1909

WORLD HEALTH ORGANIZATION

ORGANISATION MONDIALE DE LA SANTE

WHO/ONCHO/85.165
WHO/VBC/85.922

ENGLISH ONLY
(avec résumé en francaise)

ONCHOCERCIASIS IN SUDAN: THE DISTRIBUTION OF THE DISEASE AND ITS VECTORS[1]

by

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1. INTRODUCTION

This review is presented as a compendium of information on onchocerciasis ("river blindness") and its vectors for use by the Sudanese Government in preparing a national strategy against the disease (Jones, 1979), following the guidelines for the prevention of blindness formulated by WHO (1976). Although no detailed survey of the prevalence and severity of onchocerciasis in Sudan has been conducted, experienced workers have concluded that this disease in Sudan constitutes a serious health problem with clinical manifestations as severe as in any of the other affected regions of the world (Anderson et al., 1974; Duke, 1976b).

Recently Baker & Abdelnur (1984) showed that localized (focal) vector control can be an effective strategy for reducing onchocerciasis transmission to a level tolerable to the communities afflicted. A tolerable level of onchocerciasis transmission, as defined by Thylefors et al. (1978), is one at which there is no visual handicap due to the disease (though the skin lesions of onchocerciasis should not be neglected as they can cause considerable pain and discomfort).

The present review, therefore, considers onchocerciasis in Sudan focus by focus, concentrating on those foci most severely afflicted with blinding forms of the disease (i.e. foci requiring priority control) and on information needed to prepare control strategies in these foci. Besides providing information on the prevalence and severity of the disease, and the identity, distribution and abundance of the vectors, it describes in detail the known foci of blinding onchocerciasis: their location, size, accessibility, human population, climate, vegetation and the prospects for focal control. However, the extensive studies on the pathogenesis, immunology and chemotherapy of onchocerciasis in Sudan are beyond the scope of this review.

Onchocerciasis transmission in Sudan was last fully reviewed by Marr (1977) and briefly by Raybould & White (1979). A classic series of papers by Lewis (1948, 1953a,b, 1956, 1957) established the identity of the vector, its distribution, behaviour and ecology (summarized by Abushama, 1974). Surveys of the disease itself in Sudan have been conducted by Kirk et al. (1959), Haseeb et al. (1962), Satti (1973) and Beiram (1974). Much of the work on onchocerciasis in Sudan (including several of these surveys) has not been formally published, and any attempt to review onchocerciasis in Sudan without referring to unpublished material would be very incomplete.

The present review of onchocerciasis is limited to the human disease, Bashir (1984) having reviewed animal onchocerciasis in Sudan. Simulium damnosum Theobald which was identified in the 1960s as the vector of onchocerciasis in the Sudan, was later found to consist of several species, up to 26 having been identified (Dunbar & Vajime, 1981). These can be reliably separated only by fixing, staining and examining the polytene chromosomes in the larval salivary glands, while the adults can only rarely be separated (Peterson & Dang, 1981). Therefore, old records of the S. damnosum species complex and new records in which the member of the S. damnosum species complex has not been identified, are referred to as S. damnosum sensu lato (s.l.). where identification has been made, the species name is given: S. damnosum sensu strictu (s.s.) or S. sirbanum Vajime & Dunbar.

2. THE DISTRIBUTION OF ONCHOCERCIASIS AND ITS VECTORS IN SUDAN

Onchocerciasis in Sudan is found in three areas, reflecting the distribution of swiftly flowing rivers and streams in the country (see Fig. 1):

(i) northern Sudan, between the third and fifth cataracts of the Nile (latitude 18° - 2°N);

(ii) eastern Sudan - near the Ethiopian border (mainly between latitudes 6°N and 12°N); and

(iii) southern and western Sudan - between the Bahr El Arab (latitude 10°N) and the Nile (longitude 31°E).

Fig. 2 shows the foci where onchocerciasis, both blinding and non-blinding, has been discovered, Fig. 3 shows the maximum distribution of the disease in Sudan and Fig. 4 shows the known distribution of the vectors, S. damnosum s.l. Table 1 lists the known foci of onchocerciasis and Table 2 the known localities of S. damnosum s.l.

2.1 Northern Sudan

Onchocerciasis in northern Sudan, between the third and fifth cataracts of the Nile, is the most northerly focus in the world. It was first discovered by Morgan (1958) in patients from the area presenting to a Khartoum skin clinic, though S. damnosum Theobald. s.l. had been known in the area for many years (see Lewis, 1948, who also summarizes the old records of travellers). A notable focus occurs at Abu Hamed (19°30'N, 33°20'E) which is accessible throughout the year since it lies on the railway line from Khartoum to Lake Nasser. Upstream at the sixth cataract (the Sabaloka gorge), where S. damnosum s.l. was found commonly by Gassouma (1972) though not by Lewis (1953b), onchocerciasis seems to be absent.

Anderson et al. (1974) found only low levels of skin microfilariae in the Abu Hamed focus, though often associated with severe dermal onchocerciasis. Ocular lesions were mild and only rarely observed. These authors concluded that no blindness could be attributed to onchocerciasis in this focus. This clinical picture has been confirmed by Williams et al. (1984). A case of sclerosing keratitis has recently been observed in a patient from Karima (El Sheikh, pers. comm.).

Although S. damnosum s.l. is a voracious man biter in this area and both S. damnosum s.s. and S. sirbanum Vajime & Dunbar have been identified from larvae collected from the Nile by Dunbar (1969) and Vajime (in Marr, 1977) respectively, none of the many thousand man-attracted S. damnosum s.l. has been found to contain developing stages of Onchocerca volvulus Leuckart (Gassouma in Marr, 1977). Beiram (1974) reported the results of research by Gassouma showing that these flies could take up microfilariae from the southern foci and allow their development to the third infective stage. Whatever the intake, however, only a maximum of two worms developed. It is most likely, though not proved, that S. damnosum s.l. is the vector. While Culicoides kingi Austen has been found to be the vector of O. gutturosa Neuman in Khartoum (El Sinnary & Hussein, 1980), certain species of Culicoides cannot ingest O. volvulus microfilariae (Gibson & Ascoli, 1952; Crisp, 1956). S. griseicolle Becker is a major pest of man in northern Sudan where it is known as "nimitti" (Lewis, 1948, 1954). It crawls over the skin, particularly over the face, sometimes producing serious allergies (El Bashir et al., 1976), but it rarely bites man (mainly behind the ear) and few flies become engorged (Lewis, 1948). S. griseicolle, which can mature eggs without a blood meal and by feeding solely on raisins (Lewis, 1953b), prefers to bite birds and donkeys (King, 1908, 1923). Deaths in turkeys (Garside & Darling, 1951) and losses in chicken production (El Jack et al., 1976) from these bites have been reported.

Assuming that S. damnosum s.l. is the vector, then the low transmission rate may, as Gassouma (1972) suspects, be caused by the cool minimum night temperatures (below 10°C during the main biting season) which would be responsible for slowing microfilaria development, the poor survival of the worm in the fly and the low parous rate of the vector population, implying that few vectors survive to take more than one blood meal. An average parous rate is given as 23% though Ovazza (1970) believes that the whole day's catch may not have been dissected to give an accurate sample.

Anderson et al. (1974) also suggest that the short transmission season might further reduce the prevalence of the disease. However, the potential for transmission exists in every month of the year except in July, August and September (breeding occurs from October to May, vector biting is at its peak in February/March with up to 1000 bites per man per hour at Abu Dis according to Gassouma, 1972), but even then, small breeding refuges may be maintaining the population while the Nile is in flood (Le Berre, 1972). The length of the transmission season is therefore certainly comparable to that in other hyperendemic foci in Africa.

