THE MOSQUITOS OF THE JEBEL AULIYA RESERVOIR ON THE WHITE NILE.

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(Plate XII.)

The Jebel Auliya Reservoir extends some 530 kilometres up the White Nile from the Jebel Auliya Dam, its effect being felt above Renk (Hurst, 1944). The purpose of this great reservoir is to store part of the flood water of the White Nile for use in Egypt during the low river period and is but a part of the scheme, not yet completed, for the training of the Upper Nile. The area under consideration comprises the reservoir, with its thousands of acres of seasonal swamps, and the adjacent land with irrigated areas and rain water pools. Apart from the malarial mosquitos, potential vectors of yellow fever (Lewis, 1947) are also of interest because steamers from the yellow fever area travel northward through the reservoir and meet the railway by which infected individuals might travel to other parts of the country. In addition to the transmission of disease, great discomfort is caused to men and animals by the bites of vast numbers of mosquitos of several species, and, since their existence is mainly due to the reservoir condition, the control of all mosquitos is regarded as a reasonable aim.

The present paper is based mainly on the results of several visits to the reservoir between 1937 and 1946 and it is intended to continue observations, particularly on the bionomics of *Anopheles rufipes*, Gough, and *A. pharoensis*, Theo. Most of the work was done before the reservoir had reached its highest level and even now the conditions of plant growth are not completely stabilised. Lewis (1947) discussed the biting habits of some species. Newhouse (1939) has referred to the possibility of raising the reservoir at some future date.

GENERAL DESCRIPTION OF THE AREA.

It is convenient to consider three sections, the Jebelein section (from Renk to Kosti Bridge), the Kawa section (from Kosti Bridge to Shabasha) and the Geteina section (from Shabasha to Jebel Auliya) (Map 1).

Topography and Climate.

The land slopes gently down to the river and consists of an alluvial clay plain with some sandy areas and a few scattered rocky hills. Average shade temperatures at Dueim, in degrees centigrade, are as follows (Climatological Normals, 1938) :—

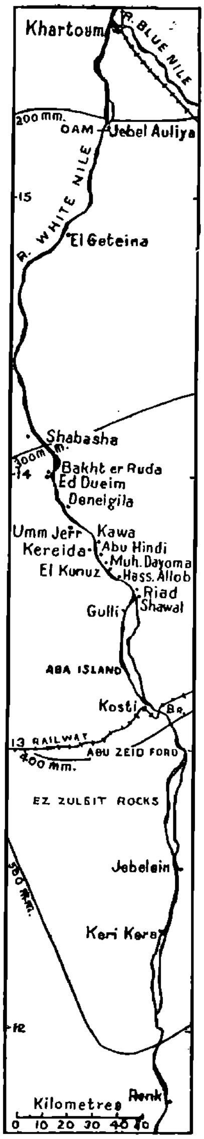
	Annual	December	June
Maximum	37·0	33·7	39·5
Mean	27·3	23·1	30·7
Minimum	20·0	15·5	23·9

The prevalent wind is northerly from October to April and southerly from May to September. At Renk the average annual rainfall is 518 millimetres and at Jebel Auliya 207. Other information on rainfall is given in Map 1 and fig. 1.

Population and Land Vegetation.

Most of the Jebelein section is occupied by Arabs but the boundary between the area of the Arabs and that of the Nilotic negroid people is near Renk. In this southern part of their area the Arabs do not live near the river, mainly owing to the attacks of mosquitos on themselves and Tabanid flies on their cattle, but lead a nomadic life, camping by the river in the dry season and going inland in the rains. There are, therefore, very few villages apart from a few places where steamers call. Much of the country inland is covered with thorn scrub.

In the Kawa and Geteina sections there are many villages and, before the dam began to operate, large quantities of millet were grown on the land left by the falling river. Many of the people have been moved inland, mainly to irrigation pump schemes, to compensate them for the loss of land and collapse of houses due to erosion and seepage, and to reduce the danger of malaria and schistomiasis. Vegetation is sparse in the Kawa and Geteina sections and houses are situated in compact villages surrounded by the wind-swept plain. In the Kawa and Geteina sections most riverain villages were in one of two types of situation with regard to breeding places of mosquitos. In one the village stood near the edge of a swamp in which many *A. pharoensis* bred. In the other the village was on a comparatively steep bank near which were a few inconspicuous pools containing larvae of *A. gambiae*, Giles. At first sight the former, with its great numbers of mosquitos, appeared the more unhealthy. These two typical sites are discussed below in the section on *A. pharoensis*. Many of the people keep cattle and goats.



Map 1.—The Jebel Auliya Reservoir area, showing places mentioned and isohyets. The river banks are at the natural high level and pump irrigation schemes are omitted.

The River.

The reservoir lies in the part of the river known as the desert reach (Ball, 1939). In this reach the average slope of the river is very low, less than one centimetre per kilometre. The natural annual variation in level is small, and there is very little erosion or deposition of silt. Before the dam was built the yearly Blue Nile flood dammed up the White Nile to a distance of over 150 kilometres above the present dam (Newhouse, 1939). Willcocks and Craig (1913) stated that this ponding extended at least as far as Hillet Abbas, near Kosti, 255 kilometres from the dam site, and described the water as a pulsating lake rather than a river. MacDonald (1920) wrote that it did not extend more than 275 kilometres in a very high flood year. This effect is seen in fig. 2. Lyons (1906) described the flooding of low-lying land, usually till October, and stated that the maximum width of the river reached six to seven kilometres in places.

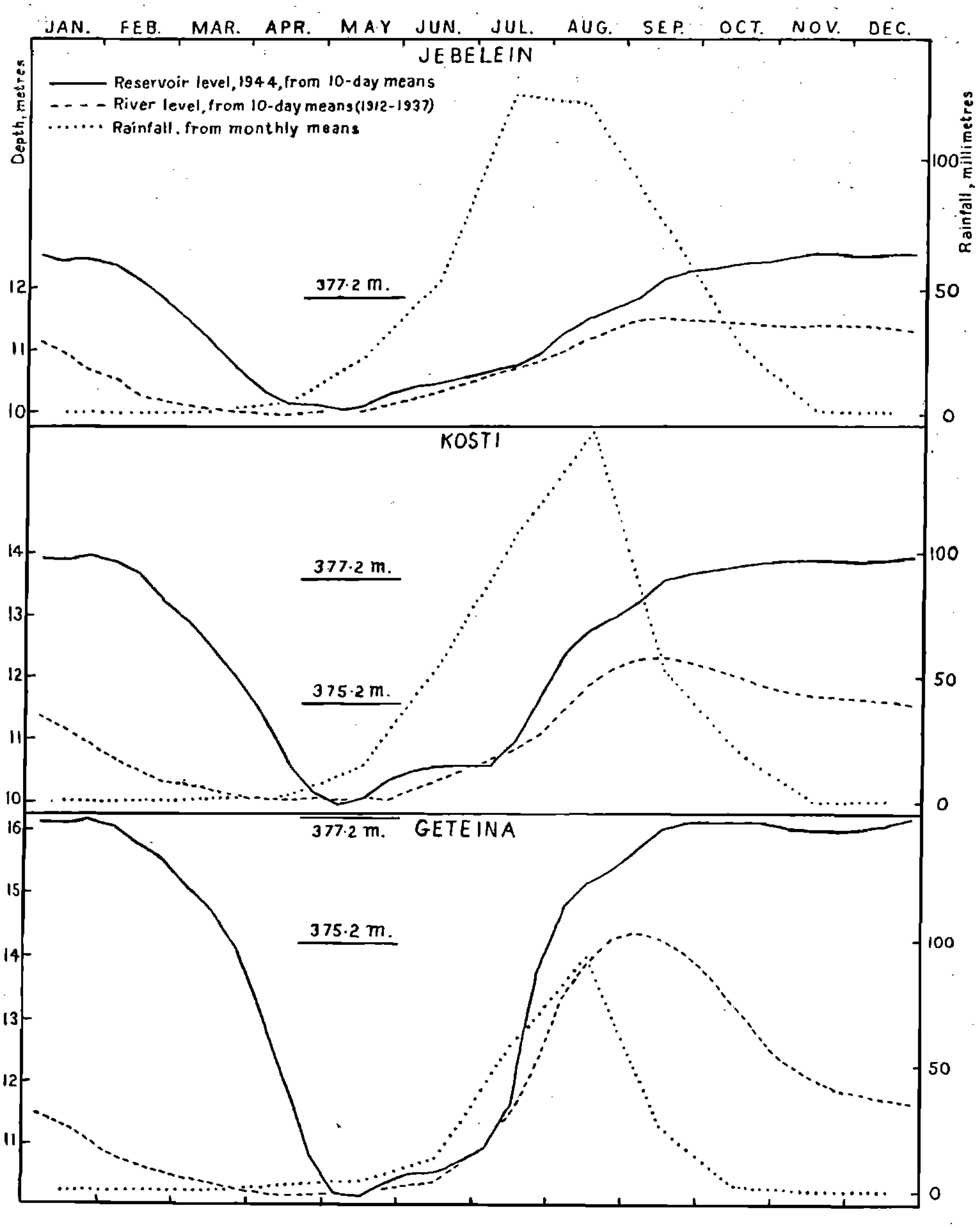


Fig. 1.—Showing mean natural river levels, reservoir levels and rainfall at three places. The Kosti levels are read at Rabak, near the bridge. The zeros of the Jebelein, Rabak and Geteina ganges are 365·38, 363·64 and 361·04 metres above sea level respectively. The full storage level is 377.2 metres and the 375·2 level is indicated to show the approximate lower level of shallow swampy water.

