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J. Zool., Lond. (1974) **173**, 199–223

Ecological studies on crater lakes in West Cameroon. Debundsha Lake

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(*Accepted 13 November 1973*)

(With 17 figures in the text)

Cape Debundsha receives 10 m (400 inches) of rain per year, and the water of the small crater lake on the cape has one of the lowest conductivities in Africa (11–13 μmho/cm/20°C). The lake has a maximum depth of 13·5 m. At the time of our visit in April 1972 the lake was stratified with a depletion of oxygen in the hypolimnion. The phytoplankton was dominated by *Botryococcus*, and the zooplankton was dominated by the ostracod *Oncocypris debundshae*. Both these organisms are closely associated with the surface film. Other zooplankters included *Thermocyclops hyalinus*, and in deeper water during the daytime the larvae of *Chaoborus ceratopogones*.

The fauna of the lake includes 12 species of testacean rhizopods, six species of rotifers, two oligochaetes, one snail, seven crustaceans, 15 insects and three acarines. Of the last group two species were new to science and one had been found only once previously. The ectoproct polyzoan, *Lophopodella carteri*, is recorded for the first time from West Africa, and the second time from Africa. The general impression of the fauna is one of sparseness, with an unusually high proportion of larval Odonata.

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Introduction

Cape Debundsha (8°29′E, 4°6′N) has one of the highest rainfalls in the world, with an annual precipitation of 10·47 m (412·2 inches) (Kendrew, 1922). On the cape is a small crater lake (Fig. 1), about 250 m across, whose water has one of the lowest conductivities recorded in Africa. The lake lies in a steep-walled crater set in untracked forest, and the difficulty of access is said to have prevented anybody from reaching the water's edge before. No account is available of the fauna of this lake.

We visited the lake on 23 and 24 April 1972 with Peter Moore of the Helminthiasis Research Unit, Kumba. On the second day a local porter carried our inflatable rubber boat up to the lake and we were able to make soundings, to measure the conductivity, temperature, oxygen concentration and pH at various depths, and to sample the plankton and the shore benthos. Because special interest attaches to the fauna of a lake of such low conductivity, we have tried to identify as many species as possible in the present rudimentary state of knowledge of the freshwater fauna of West Africa.

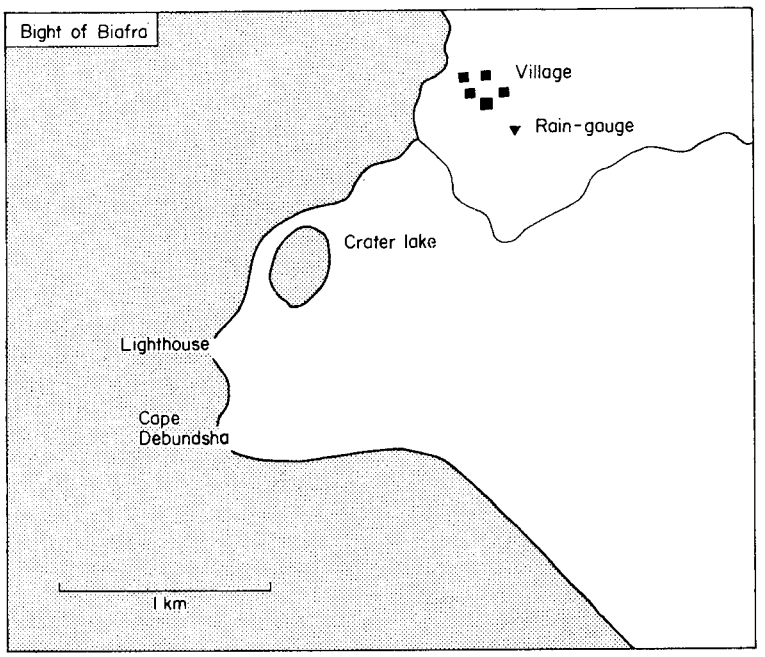


FIG. 1. Sketchmap to show the location of Debundsha Lake.

Structure of the lake basin

The lake is surrounded by forest and the form of the land is difficult to see. Figure 2 gives our impression of the structure of the lake basin, based on our attempts to reach the

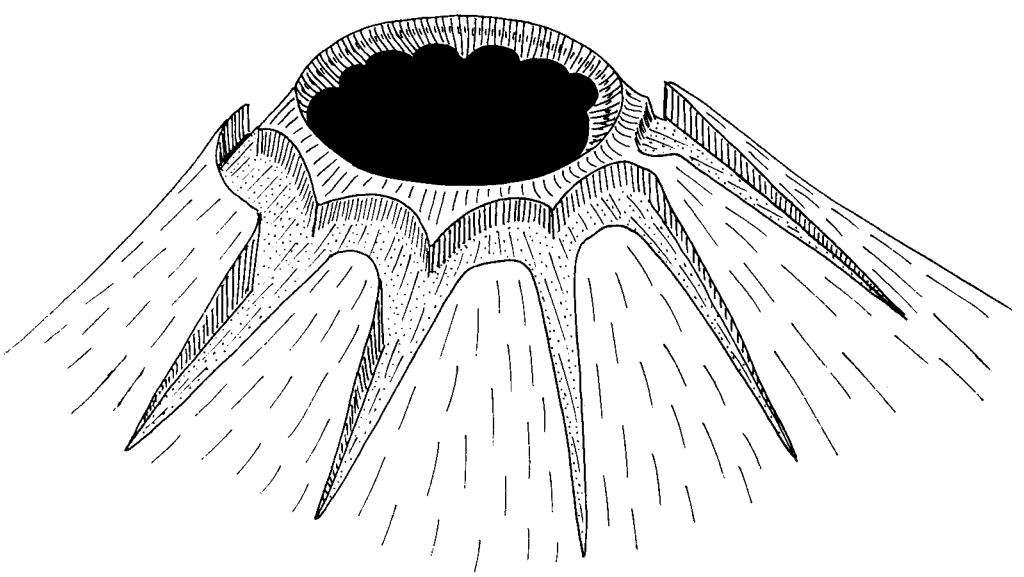


FIG. 2. Diagrammatic impression of the structure of the land around the lake. The numbers and dimensions of the buttresses and gullies around the lake are unknown.

lake. Several times we made our way along one or other of the outer buttresses to find ourselves separated from the crater rim by a vertical walled gulley up to 10 m deep. Eventually we found one buttress with a narrow connection to the rim, like that shown on the right hand side of Fig. 2, where we could cross to the crater rim and then use a tangle of lianas to climb down a vertical wall about 5 m high. From this wall the inside of the crater descended steeply to the lake. The present structure of the lake appears to be a secondary cone developed inside a primary cone. The secondary cone was only slightly smaller than the primary cone, and the upward thrust of material during the formation of the secondary cone may have cracked the outer walls of the primary cone, giving a series of buttresses separated by gullies. The edge of the crater rim is very narrow, barely 20 cm wide. We take this, together with the steep slopes of the crater wall, as an indication that the lake is of no great age.

Physico-chemical stratification of the lake

The shores of the lake are very steep, more or less directly continuous with the slope of the crater wall, and vertical in some places. At intervals there are buttresses projecting a few metres into the lake. Above the lake the crater walls are forested and vary in height from 4 to 20 m.

Soundings were made with a lead weight attached to a nylon line marked off in metres. Only 5 m from the shore the depth was 5 m. The greatest depth we found was 13·5 m.

Water samples were taken with a 5 l Patalas sampler. The temperature of the water in the sampler was measured immediately after being brought to the surface. The temperature decreased from 31·8°C at the surface to 29·2°C at 10 m (Fig. 3).

Oxygen was measured *in situ* with a silver-carbon electrode attached to a portable meter by 20 m of cable. There was gradual decline in oxygen concentration between 3 and 7 m, but between 7 and 9 m there was a rapid fall, so that at 11 m there was only 0·5 mg oxygen per litre.

The pH of the water was estimated using bromo-thymol blue and diphenol purple as indicators in a Lovibond comparator. Inaccuracies are likely to occur when this method is used in poorly buffered waters, but as the amount of indicator used was constant the change in colour will reflect at least a change in the buffering capacity if not the actual pH. The results (Fig. 3) indicate that there was a change which followed the change in oxygen concentration. The estimated pH fell from 7·6 to 5·9 between 4 and 10 m.

It is evident from the curves for oxygen and pH that the lake was stratified, and that there was considerable depletion of the oxygen in the deeper layers. In spite of being very close to the sea the lake is sheltered from wind by the steep forested crater walls, so that the stratification is not very likely to be disturbed.