S. damnosum s.l. is larger than in the southern foci where the same cytotypes are present, as well as being more voracious (even entering rooms to bite man) and commonly found in mating swarms (Gassouma, 1972, in Marr, 1977). Lewis (1948) found S. damnosum s.l.

breeding on mud near Dongola - an unique observation. S. damnosum s.s. has a different proportion of floating inversions compared to this species in other parts of Africa (Dunbar, 1971), though Gassouma (pers. comm.) believes that only S. sirbanum occurs in this area and that S. damnosum s.s. was identified from poorly preserved specimens. Procunier & Barbeiro (1984) have now shown that the Abu Hamed population at El Saalb is monomorphic S. sirbanum lacking sex chromosomes and autosomal inversion polymorphisms, implying that this is an isolated vector population. Morgan (1958) thought that the clinical picture was substantially the same as in the hyperendemic southern foci and that the disease could well have been introduced to the area by southern labourers. Anderson et al. (1974) observed that when patients with similar microfilaria loads were compared, the skin lesions in Abu Hamed were more severe than in the southern foci. A more recent comparison of patients from Abu Hamed with patients from the southern focus of Pongo Nuer revealed that there were no significant differences in the clinical manifestations of the disease in the two communities, differences in the clinical picture depending primarily on the parasite load (Mackenzie, pers. comm.). Mustafa et al. (1979) found no apparent difference between the northern and southern foci in the nutritional status of those with onchocerciasis. With only such littte evidence for differences in both the disease and the vector, it is not yet clear whether or not this northern focus of onchocerciasis is caused by an Onchocerca-Simulium complex (as defined by Duke et al., 1969) different from that in the hyperendemic southern foci.

Although onchocerciasis in this focus may produce severe skin lesions, there are none of the severe ocular forms of the disease so that control cannot be considered a major priority. The upstream end of Mograt Island near Abu Hamed received two treatments with the organophosphate insecticide temephos (Abate manufactured by American Cyanamid Co) in 1976 (Gassouma, pers. comm.). The insecticide was applied with limited equipment, and the results were poor because one side of the island took most of the product and that was the side with less vector breeding. Ovazza (1979) quotes an average flow of 1800 m^3 per second for the Nile at Atbara during November. Thus to dose this river with temephos (Abate 200-E) to kill the vector larvae would require 270 litres of insecticide, applied weekly for every 30 km of river. The quantities involved make such an operation prohibitively expensive.

In conclusion, the absence of serious ocular lesions and the impracticality of mounting a vector control operation on a river of such great volume limits intervention in this focus of northern Sudan to personal protection and treatment methods.

2.2 Eastern Sudan

Foci of onchocerciasis that extend into Ethiopia (Raybould & White, 1979) are likely to occur along all the rivers flowing quickly down from the Ethiopian highlands, mainly between latitudes 6°N and 12°N. As the rivers enter Sudan, they soon slow down, confining vector breeding sites to a narrow belt close to the border with Ethiopia. Onchocerciasis in eastern Sudan was discovered in 1945 by Pratt (Kirk et al., 1959) and defined by Bloss (1949) and Satti (Kirk et al., 1959) as extending northwards from Pibor with serious ocular onchocerciasis along the Khor Yabus (10°N, 34°E). Abdalla (1974) confirmed the severity of the focus at Khor Yabus and collected many S. damnosum adults, larvae and pupae but undertook no ocular examinations. Gassouma (pers. comm.) reports that in some areas only the vector is known but no recent cases of onchocerciasis have been recorded. Thus at Kashm El Girba, along the river Dinder and along the Blue Nile below the Roseires dam, no onchocerciasis cases have been reported though at Kashm El Girba vectors bit from July to October, with a rate of 2 bites per man/hour in September. Moreover, sporadic vector breeding has been found throughout the year between the Sennar dam and Damazine with the highest biting rates at Sennar in February (27 bites per man/hour). Lewis (1966) suggested that the Roseires dam had increased the S. damnosum s.l. population. Le Berre (1972) reported that onchocerciasis existed in the Gezira but that it was not severe. S. damnosum s.l. have been collected on the Atbara river (latitude 14°N) at Wadi Arud and at Gallabat by Lewis (1948), Le Berre (1972) and Gassouma (pers. comm.), but onchocerciasis in this area is not severe and it is not known to what extent this northern part of the focus extends into Ethiopia (Raybould & White, 1979). Gassouma (pers. comm.) observed no blindness from onchocerciasis among the mainly northern Nigerian and Chadian people living beside the Atbara river. Vectors were found from July to December with the maximum biting rate in September. Abdalla & Abu Bakr (1975) found some impaired vision and corneal opacities but no choroidoretinal degeneration in the West African immigrant population of Wad Kaoli, Mushra Ghanam and Birkait Nurein, three villages near the upper Atbara river.

Onchocerciasis in eastern Sudan has thus been little studied and knowledge of its distribution is incomplete. Khor Yabus, the one serious focus so far identified, is inaccessible in the rainy season when onchocerciasis transmission is occurring. With onchocerciasis straddling the border with Ethiopia, any attempt to control vector populations may depend on being able to coordinate control operations.

2.3 Southern and western Sudan

In this large area of some 250 000 km^2 which represents a tenth of the Sudan land mass and is situated between the Bahr El Arab (latitude $10^{\circ}N$) and the main Nile (longitude $31^{\circ}E$), onchocerciasis can be found along all the rivers flowing north and east from the watershed dividing the Nile and the Zaire/Congo river systems. This watershed also marks the international border with the Central African Republic and Zaire. By the time these rivers are about 500 km from the watershed, they begin to enter the flat alluvial flood plains where water flow becomes too slow for vector breeding. Onchocerciasis is thus mainly restricted to a 500 km wide band along the border.

Early reports mention the high frequency of night blindness among the local population (Intelligence Department, Sudan Government, 1911) and the presence of skin lesions known as craw-craw (Ensor, 1908), but it was not until 1932 that Bryant (1932, 1935) reported the first case of blindness associated with onchocerciasis infection in this area. No detailed investigation of the distribution of the disease has been made to date. The little information available must be assembled from a variety of sources, many unpublished. This paucity of information reflects the poverty of the mapping and census data. The basic 1:250 000 maps were prepared by the British in the 1930s from ground surveys and include much which is apocryphal, including the spurious river Wau. The lastest census (February 1983) is the most accurate but figures in some of the rural areas are only approximate.

The rural density ranging from 10 to 25 inhabitants per km^2 is highest in the extreme southern watershed district close to the Zaire border and on the alluvial plains to the north and east, both of these areas being on the edge of the onchocerciasis focus. The ironstone plateau land in between is very sparsely populated but here, almost without exception, every riverine community is afflicted with serious blinding onchocerciasis. These three areas: the southern watershed, the alluvial plain, and the ironstone plateau are dealt with separately below.

2.3.1 The southern watershed

The south of the Equatoria Region, lying near the Zaire border, has fertile lateritic soils and a good 1400 mm annual rainfall. There are many small watercourses, the headwaters of the Sue, Ibba, Gel and Naam rivers, but, because the slope is gradual, the normal rapid river run-off stage is not apparent and water flow is generally too slow for vector breeding. On the other hand, the headwaters of the rivers to the north and west (from the Bussere/Nummatina to the Bahr El Arab) do not flow through such fertile land: there is rapid run-off from a comparable rainfall, shallow soil and the land is almost uninhabited.