In the Jebelein section a flood plain several hundred metres wide extends for great distances, and bears long narrow furrows parallel to the main channel. Near Kosti Bridge this natural flood plain disappears. In the Kawa and Geteina sections, except opposite Aba Island, the left bank usually slopes gently down to the river and the right is usually comparatively steep and sandy, possibly owing partly to drifting sand which is brought by the prevailing north-east wind in the dry season.

There are many islands in the reservoir area.

The Reservoir.

Water is stored from September to February, the storage level being 377·2 metres above sea level and the storage capacity three thousand million cubic metres (Hurst,

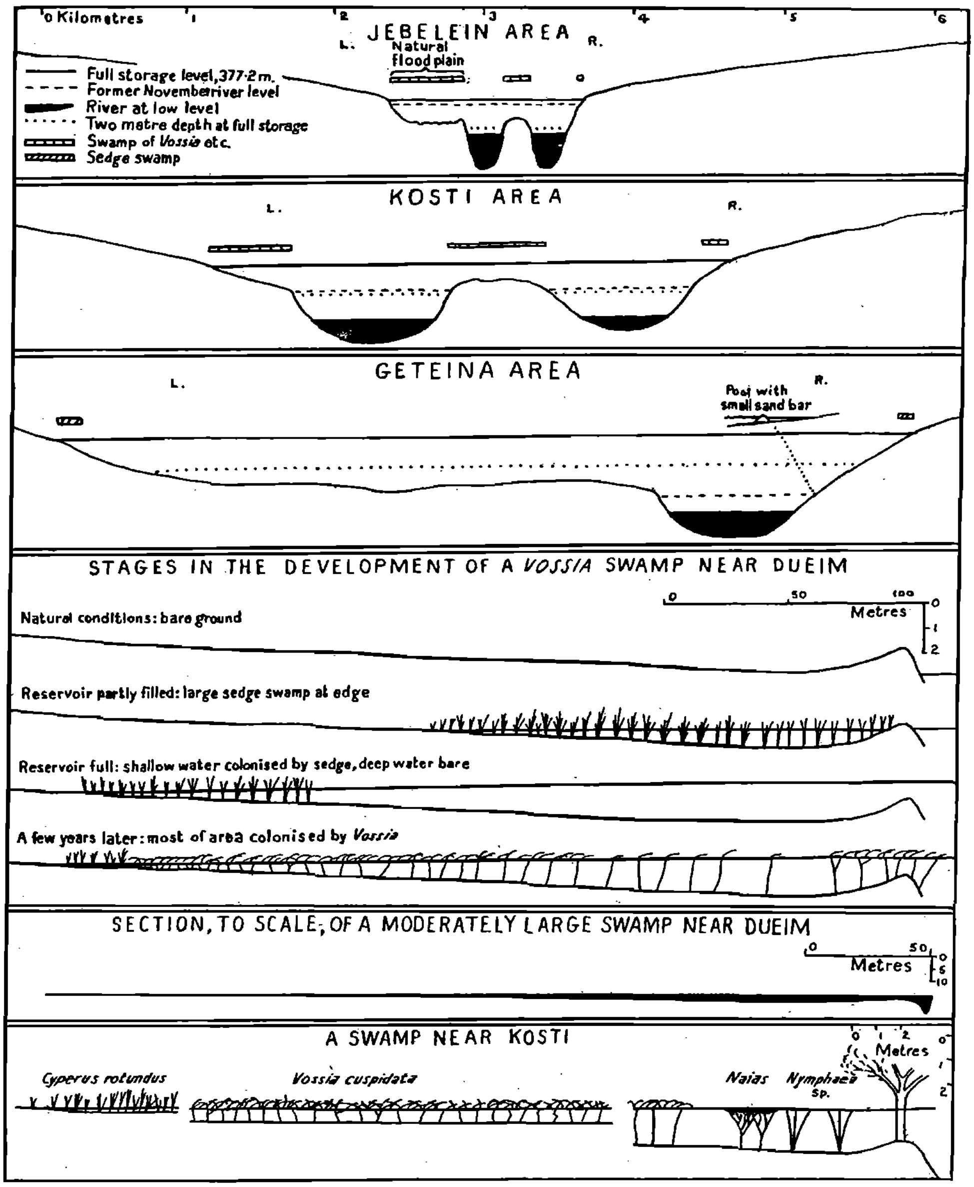


Fig. 2.—Sections at various points along the reservoir; all measurements are approximate and the upper three sections are generalised diagrams.

1944). Newhouse (1939) gave the maximum area as 1,318 square kilometres. In the Kawa section the level varies about 40 centimetres during the full storage period because at times the water is banked up by the action of wind and by the curve formed at the junction of the river slope with the flat surface of the reservoir. The "backward curve" is effective between Jebelein and Shawal and its position is influenced by variations in the natural flow of the river. The effect of the wind can be seen west of Umm Jerr when the water flows from north to south through a bridge over a depression flooded by the reservoir. At full reservoir level large areas of shallow water exist. In the Jebelein section these generally comprise the flood plains and islands, with the normal flooding deepened and extended for a long period, and in the Kawa and Geteina sections the shallow areas consist of the islands and of areas which were normally the dry land on each side of the river (fig. 2). In several places, particularly north of Dueim, where there is not much rain water which would be held up, banks have been built to protect certain areas from flooding.

Malaria.

Malaria occurs throughout the area and appears to have increased since the dam was constructed. During a survey made in the winter 1943 and February 1945 the heaviest incidence was among people living within a mile of the river bank or of pump irrigation schemes. In some years rain-water swamps far from the river appear to be responsible for much malaria. Further reference to the disease is made in the section on species of mosquitos.

Present-day Breeding Places and aquatic Vegetation.

The following paragraphs refer chiefly to the area north of Jebelein where breeding places are very scarce from March to July.

The main swamps.

These are considered as being exclusive of the marginal area within a few metres of the shore. The breeding conditions are determined by the prevalence of various aquatic and semi-aquatic plants which affect mosquitos in different ways. Some afford sites for oviposition; some, by reason of their compact structure or growth, afford direct protection in the shape of small spaces in which larvae can escape from predators larger than themselves; some protect breeding areas from wave action; some hinder the growth of plants favourable to larvae.

Many plants afford sites for oviposition but the dense surface-growing species are particularly attractive to *A. rufipes* and *A. pharoensis*.

Plants that afford some protection, particularly when mingled with plant fragments, pieces of gelatinous brown alga or a thick growth of *Spirogyra*, are the semi-aquatic grasses *Vossia cuspidata* Griff. (small variety), *Echinochloa stagnina* Beauv. and *Vetiveria nigritana* Stapf., the sedge *Cyperus rotundus* Linn., flooded land grasses and herbs, and the less abundant plants *Neptunia oleracea*, Lour., *E. pyramidalis* Hitch & Chase, *Ipomoea reptans* Poir. and *Jussieua repens* Linn. Plants which afford greater protection are *Pistia stratiotes* Linn. and *Azolla* sp. and the under-water plants *Naias pectinata* Magnus, *Vallisneria aethiopica* Fenzl., *Spirogyra*, *Ceratophyllum demersum* Linn. and the gelatinous alga. Sedge and other plants sometimes come into this category if they die and fall on the water or are trodden flat by man, cattle or hippopotamus. *N. pectinata* was important in the first years of dam operation when the water was lowered to the level of this plant in the autumn.

Protection from wave action is effected chiefly by larger plants such as the tree *Acacia arabica* Willd., papyrus (*Cyperus papyrus* var. *antiquorum* Clarke), the large variety of *V. cuspidata* known as *umm suf*, *Juncellus alopecuroides* Clarke and various grasses.

The growth of many plants is hindered by *A. arabica*, *V. cuspidata*, *I. reptans* and the broad-leaved *J. repens*.

Many other water plants occur which have little or no effect on breeding conditions of mosquitos.