The conductivity of the water was measured with a Dionic water tester; it is among the lowest in Africa (cf. Talling & Talling, 1965). In the top 4 m of water the conductivity was 12 μmho/cm/20°C; at 6 m it fell to 11 μmho. This curious fall was confirmed by making triplicated measurements at depths above and below 6 m. Near the bottom the conductivity rose to 13 μmho, perhaps because of the increase in hydrogen ions indicated by the measurements of pH. The low conductivity of the water may be attributable to the high rainfall coupled with the small drainage area of the crater basin. The area of the total drainage basin is probably not more than 50 % greater than the area of the lake itself.

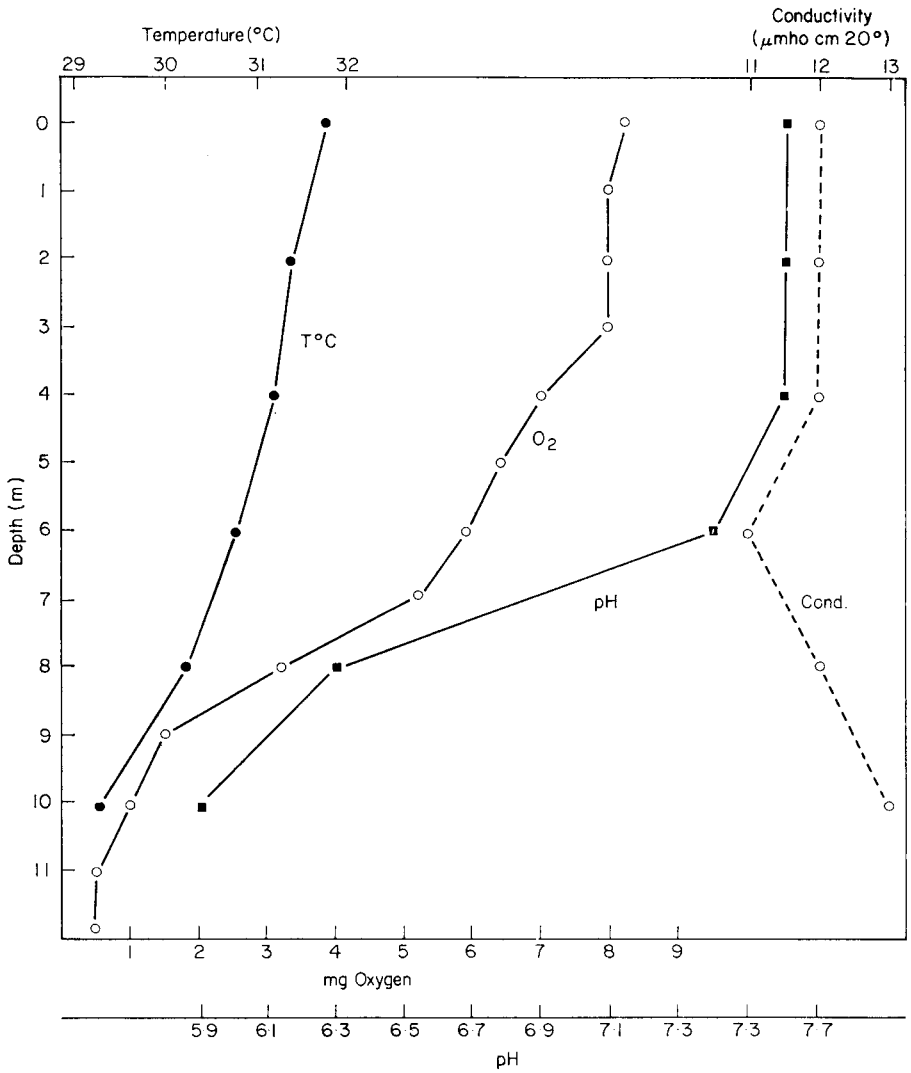


FIG. 3. Debundsha Lake; physico-chemical stratification, April 1972.

The phytoplankton

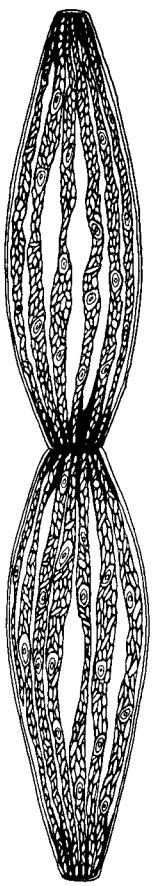
We used standard phytoplankton nets of mesh size 65 μm supplied by the Windermere Laboratory of the Freshwater Biological Association. These nets retained zooplankton and the larger members of the phytoplankton.

The net phytoplankton was dominated by clumps of *Botryococcus* varying in colour from green to red. Most of the material of this species floated at the top of the samples. This genus is known as a dominant form in some European oligotrophic lakes (Naumann, 1931) and has been found abundantly in Lake Toba, Sumatra (Ruttner, 1952).

The net samples also contained a few specimens of a *Planktosphaeria* sp. and a few desmids of the genus *Staurastrum*.

Desmids were among the commonest algae in the lake, not so much in the plankton of the open water, but more frequently in samples taken from the shore. They included some particularly large forms (Figs 4 and 5). Members of the genera *Staurastrum*, *Micrasterias*, *Pleurotaenium*, *Cosmarium*, *Closterium*, and *Euastrum* were found. In addition there were diatoms of the genera *Stauroneis* and *Fragilaria*.

One of the desmids of the genus *Cosmarium* was infected with a simple holocarpic



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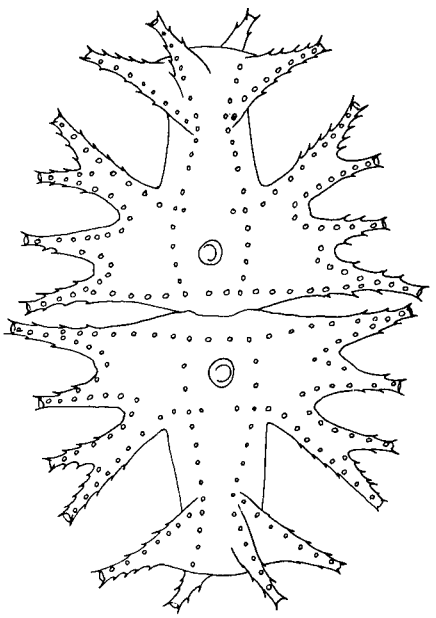

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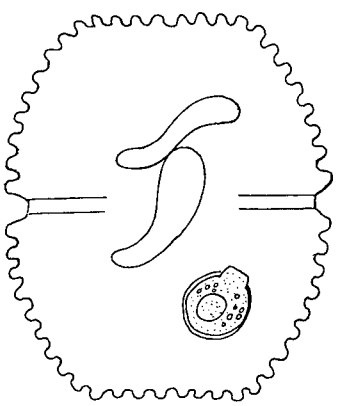

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FIGS 4 to 6. Desmids from Debundsha Lake. 4. *Pleurotaenium ovatum* var. *elephantinum* forma *sansibarense*, actual length 1440 μm. 5. *Micrasterias mahabuleshwarensis* variety with both lateral lobules subdivided, actual length 150 μm. 6. *Cosmarium* infected with a holocarpic fungus.

fungus (Fig. 6) with a globular thallus 13 μm in diameter. Two curved transparent tubular structures within the desmid may be empty sporangia.

We also found some blue green algae among the debris in shallow water, and in the gut of the ostracod *Oncocypris*. Some of the algae from *Oncocypris* had gas vacuoles, and were probably floating near the surface when eaten by the ostracod, but they were too small to be retained by the nets.

Systematic account of the fauna

Phylum Protozoa

Class Sarcodina

Subclass Rhizopoda

Order Testacida

All the testaceans except *Centropyxis aculeata* were found in debris from shallow water.

Family Arcellidae

Arcella megastoma Penard

The diameter of the test of the single specimen was 182 μm, and the pseudostome was 81 μm across. This species has previously been recorded in West Africa by Decloitre (1953) and Green (1963); it has a widespread distribution from France to S. America and Australia.

Family Difflugiidae

Difflugia gramen Penard var *achlora* Penard

The test of the single specimen was 48 μm long, and the trilobed pseudostome about 23 μm in diameter. A small collar was present. This specimen is slightly smaller than the dimensions given by Penard (1902), and very much smaller than the specimens recorded from the River Sokoto in Nigeria (Green, 1963).