The people living in the southern watershed area, principally the Azande, are experienced cultivators (Ferguson, 1948). The larger watercourses, where onchocerciasis transmission can be expected, are generally visited only in the early dry season for fishing (Bloss, 1949). While no detailed survey has been carried out, serious blinding onchocerciasis is probably confined to the few communities which stay close to the larger watercourses throughout the year either for fishing or because, having been moved to the river crossings by the British during the anti-trypanosomiasis campaign or for road maintenance, they have stayed, e.g. Duma, Mupoi (also a mission), Ringasi and Ibba. Bryant (1935) reported that the Bellanda and Bongo, who previously inhabited this region until expelled by the Azande, said that they only began to suffer from blindness when they had to move north to the ironstone plateau area.

The potential for onchocerciasis to develop into a major health hazard was observed in Maridi (Satti, 1973; Marr, 1977) where a dam, built in 1957 to provide the town with water, produced an ideal S. damnosum breeding site, during the rainy season as water cascaded over the dam wall. Within ten years, onchocerciasis had become the second highest cause of hospital admissions. On 12 January 1964, 364 S. damnosum s.l. were caught and on two rainy days in July 1964, (12.7 and 13.7), 162 and 119 flies were caught respectively in a day's catch. Today, onchocerciasis is no longer a health problem in Maridi due to the initiative of the dam engineer who regularly pours spent engine oil along the dam wall.

East of Maridi, onchocerciasis seems to be rare. At Yei, where the river Yei flows swiftly through the town with gardens on its banks, the gardners, when asked, said that they had not seen nor been bitten by blackflies. However, both ourselves on 15 December 1982 and Lewis in 1948 found S. damnosum s.l. larvae in the river. Enarson (1976) reported dermal onchocerciasis at Iwatoka, north of Yei. Downstream at Mundri (150 km to the north), our observations on 8 December 1982, confirmed those of Lewis (1953a) who reported that, although S. damnosum s.l. can be commonly found in the rocky river beside the town, onchocerciasis is rare while it is known to be prevalent further downstream. It is possible that S. damnosum in this area is a nonanthropophilic member of the species complex, such as the "Nkusi" form described by Dunbar (1971) from the neighbouring West Nile District of Uganda. However, Dunbar (1978) found this form to be a vector of onchocerciasis in Tanzania and Meredith (pers. comm.) considers it impossible to assign the larvae we collected from this area to "Nkusi" because the original description is not clear. The possibility of a different Onchocerca strain with lower pathogenicity compared to the strain in the savanna cannot be ruled out, given the different savanna and forest Onchocerca-Simulium complexes akin to West Africa (Duke et al., 1969). In addition, Woodman (1949) has suggested that the low incidence of blindness in the south may be due to the greater amount of vitamin A in the diet, a view supported by Lorenzen (1948), while Abbott (1949) found that the population still showed serious vitamin A and riboflavin deficiencies. Satti (1948) cured a number of boys suffering from night blindness in Wau with vitamin A therapy. Vitamin A deficiencies are likely to be seasonal. For example, in May 1981 (the mango season), Mackenzie et al. (1984) found above normal levels of vitamin A in Pongo Nuer which is a hyperendemic focus of onchocerciasis in the ironstone plateau.

Further east along the main Nile, onchocerciasis is reliably recorded only from communities near Juba, i.e. Logo, Kolye, Tokiman and Buduge which are close to the junction of the river Kit with the Nile 6 km south of Juba, and from Lado which is 25 km north of Juba (Woodruff, pers. comm.). Of the approximately 1500 people in the communities near to the mouth of the river Kit, about two-thirds were found to be infected. Low microfilaria loads were associated with some serious ophthalmic complications including one eye blinded by iritis caused by onchocerciasis. Adult S. damnosum s.l. were caught biting man on 4 September 1982 but the breeding sites of the vector remain undiscovered. Although larval and pupal collections have been made frequently from the Kit and twice from the Bedden rapids (on the Nile 30 km south of Juba), only S. griseicolle, S. bovis de Meillon and S. adersi Pomeroy have so far been found. The Nile south of Juba flows very swiftly with many potential Simulium breeding sites, the river level varying but little during the year. The Kit river has, however, a highly seasonal flow. If transmission occurs throughout the year as reported by the local population, this would implicate the Nile in providing the vector breeding sites and in this case vector control would be impractical. If transmission is seasonal, then the Kit river may be implicated and, because of the much lower discharge, vector control could be considered.

At Nimule, the Nile enters Sudan from Uganda with phenomenal force at the Fula rapids. Lewis (1953a), Gassouma (pers. comm.) and ourselves (on 11 December 1982) found the rapid margins to be carpeted with thick algae and thus unsuitable for Simulium attachment, though S. adersi was common upstream. Fishermen live on the rocks beside the rapids but have no knowledge of biting blackflies. However, Marr (1977) reported that in 1963, many S. damnosum s.l. were found upstream from the Fula rapids and that the Nimule Girls Boarding School was sufficiently heavily infected, for the girls to introduce onchocerciasis to Maridi, when transferred to that town. Samson Django, a Maadi from Nimule and recently trained as an onchocerciasis vector collector in Wau, says that he has been bitten by blackflies beside the Nile at Nimule (where they are known as "logurutumwi") but never in great numbers. At 20 km to the north, the fast-flowing river Aswa does not seem to support S. damnosum s.l. breeding according to Lewis (1953a) and ourselves (on 10 December 1982), though many S. arnoldi Gibbons or S. bovis were present. Lewis (1953a) reports S. damnosum s.l. from the Kajo Kaji District (60 km to the northwest). McCrae & Henderson (1969) collected this species in Fredeen and, using CDC traps, in the neighbouring Ugandan villages of Ara and Dufile. Although no S. damnosum s.l. were caught on man, local residents say that they have been bitten by these flies especially when near cattle or the larger wild ungulates and one resident was found infected with O. volvulus. No developing stages of the potential vector were found nor did any of the streams seem suitable for this species to breed. It was concluded that the Main Nile at the Fula rapids was likely to be responsible. With so many potential breeding sites for onchocerciasis vectors and so few observations, further work is needed to determine the situation in this area.

The Imatong mountains, rising to 3187 m, produce many swiftly flowing streams suitable for Simulium breeding. McCrae (1975) found S. neavei Roubaud and visible signs of onchocerciasis on the Ugandan side of the Imatong range but no sign of this vector or the disease is known from these mountains in Sudan. Lewis (1948, 1953b) collected 13 other simuliid species in this area but of these only S. dentulosum Roubaud is attracted to man, on whom it settles without biting (Lewis, 1953b, 1957). Gassouma (pers. comm.) lived in this area for a year without observing the vectors and we were unable to find them during our visit on 11 December 1982 nor were the local population aware of the flies as described. However, Lewis (1953a) does record S. damnosum s.l. from Farajok on the Ateppi river to the west of the Acholi mountains, a western arm of the Imatong range, and, more recently, Enarson (1976) found advanced onchocerciasis cases with skin changes and subcutaneous nodules from the neighbouring village of Lerowa. The distribution of the disease and the identity of the vector in this area need to be confirmed by further studies.

In conclusion, the southern watershed area though poorly studied, seems to contain few serious foci of blinding onchocerciasis, especially east of Maridi, where the status of the disease and the vector is uncertain. However, this area does need detailed investigation, especially as it is suspected of providing refuges for the vectors when the rivers downstream beside the hyperendemic foci have stopped flowing in the dry season. In late April 1982, we examined many watercourses in the southern watershed area west of Maridi, but with the rains over one month late, only the river Ringasi below the road bridge at Ringasi was flowing. S. damnosum s.l. was collected here thereby suggesting that, in normal years, the southern watershed area could provide ample refuges for the vectors. In addition, the perennially flowing river Uele, which contains many hyperendemic foci of onchocerciasis (Fain & Hallot, 1965), lies only 120 km to the south over the watershed in Zaire. Invasion from the river Bomu which forms the border between Zaire and the Central African Republic and has hyperendemic foci of onchocerciasis (Fain & Hallot 1965), can also be expected.