Three plants deserve further mention owing to the large areas which they cover, the creeping grasses *V. cuspidata* (small variety) and *E. stagnina*, and the sedge *C. rotundus*.

V. cuspidata and *E. stagnina* sometimes grow singly in as much as 3 and 1½ metres of water respectively but often form large rafts, many acres in extent, of dense growth anchored by stems to the bottom, the former species predominating. Such creeping-grass swamps, sometimes thousands of acres in extent and over one kilometre wide are found in water between a few centimetres and 1½ metres deep, that is, in the large areas of the lateral swamps and on submerged islands, in the Jebelein and Kawa sections. North of Shabasha the creeping grasses are found but grow sparsely and in shallower water. These grasses, which, at Kosti at least, survive the dry season in vegetative form, grow to some length in the early rains and, as the water rises, the foliage rises with it. Under the rather unusual conditions of the Sennar reservoir they can flourish in 380 centimetres of water (Andrews, 1945), but in the Jebel Auliya Reservoir they cannot keep pace with the more rapid rise of the water except in shallower places. Grazing by animals in the dry season and, in the north, the low rainfall, operate against the creeping grasses by preventing them from growing to a sufficient length to survive in deep water. Fig. 1 shows how little rain falls before the water rises at Geteina. In shallow water where animals graze the grasses have a thick mass of aquatic roots but little foliage.

C. rotundus is a land plant which can live in water; by means of its tubers and deep root system it can survive a long period of drying (Andrews, 1940). Owing to its erect habit and moderate height it can only live in shallow water, usually less than a metre deep, and its slender leaves can easily be overshadowed by a denser growth of other plants. It grows freely in the shallow water of the Geteina section; it also forms sedge swamps in the Kawa section but here and in the Jebelein section the creeping grasses occupy much of the shallow water.

Of the other plants many species occur in the swamps of the Jebelein section. In the Kawa section the smaller species tend to grow in the sedge swamps where they are not overshadowed by the creeping grasses. *E. pyramidalis*, which grows among the creeping grasses, is common at Jebelein and Kosti and was found as far north as Kawa in 1945. *V. nigritana* is common in the sedge swamps between Kosti and Geteina and probably further afield. In 1945 no papyrus was seen north of Kosti bridge or some kilometres south of it and the most northerly *umm suf* was on Warilat Island just north of Kosti.

South of Jebelein the swamps have been little studied since the population is small. Numerous water plants exist, including papyrus, and the large variety of *V. cuspidata* predominates.

The river margin.

In swampy areas this consists of the edge of the swamp, which is often differentiated from the rest by the presence of foot and hoof marks, the treading down of vegetation and cultivation by simple irrigation methods. In many areas without swamps a common type of breeding place is formed by small creeks blocked by sand or floating debris. Small pools, bare of vegetation, are formed by wave action which builds up low sandbanks that enclose the pools.

Rain-water pools.

These are very variable in number and extent.

Areas irrigated by pumps.

Thousands of acres of cotton and other crops are irrigated from July to February and numerous small pools would form in minor channels if control were relaxed.

Miscellaneous breeding places.

Breeding places of minor importance are wide wells, water-filled boats, tanks, tree-holes and water-jars. Few pools remain after the river has fallen because the natural drainage carries the water away.

A note on the northern section and rainfall.

Several important features of the northern section are due to low rainfall. The steepness of the right bank is probably due partly to drifting sand made possible by the arid conditions. This formation and the scarcity of aquatic vegetation allow the development of small pools by wave action. Comparatively small areas of creeping grass develop. North of Dueim it has been easy to protect large areas from flooding by building banks since little rain water accumulates behind them.

The Effect of the Dam on Breeding Conditions.

The writer did not visit the area till after the dam had begun to operate. Many of its effects can be conjectured, however, from a study of old descriptions and of conditions during the transition period (1937–1942), when the flooding was increased by stages, and by comparing conditions above and below the dam and seeing conditions above the dam at low water.

The Jebelein Section.

This has been altered less than the other two and was infested with mosquitos before the dam was built, owing to the existence of the above-mentioned flood plain. Boulenger (1907) wrote of mosquitos beginning south of Goz Abu Gumah (near Kosti) during a southward journey made in January 1901.

Reservoir conditions have deepened the swamps and lengthened the period of flooding. In the south the effect is very small but in the north new sedge swamps have been formed. Another effect is the reduction in floating papyrus (as at Jebelein) corresponding to that in the Kawa section.

The Kawa Section.

Before the dam began to operate, and when the White Nile was dammed annually to a considerable extent by the Blue Nile, some vegetation must have grown in the lateral swamps. Willcocks and Craig (1913) mentioned flooding without swamp formation 30 kilometres north of Kosti Bridge. Whatever sedge swamps did exist during the flooding period have been greatly increased, creeping grass swamps have developed, and the period of flooding has been lengthened.

An important feature was caused by the masses of papyrus and *umm suf* (*V. cuspidata*) which annually drifted down on the flood from the great swamps. In the ponded part of the river when the current was reduced this " sadd "* vegetation became stranded in two or three metres of water. In the shallow water between the papyrus and the banks a swampy strip was formed of grasses and other plants, some of them *Pistia* and *I. reptans* brought down with the papyrus. Papyrus, stranded along the edges of swamps, protected them from wave action and intensified the breeding of mosquitos. A strip of stranded papyrus near Kosti is shown in a photograph by Vageler and Altern (1932). The sadd was regarded by the inhabitants as a source of mosquitos, probably owing to the papyrus-protected swamps. Although the papyrus plants alone probably did not bring the larvae, since the plants are often surrounded by small fish which can penetrate among the rhizomes, some larvae might have been brought down by the large floating masses such as those on which men could walk.

In 1937 there were dense masses of papyrus at Kosti bridge and for great distances down to and beyond Shawal the banks were lined with it (Pl. XII, fig. 1). The most northerly piece was seen opposite Dueim where *umm suf* also had stranded. Balfour (1904) stated that sadd was rarely encountered north of Dueim. Casati (1891) mentioned vast tracts of *Vossia* and papyrus near Kawa in July 1880. At Kosti in 1937 booms were being used to ward off floating masses of sadd from the quay and a steam tug was being used in the removal of stranded masses. Floating sadd passed Kosti in varying quantities each year and in 1901 (Boulenger, 1907) was not seen as far north as Kosti. That it has not always reached this latitude is shown by Schweinfurth's (1874) record of sailing up the Nile in 1869 and getting his first sight of papyrus west of the Bahr el Zeraf mouth. Other authors mention various northern limits and it appears that the amount of sadd drifting downstream has varied from time to time according to the height of the river and the condition of channels through the Sadd.

Baker (1866), who sailed up the White Nile in December 1862, alluded to the inundation of land on each side of the river and to the descent of vegetation from upstream. After referring to the area flooded during the rains near Dueim he writes of the acacia forest between Dueim and Jebelein, probably near Kosti : " . . . on a closer approach the forest proves to be a desolate swamp, completely overflowed ; a mass of fallen dead trees protruding from the stagnant waters, a solitary crane perched here and there upon the rotten boughs ; floating water plants massed together, and forming green swimming islands, hitched generally among the sunken trees and branches ; sometimes slowly descending with the sluggish stream, bearing, spectre-like, storks thus voyaging on nature's rafts from lands unknown. It is a fever-stricken wilderness—the current not exceeding a quarter of a mile per hour—the water coloured like an English horse-pond ; a heaven for mosquitoes and a damp hell for man ; fortunately, this being the cold season, the winged plagues are absent."

It was expected by some that the creation of vast swamps would allow floating papyrus to approach Khartoum and to choke the reservoir. In fact the opposite has happened as was foretold by Sir Murdoch MacDonald (1920). The floating masses reach the ponded water further upstream than before and tend to strand between Renk and Jebelein. As the water rose higher each year less papyrus drifted past Kosti and in October 1945 and 1946 not a single plant was seen near Kosti bridge. Although 1945 was a year of low flood and little papyrus came down the river, nevertheless the " papyrus-protected " swamps of the Kawa section are probably a thing of the past. This great alteration in the aquatic flora appears to extend at least from Jebelein to Kawa.

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* " Sadd " means a block in Arabic and was applied to the masses of vegetation which blocked the Upper Nile in the swamp or Sadd region.

Altogether, the reservoir conditions have had the effect of creating extensive grass and sedge swamps by flooding, have filled small watercourses by maintaining a constant high level, have increased the effect of the waves in building up the small sand bars which enclose pools and have brought to an end the papyrus-protected swamps. Many acacia trees are likely to be killed and experimental plantations are being made which may change breeding conditions.