Difflugia limnetica Levander

Our three specimens had pale yellow brown tests 113 to 123 μm long and about 100 μm wide. They had weakly developed collars and the pseudostome had three poorly defined lobes in one specimen and four in the other two. There are numerous records of this species in West Africa (Gauthier-Lièvre & Thomas, 1958).

Difflugia tuberculata Wallich

We found one specimen with a test length of 130 μm. This species has previously been recorded in West Africa (Gauthier-Lièvre & Thomas, 1958; Green, 1963).

Centropyxis aculeata (Ehrenberg) Stein

A specimen was taken in a plankton haul from a depth of 11 m. The test had three spines, and a diameter of 97 μm. This is a cosmopolitan species.

Centropyxis eurystoma Deflandre

We found one specimen of this small species. The test had a diameter of 59 μm and the pseudostome was 28 μm across. This pseudostome is slightly smaller than the dimensions given by Deflandre (1929) in his original description, but falls within the range given by Decloitre (1953) for specimens from French West Africa. This species has been recorded from Europe, Africa and Java.

Centropyxis marsupiformis (Wallich)

This species was originally included in the genus *Difflugia*, and was figured as *D. constricta* by Leidy (1879). Deflandre (1929) placed it in the genus *Centropyxis*. Two

specimens were found in debris from shallow water. The greatest diameters of the two tests not including spines, were 74 and 54 μm, and the pseudostome was 38 μm at its widest. These dimensions are well below those given by Deflandre (1929), but Decloitre (1953) has recorded a specimen with a test 61 μm long from Tanaf in French West Africa. This species has also been found in France, U.S.A., Congo and Java.

Trigonopyxis arcula (Leidy)

Both our two specimens' tests were 130 μm in diameter, and both had the characteristic triangular pseudostome. This species has been recorded over a wide range including Europe, North and South America, Africa and Java.

Family Euglyphidae

Euglypha acanthophora (Ehrenberg)

Two specimens had tests 52 and 55 μm long and their spines reached a length of 26 μm. This appears to be a cosmopolitan species.

Euglypha ciliata Leidy var. *glabra* Wailes

A single specimen was found in debris from shallow water. The test was 58 μm long and lacked spines. Around the pseudostome there were eleven toothed scales. The typical form of this species is probably cosmopolitan, but the variety *glabra* has previously been recorded only from Europe.

Sphenoderia splendida (Playfair) Deflandre

The tests of our two specimens were clear and hyaline, 48 μm long and 21 μm wide. The scales were about 8 μm in diameter, and the pseudostome about 8 μm across. The cytoplasm was well preserved in one specimen, and the nucleus had a single large nucleolus. There are few records of this species, but they are widespread, from France to West Africa and Australia.

Trinema enchelys (Ehrenberg)

The tests of several specimens ranged in length from 37 to 48 μm, with a pseudostome 13 μm in diameter. The scales were about 7 μm in diameter and were slightly overlapping. The pseudostome was surrounded by a ring of pores. This appears to be a cosmopolitan species.

Class Ciliata

Order Peritricha

Family Epistylidae

A colony of an epistylid was found attached to a piece of arthropod cuticle among debris from shallow water. The total length of the colony was about 600 μm, and the individuals ranged from 80 to 100 μm in length. The stalk of the colony was evenly dichotomous. Smaller colonies were found attached to larval libellulids.

Class Rotifera
Order Monogononta
Family Brachionidae
Colurella obtusa (Gosse)

A single specimen was collected in shallow water. The length of the lorica was 48 μm and the toes were 13 μm long. This appears to be a cosmopolitan species.

Family Lecanidae
Lecane luna O. F. Müller

Two specimens were collected from shallow water. In both the lorica was 133 μm long and the length of the toes was 48–52 μm including the terminal spike of 9 μm. This is a cosmopolitan species.

Lecane ploenensis (Voigt)

A single specimen was found in a plankton haul from the middle of the lake. The lorica was 137 μm long and the length of the toes was 58 μm. There were no claws on the toes. The dimensions of this specimen fall in the middle of the range given by Voigt (1957). This species has been recorded as abundant everywhere in weedy ponds in the United States (Harring & Myers, 1926), and more rarely in Europe. Voigt (1957) regards it as being most frequently found in pools containing *Sphagnum* and *Utricularia*. Such pools are usually acid and poor in dissolved salts. This rotifer has also been recorded from water of low conductivity in the Mato Grosso, Central Brazil (Green, 1972).

Family Testudinellidae
Testudinella patina (Hermann)

A single specimen was collected with a plankton net thrown into the lake from the shore. The length of the lorica was 172 μm and width 156 μm. The foot opening was circular. This is a cosmopolitan species.

Hexarthra mira (Hudson)

A few specimens were found in plankton samples taken from the middle of the lake. This species seems to tolerate a very wide range of conductivities, from acid moorland pools to brackish water.

Family Trichocercidae
Trichocerca sp.

A single specimen of an unidentified species of *Trichocerca* was found in one of the plankton samples. The anterior end was damaged, so that specific identification was not possible.

Phylum Annelida
Class Oligochaeta
Family Naididae
Pristina longiseta Ehrenberg

Two specimens were found among debris taken from shallow water. This is a widespread, possibly cosmopolitan, species.

Allonais paraguayensis Michaelson

A single specimen was found among debris from shallow water. This is also a widespread species, and has been recorded from Asia, Africa and the Americas (Brinkhurst & Jamieson, 1971).

Phylum Mollusca
Class Gastropoda
Order Pulmonata
Family Planorbidae

Bulinus camerunensis Mandahl-Barth

This species was identified by Dr C. A. Wright from specimens collected by Peter Moore. The specimens were small and thin-shelled when compared with specimens from the type locality, Lake Barombi Kotto. The known distribution of this species, and other snails in West Cameroon, is discussed by Wright (1965).

Phylum Ectoprocta
Class Phylactolaemata
Family Lophopodidae

Lophopodella carteri (Hyatt)

Several statoblasts of this species were found. They are of a characteristic shape (Fig. 7) and have three or four hooked projections at each pole. The length varied from 780 to 800 μm excluding the projections, and the width was 600 to 615 μm. The central capsule was about 420 μm long and 325 μm broad. The terminal processes varied in length between 30 and 60 μm and they bore strongly recurved lateral hooks (Fig. 8). The form of these terminal processes clearly separates *L. carteri* from the other known species in the genus. The size of the statoblasts is slightly smaller than the dimensions given by Lacourt (1968) in his monograph, but is well within the range of variation that one might expect to find within a single species.

This is only the second record of this species in Africa. The first was made by Beauchamp (1936) who found it among material collected from the Athi River in Kenya. The species is widely distributed in Asia, from India to Japan, and has been recorded in Australia. It has also been accidentally introduced into botanical gardens in North America.

Class Crustacea
Subclass Branchiopoda
Order Cladocera
Family Macrothricidae

Ilyocryptus spinifer Herrick

This is a pan-tropical bottom-dwelling species. Two specimens were found among debris collected from shallow water.

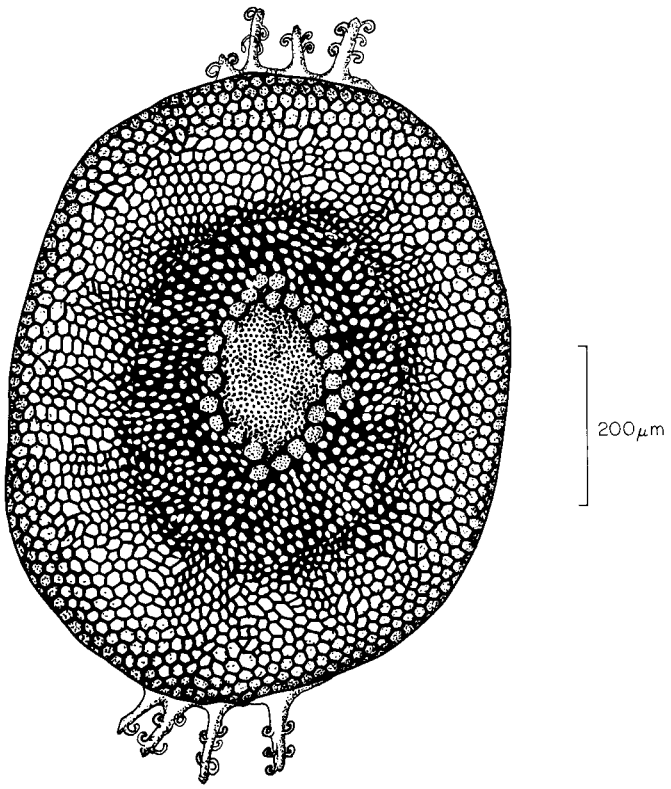


FIG. 7.

