of the number of species from forest to savanna is not supported by analyzing these sites (Tab. II). Species totals ranged from 33-90 at the forest sites (mean 59.6) and 33-92 (mean 49.2) at the savanna sites. Species totals are about the same at the two best-sampled sites, Monts Nimba in the forest and Korhogo in the savanna. The best-surveyed site in Ghana, Mole National Park (MARSHALL & GAMBLES, 1977), supported only about half as many species as the best-surveyed sites in Côte d'Ivoire, but much larger areas were sampled at Korhogo and Monts Nimba. A more thorough survey from all of these sites would provide a more rigorous test of the hypothesis. In addition to more comprehensive collections from these areas, sampling of several additional sites in the drier northern and eastern regions of Ghana might demonstrate a decline in number of species as the terrestrial habitats changed from wet to dry.

The second aspect of this biodiversity gradient hypothesis is the turnover in species composition. This was tested by analyzing the similarity between all pairs of sites. Similarities were calculated as C/T, where C is the number of species in common for each pair of sites and T is the total number of species for the two sites combined. The similarities were surprisingly low, ranging from 0.08-0.39 (mean 0.21). It is important to note that the breadth of habitat types sampled, as well as the thoroughness of each survey, will affect the species list strongly, but as sampling is more thorough and species lists become larger, more similarities would be predicted. This is clearly not the case (Fig. 3), as there is no such increase (for all comparisons, $r^2 = 0.009$). If there were a distinct difference between forest and savanna species, we would predict more similarity among forest sites and among savanna sites than between forest and savanna sites, but the slight difference (mean similarity among forest sites 0.25, among savanna sites 0.24, between forest and savanna sites 0.19) is not significant.

The very substantial (>60%) turnover in species from site to site may be a combination of inadequate sampling at many sites and rather different habitats sampled at many of the sites. Nevertheless, it is consistent with a hypothesis that many tropical Odonata species are habitat specialists, so a substantial turnover would be expected between sites that were not exactly the same ecologically.

Ghana lies at the eastern edge of the Upper Guinea Forest Zone (KINGDON, 1989), but its fauna should be typically West African. Little has been written about the differences between the West African Odonata fauna and those of Central, East,

and South Africa, so we have attempted to analyze the present list of species known from Ghana in relation to the rest of Africa. Simple comparisons between country lists should furnish at least an indication of biogeographic relationships, so we have compared the Ghana list with those from Guinea (LEGRAND & GIRARD, 1992), Côte d'Ivoire (compiled from numerous references), Nigeria (VICK, 1997), Cameroon (VICK, 1997, 1999), Kenya (CLAUSNITZER, 1999), Botswana (PINHEY, 1976), Zimbabwe (PINHEY, 1984a), Mozambique (PINHEY, 1981a), and South Africa (PINHEY, 1984b, 1985); see Table III.

Ghana shares the most species with Guinea and Côte d'Ivoire, in the Guinean forest zone to the West of the Dahomey Gap, but interestingly, almost as many with Nigeria and Cameroon, to the East of the gap in the Congolean forest zone. Not surprisingly, Ghana is more dissimilar to Kenya, at a greater distance to the East, and still more to the southern African countries used in the comparison.

The Central African rain forests are far more extensive and, in general, hold more species than the similar forests of West Africa (SAYER et al., 1992), but there has been no comparison of the odonate faunas of these two regions. We compiled a list of the Odonata known from the countries from Guinea-Bissau to Benin (1,044,327 sq km) West of the Dahomey Gap and from Nigeria and Cameroon (1,376,170 sq km) East of the gap. Of the 275 species known to occur in those countries West of the gap, 62 (23%) are not known to the East. Of the 302 species known to occur in Nigeria and Cameroon, 89 (29%) are not known to the West. Thus it appears that at

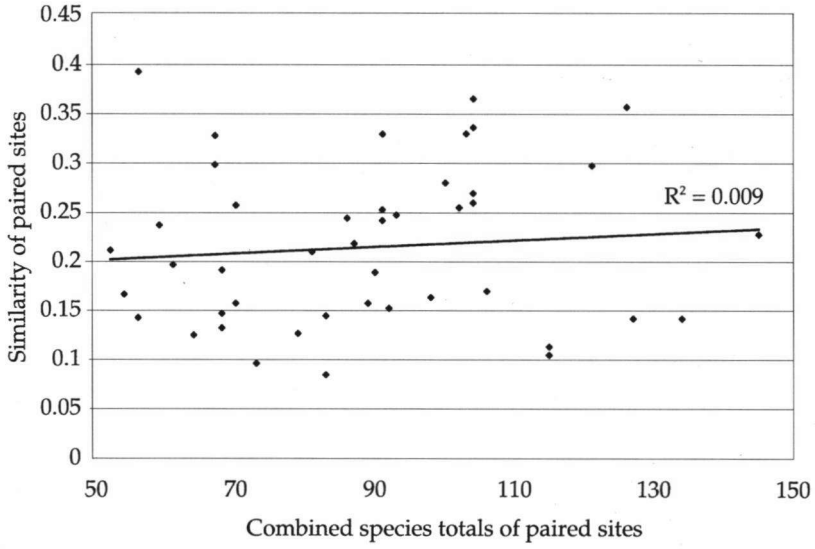

Fig. 3. Odonata species diversity and similarity in West African sites.

least the northern edge of the Congolean forest region, in Nigeria and Cameroon, is not greatly richer in either species or endemics than the Guinean forest region. With the addition of about 45 additional species known from Gabon and the Congo (PINHEY, 1962a; LEGRAND, 1975), the overall odonate fauna of Central Africa is indeed richer than that of West Africa but not by a very great degree. Perhaps a better indication of the special nature of the Congolean forest is the presence there of the rather isolated endemic genera *Pentaphlebia* (Amphipterygidae), *Nubiolestes* (Perilestidae), *Nesolestes*, and *Neurolestes* (Megapodagrionidae), none of which occur in the Guinean forest.

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