During the transitional period a striking succession of plant colonisations occurred in parts of the Kereida-Shabasha swampy areas. At first great stretches became overgrown with *C. rotundus* as the lowest land was flooded. This next became too deep for sedge which grew only in a belt along the newer shore line. Much of the deeper water was then colonised by *E. stagnina* and *V. cuspidata.* The three stages were thus: (1) large sedge swamps, (2) small sedge swamps, and (3) small sedge swamps with large grass swamps (fig. 2). *V. nigritana,* a common swamp grass in the southern Sudan, was first seen in the reservoir at Kereida in 1944.

The Geteina Section.

Before the dam was built some temporary swamps may have been formed during the damming of the White Nile by the Blue. The changes have been essentially the same as in the Kawa section except that the sedge swamps are smaller; there are no large creeping grass swamps, and papyrus never existed.

Predacious Insects and Fish.

There are some large areas of swamp where plants do not grow compactly and larvae are scarce, probably owing to the action of predators. Carnivorous insects are common and among them the Belostomid Hemipteron, *Sphaerodema nepoides*, F., is conspicuous.

Barbus stygmatopygus, Boulenger.

This small cyprinid is common but its habits are unknown.

Micralestes acutidens, Peters.

This small, very active, characinid, allied to the ferocious tiger fish, commonly cruises near swamp plants. It does not appear to penetrate vegetation but perhaps eats mosquito larvae which leave the protective plants as they have been seen to do in water where fish are few.

Aplocheilichthys loati, Boulenger.

Pekkola (1919), writing of this top-minnow and *E. marnoi* and *E. bifasciatus* in the Upper White Nile, stated that they swam near the surface in shoals of about 4 to 50, that they fed exclusively on insects which they caught on the surface, and that they were observed beginning to spawn in August. Boulenger (1907), writing of *A. schoelleri,* which is very closely related to *A. loati,* stated that it was oviparous and hung its eggs in bunches to the twigs of plants by means of small threads. *A. loati* is very common in the reservoir. A specimen taken near Kawa was found to contain the remains of 38 insects, including three second-stage larvae of *Culex poicilipes,* Theo., and one first-stage Anopheline, but the fact that mosquito larvae are often found in the presence of this fish shows that it only exercises partial control over them. This species cruises in shoals at the surface in spaces among swamp vegetation and will cross open spaces. It passes into main irrigation canals through the pumps.

A. loati was common at Shawal on 19.xii.37 and is often abundant in the Jebelein section. In view of its absence on the Blue Nile it seems unlikely that this swamp-living top minnow can survive during the low water period in the main river with its many large carnivorous species, and the scarcity or absence of the fish in the Geteina section might be explained by supposing that it only lives permanently far to the south in the Jebelein section. In this area (near the Abu Zeid Ford) residual pools were seen in the swamps in April 1945 (although no fish were found) and other possible dry season refuges were patches of *Vossia cuspidata* anchored in lateral channels and near islands. *A. loati* was seen at Kosti on 8.vii.39 and was abundant at Gulli and Riad in September 1939. It has been seen as far north as Dueim (29.i.39) and Bakht er Ruda (11.ix.39). At Kereida none could be found on 22.i.39 or 12.ix.39; one was seen there on 18.x.39 but the scarcity of this species in the area, in contrast to Kosti, was surprising. At Bakht er Ruda on 29.i.39 no *A. loati* and few predacious insects were seen in sedge swamps and mosquito larvae were very numerous. At Dueim on 16.xii.46, however, the fish was abundant.

Repeated attempts to maintain stocks of *A. loati* and *Epiplatys marnoi* in the ten-square-metre pools at Wad Medani were unsuccessful although such pools can support large numbers of *Gambusia holbrooki* and *Lebistes reticulatus*. In March 1940, 319 *A. loati* and 87 *E. mernoi* were placed in two pools but a year later the numbers were only 125 and 7 respectively.

Epiplatys marnoi Steindachner.

This brown diagonally-striped cyprinodontid is less common than *A. loati*. It appears to spend more time in vegetation and to leave it less readily and does not usually swim in shoals. Many of this species were seen with numerous Anopheline larvae among *Potamogeton* sp. in Lake No in the Sadd Area. Nine were dissected and no mosquito larvae found in them, evidently owing to the protection afforded by plant fragments. Material was then collected from one square metre of the water surface and left in a basin for 25 minutes. In seven fish then dissected one or more Anopheline larvae, evidently exposed by the disturbance, were found in each. *E. marnoi*, when kept in glass jars, has been found to breed in April. It is often abundant in the Jebelein section and has been found at Kosti on 15.vii.39 and often in later months. An allied species, *E. bifasciatus* Stdr. has been found at Kosti and Gulli.

Haplochromis multicolor, Schoeller.

This small cichlid, which holds its young in its mouth, lives in thick vegetation, usually below the surface. It multiplies rapidly in captivity and feeds readily on larvae of *Aëdes aegypti* but often fails to eat those of *Culex univittatus* and does not prevent Anophelines breeding in stock ponds. It was found breeding at Abu Zeid on 22.xii.38 and is sometimes seen at Kosti.

Tilapia spp.

The young soon grow too large to eat mosquito larvae, if they do so at all. These fish eat algae attached to water plants and probably in so doing expose mosquito larvae to the attacks of top minnows. These and other moderately large fish in the swamps probably eat top minnow.

THE MOSQUITOS.

The following 43 forms of Culicidae have been found in the area :—

Chaoborus ceratopogones, Theo.

Anopheles
- (*Anopheles*)
  - *coustani* var. *ziemanni*, Grünb.
- (*Myzomyia*)
  - *nili*, Theo.
  - *funestus*, Theo.
  - *wellcomei*, Theo.
  - *gambiae*, Giles
  - *rufipes*, Gough
  - *pharoensis*, Theo.
  - *squamosus*, Theo.

Uranotaenia
- *balfouri*, Theo.
- *mashonaensis*, Theo.

Aëdomyia
- *africana*, N.-L.

Ficalbia
- (*Mimomyia*)
  - *splendens*, Theo.
  - *hispida*, Theo.
  - *lacustris*, Edw.
  - *mimomyiaformis*, Newst.
  - *plumosa*, Theo.
- (*Etorleptiomyia*)
  - *mediolineata*, Theo.
- (*Ingramia*)
  - *uniformis*, Theo.

Taeniorhynchus
- (*Coquillettidia*)
  - *metallicus*, Theo.
  - *chrysosoma*, Edw.
- (*Mansonioides*)
  - *africanus*, Theo.
  - *uniformis*, Theo.

Aëdes
- (*Stegomyia*)
  - *aegypti*, L.
  - *metallicus*, Edw.
  - *unilineatus*, Theo.
  - *vittatus*, Big.
- (*Aëdimorphus*)
  - *arabiensis*, Theo.
  - *ochraceus*, Theo.
- (*Banksinella*)
  - *circumluteolus*, Theo.

Culex
- (*Lutzia*)
  - *tigripes*, Grp.
- (*Culicomyia*)
  - *nebulosus*, Theo.
- (*Mochthogenes*)
  - *simpliforceps*, Edw.
- (*Culex*)
  - *poicilipes*, Theo.
  - *bitaeniorhynchus*, Giles
  - *ethiopicus*, Edw.
  - *univittatus*, Theo.
  - ,, var. *neavei*, Theo.
  - *pipiens*, L.
  - ,, subsp. *molestus*, Forsk.
  - *antennatus*, Beck.
  - *decens*, Theo.
  - *perfuscus*, Theo.

TABLE I.

Mosquito larvae collected in the Kosti swamps, exclusive of the margins, between July 1939 and February 1941 (percentages in italics).

A. coustani var. *ziemanni*[1]	32	*5*	*U. balfouri*	61	*2*
A. funestus	3	*0·4*	*Aë. africana* ...	23	*1*
A. wellcomei	179	*26*	*F. splendens* ...	1,387	*41*
A. gambiae	20	*3*	*F. lacustris* ...	2	*0·1*
A. rufipes	125	*19*	*F. mimomyiaformis*	84	*3*
A. pharoensis ... ... } *A. squamosus* (very few) ... }	318	*41*	*F. mediolineata* ...	5	*0·2*
			C. poicilipes ...	1,412	*42*
			C. bitaeniorhynchus or *ethiopicus*	71	*2*
			C. univittatus, etc.[2]	351	*10*
	677			3,396	

[1]Probably none of type form. [2]Var. *neavei*, *C. decens* and *C. antennatus*.

TABLE II.

Larvae and pupae collected in the Kosti swamp (except the margin) between November 1942 and February 1943.