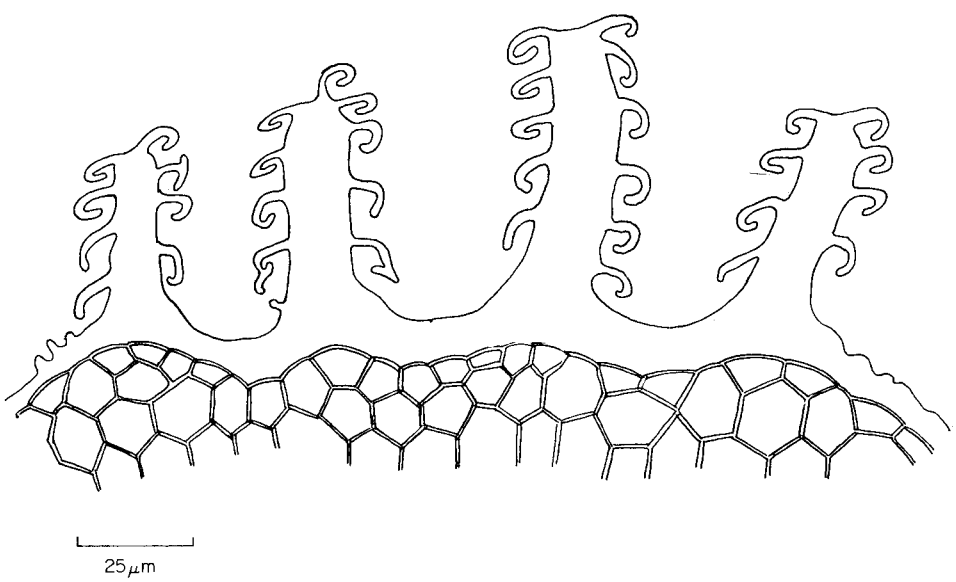


FIG. 8.

FIGS 7 and 8. 7. Statoblast of *Lophopodella carteri*. 8. Detail of terminal processes.

Family Chydoridae

Chydorus eurynotus Sars

A single specimen was found in debris collected from shallow water. This appears to be a pan-tropical species, with records from South America, East and West Africa, India and Australia (Smirnov, 1971). Goulden (1966) has raised a question about the identification of some of the African records, and thinks that they may refer to specimens of *C. pubescens* Sars (=*C. ciliata* Poggenpol according to Smirnov) without the characteristic pubescence. We have compared specimens from the Mato Grosso with specimens from the River Sokoto in Nigeria, and with the specimen from Debundsha Lake, and are convinced that they all belong to one species that agrees with Sars' (1901) original description of *C. eurynotus*.

Pseudochydorus globosus (Baird)

A single specimen of this widespread species was found among debris taken from shallow water.

Subclass Ostracoda

Order Podocopida

Family Darwinulidae

Darwinula serricaudata Klie

Four specimens were found among material collected from shallow water. All were females, and two of them each had three eggs inside their shells. The length of the shell was 0·59–0·61 mm and the maximum height 0·22–0·23 mm. The tip of the abdominal process was characteristically serrated in the manner illustrated by Klie (1935). This species has been found previously in the Ivory Coast.

Family Cyprididae

Oncocypris debundshae Green

This species, recently described by Green (1973), was abundant in plankton samples taken in the middle of the lake, and inshore. Most individuals were found very close to the surface. Fryer (1956) has described the way in which the closely allied *O. mulleri* (Daday) swims on the underside of the surface film. Examination of the gut contents of 14 individuals showed that most had been feeding on coccoid blue-green algae, mostly with gas vacuoles. A few specimens contained naviculoid diatoms. None was found with *Botryococcus*, in spite of its dominance of the phytoplankton.

Zonocypris sp.

Two females were found in material collected from shallow water. In the general proportions of the shell they resemble *Z. laevigata* Klie (1935), but without males it is not possible to be certain of the identity.

Subclass Copepoda

Order Cyclopoida

Family Cyclopidae

Mesocyclops (*Thermocyclops*) *hyalinus* (Rehberg)

This species was present in all the plankton samples taken in the middle of the lake. The adult females ranged in length from 0·60 to 0·62 mm, and they carried two or three eggs in each egg sac. Measurements of 17 eggs from four females gave mean diameters of 72·1 × 64·3 μm. These eggs are distinctly smaller than eggs of the same species from Barombi Mbo (Green, 1972), although the females are slightly larger than those from Barombi Mbo.

Class Insecta

Order Odonata

Suborder Zygoptera

Family Coenagriidae

Enallagma buchholzi Pinhey

These very small zygopterans, marked with bright turquoise blue and black, were numerous around the shore of Debundsha Lake, often settling on the surface of the water. Our two males (Fig. 9) agree well with Pinhey's (1971) description of *E. buchholzi*, known only from the nearby island Fernando Po. But ours, with abdomen lengths of 18·5 and 19·5 mm, are smaller than the type (abdomen length 23 mm). They differ from the related small species *E. vansomereni* Pinhey in the black mark at the base of the labrum; in that the line joining the postocular spots is not continuous; in the greater number of postnodal crossveins in the forewings; and in details of the male appendages.

We have 15 apparently conspecific zygopteran larvae from Debundsha Lake. Of the three final-instar larvae one lacks most of the abdomen, one is a male, and the other, a female, is illustrated in Fig. 10. The occurrence of these larvae with adults of *E. buchholzi* suggests that they may be the larvae of that species, and this is supported by the venation of the larval wing-pad (Fig. 9(c)); by the slender antennae, abdominal keel and labium shape like those of the larva of the related *E. nigridorsum* Selys described by Pinhey (1959); and by the labium and caudal lamellae like those of probable *E. vansomereni* larvae in the collection of R. M. Gambles. The description that follows is based on the female early final-instar larva. The other two later final-instar larvae agree with it except where differences are noted in brackets.

Length from labrum to base of caudal lamellae 9·5 mm (10 mm in the male). Caudal lamellae 5 mm. Head width 2·6 mm (male 2·7 mm). Colour pale, with a dark band near the distal end of each femur. The abdomen bears a prominent, pale, lateral keel on segments 1–7, edged anteriorly on each segment with a dark series of small spinose setae. There is a dark spot anteriorly on each side of segments 2–7. Antennae slender, of seven segments. Labium (Fig. 10(d)) with small spinose setae on the distal margin of the median lobe. Premental setae 5+5; palpal setae 6+6. Lateral caudal lamellae (Fig. 10(c)) slender, tapering to a point, marked with a dark transverse band distally. (The undamaged lateral caudal lamella on the male larva is marked with a red-brown spot at the infraction.)