2.3.2 The alluvial plain

The rivers flowing north and east from the Nile/Congo watershed leave the ironstone plateau and enter the flat alluvial clay grasslands, known locally as "toich", inhabited by the Dinka and their large herds of cattle. The rivers widen, slow down and, except for the river Jur, lose their channel as the water spills out on to the flood plain, entering the permanent marshy areas near the main Nile, known as the "sudd". Of the 11.5×10^9 m^3 discharging into this area - a catchment of some 275 000 km^2 (Hurst & Black, 1931) - only 0.6×10^9 m^3 (5%) reaches the Main Nile (Jonglei Investigation Team, 1954).

Only on the southern and eastern borders of this land do the rivers flow fast enough for S. damnosum s.l. to breed. Small foci of onchocerciasis are, however, found where ironstone sills are exposed in the river bed as at Wan Alel, 40 km north of Tonj on the river Tonj (Ibba), and at Allel, 17 km north-west of Yirol on the Yei river (discovered by Bryant, 1935), or where rocky causeways have been built to carry road transport across rivers in the dry season, e.g. at Paye, 20 km west of Yirol. Water flowing over these rocks and causeways at certain river heights provides excellent vector breeding sites. While blinding onchocerciasis is well known at the above-mentioned sites, few surveys have been made and it is not known how far onchocerciasis extends into the alluvial plain. Kaneene (unpublished) found 17% positive for onchocerciasis out of 70 persons examined in the village of Madol, 50 km north-east of Aweil on the river Lol; and in Awuluch, close to Aweil but also in the "toich", 18% of 71 examined were positive.

Baker & Abdelnur (1984) observed that when the number of vectors attracted to man at riverside collection sites in wooded areas with a riparian tree fringe (to the south-west) was compared with that at riverside collection sites in a wide flood plain with few trees (to the north-east), a markedly lower number of vectors was found in the latter. The inhabitants of the alluvial plain thus appear to be protected partly by the scarcity of vector breeding sites and partly by the vectors' avoidance of the area. As only a few isolated foci of blinding onchocerciasis are present localized vector control by bulldozing the causeways and dynamiting rocky outcrops in the river bed could be a highly effective strategy for controlling onchocerciasis in this area.

2.3.3 The ironstone plateau

This large area, lying between the fertile southern watershed and the alluvial flood plains to the north and east, contains the most serious foci of blinding onchocerciasis in Sudan. The area is generally unattractive to human settlement and is sparsely inhabited, resembling in many ways the middle belt of Nigeria (Pullan, 1964) and areas further west within the Onchocerciasis Control Project (Walsh et al., 1979). The lateritic soil is shallow, on ironstone and the basement complex, except in the river valleys, where the onchocerciasis and trypanosomiasis vectors may be abundant. Rainfall with an annual rate of 1100-1300 mm and an annual variation of 15% (El-tom, 1975), is especially variable in the early months of the rainy season. The deciduous savanna woodland with dominant species such as Isoberlinia doka Craib & Staf (Wickens, 1976) is slow to regenerate due to the shallowness of the soil and the action of fires. Communications are poor with few roads. Most of the population is found to the north and east of this area, where the valleys contain more alluvial soil, where communications are better and where the Dinka people are closer for trading purposes.

This area has been subjected to many population pressures. In the last century, the slave trade greatly reduced many tribes, while the Azande, invading from what is now Zaire and the Central African Republic, pushed the Bellanda (Bviri and Bor) and Ndogo northwards away from the fertile southern watershed region (Evans-Pritchard, 1931; Tucker, 1931). A combination of these factors decimated tribes such as the Bongo (Evans-Pritchard, 1929). In this century, the British ordered many tribes to move for administrative reasons, for road maintenance works and for trypanosomiasis control. In the 1960s, the civil war caused extensive migration into Zaire and the Central African Republic. When peace came in 1972, many people returned and moved into the towns, especially Wau, and this movement has grown in recent years.

Such population movements have had a considerable effect on onchocerciasis distribution and prevalence, preventing any natural adaptation to the disease by the people. As noted earlier, Bryant (1935) reported that the Bellanda and Bongo said that they only began to suffer from blindness when they were expelled from the southern watershed area by the Azande and obliged to move to the ironstone plateau. However, Cruickshank (1934) also reported that when the Bellanda moved into an area beside the river Sue forcing the Bongo to give them most of their land, the Bellanda believed that the ensuing blindness was caused by the Bongo poisoning the water. Blindness was also blamed on the splashing of buffalo blood on the eyes during an argument and on spells (Cruickshank, 1962).

The most affected communities were those established for administrative reasons or to further the economy of the region. Mvolo, a heavily infected Jur Beli village beside spectacular rapids on the Naam river, was set up by the British as a local court. The Feroge were moved in 1930-31 by the British to the site of Khor Shammam, a village now containing many people blinded by onchocerciasis. Cruickshank (1934) records the plight of the Shatt who used to live by the Pongo river. Attributing the blindness and skin disease to the flies biting by the river, they left of their own accord. They were ordered back by the government in 1924 and later Cruickshank (1934) found them to be suffering severely from blindness. Santandrea (1964) describes the blindness, epilepsy and ill health which afflicted the Sere when they were moved to the Pongo river and the Woro when they were moved to the Kuru river: "After repeated efforts to quit that inhospitable land, they ran away by common consent. The administration was thus practically forced to give a post factum approval to the illegal move, which no human power could prevent". Both the Woro (the river Kuru is now deserted) and the Sere (confined to the small village of Momoi south of Wau) are now almost extinct.

The village of Pongo was moved to Khorgana in 1952 because the Gai people were so heavily infected with onchocerciasis. A further case of community desertion occurred at Raffili, a Catholic mission built in 1911 beside the Sue river just downstream of a major series of rapids caused by the outcropping of basement complex rocks. Onchocerciasis was found to be severe in the 1940s (Kirk, 1947) and in the early 1950s the mission was abandoned and moved to Peile, 28 km to the north (12 km inland). In recent years the community at Bo was also abandoned.

Other riverine communities seriously infected with onchocerciasis can be found associated with saw mills (Pongo Nuer), teak plantations, (Nummatina, Akanda, Ngohalima, Nyalero, Nyikijo, Nyinakok, Nyinchon - all on the Bussere, Sue and Jur rivers near Wau), farms (Ngosulugu, Bussere), schools (Bussere and Agok), industry (the canning and beer factories near Wau) and the road camps built to maintain causeways and run ferries (Bussere and Paye). In several places, road bridges have now been built but the old causeways remain, providing good breeding sites for the vector populations at rising and falling water levels (Sopo, Kuru, Wau and Bo).

The people who have lived longest in this area and have been least affected by the disturbances are the Jur and the related Shilluk-Luwo tribes, the Shatt and the Manangeer. The latter are separated from the Dinka by Tucker (1931), though they are often known as the "fishing Dinka" and regard themselves as part of the Dinka "naath" - the Palyoupiny of Leinhardt (1961). The Jur, who call themselves "Luwo" ("Jur" is Dinka for foreigner) live between Aweil and Tonj, just to the south and west of the Dinka with whom they trade. They are accomplished shifting cultivators, living in small family groups scattered through the bush in areas of fertile soil. Some communities can be found near the riverside and fish is an important part of their diet. Fishing is mainly carried out during the dry season when they also grow tobacco on the river banks. Many communities, however, live well away from the riverside and this positioning of their houses, often far from the river, may be partly an adaptation to onchocerciasis. The Shatt, a small, little known tribe living on the Wau-Deim Zubeir road near Yabulu and west of Aweil, are renowned hunters. The fishing Dinka live west of Aweil, especially on the Kuru river and are heavily infected with onchocerciasis (Kaneene, unpublished).