Square metres examined ...	5	2	2	2	1	1	1	2	1	1	1	1	1	0·5	1	22·5
Species of third- and fourth-stage larvae and pupae	*C. rotundus*, open	*C. rotundus*, normal	*E. stagnina* and *V. cuspidata*	*C. rotundus*, trodden	*C. rotundus*, recumbent	*C. rotundus*, semi-recumbent	*C. rotundus*, thick	*Vallisneria* sp.	Mixed submerged plants	*Spirogyra*	*I. reptans*	*N. oleracea*	*E. pyramidalis*	*P. stratiotes*	*Azolla* and some *P. stratiotes*	Totals
A. coustani var. *ziemanni* ...	—	—	—	—	—	3	6	—	—	—	—	—	—	—	—	9
A. wellcomei	—	5	—	—	1	123	25	—	—	—	—	—	—	—	—	154
A. gambiae	—	—	—	5	—	—	—	—	—	—	—	—	—	—	—	5
A. rufipes	—	2	—	26	4	—	—	48	116	62	1	—	—	—	—	259
A. pharoensis	—	2	1	21	28	—	15	18	90	9	2	2	2	2	1	193
U. balfouri	—	—	—	4	8	4	—	—	—	—	—	—	—	—	—	16
U. mashonaensis	—	—	—	2	3	3	—	—	—	—	—	—	—	—	—	8
F. splendens	—	—	2	—	—	—	—	—	1	1	8	7	—	59	70	148
F. mimomyiaformis	—	—	—	1	6	1	—	—	—	—	1	3	—	—	2	14
F. uniformis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	3
C. simpliciforceps	—	—	—	—	—	9	—	—	—	—	—	—	—	—	—	9
C. poicilipes	—	—	1	17	13	1	2	7	70	16	—	1	2	—	—	130
C. ethiopicus or *bitaeniorhynchus*	—	—	—	22	—	—	—	2	—	—	—	—	—	—	—	24
C. decens	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	2
Total (all stages)	1	17	11	452	438	536	83	223	434	279	21	33	10	80	89	—
Per cent. beyond second-stage	—	53	36	22	17	27	58	34	64	32	57	39	40	76	85	—
Fourth-stage and pupae ...	0	5	3	21	34	68	29	19	84	14	6	6	1	42	50	—
Anophelini	1	17	3	289	297	373	81	183	329	242	4	13	8	4	1	—
Culicini	0	0	8	163	141	163	2	40	105	37	17	20	2	76	88	—

TABLE III.

Some collections of adult mosquitos (percentages in italics).

Species	Biting man outdoors in evening								Outside house screening in evening		In house in evening	In houses by day				
	Jebelein 8.i.43 ½ hour		Shabak 26.i.39		Kosti, xi.42, i.43, three half-hour catches		Kereida, 18.x.39		Kosti, house far from river 3 evenings viii.ix.39	Bakht er Ruda 20.x.39, 1 house	Bakht er Ruda 21.x.39, house far from river	Jebelein, 20.i.43, one house	Kosti, vii.39–ii.41, various collections of Anophelines		Kosti, xi.42–ii.43, 48 houses near river	
A. coustani var. *ziemanni*	77	*32*	12	—	61	*7*	3	*1*	4	—	—	—	—	—	1	*0·4*
A. funestus	—	—	—	—	—	—	—	—	—	—	—	34	22	*2*	1	*0·4*
A. wellcomei	2	*1*	63	—	119	*10*	—	—	1	—	—	—	11	*1*	—	—
A. gambiae	—	—	—	—	—	—	—	—	8	28	11	—	1140	*85*	111	*42*
A. rufipes	—	—	—	—	—	—	—	—	—	1	33	—	129	*10*	144	*55*
A. pharoensis	17	*7*	59	—	434	*47*	289	*99*	74	59	5	—	35	*3*	6	*2*
T. uniformis	98	*40*	13	—	2	*0·2*	—	—	6	—	—	—	—	—	—	—
C. poicilipes	3	*1*	15	—	287	*31*	—	—	7	—	—	—	—	—	—	—
C. antennatus	47	*19*	11	—	28	*3*	—	—	—	—	—	—	—	—	—	—
Other species	4[1]	*2*	1[2]	—	—	—	—	—	18[3]	1[4]	1[4]	—	2[4]	*0·1*	—	—
Total	248		174		931		292		118	89	50	34	1339		263	

[1] 1 *A. nili*, 3 *T. africanus*.

[2] 1 *A. nili*.

[3] 2 *Aëdom. africana*, 1 *F. splendens*, 1 *Aëdes metallicus*, 14 *Culex* spp.

[4] 1 *A. squamosus*.

TABLE IV.

Mosquitos collected in seven 15-minute periods near Kosti on 10.xi.42 by one person standing at the edge of the swamps. The first *C. poicilipes* was caught after 25 minutes and the first *A. pharoensis* after 27 minutes ; the period of most active biting appeared to be between 28 and 50 minutes after sunset.

Minutes after sunset	0–15	15–30	30–45	45–60	60–75	75–90	90–105	Total
A.c. var. *ziemanni*	—	2	1	4	—	—	—	7
A. pharoensis ...	—	9	113	34	23	7	9	195
C. poicilipes ...	—	6	51	29	19	10	3	118
C. antennatus ...	—	1	2	—	—	—	—	3
Total ...	0	18	167	67	42	17	12	323

Although a few species occur in vast numbers the total is only about a third of those known in the Sudan. The reason is evidently that the main breeding places, although large, are only suitable for swamp-breeding species and that the area is too far north for many of these to flourish. In addition, much of the swamp has to be recolonised each year.

The Jebelein Section.

A. coustani var. *ziemanni* is common. Table III shows the number of this and other species caught at Jebelein (named after its two rocky hills) a place noteworthy as being the most northerly point on the river at which *A. funestus* is common. This species has also been found at Renk and Keri Kera and probably occurs over a wide area south of Jebelein. Most of the species occur in the Jebelein section. *F. hispida, T. africanus* and *C. perfuscus* are known as far north as Jebelein and many species extend into the Kawa and Geteina sections. *T. metallicus* has been recorded from Renk and probably occurs further north.

The Kawa Section.

Some results of collecting mosquitos under various conditions in this area are summarised in Tables I to IV. The square metre areas in which larvae were collected were approximately judged by measured sweeps of a large net of known diameter, the tenacity of the vegetation often precluding a more accurate method.

In the Dueim area most of the less common species found near Kosti are unknown and *A. c.* var. *ziemanni* and *A. wellcomei* are generally few. Catches at Kereida and Bakht er Ruda (Table III) show a comparatively small number of species.

In the Kawa section are the most northerly known limits, in the reservoir area, of several swamp-breeding species. These are *A. nili, A. funestus, U. balfouri, U. mashonaensis, Aëdomyia africana, F. lacustris, F. mimomyiaformis, F. plumosa, F. mediolineata, F. uniformis, C. ethiopicus* and *C. decens* at Kosti, *C. bitaeniorhynchus* at Gulli, *T. chrysosoma* at Shawal, *A. wellcomei* at Kereida and *F. splendens* and *C. antennatus* at Dueim.

Larvae.

The principal species breeding in the swamp area at Kosti are *A. wellcomei, A. rufipes, A. pharoensis, F. splendens* and *C. poicilipes* ; in the winter they constituted 91 per cent. of the larvae identified.

In Table II the figures for fourth-stage larvae and pupae in known (though small) areas give an idea of the probable amount of breeding in different types of vegetation at Kosti. In the main sedge and floating grass swamps the number varied from less than one to about two per square metre, and in the patches of submerged plants and damaged sedge from 10 to 68. The number was high in *Pistia* and *Azolla* but most of the larvae were *F. splendens*.

Although the areas sampled were small, the percentage of individuals beyond the second stage appears worthy of note. It is low in some of the plants with the highest number of larvae. This would be surprising if the number of larvae depended on protection from predators. The figure might be explained by supposing that the plants affording greatest protection also afford the best sites for oviposition and that some of the crowded older larvae disperse to neighbouring areas.

The record of *A. gambiae* in Table II calls for comment. This species does not normally breed in the swamps away from the margin except occasionally in tracks near the shore. In the instance noted the track was made by people wading through the sedge and the larvae were found 20 metres from the shore. Such breeding places are an extremely small proportion of the swamps and are easily detected.

A. wellcomei breeds principally in thick sedge, here and at Jebelein.

As may be seen from the tables, several Culicines have only been found rarely and some only once. Possibly these species spread occasionally from the south.

The swamp margins, rain water pools and occasionally pools in irrigated land are the main breeding places of *A. gambiae* and *C. univittatus*. In the swamp margins *A. gambiae* breeds chiefly in places where the vegetation is disturbed by human activity and where land vegetation has been flooded by the river. The small flooded creeks, already mentioned, are important breeding places of *A. gambiae*. In the cotton growing area of the Gezira Irrigation Scheme it has been found that *A. gambiae* tends to breed mainly near villages. This tendency probably exists also in the White Nile pump schemes and may account for the fact that many breeding places far from villages, apparently suitable in other respects, are devoid of larvae.