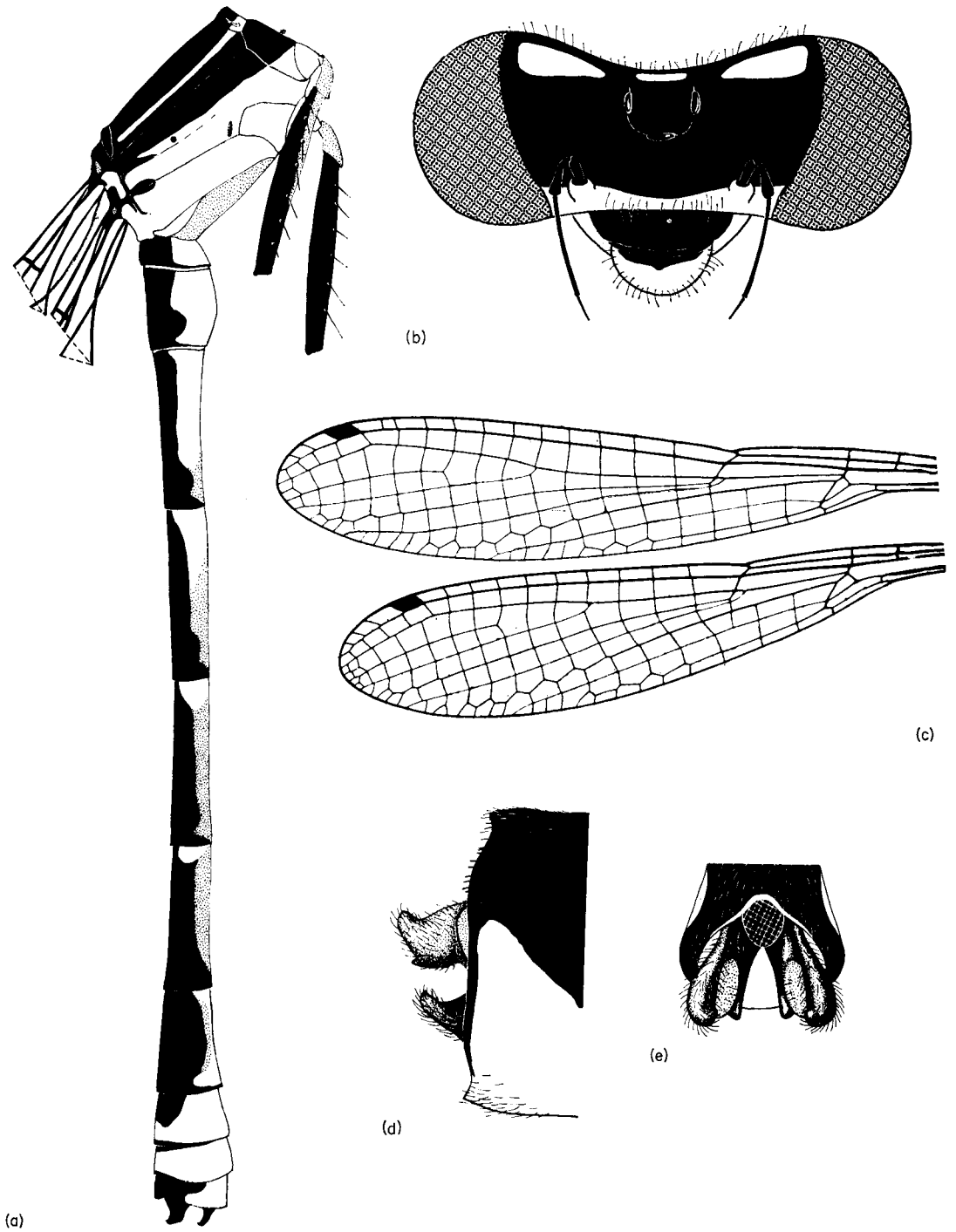


FIG. 9. *Enallagma buchholzi* male. (a) Thorax and abdomen, from the right; (b) head; (c) wings; (d) appendages, from the right, and (e) from above.

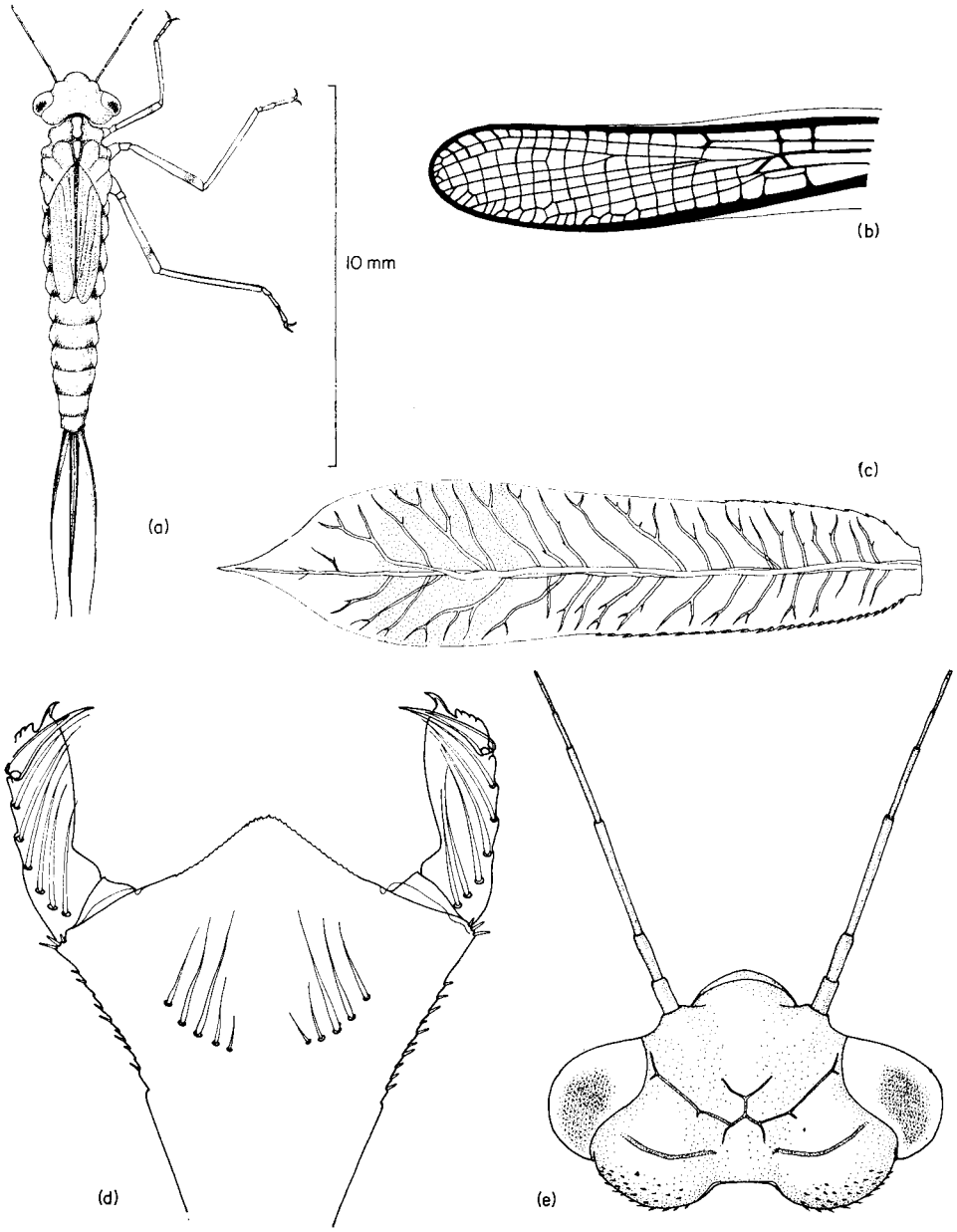


FIG. 10. Final-instar larva of *Enallagma buchholzi*. (a) Dorsal view of larva; (b) venation of left anterior wing pad; (c) right caudal lamella, from the right; (d) labium; (e) dorsal view of head.

In the smaller larvae the stout antenodal setae reach more than halfway along the caudal lamellae on both dorsal and ventral margins, and the labium bears fewer premental and palpal setae than it does in the final-instar larvae. The smallest (body 6·5 mm; caudal lamellae 3 mm; head width 1·3 mm) has three large and one small setae on each side on the prementum and 4+4 palpal setae. Eight other larvae have 4+4 premental and 5+5

palpal setae. Three others have 4+4 premental setae with one or two small additional setae on one or both sides. Two of these larvae have 5+5 palpal setae and the third, a penultimate-instar larva, has 5+6 palpal setae.

Suborder Anisoptera

Family Libellulidae

We have 16 libellulid larvae of two species. Members of both species carry numerous epibiotic epistylid peritrichs.

Urothemis sp. (Fig. 11)

Ten larvae probably belong to the genus *Urothemis*. The venation on the wingpads of the only final-instar larva identifies it as *Urothemis* in Pinhey's (1962) key, and the larvae