Thus during the last century, many factors would appear to have contributed to the spread and increase in severity of onchocerciasis in this area. The population movements have disrupted natural adaptations to the presence of onchocerciasis, communities have been established close to potential onchocerciasis vector breeding sites and vector breeding has often been encouraged by the building of causeways. Bryant (1935) suggested that the disease was spreading. According to interviews with the local inhabitants, the disease had been rare in Wau until seven years previously, was unknown in Yirol until 1933 was only of three years duration in Mvolo in Wan Alel and had only started in Mvola after an Azande raid in 1910; while the biting blackflies were much more common than 30 years earlier. It is possible that the building of causeways during this period may have increased the vector population and consequently disease transmission in certain foci. Satti (1973) suggested that the disease was still spreading.

The distribution of onchocerciasis is localized, however, mainly due to the localized distribution of the human population. Of the total river length of 5000 km between Bahr El Arab and the Nile suitable for S. damnosum s.l. breeding (a quarter of the maximum river length sprayed in the Onchocerciasis Control Project in West Africa), an enormous potential area for onchocerciasis, only a very small proportion of the river banks are inhabited. The available information on the foci of onchocerciasis along each of these rivers is reviewed below.

2.3.3.1 The Bahr el Arab

This river, and particularly its headquarters, the Adda and the Umbelasha, lies mainly in the southern part of the Darfur region. The discharge of the Bahr El Arab is approximately 0.32 milliards per year. The onchocerciasis foci are remote being situated 260 km by dry season road south of Nyala (a railhead) to Radom, 180 km by dry season road to Raga from Kafia Kingi and a further 500 km from Wau (also a railhead). Gassouma (in Marr, 1977 and pers. comm.) first reported the disease, suggesting that these foci were a natural extension of foci in Chad and the Bahr El Ghazal region to the south-east, though the disease was not as severe. A visit in March 1984 by El Sheikh et al. (1984) revealed a much more serious picture of onchocerciasis. At Radom of the 157 persons examined, 31% had a positive skin snip with 2% blind, and at Titribi, a small village close to Radom but nearer the river bank, of the 111 examined, 67.98% were positive for onchocerciasis with 4% blind. At Kafia Kingi, of the 53 examined, 32% had a positive skin snip with 2.8% blind. The nomadic people visit the Bahr El Arab as a reliable source of water mainly in the dry season and are thus unlikely to be infected. However, the stable, predominantly Kresh communities on the upper Bahr El Arab appear to live in hyperendemic foci of onchocerciais.

Access to and within the area is very difficult in the rainy season when onchocerciasis transmission occurs (accounting for the absence of vector records from the area). The discharge of the Bahr El Arab quoted above, is from a gauge station far downstream and new river gauges need to be erected before the discharges of the Adda and Umbelasha can be calculated for insecticide spraying. The river beds are generally sandy with occasional rocky outcrops which might be dynamited. The relocation of the people living in the most severely affected foci may be considered.

2.3.3.2 Rivers Raga and Boro

Communities along these two rivers, while never subjected to a detailed epidemiological survey, probably contain some of the worst manifestations of onchocerciasis in the world. The Feroge community of Khor Shamman (13 km NE of Raga) and the Ngulgule/Ngbandala communities of Gossinga (30 km NE of Raga) and Deleiba (46 km NE of Raga) are notorious but Raga itself and the Kresh/Yule communities along the road to Boror are known to be infected with onchocerciasis, though the prevalence and severity there is unknown.

A visit to Khor Shammam was made by Satti (1948) who, among some 2000 persons, found 110 to be blind (i.e. 5.5% blindness), including two young children, while 41 out of 74 persons examined had nodules. Attempts to treat the villagers were started in the early 1960s but had to be stopped because of the civil disturbances. Reinhardt (1975) examined 150 people in the same community and found 90% with a skin snip positive for onchocerciasis, 80% with nodules and 50% blind or nearly blind. In the age group between 15 and 25 years old, 3 out of 17 males were economically blind while 16 out of 52 males (31%) over 15 years old and 8 out of 42 females (19%) over 15 years old were economically blind. Our recent visit in 1982 confirmed the continued severity of onchocerciasis in these communities, especially in Gossinga where blind boys between 10 and 14 years old were seen. The recent February, 1983, census shows that the population of the most severely affected villages in the Raga District is 8675. If the age distribution figures are assumed to be comparable to those found in the Onchocerciasis Control Project in West Africa (Dietz, 1982), then 60% (5200) will be over 15 years old. If Reinhardt's figures are accurate and an average of 25% of those (male and female) over 15 are economically blind, then some 1300 blind people might be expected, or 15% of the total population. At present, a medical assistant in Raga is treating 50-75 people per month with the standard Sudanese regimen of suramine and about 75% of these patients, mostly schoolchildren finish the course. Those failing to complete the course are hindered by the long distances from their village to Raga. It is clear that this treatment is providing relief to only a very small proportion of those suffering from onchocerciasis.

Although onchocerciasis itself was known from the area, Lewis (1953b) did not record the presence of S. damnosum s.l. The first collections of this vector from the Raga District (Marr, 1977) were made in October 1963, January 1964 and June-September 1964. The vector was rare in January (5 flies at Gossinga on 13 January 1964, none at Khor Shammam on 14 January 1964 nor at Raga on 11 January 1964) and common in the other months (maximum daily catch of 1078 at Raga on 10 July 1964). Monthly biting rates at Raga for July to September 1964 were 19 685, 21 088 and 11 379, respectively; at Khor Shammam they were 9777, 5682 and 2708, respectively; and at Gossinga for July and August 1964, they were 837 and 930, respectively. In 1982 we collected 8 flies at Raga between the hours of 16:00 and 18:00 (on 27 November 1982) and we found many S. damnosum s.l. larvae and pupae in the river Raga beside Khor Shammam (on 28 November 1982). Meredith (pers. comm.) subsequently identified 30 S. sirbanum and 3 S. damnosum s.s. from this collection.

Raga itself is 320 km by rough all season road from Wau, the nearest railhead. The road west to Boro is bad but may be passable throughout the year. The road north-east is impassable beyond Khor Shammam during the rainy season due to a ruined bridge and short stretches of marsh.

Neither the Raga nor the Boro and Sopo rivers have gauges from which river discharges and thus insecticide volumes can be measured. Access to the Boro and Sopo rivers in this area is very difficult. The village of Gossinga may receive flies from both the Boro and the Sopo, with flies from the latter river possibly using the Khor Lujo as a flight line. Thus the application of insecticide and evaluation of its efficacy in this focus would not be an easy task. The river Raga flows past Raga (50 m wide with 15 m high banks and a rocky bed) and Khor Shammam (50 m wide with 5 m high banks and a sandy bed with reed islands) at a relatively steep gradient and there appears to be no man-made or other structures which could be removed. For historical reasons, it seems unlikely that the Feroge, Ngulgule and Ngbandala in Khor Shammam, Gossinga and Deleiba would be prepared to move.

2.3.3.3 Rivers Sopo, Biri, Pongo, Kuru, Lol and Getti

These rivers of which the first four join together to form the Lol, can be discussed under a same heading because they only have communities on their banks where they are crossed by the Wau - Deim Zubeir - Raga road (though the banks of the river Kuru, where crossed by this road, are now deserted) and 50-200 km downstream where the Jur, Shatt and Dinka (including the "fishing Dinka") can be found.