The common man-biting Anophelines are *A. gambiae* (with a relatively very small breeding area), *A. rufipes* and *A. pharoensis*. *A. wellcomei* has a restricted breeding area and is probably far less numerous than the two latter species. *A. rufipes* breeds in large numbers in some swamps.

Adults.

Near Kosti, on most evenings during the breeding season, great numbers of mosquitos fly from swamps towards the town. Catches (Tables III and IV) show that most of those which bite man near swamps at this time are *A. pharoensis*. So many mosquitos take part in these flights that a half-hour catch on 6.i.43 by one person yielded 400 mosquitos. Many of these mosquitos reach the town, as is shown by the fact that many *A. pharoensis* can be caught among the houses soon after the flight begins. In the morning, however, only small numbers of this species can be found by careful searching. *A. rufipes*, on the other hand, is common in the houses and sometimes outnumbers *A. gambiae*. It is less endophilic than *A. gambiae* however ; at Kosti, in spite of its vast breeding area, it is little more numerous in houses than *gambiae*, which has a very small breeding area.

Two catches were made at Kosti in December 1945 which give some information on the feeding habits of some species. The mosquitos were caught near the swamp on a man wearing shoes, trousers and shirt and on a calf five metres from him, the total time being about 45 minutes. The figures are as follows (percentages are in italics). The catch on the calf might have been larger if the animal had not been restive.

	Man		Calf	
A. coustani var. *ziemanni* ...	2	*0·9*	3	*2*
A. wellcomei	53	*23*	26	*21*
A. pharoensis	106	*47*	53	*44*
T. uniformis	3	*1*	10	*8*
C. poicilipes	57	*25*	7	*6*
C. univittatus	1	*0·4*	—	—
C. antennatus	4	*2*	22	*18*
	226		121	

A striking feature of collections of adult Anophelines hitherto made in this area is the high proportion of females in the later stage of ovarian development. Thus of 171 females of *A. gambiae* and *A. rufipes* collected at Kosti in January and February 1943, 98 (57 per cent.) were in stage five. Of the *A. rufipes*, 82 were collected in February and 68 (83 per cent.) of these were in stage five. Christophers and others (1941) found that, even though many breeding places were dry, an accumulation of females in the last stages of gravidity was rare and it appeared that even when there were no breeding places Anophelines managed to get rid of their eggs when they became mature. At Kosti breeding was continuous and there were breeding places near the town.

The high proportion of " ripe " females does not appear to be a peculiarity of the reservoir area since it has been noted in *A. gambiae* and *A. pharoensis* (with its very different habits) at Sennar and near Wad Medani where the Anophelines collected in villages in October and November 1946 were as follows :—

	Males	Females	Ovarian stages of those dissected I–III	IV, V
A. gambiae	354	2,677	859	1,028
A. rufipes	272	351	112	160
A. pharoensis	0	1	1	0

A. rufipes and *A. pharoensis* are further discussed below.

The Geteina Section.

A. gambiae, *A. rufipes*, *A. pharoensis*, *C. poicilipes* and *C. univittatus* are the common species. *A. gambiae* breeds in the pools formed by wave action.

The Effect of the Dam.

There are some old records of mosquitos which may be mentioned although they give little or no indication of changes in the mosquito fauna. Balfour (1904, 1906) recorded some swamp-breeding species at Renk, Jebelein and near the site of Kosti Bridge. Mr. W. Ruttledge has recorded (in Government files) *A. funestus* at Kosti in September 1935, *A. pharoensis* and *T. uniformis* at Kosti in October 1933, and *A. wellcomei* at Jebelein in September 1933.

There is an acacia plantation near Khartoum on the White Nile where *A. pharoensis* breeds in years when enough rain falls for herbage to grow before the river rises. Similar conditions probably arose in the Geteina section before the dam was built.

In the Jebelein Section the dam has had the effect of prolonging the breeding season.

In the Kawa and Geteina sections the dam has evidently vastly increased the numbers of *A. pharoensis* and other species in the swamps and greatly lengthened the breeding season. On the other hand, by preventing the formation of "papyrus-protected" swamps in the Kosti-Kawa area, it has reduced breeding near many villages situated on relatively steep banks. *A. gambiae* sometimes bred on the shore edge of these swampy strips. By increasing the formation of pools protected by sand bars the reservoir has apparently increased the breeding of *A. gambiae*. In general one may conclude that the reservoir conditions have prolonged the mosquito breeding season, increased the number of *A. gambiae*, and vastly increased those of *A. rufipes*, *A. pharoensis* and other swamp breeders.

Some residents at Kosti considered that mosquitos were fewer in 1945 and 1946 than before and some at Dueim reported apparent reduction in 1946. If this is true it may have been due to the increase of *Vossia* grass over sedge.

Observations on certain Species.

Chaoborus ceratopogones, Theo.

An adult was found at Kosti in January 1944.

Anopheles wellcomei.

At Kosti this species appears to breed entirely in sedge swamps. Its larvae are easily collected with a net in spite of its climbing habit noted by Lewis (1939). Although a common species at Kosti, *A. wellcomei* is rarely found in houses and seems unlikely to be of any importance as a malaria carrier. On 27.i.39 a female was seen biting at 08.30 hours in a swamp south of Kosti.

A. gambiae.

The breeding habits and adult behaviour of this well-known species are as would be expected. In the swamps its larvae are only found near the shore, especially in disturbed vegetation. It breeds near and far from villages. It is probably the main vector of malaria. Reference to this is made in the section on *A. pharoensis*. On rare occasions single females have been found biting at dusk far from villages.

A. rufipes.

This is the only species, apart from *A. gambiae,* which is commonly found in houses between Kosti and Jebel Auliya. If, as is probable, it transmits malaria on the White Nile, its control constitutes a considerable problem as its breeding places are far more extensive than those of *A. gambiae*. It has been found at many places between Keri Kera and Jebel Auliya and, although near the northern limit of its distribution in the Sudan, evidently occurs all along the reservoir. While considering this species it is of interest to note that it is abundant at Rahad in Kordofan Province during the rainy season. Anophelines collected in buildings there included 116 of *A. rufipes* and 4 of *A. gambiae*. In the neighbouring inland swamp 108 larvae of *A. rufipes* were obtained and 11 of other Anophelines but none of *A. gambiae*. At El Amira in the same Province 22 larvae of *A. rufipes* and one of *A. gambiae* were found in a grassy pool and at Ghabsha and Sherkeila *A. rufipes* was commoner in houses than *A. gambiae*.

A. rufipes evidently breeds most profusely in sub-surface vegetation, where it sometimes outnumbers *A. pharoensis*, and in recumbent *C. rotundus*. These breeding places appear to be preferred sites for oviposition as well as places where the larvae are protected from predators. It occurs among erect sedge but not always; at Bakht er Rùda, on 29.i.39, 252 Anopheline larvae from the large sedge swamp were examined and all were *A. pharoensis*. *A. rufipes* does not appear to breed much in the floating-grass swamps unless the foliage is eaten off by cattle. At Wad Medani its larvae have been found in a seepage pool in the dry season.

In the Northern Sudan *A. rufipes* has been found biting man, cattle and sheep.

The nocturnal behaviour differs from that of most species. It has never been taken in collections of mosquitos biting at dusk near breeding places in the reservoir area nor in any such catches of more than 3,500 mosquitos in various parts of the country. At this time of the evening, however, it has, at three places, been found biting several hundred metres from the breeding place. At Kosti a few were found biting, with a few of *A. gambiae* and other species, far from houses and over 500 metres from the edge of the swamp where many mosquitos were biting at the same time. Near Hawata, in Kassala, Province, a few females of *A. rufipes* and *A. gambiae* were seen biting man at dusk in an open sesame field 500 metres from the nearest breeding place. At Rahad the writer collected mosquitos near a swamp and immediately returned to the town to find *A. rufipes* biting a calf and a sheep out of doors. It may be that these more or less endophilous species do not normally bite unless they are in or near houses and that many, failing to find houses, are stranded in open country at dawn and rest in soil cracks, biting if any person happens to approach the spot on a subsequent night. *A. rufipes* has seldom been found in the evening in the screening of houses but may not infrequently be seen biting in houses in the evening as at Bakht er Ruda (Table III).

The prevalence of *A. rufipes* and *A. gambiae* in houses by day at Kosti and elsewhere and the large proportion of "ripe" females have been noted above. At Rahab, adults of *A. rufipes* were found resting in a hedge near houses. The figures for the Wad Medani area suggest that males of *A. rufipes* tend to rest in houses more than those of *A. gambiae*.