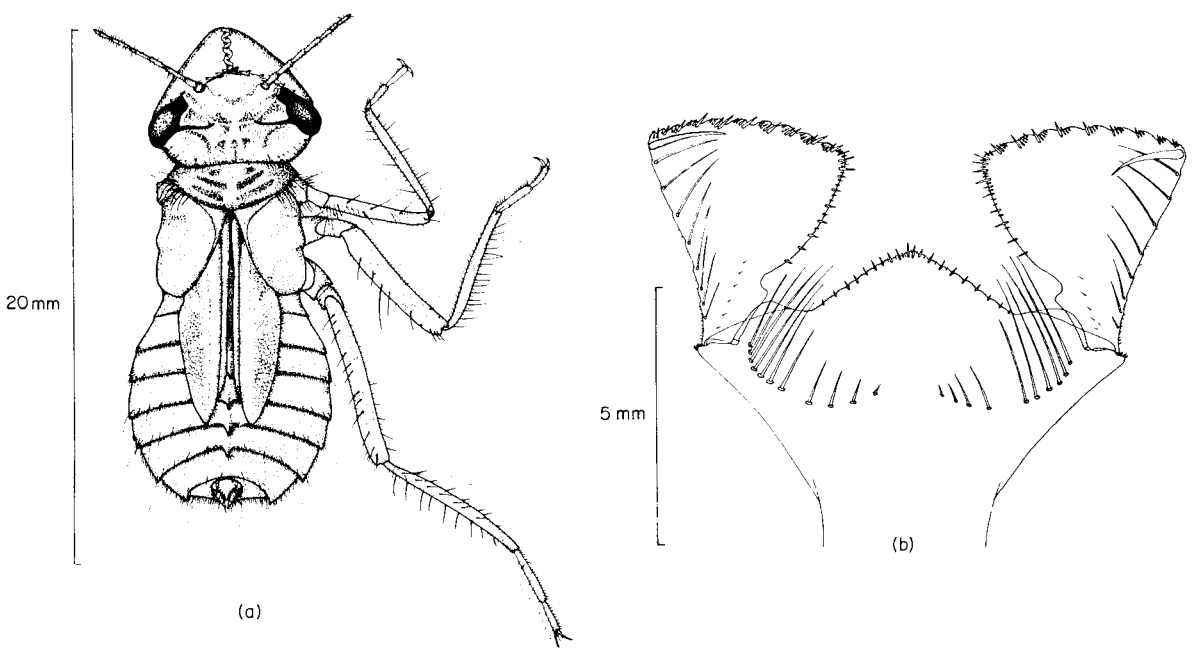


FIG. 11. Final-instar larva of *Urothemis*, possibly *U. assignata*. (a) Dorsal view of larva; (b) labium.

have the very large head and labium seen also in *Macrodiplax cora* (Brauer) (Lieftinck, 1962), another member of the Urotheminae. An exuvia of *Urothemis edwardsi* (Selys) from Nigeria, in the collection of R. M. Gambles, resembles ours, particularly in the form of the head and the labium. It differs in details involving shape, labial setae and abdominal spines. Our specimen is broader (head width 6·5 mm, length 18 mm) than the exuvia of *U. edwardsi* (head width 6·0 mm, length 21·5 mm). Ours has 8+8 palpal and 11+10 premental setae, whereas *U. edwardsi* has 9+9 palpal and 15+14 premental setae. The lateral spines on segments 8 and 9 of the abdomen and the mid-dorsal spines on segments 4 to 8 are longer in *U. edwardsi* than they are in our specimen. Ours is probably a different species of *Urothemis*, possibly *U. assignata* (Selys).

? *Orthetrum* sp.

Six young larvae with relatively smaller heads and with densely setose legs resemble Pinhey's (1959) description of the larva of *Orthetrum caffrum* (Burmeister) in the absence of median dorsal or of lateral abdominal spines; the relatively long anal pyramid; the shape of the anterior margin of the prementum; the crenulate margin of the labial palps; and the long slender movable spine. The shape of the head conforms with Barnard's (1937) drawing of that of an *Orthetrum*.

Order Ephemeroptera

Family Baetidae

Cloeon sp.

A single nymph was found among debris in shallow water. The first six pairs of abdominal gills were double, and the outer tails were setose only on their inner borders.

Order Hemiptera

Family Notonectidae

Anisops pellucens Gerstaecker

Four specimens were collected from the shallow regions of the lake. Two males were present, and they were 9·0 mm in length. The form of the rostral prong, the strigil and the detailed chaetotaxy of the fore-limb agreed with the figures given by Brooks (1951). The posterior margin of the pronotum was medianly emarginate. This species is widespread in Africa, ranging from South Africa to Senegal.

Family Nepidae

Ranatra parvipes Signoret

A single specimen was collected from shallow water. Jaczewski (1926) gives a re-description of this species which has a widespread distribution in Africa, ranging from Madagascar to Egypt and Dakar. Numerous specimens are present in the collection of the British Museum (Natural History), and have been compared with the present individual.

Family Corixidae

Micronecta eupompe Hutchinson

Two males and two females were collected from shallow water. This species was originally described from Ethiopia (Hutchinson, 1930), and the description was extended from further specimens collected in Uganda (Hutchinson, 1932). One of the males from Debundsha has been compared with the type specimen in the British Museum (Natural History).

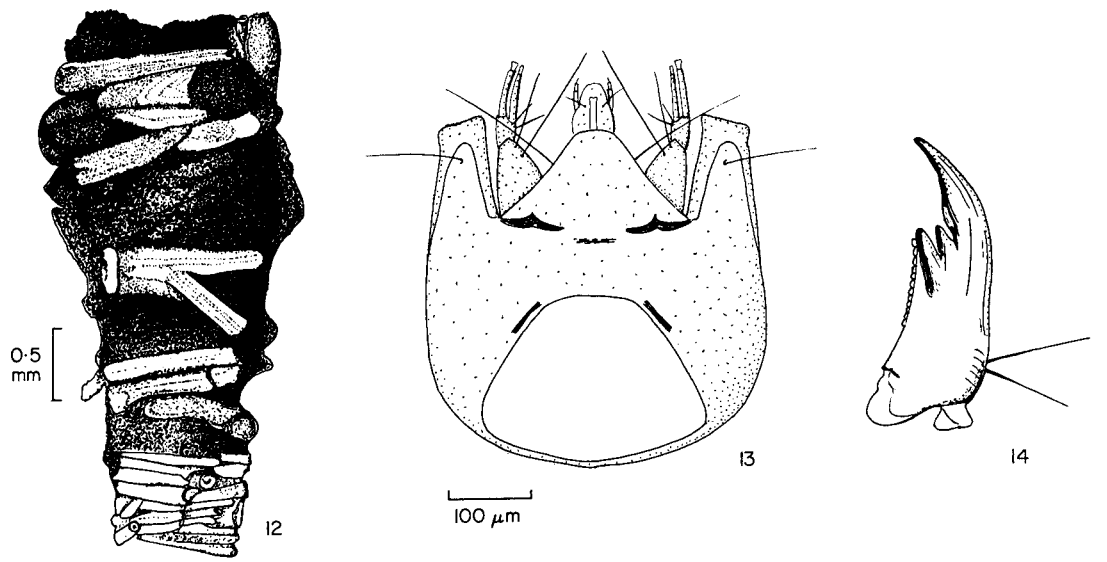
Order Trichoptera

Family Leptoceridae

Oecetis sp.

Two small caddis larvae were found among debris in shallow water. The cases (Fig. 12) were about 3·5 mm long and made of plant debris. At the posterior end of the case the

material was arranged regularly across the longitudinal axis of the case, but anteriorly the arrangement was less regular. The head capsule of the larva is shown in Fig. 13, and the characteristic mandible in Fig. 14. Although they were so small these larvae were apparently predators, as is well known for other members of the genus (cf. Ross, 1944). The gut of one of the specimens contained fragments of some other insect's legs.



FIGS 12 to 14. *Oecetis* sp. larva. 12. Case. 13. Ventral view of head capsule with mandibles removed. 14. Mandible.

Order Coleoptera

Family Gyrinidae

Dineutus subspinosus Klug

A single specimen (Fig. 15) was taken from the surface of the lake, close inshore. Professor Per Brinck identified the specimen. This species is widespread in Africa; it is most abundant in open country, being rare or local in the tropical rain forest areas (Brinck, 1955).

Order Diptera

Family Ceratopogonidae

? *Bezzia* sp.

A single larva was found among debris in shallow water. The head was well sclerotized, and about three times as long as wide; the front of the head was rounded. No prolegs were present. The anal hairs were slightly shorter than the length of the last segment. These features indicate that the larva may belong to the genus *Bezzia*, but the genera *Probezzia* and *Palpomyia* are also possibilities (cf. Thomsen, 1937). The shape of the head clearly places the larva among these carnivorous genera rather than among the shorter-headed herbivorous genera.

Family Chironomidae

Four distinct larval forms were found.

Chironomine sp. A

The labial plate of this species had a median tooth shorter than the innermost lateral teeth (Fig. 16(a)). Three larvae of this type were found among debris from shallow water.

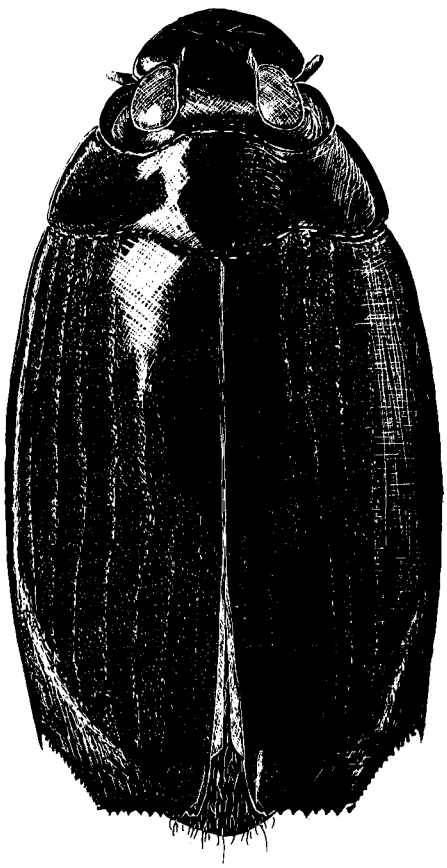


FIG. 15. Adult female of *Dineutus subspinosus*, actual length 7 mm.