Although present, the prevalence and severity of onchocerciasis at Sopo and Biri is unknown. S. damnosum s.l. was found to be very common at Biri and Sopo in June/July 1964, with 1059 flies collected on 12 June 1964, 819 flies on 7 July 1964 at Sopo and 50 flies on 9 January 1964 also at Sopo. We collected S. damnosum s.l. (27 November 1982) both on the old, abandoned causeway at Sopo and among the rocks below the bridge over the river Biri from where six S. damnosum s.s. were identified (Meredith, pers. comm.).

Both Khorgana and the saw mill at Pongo Nuer are major foci of blinding onchocerciasis (Kaneene, unpublished; Mackenzie et al., 1984; O'Day et al., 1984). At Pongo Nuer, 94% of the 199 persons examined had a skin snip positive for onchocerciasis, 45% showed microfilariae in the eye and 43% had ocular lesions. At Bissellia, beside the small, slow flowing River Getti, 96% of the 51 persons examined were skin snip positive, 21% had microfilariae in the eye and 30% showed ocular lesions. From a larval collection made at Pongo Nuer on 14 August 1921 two S. sirbanum were identified (Meredith, pers. comm.). At the Pongo road bridge collections on 5 January, 7 June, and 4 July 1964 produced 168, 161 and 959 flies respectively. At Pongo Nuer on 1 and 2 May and 9 June 1981, 10, 7 and 44 flies were caught respectively. At Bissellia on 5 January and 5 June 1964 and 10 June 1981 none, two and one fly were caught respectively.

Information from the Aweil District downstream is more scanty, though Kaneene (unpublished) showed that the "fishing Dinka" on the river Kuru west of Aweil were heavily infected, with 50% infected out of 50 examined at Chalcow and 77% out of 64 at Nyiryet. The Jur at Kangi near the Pongo were observed to be heavily infected by Duke (1976b), as were the Jur and Dinka downstream at Pongo Aweil with 94% infected out of 212 examined (Kaneene, unpublished). At Pongo Aweil, 2 and 45 flies were caught on 14 May and 19 July 1964 respectively. At Getti, none and 112 flies were caught on 12 May and 20 July 1964 respectively.

Access to these communities is possible throughout the year except for the ones on the river Kuru west of Aweil. River gauges exist at Nyamlell (on the river Lol), Pongo Aweil and Getti. The Lol and Pongo together have an annual discharge of 4.23 milliards (Jonglei Investigation Team, 1954). The generally localized distribution of these foci, often of great severity, suggests that a localized vector control programme might be the most effective in tackling the disease in this area.

2.3.3.4 Rivers Bussere, Sue and Jur

The Bussere and Sue rivers meet to form the Jur river just south of Wau, the capital of the Bahr El Ghazal region. The onchocerciasis foci along these three rivers in the neighbourhood of Wau have been studied in more detail than any of the others in Sudan. The most serious foci of blinding onchocerciasis can be found along the Bussere river. Differences in the prevalence and severity of the disease along the three rivers can be related to their different characteristics. The situation of onchocerciasis in this area can be considered in some detail as it is the only area in Sudan for which extensive data are available on not only the tranmission of the disease but also its prevalence and severity.

The Bussere river, which rises in uninhabited land on the watershed forming the international border with the Central African Republic, receives one major tributary, the Nummatina (200 km from its source), before joining the Sue river 125 km downstream. The Nummatina rises in country sparsely populated by Azande. The Sue, however, has travelled twice as far (500 km) as the Bussere by the time they meet to form the Jur. For the first 270 km of its length, the Sue is the main collector of the run-off from the fertile southern watershed area, though for much of this distance it goes through uninhabited land and is visited mainly during the dry season for fishing. As both rivers traverse the ironstone plateau, they are almost devoid of human settlements, until latitude 7°15'N where the isolated Bellanda forestry post of Nummatina at the Bussere-Nummatina confluence and the first Jur settlements on the Sue river are reached. On the Bussere river, the next community, Akanda, is found a further 59 km downstream and then, for the 70 km to Wau a number of predominantly Bellanda (Bviri) communities (though with some Bongo and Jur people) associated with teak plantations, farms, the ferry (and causeway), schools and factories can be found. On the Sue, apart from the teak plantation and road camp at Nyikojo, the 70 km upstream from the confluence with the Bussere are inhabited uniquely by scattered Jur communities, though during the dry season, the Dinka may graze their cattle upstream beside the river. The Jur river banks are inhabited by Jur and Dinka people as the river flows northwards from Wau.

The annual discharge of the Bussere river is, at 1.5 milliards per year, approximately half that of the Sue river. However, having flowed for almost all its length through the ironstone plateau (which is subject to rapid run-off) and at a steeper gradient than the Sue, it has a faster flow, depositing a coarser sediment of sand and gravel, it is the first to arrive (often in spate) at the beginning of the rainy season (though occasionally flowing throughout the year) and its water level is subject to much greater fluctuation. The Sue receives its last major tributary, the river Bo, 120 km upstream from Wau where the river cascades over a large outcrop of basement complex rocks above the old abandoned mission at Raffili. For 80 km upstream from the confluence, the Sue flows slowly in a 2-3 km wide grassy flood plain depositing fine sediment and rarely speeding up except at the few sharp bends and in areas where the river bed has rocky outcrops. The Bussere enters this flood plain only 9 km above its confluence with the Sue, generally having a well developed riparian tree fringe with the savanna woodland often coming down to the riverside. The river current of the Bussere increases in speed at many sites where bends, islands, trees, man-made causeways and rocks, naturally outcropping in the river bed, obstruct the river flow. The Jur river, with an annual discharge of 4.5 milliards, is the largest river west of the Nile in Sudan and the only one to have a discernible channel to the main Nile near Malakal (400 km away), towards which it flows through a wide flood plain with ever decreasing velocity.

Distribution of the disease

The greater severity of onchocerciasis along the Bussere river is thus partly due to the larger population living on its river bank and partly to the more optimal conditions for vector breeding such as faster water flow and more breeding substrates.

The early work in the Wau area along these rivers has been reviewed by Kirk et al. (1959) and Haseeb et al. (1962). Cruickshank (1934) who examined 980 people in the area found 4.5% blind. Kirk (1947) who examined 433 people from Wau, the Raffili area of the rivers Sue and Pongo, found 66% with skin snips positive for onchocerciasis. He was also able to correlate the incidence of ocular lesions with the distance of the community from the vector breeding sites in the river.

A survey of the prevalence of onchocerciasis and of its ocular manifestations in 823 people from Bahr El Ghazal and Equatoria was carried out by Torroella and Dawood (Torroella, 1961; also reported by Choyce, 1964). They found an overall prevalence rate of 41%, with ocular symptoms present in 36% of those infected, though it was not always possible to ascribe ocular lesions to onchocerciasis. Of the 823 persons examined 3.2% were "economically blind" (5.6% of those infected and 1.5% of those not found to be infected).

As a result an onchocerciasis control project in Wau was started in July 1961. Following pilot chemotherapy trials, a clinic was set up in 1962 where a standard Sudanese regimen of suramin (Antrypol) was administered. By 1979, almost 15 000 people had begun treatment but only a third of these completed the full course (Jones, 1979). Between 1962 and 1964 a random sample of the population within a 50 mile radius of Wau was examined (Beiram, 1974). Of the 2897 (2111 males and 786 females) examined, 62% had positive skin snips and 22.5% had ocular complications. As Duke (1976b) has pointed out, such a survey was of limited use and it was not until the work of Anderson et al. (1974), who carried out surveys of schoolboys in Wau primary and secondary schools and of those living beside the Bussere Ferry that results from accurate community based studies were reported. Of 43 Wau primary-schoolboys (aged 12-15 years), 19 (44%) showed skin atrophy, most probably due to onchocerciasis, while ocular onchocerciasis was found in 4 or 5 boys (9%). Of the 130 students examined in Wau secondary school, 61 (47%) showed skin atrophy probably from onchocerciasis and 25 (19%) showed disc-shaped corneal opacities. At the road camp beside the Bussere Ferry, 41 males and 12 females (i.e. 90% of the population) were also examined and 74% were found to have a positive skin snip, even though most of them had settled there only 18 months earlier. Corneal microfilariae were found in 36%, microfilariae in the anterior chamber in 15% and 5 people (9%) were blind.