It is evident that *A. rufipes* should be classed as a house-haunting species in the reservoir area since many bite in houses by night and many remain in houses by day. It also resembles the endophilous *A. gambiae* in its absence from catches near breeding places about dusk and occurrence out of doors far from water at this time. It is, however, difficult to understand why, if it is an endophilous species more are not found in houses by day. Until more is known of this species it seems advisable to regard *A. rufipes* as a less important vector of malaria than *A. gambiae*.

A. pharoensis.

The bionomics and possible relation to malaria of this species are of great interest because it occurs in millions in the reservoir area, breeds in large numbers in the Sennar Reservoir and flooded Blue Nile basins and is common in many other parts of the Sudàn.

In the Northern Sudan it breeds in almost any swamp or pool overgrown with vegetation.

It has been seen how this species will bite man in great numbers near swamps for a limited period. Dusk catches a few hundred metres inland do not yield great numbers. It has been noticed after this period when many have been biting people on steamers that large numbers of females, many of them unfed, will rest for some time on the deck structures in the vicinity. Perhaps after this they bite at various times during the night as Haddow (1942) has found in Kenya. The preference for resting by day in vegetation rather than houses is amply illustrated at Kosti and other places where, after the immense nightly invasions, very few can be found in houses although some can almost invariably be seen in the small sheaves of millet straw which are stacked against some of the houses. At Sennar, where there is much *E. stagnina* and many of the huts have straw porches, many adults can be found in these types of " foliage ". When grass grows near the river bank at Kosti *A. pharoensis* can be found in it. The disappearance of great numbers of this species from the town during the night or morning is remarkable and it is supposed that they leave the town to seek shelter in vegetation and that many die in the dry country beyond the town.

Unusual records are of two females biting man at 13·15 hours in strong sunlight in a swamp at Kereida in January 1939, and of a female biting at 09.00 hours in a screened cabin of a steamer in the Sadd.

From the information collected by Evans (1938) it appears probable that this species is not an important vector of malaria in most parts of Africa but may be important in some. Garnham (1945) has discussed the strange differences in capacity to carry malaria exhibited by this species. Evans refers to Symes's observations on its preference for feeding on cattle rather than people, and Haddow (1942) has observed its zoophilism. Although Henderson (1932) stated that it was probably one of the chief vectors in the Upper Nile Province he gave no particular reasons for this conclusion.

In the reservoir area we know that *A. pharoensis* readily bites man and animals, that it normally leaves houses before daytime, and that many females rest in vegetation and very few in houses in relation to the numbers breeding. There is little or no vegetation near most houses during most of the breeding season, and the villages are not surrounded by breeding places but normally separated from the one main breeding place by a stretch of barren wind-swept ground. It is unlikely therefore that there is a close association between people and females of *A. pharoensis* resting in vegetation.

It has been assumed for the present, as a working hypothesis, that the species is of little importance as a vector of malaria in the area in comparison to *A. gambiae*. The following are several pieces of circumstantial evidence which seem to support this view. In considering some of them the two types of village site described above, near large swamps and near steep banks, should be remembered.

At Sennar, where conditions somewhat resemble those at Kosti, strenuous efforts were being made in 1936 to remove a growth of *E. stagnina* covering several hundred acres and breeding many *A. pharoensis*. It was decided, for the time being, to discontinue this work and to concentrate on the control of *A. gambiae*, although arrangements were made to treat the swamp with Paris green if it proved necessary. Although there is still some malaria this policy of ignoring the swamp is still followed.

Another example which seems to indicate the importance of *A. gambiae* rather than *A. pharoensis* is the state of certain riverain villages in 1941, a year when the rainfall was low and there was thus little inland breeding of *A. gambiae* to interfere with a comparison between villages with different types of river breeding places. The removal inland of four villages near Kawa (Abu Jindi, Muhammad Dioma, Kunuz and Hassan Allob) was being strongly urged owing to severe outbreaks of malaria. All these villages were situated on steep banks near small *A. gambiae*-breeding creeks, and at the same time there was no report of much malaria from Bakht er Ruda, Shabasha and Deneigila, villages situated near large *pharoensis*-breeding swamps.

At Kosti, in October 1942, there was a severe outbreak of malaria apparently due to *A. gambiae* breeding abundantly in pools produced by a sudden drop of 40 cms. in the reservoir level at the end of the rains when gravid females of *A. gambiae* were plentiful. In November the pools dried up and the outbreak declined despite the fact that great numbers of *A. pharoensis* were still sweeping into the town every night from the main swamps.

The educational centre of Bakht er Ruda is situated near the edge of a large swamp, in which great numbers of *A. pharoensis* and, until recently, few other Anophelines bred, not far from an irrigated area in which a few *A. gambiae* are sometimes found. The Province Medical Inspector, in his annual report for 1941, stated that in 1940 and 1941 recorded cases of malaria were only 8 and 6 per cent. respectively and that, although the swamp had bred large numbers of mosquitos, the available evidence indicated that conditions had not deteriorated as a result of the filling of the reservoir but had improved.

From 1943 to 1945 Dr. H. D. Fairman was in charge of medical work in the reservoir area and made some observations on malaria and studied past records. In an unpublished report he stated that in general there was a high splenic index and a low parasite index for villages within one mile of the river or the nearest cultivation. After referring to villages with a high rate of malaria he wrote of a village near Bakht er Ruda. " An exception is Shabasha which, although situated on the river bank within less than ½ mile of a large swamp, shows a low splenic and parasitic index. This is in conformity with the low incidence of malaria recorded at the dispensary. The people complain bitterly of nuisance from mosquitos [almost certainly *A. pharoensis*] and the site appears bad." He stated, however, that the results of the examination of the village should be confirmed.

Referring to the whole reservoir area Fairman wrote " Certainly the increase of malaria does not seem to be commensurate with the vast numbers of the swamp breeding species and there appear to be sufficient *A. gambiae* to account for the increase of malaria." It should also be remembered that any general increase in malaria may have been partly due to *A. rufipes*.

Although there is no precise evidence of the rôle of *A. pharoensis* in the area it seems almost self-evident that this species is much less important than *A. gambiae*. It is a common experience to stay in a town on the Blue Nile, where malaria is prevalent and Anophelines (*A. gambiae*) are very seldom noticed, and to visit a town on the White Nile where there are not many cases in spite of vast numbers of *A. pharoensis*.

A. squamosus.

This species is not an important constituent of the mosquito fauna but it is probably widely distributed. Its identification is not always easy because its larvae closely resemble those of *A. pharoensis*, but adults have been identified from Jebelein, Kosti and Bakht er Ruda. It occurs chiefly in the rainy season and its larvae have been found, usually with *A. gambiae*, in sedge and flooded land grass in the swamps and in grassy rain pools.

Species of Aëdes.

A. unilineatus and *A .vittatus* have been found at Jebelein, *A. aegypti*, *A. metallicus*, *A. arabiensis*, *A. ochraceus* (in an inland swamp) and *A. circumluteolus* at Kosti, and *A. metallicus* and *A. fowleri* at Dueim.

Culex tigripes, C. nebulosus, C. pipiens and subsp. molestus.

C. tigripes has been found breeding during the rainy season in wells, boats and tanks in a few places between Renk and Geteina. The other three mosquitos have been found at Kosti and *C. nebulosus* also at Dueim and Jebel Auliya.

CONTROL MEASURES.

The Jebelein Section.

In this area of extensive swamps and few inhabitants, where the widely-breeding *A. funestus* occurs, intensive house-spraying appears to be the feasible method of control in the few villages that exist.

The Kawa and Geteina Sections.

The removal of villages has already been mentioned.

A. gambiae.

The breeding places of this species are comparatively small and well defined and can be treated with DDT dissolved in oil or with Paris green.

A. rufipes.

Pyrethrum spray is used in houses against this species, which is assumed to be of some importance as a vector of malaria and parts of the swamps are treated with Paris green dust or DDT in oil.

The control of aquatic plants is probably not practicable owing to expenses; also interference with creeping *Vossia* (an excellent fodder grass) which evidently represents the climax of plant succession over great areas, would probably allow *Naias* to grow in large quantities followed by a great increase in mosquitos, particularly *A. rufipes.*

A possible method of partial control is to use cultivators to bank off areas of swamp with permission from the Irrigation Authorities.

A very small quantity of creeping grass and *E. pyramidalis* is removed for fodder.

From observations of the larvae it is evident that treading down of the vegetation should be avoided as much as possible.