Chironomine sp. B

This species was readily distinguished by the form of the labial plate (Fig. 16(b)). A single specimen was found among debris from shallow water.

Calopsectra sp. sensu lato

The third type of larva had elongated antennal tubercles, and Lauterborn organs with long stalks (Fig. 16(c)). The paralabial plates were narrow and close together in the midline (Fig. 16(d)). A single larva of this type was found among debris from shallow water.

Pentaneura sp.

A single tanypodine larva was found with a head capsule twice as long as wide. The ligula (Fig. 16(e)) has the same general form as that figured by Johannsen (1937) for *P. flavifrons*, but differs in detail from that species and from *P. nilotica* figured by McLachlan (1969).

Family Chaoboridae

Chaoborus ceratopogones Theobald

Chaoborus larvae taken in 11-m vertical plankton hauls were identified as *C. ceratopogones* by comparison with Verbecke's (1957) description, and with larvae from Lake

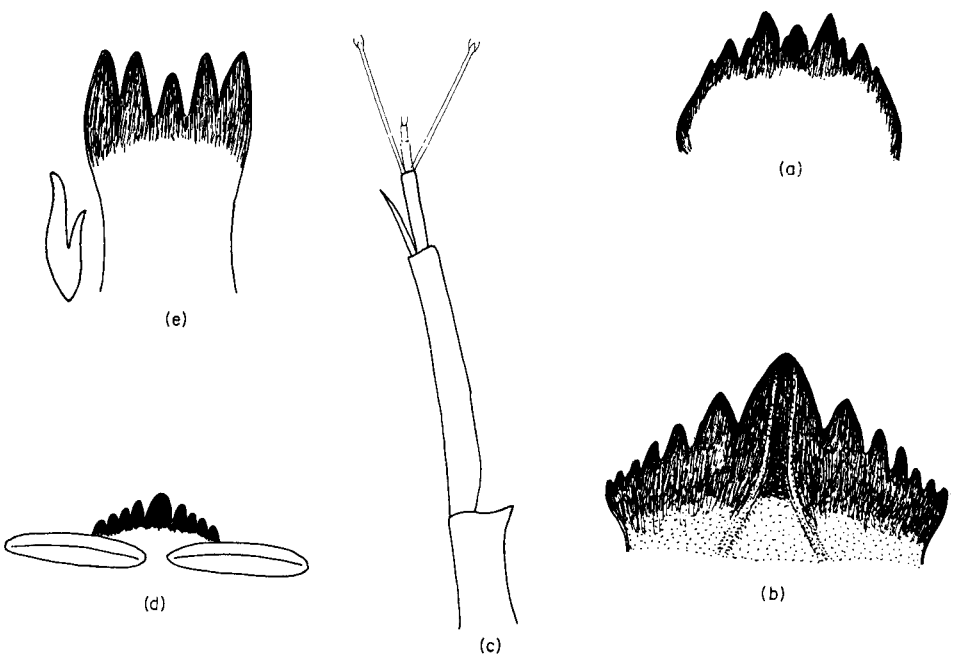


FIG. 16. Chironomid larvae from Debundsha Lake. (a) Chironomine sp. A, hypostomium; (b) chironomine sp. B, hypostomium; (c) *Calopsectra* sp., antenna on antennal tubercle; (d) *Calopsectra* sp. hypostomium; (e) *Pentaneura* sp., ligula.

Kotto that were associated with an adult of that species (Green, 1972). The Debundsha larvae were mostly in their third and fourth instars and had antennal lengths of 233 μm and 360–390 μm respectively. When the number of setae in the mandibular fan (ten for the third-instar larva and 14 for the fourths) was plotted against the antennal length these specimens lay along the same line as specimens from Lakes Kotto and Soden. Their position intermediate between specimens from these two lakes confirms the conspecificity of the larvae from the three sites (see Green, 1972). The larvae from Barombi Mbo are quite distinct (Green, 1972) and should not be included in *C. ceratopogones* without examination of adults as has recently been done by McGowan (1972).

Class Arachnida

Order Acari

Suborder Trombidiformes

Family Halacaridae

Limnohalacarus africanus Walter

Among debris collected from shallow water there was a single nymph agreeing with Walter's (1935) excellent description. The only difference was that the genital plate had ten cupules on each side instead of eight as given by Walter. This species has been found only once before, at Banfora in the Sahara.

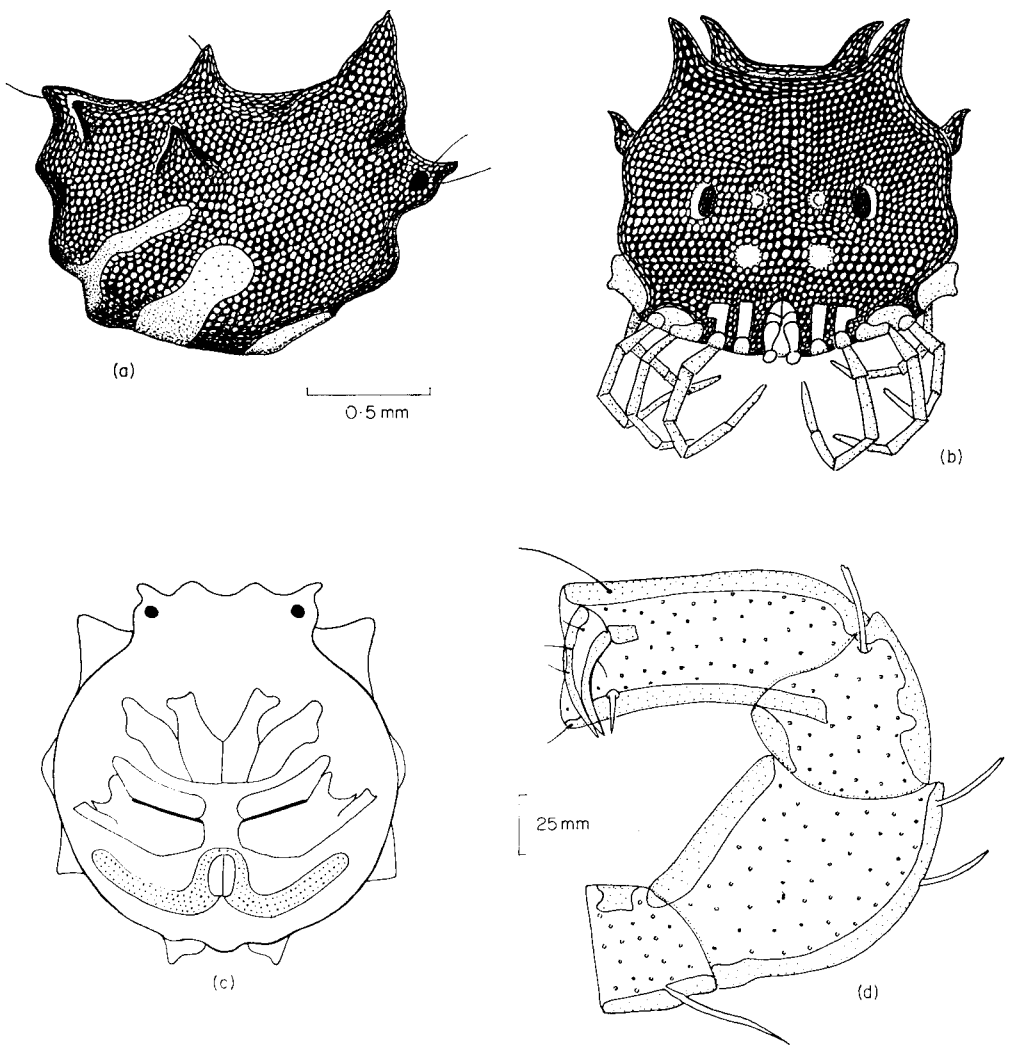


FIG. 17. *Arrenurus moorei* **n. sp.**, adult female. (a) Lateral view of body; (b) anterior view; (c) ventral view; (d) palp. (a), (b) and (c) are drawn to the same scale.