Jones (1979) reports a return visit by Anderson, Fuglsang and colleagues to the Bussere Ferry Road Camp, seven years after its establishment. Of the 94 people (i.e. 80% of the population) seen, 77% had positive skin snips and of the 58 examined ocularly, 57% had microfilariae in the cornea, 43% had microfilariae in the anterior chamber, 24% had eye lesions and 3% (of the 94 examined) were bilaterally blind. Of the 24 examined who were under 10 years old, 11 had positive skin snips, and of the 8 given an ocular examination, one had microfilariae in the cornea and two had microfilariae in the anterior chamber. In the 16 examined belonging to the 10-20 year age group, 11 had positive skin snips, and of the 11 given an ocular examination, 7 had microfilariae in the cornea and 3 in the anterior chamber. They also conducted an epidemiological survey of Ngohalima (again based on 80% of the population) and of adult male workers at the Halima Experimental Farm, 4.5 km inland. At Ngohalima 76 persons were seen and 47 at Halima, of whom 12% and 0% respectively were found to be bilaterally blind. Of the 66 and 47 persons in the two communities who were given a detailed ocular examination, 55% and 60% respectively had microfilariae in the cornea, 26% and 34% had microfilariae in the anterior chamber, 29% and 21% had eye lesions. At Ngohalima, in the under 10 year and 10-20 year age groups, 16 and 13 subjects respectively were examined, of whom 10 and 11 had positive skin snips, 8 and 13 were given an ocular examination, 3 and 9 had microfilariae in the cornea, 0 and 4 had microfilariae in the anterior chamber, 0 and 4 had eye lesions while 0 and 1 were bilaterally blind.

These hyperendemic foci were examined again, more briefly, by Kaneene (unpublished) in 1981. At the Bussere Road Camp, of the 50 examined, 74% had a positive skin snip and at Ngohalima, 43 out of the 45 examined (96%) had a positive skin snip. A survey at Bussere itself, which included a number of schoolchildren, revealed a 60% prevalence among the 176 examined. At the forestry station of Nummatina near the confluence of the Bussere and Nummatina rivers, 64% of the 106 examined showed a positive skin snip. More detailed surveys were conducted at the canning factory school on the Bussere river near the confluence, on 263 children under 15 years old, at Nyikijo on the Sue river on 140 people and at Nyinakok on the Jur river on 45 inhabitants (Mackenzie et al., 1984). At the three communities, 29%, 71% and 77%, respectively, showed a positive skin snip. Of the 75 canning factory schoolchildren infected, 52% had fluffy corneal opacities and 36% had microfilariae in the anterior chamber. At Nyikijo, 24 persons (17%) had eye lesions of whom 10 had microfilariae in the anterior chamber. At Nyinakok, 44% had ocular lesions, 21% microfilariae in the eye and 52% showed a visual acuity below 6/6. The ocular symptoms cannot easily be compared since they were assessed in different ways in the three communities but at neither Nyikijo nor Nyinakok were blind people reported. A Dinka village called Nynalel, situated near Nyinchon, between Nyinakok and Wau, was also examined with 45% of the 75 males and 32% of the 81 females being found positive, giving for the 86 adults a 52% positive skin snip rate and for the 67 children under 18 years a 22% positive rate.

The results from two other recently conducted surveys are available. Bashir (1984) in a survey conducted with Galal examined by skin snip 90 males from the Canning Factory and 47 males and 46 females from Agok. An overall prevalence of 56% was found with 34% of the Canning Factory men, 57% of the Agok men and 100% of the Agok women positive for onchocerciasis in the buttock skin snip. Tizazu & Mburu (1983) carried out a survey in the villages of Moruco and Mbiri (south of Raffili on the river Sue) where of the 57 and 85 persons examined, respectively, 5.3% and 7.1% had a vision under 6/61. It is not clear, however, how these investigators distinguished between visual loss from onchocerciasis and that from cataract or non-onchocercal corneal opacity.

Distribution of the vector

Lewis (1948) was the first to record S. damnosum s.l. from these rivers. In addition to his pioneering work in Mvolo, Lewis (1953a) dissected over 2000 vectors caught and preserved by the mission at Raffili during 1950-1951. No attempt was made to record biting population levels. Of the 1363 rainy-season caught flies, 10 contained vermiform, third-stage larvae, but none were found in the 863 flies collected during the dry season (November-April). Since dissection of preserved material is unreliable and since the collections were not conducted systematically, no conclusions on the vector biting rate or transmission potential can be made. At eight sites upstream and inland near the river Sue 265 flies were also collected and dissected showing that vectors could be found up to 33 km from the headwaters of the river Sue (Lewis 1953a). Vector collections were made in January, May and July 1964, at Raffili Peile, the Bo river and Moruco, showing that vectors were very common in these three months except at Peile (the new site for the Raffili mission inland) where vectors were only found in May. In 1981 and 1982 biting vectors were found to be very common at Raffili and Bo bridge (on 9 May 1981) and the old causeway above the Bo river bridge was shown to be a major vector breeding site (collections made on 9 May 1981, 2 October 1982 and 17 December 1982).

Systematic collections and dissections of S. damnosum s.l. in the Wau area began in January 1964 but for 7 years (January 1965 - December 1971) they had to be suspended due to civil disturbances. The collections, especially in the 1970s, were made predominantly in the Wau urban area. Following the recommendations of Le Berre (1972), the insecticide temephos was applied to the Bussere and Wau causeways in early December 1974, for two breeding seasons; this was discontinued because of problems with the boat (Gassouma, pers. comm.).

Beiram (1974) has summarized much of this work, but the summaries are sometimes difficult to reconcile with the surviving original data sheets. Bashir (pers. comm.) recommends that these figures be considered as offering only an approximate picture of the monthly biting rates given the difficulties in supervising the vector collectors. The information obtained on transmission is also unreliable. However, two features appear clearly: (1) a marked bimodal vector biting distribution with peaks in June/July and December/January/February, which is a common feature of rivers with breeding sites, such as causeways, considered to be optimum sites at rising and falling water levels (Le Berre, 1966); (2) biting levels at Wau were much higher in 1964 (i.e. annual biting rate - ABR - of 25 530 and 28 745 at two sites at Wau respectively, without data from September or October) and 1972 (ABR 34 539) compared to 1973 (ABR 1784 with no collection in September or November) or 1974 (ABR 575 with no collection in September). This second feature is harder to interpret but may have been related to the building of the new bridge upstream from the causeway. This bridge was finished on 23 May 1974, when the causeway would have been abandoned and not repaired. If the causeway was not repaired, it would not provide such an obstruction to water flow and thus would not be such a good vector breeding site. However, this does not explain the big reductions in vectors in 1973 before the causeway was abandoned. Possibly, the bridge building operations themselves or pollution from the town may have been responsible. Gassouma (unpublished) concluded that the later vector control operation had been responsible for only a 20% vector reduction and that, for greater reductions, the control of the major Bussere river breeding site (the Bussere causeway) was required.