Two experiments have been made on the use of *Gambusia affinis holbrooki.* This fish breeds much more readily in captivity than the indigenous *A. laoti* and can therefore be released in large numbers before *A. loati* has had time to colonise the swamps. At Kosti 25,000 *Gambusia* were released at the south end of the sedge swamp north of the town between 5th and 12th September 1945. A month later *Gambusia* could easily be found several hundred metres away and had evidently multiplied greatly. On 16th December large numbers were found one kilometre north of the point of release. The species appeared to have colonised an area of about 20 hectares, but never reached the density attained in stock ponds from which other fishes are excluded. North of this *A. laoti* was abundant and no *Gambusia* was seen. In the areas occupied by both these fishes, mosquito control larvae could easily be found and only partial control resulted from their presence. It seemed probable that *A. loati* had prevented the northward spread of *Gambusia,* and in September 1946 1,000 *Gambusia* were released at Dueim where *A. loati* was thought to be scarce. Three months later *A. loati* was seen to be common and no *Gambusia* were seen.

A. pharoensis.

The treatment against larvae of this species, the control of which is desirable because it probably transmits some malaria and because of the discomfort it causes, is similar to that of *A. rufipes.* Growth of thick vegetation near houses and the stacking of straw near them are discouraged to prevent close association between man and *A. pharoensis.*

Culicines.

The control of potential yellow fever vectors has been discussed by Lewis (1947). *C. poicilipes* is the only troublesome biter and can be partially controlled by the use of DDT in oil.

Larvicidal dusts.

Floatable Paris green has been used for many years in parts of the area. It is applied as a one per cent. mixture in dust, usually by hand but sometimes by hand-

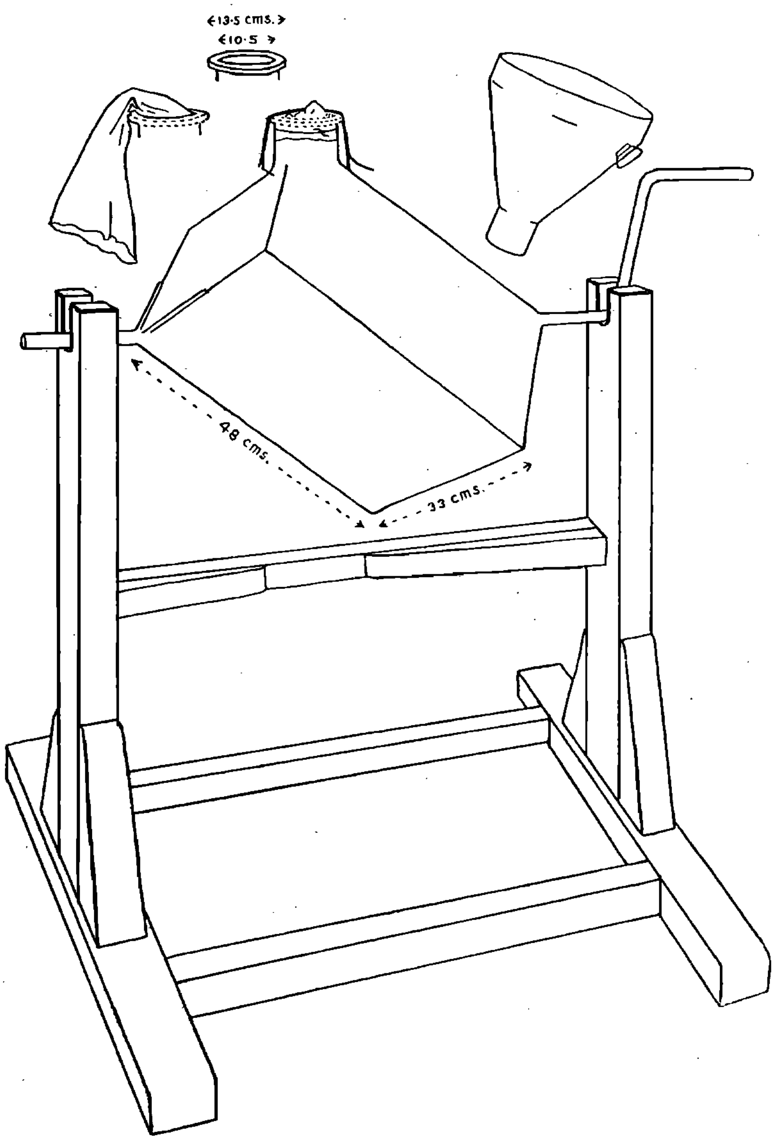

Fig. 3.—Paris green mixer closed by sleeve strapped into opening and showing the handle used as a brake. Small figures show sleeve open, dimensions of opening and funnel for filling.

operated rotary blowers in boats. At present it has certain advantages over some other available insecticidal dusts; it floats well, can be detected with little difficulty on the water and, even if unduly concentrated, does not kill predators. Other insecticides may soon prove more effective but whatever is used it is considered that for many of the White Nile breeding places dusts are far more useful than liquids.

Dusts can drift with the wind (which usually blows from one direction) over great expanses of *Vossia* grass which is so thick that penetration by boats is difficult. They can be applied to small pools hidden beneath vegetation and to water covered with scum, and in some places to pools where deep soft mud and acacia thorns hinder a close approach. Although the snail hosts of *Schistosoma* are seldom seen in the Kosti and Dueim swamps it is often useful to employ an insecticide which does not necessitate wading in channels which may be infected with cercariae. The infrequency of rain renders dust unlikely to adhere to vegetation instead of falling on the water but, as the White Nile carries very little silt, it is necessary to search carefully for dust for dilution. At Kosti this is obtained from an island.

For Paris green a mixer is used (fig. 3) which was adapted from that figured by Covell (1941). The wide opening and lack of a screw cap facilitates quick filling and emptying and the sleeve used for rapid closing also serves to prevent the formation of a cloud of dust when the mixer is emptied. The mixer is made so that the handle can be slid into the groove of the supporting post to act as a brake during filling. The central horizontal beam is displaced laterally to allow for emptying and the base made to allow room for a tin to receive the mixture.

SUMMARY.

The mosquitos of the reservoir area have been studied mainly with the object of planning suitable methods of controlling malaria. This paper is an account of the work done so far.

The diversity of conditions in the area, which is of such length that it has been divided into three sections, is described with special reference to the river and reservoir levels, predacious fishes, breeding places of mosquitos and water plants among which mosquitos breed.

The mosquito fauna of the area is described and observations on the breeding places and adult habits of the principal species are recorded. The large proportion of "ripe" females among Anophelines dissected is noted.

The probable effects of the reservoir conditions on the mosquitos are discussed.

Notes are given on certain species, and the relation of *A. rufipes* and *A. pharoensis* to malaria are discussed from circumstantial evidence. The former is provisionally regarded as a vector.

Control measures are described with particular reference to *A. funestus* (in the south), *A. gambiae* and *A. rufipes*, the latter being a vector of malaria expensive to control in the larval stage. The value of insecticidal dusts in the area is discussed.

Acknowledgements.

The writer is much indebted to many officials of the Sudan Government who have served in the area; particularly to Dr. H. Richards and Dr. H. D. Fairman of the Sudan Medical Service for information about malaria and general conditions; to Miss E. M. Trewevas of the British Museum (Natural History) for the identification of some fishes; to the Chief of the Research Division of the Department of Agriculture and Forests for many facilities; and to Dr. F. W. Andrews, Chief Economic Botanist, for the identification of aquatic plants.

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Fig. 1.

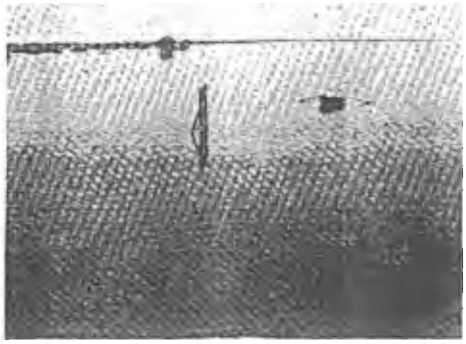

Fig. 2.

Fig. 3.

Fig. 4.

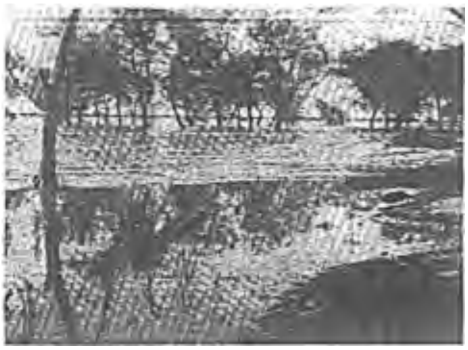

Fig. 5.

Fig. 6.

Fig. 1. Papyrus and associated swamp seen from Kosti Bridge in December 1937, looking north.
Fig. 2. The same area in October 1945. Papyrus is absent owing to the effect of the reservoir.
Fig. 3. Small swamp protected by papyrus in the Gulli area in December 1938.
Fig. 4. *Vossia* swamp at Kosti in 1945.
Fig. 5. Pools formed by wave action at Dueim in December 1938.
Fig. 6. Pools formed by wave action near Geteina in October 1945.