Family Arrenuridae

Arrenurus moorei **sp. n.**

Female. Body 1·55 mm long, 1·41 mm wide. General form globular with ocular projections and eight dorsolateral projections (Figs 17(a),(b)). Acetabular plates narrow and curved. Gonopore 150 μm long and 130 μm wide. The palp is shown in Fig. 17(d). Dorsal lengths of the palp segments are PI—51 μm, PII—110 μm, PIII—75 μm, PIV—136 μm.

This species has a distinct body form which separates it from all other species of the genus. In ventral view there is a slight resemblance to *A. discretus* Cook (1966), but the anterior dorsolateral processes are much larger than in *A. discretus*, and are clearly visible from below. Male unknown.

This species is named in honour of Mr P. Moore who accompanied us on our visits to the lake. The type female is deposited at the British Museum (Natural History). Registration number 1974: 1.

Suborder Cryptostigmata

Family Malaconothridae

Trimalaconothrus heterotrichus Wallwork

This species was described from the three specimens that we collected among debris in shallow water. It is unusual among the Cryptostigmata in being viviparous, a feature that is apparently associated with an aquatic mode of life in this group (Wallwork, 1973).

Vertical distribution of the zooplankton

The zooplankton was sampled by means of vertical hauls at three stations in the lake. At one of these stations hauls were made from 11 and 5 m, at the second station hauls were made at 11, 5 and 1 m, while at the third a single haul from 11 m was taken. The results are shown in Table I.

TABLE I

Debundsha Lake. Numbers of zooplankters in vertical hauls from three stations. The numbers have been calculated per square metre of lake surface

Station	1		2			3
Depth of station (m)	11		11			11
Depth of haul (m)	11	5	11	5	1	11
Chaoborus larvae	245	0	122	20	0	204
Oncocypris debundshae	12,118	11,036	10,690	13,974	13,219	13,301
Thermocyclops hyalinus	3284	3652	3468	4631	2244	6202
Nauplii	632	755	571	796	816	612
Rotifera	61	41	41	61	20	41
Total	16,340	15,484	14,892	19,482	16,299	20,360

The samples were dominated by *Oncocypris debundshae*. This ostracod could be seen in large numbers in the top few centimetres of water, and the vertical hauls show no significant increase as the depth increases from 1 m downwards. The next most abundant zooplankter was *Thermocyclops hyalinus*, of which most individuals were in the top 5 m.

The nauplii of *T. hyalinus* also appeared to be mainly in the top metre of water. In contrast the larvae of *Chaoborus ceratopogones* were more abundant in the deeper hauls, and were absent from the top metre and one of the 5 m hauls. These samples were taken in the middle of the day. It is probable that the *Chaoborus* larvae migrate upwards at night as they do in Barombi Mbo (Green, Corbet & Betney, 1973). A few rotifers were present in the vertical hauls (see p. 206), but there were not enough to draw any conclusions about their vertical distribution.

Discussion

The dominance of *Botryococcus* in the phytoplankton and the relative abundance of desmids in the shallow water clearly place Debundsha Lake in the oligotrophic series of Naumann's (1931) classification of plankton formations. Hutchinson's (1967) provisional classification of phytoplankton types puts the *Botryococcus* plankton as a separate type, characteristic of some oligotrophic North European lakes, but also found as a dominant in certain lakes in temperate South America, South Africa and in one basin of Lake Toba, Sumatra. A recent classification of the phytoplankton in water bodies in Kenya (Lind, 1968) distinguishes seven categories, but does not have a separate category for *Botryococcus* plankton. In Loydien Bay of Lake Naivasha, Lind found *Botryococcus* as a codominant with two blue greens, *Aphanocapsa* and *Dactylococcopsis*, in a region where the conductivity was 900 μmho. Thus *Botryococcus* is not always associated with waters of low conductivity and not always with desmids, although Lind did find *Staurastrum pingue* to be common in Loydien Bay.

The low conductivity of the water and the composition of the phytoplankton in Debundsha Lake both indicate oligotrophy, yet during our visit the lake was stratified, with considerable depletion of oxygen in the hypolimnion. Such stratification in a temperate lake would be a sign of eutrophy. Here it is probably due to a combination of high temperature and shelter from wind. Even a small amount of production in the epilimnion, together with any leaves from the surrounding forest, will cause some depletion of oxygen in the lower layers as the material sinks to the bottom and decays. The crater walls and the small size of the lake will reduce the mixing effects of the wind, so that the supply of oxygen to the lower layers will depend mainly on diffusion processes, which are much slower than wind-induced mixing.

The fauna of the lake, as far as we have been able to determine it, is summarized in Table II. We saw two otters in the lake and we therefore suspect that there may also be crabs (Potamonidae). We also saw several anuran tadpoles. The list of species is unusual in the proportional representation of the various groups. There is a relatively large number of species of testate rhizopods; such a feature is also found in the microfauna of low conductivity situations, such as *Sphagnum* bogs, in temperate regions.

The absence of planktonic Cladocera is a feature of the zooplankton in other crater lakes in West Cameroon (Green, 1972), but the domination of the zooplankton by an ostracod is unusual. The ostracod *Oncocypris* is specially adapted to swim and feed at the surface (Fryer, 1956), but we did not find any feeding on *Botryococcus* which also floats at the surface. Instead the main gut contents were blue-green algae, with gas vacuoles. Rotifers were exceptionally sparse in the plankton at the time we sampled the lake. The total standing crop of zooplankton (Table I) was low, and roughly similar to that of four other crater lakes in West Cameroon (Green, 1972).

Our collections from shallow water were not intended to be selective, but the larvae of the Odonata are disproportionately well represented, with three species and 30 individuals. In the same collection there was only a single larval ephemeropteran. This preponderance of larval Odonata in low conductivity tropical waters has also been noted in the Mato Grosso of Central Brazil (Green, 1970), but it is difficult to explain.

The only snail in the lake, *Bulinus camerunensis*, was thinner-shelled and smaller than specimens from Lake Kotto. In spite of their small size some of the specimens collected by Mr Moore were breeding (pers. comm. from Dr C. Wright). The specimens of the notonectid, *Anisops pellucens*, were also small for that species, the adult males just reaching the lower limit of the size range given by Brooks (1951). Our specimens of *Enallagma*

TABLE II

Summary of the known fauna of Debundsha Lake

	Number of species
Phylum Protozoa	
Class Ciliata	1
Class Rhizopoda	12
Phylum Aschelminthes	
Class Rotifera	6
Phylum Annelida	2
Phylum Ectoprocta	1
Phylum Mollusca	1
Phylum Arthropoda	
Class Crustacea	7
Class Insecta	
Order Odonata	3
Order Ephemeroptera	1
Order Hemiptera	3
Order Trichoptera	1
Order Diptera	6
Order Coleoptera	1
Class Arachnida	
Order Acarina	3
Phylum Chordata	
Class Amphibia	1
Class Mammalia	1
Total	50

buchholzi are smaller than the type series described from Fernando Po by Pinhey (1971). Some of the rhizopods were also smaller than usual. These appear to be instances of dwarfing, and they provide benthic parallels to the examples given by Green (1972) of dwarfing of the zooplankton in other crater lakes. The small size of the statoblasts of *Lophopodella carteri* (p. 207) may be yet another example, although these are reproductive bodies and not mature organisms.

On the data available at present, Debundsha Lake appears as an anomalous lake with a sparse fauna and many indications of oligotrophy, but with a depletion of oxygen in the hypolimnion. Climate and landform interact to produce this condition. The high rainfall is presumed to be responsible, together with the small drainage area of the lake, for the

low conductivity of the water, while the high temperature, together with the shelter provided by the crater walls, is responsible for depletion of oxygen in the hypolimnion.

We thank Diana Harding who drew Figs 4, 5, 7 and 15 and Margarita Petri for Fig. 12. Peter Moore of the Helminthiasis Research Unit, Kumba, accompanied us, provided us with transport and was responsible for initiating the visits to the lake. The local lighthouse keeper, called Pius, guided us to the lake, cut a path through the forest, and saved one of us from falling into the lake. Our thanks are also due to Dr E. Lind for identifying *Pleurotaenium*, Dr J. A. Wallwork for describing the new species of *Trimalaconothrus*, Professor Per Brinck for identifying *Dineutus*, Dr C. A. Wright for identifying *Bulinus*, and Robert M. Gambles for help with the dragonflies. We are grateful to Margaret Clarke for her patience in producing the final typescript.

This work was made possible by a grant from the Central Research Fund of London University and the award of a Churchill Fellowship to Dr Corbet.

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