Baker & Abdelnur (1984) confirmed this bimodal annual vector biting distribution and reported reductions in annual vector biting rates of 50-60% and in annual transmission potentials of up to 80% as a result of spraying 40 km of the Bussere river (including Bussere causeway) and Wau causeway with temephos. In the two years of study before control operations, annual biting rates and annual transmission potentials as high as 64 331 and 3916, respectively, were found at Bussere causeway, though these were much lower in the second year and at sites below Agok on the Bussere and along the Sue and Jur rivers where there is no riparian tree fringe. For the May-January period, in the two years before control operations, 2.9% of all the flies dissected were infective (with third-stage Onchocerca in the head) harbouring a mean of 2.4 infective larvae per infective fly. In the control year for the same period 2.2% of dissected flies were infective with a mean of 1.9 infective larvae per infective fly.

Of the 324 S. damnosum s.l. larvae identified from 30 collections, 92% were S. sirbanum, which were present in every collection, while only a total of 26 S. damnosum s.s. larvae were found in 12 of the collections. During the three-year study, 71 472 S. damnosum s.l. and only 5 S. griseicolle were caught on man. Lewis (1956) also found one S. griseicolle attracted to but not biting man at Lubu near Tembura. In this area, S. griseicolle includes S. bifila Freeman & De Meillon, whose adults are indistinguishable (Freeman & De Meillon, 1953); other species in the S. griseicolle group (Crosskey, 1969) are also likely to be present. None of the S. griseicolle had engorged. Unengorged S. griseicolle were also collected from cows, sheep and chicken. Bashir (1984) collected O. gutturosa, O. armillata, O. cervicalis and O. railleti in addition to O. volvulus from the Wau area.

Many onchocerciasis research workers have been attracted to this area by the presence of many communities infected with ocular onchocerciasis, their easy access, and their proximity to Wau (the capital of the Bahr El Ghazal region, where there is a railhead, an airport and a town with onchocerciasis personnel, buildings and clinic) and by the existence of comprehensive river discharge data. It is clear that the onchocerciasis clinic in Wau, while performing a valuable public service, has been unable to control the disease in this area. The work of Baker & Abdelnur (1984) suggests that a substantial reduction in disease transmission, approaching the 80% reduction attained at the foci near Bussere by larviciding 40 km of the Bussere river, could be achieved by bulldozing out the causeway at Bussere and clearing vegetation from areas of fast water flow: the apex of bends, islands and natural rocky outcrops in the river bed. Further reductions could be achieved by bulldozing the other abandoned causeways in the area: at Ngohalima (on the Bussere river), at Wau and Nyinakok (both on the Jur river).

2.3.3.5 Rivers Ibba (Tonj) and Gel

After leaving the southern watershed, these rivers are virtually uninhabited until just before the Wau-Tonj-Rumbek road where they pass the southern boundary of the Dinka. South of Tonj on the west bank of the river, there are a number of heavily infected Jur communities, which are inaccessible during the rainy season. On the east bank, there are reportedly a few Bongo communities but they are all at some distance from the riverside. At Tonj itself the status of the disease is unknown though S. damnosum s.l. larvae and pupae have been found in collections made below the bridge (on 5 December 1982) and adults in collections made by the river (80 on 5 January 1964 and 6 on 28 May 1964) and at the agricultural station (none on 7 January 1964 and 4 on 28 May 1964). The focus at Wan Alel downstream has been described above in sections 2.3.2 and 2.3.3.

Satti (1973) records onchocerciasis from the Gel river but the status of the disease on this river is unclear. The saw mill at Bahr Gel, south of Cuibet must be suspected as a prime focus because it is reported to be situated beside a rocky stretch of the river. Both rivers have gauges: the river Ibba has a discharge of 1.11 milliards per year, the river Gel of 0.55 milliards per year.

2.3.3.6 Rivers Naam, Yei and Tapari

The surprising absence of both anthropophilic blackflies and onchocerciasis at Yei, near the source of the Yei river, and the low prevalence and severity of the disease at Mundri beside the rocky, swiftly flowing Yei river, 150 km to the north, has already been noted. The prevalence and severity of onchocerciasis along the upper reaches of the Naam and Tapari is unknown. North of Mundri hyperendemic, blinding onchocerciasis is reported from all three rivers.

The best known focus is the one at Mvolo, a small Jur Beli community of about 500 people on the Naam river, which at this point "cascades through an astonishing collection of large boulders and massive crags of rocks" (Jonglei Investigation Team, 1954) providing a marvellous breeding site for S. damnosum s.l. (Lewis, 1953a; Hocking & Hocking, 1962). No attempt was made to assess the biting vector population, though 2.2-3.9% of the small numbers of flies dissected were found to have infective *Onchocerca* larvae in their heads. Transmission was found to be heaviest in the rainy season, but with river discharges recorded for every month except February and March, it is likely that some transmission occurs throughout the April-January period. On 7 December 1982, the river was very low but fast water with S. damnosum s.l. was found in two places: where water was flowing among rocks covered in Podostemaceae or very quickly down a steep rocky gorge containing fish traps. On 10 January 1964, 143 adult flies were caught in a day's catch by the bridge at Mvolo.

Hocking & Hocking (1962) reported the observations of Dr El Fadel Saed who had found over 90% of the villagers infected, with up to 10% blind and a further 20% suffering from other disabilities such as hanging groin and hernias. Woodruff (pers. comm.) examined 18 persons (mean age 29.5 years) finding serious ophthalmic complications in 15 of them, including a boy of 12 with bilateral cataracts and iritis with synechae who was close to complete blindness. Tizazu & Mburu (1983) confirmed the severity of onchocerciasis in Mvolo, finding 8% of the 125 examined with vision less than 6/60, though, as noted in section 2.3.3.4 above, it is not clear how visual loss caused by onchocerciasis was distinguished from that caused by non-onchocercal corneal opacity and uncomplicated cataract.

Information on the surrounding area is given by Enarson (1976, 1977) and Bridger (1978) and in reports from medical personnel in the area. Bridger (1978) looked at the adult population to see the proportion of blind people. North of Mvolo at Sopi, Yiri and Muke, 22.8% of the adult population of 412 were found to be blind with 23% of those blind being of "working age". Other villages surveyed which were further from the riverside were less affected. Enarson (1976, 1977) conducted a brief survey (maximum 17 adult males examined per village) of the Beli, Lori, Nyamusa and Morokodo people in Wulu, Amadi, Mvolo and Yeri Districts. He examined 243 people from 14 villages surrounding 4 rural centres and found 18 people (13%) to be totally blind. Gobel (pers. comm.) reports that onchocerciasis is severe among the Mundari living near the Tapari river where it is crossed by the Tindalo-Tali Post road on a causeway and upstream at Mijiki, 25 km from Tali Post, where 25 blind people were found. Onchocerciasis is clearly very prevalent and serious along all these three rivers north of Mundri with extensions (as referred to earlier) into the alluvial plain in the Yirol area where rocks outcropping in the river bed and a causeway provide suitable vector breeding sites.

The rivers Naam, Yei and Tapari have annual discharges of 0.64 milliards, 1.02 milliards and 0.44 milliards, respectively. The focus at Mvolo could be controlled with yearly applications of about 150 litres of temephos (Abate 200-E) at a 1982 cost of $ 1500, or $ 0.40 per head if the local population is accurately estimated as 4000. Proposals for moving the community 6 km towards Juba have met resistance from the older inhabitants of Mvolo and the success of such a move will depend very much on the provisions made for the population at the proposed new site. The focus on the Tapari river may be controlled by the bulldozing of the causeway and the construction of a bridge.

3. SUMMARY

The distribution of onchocerciasis and its vectors in Sudan has been reviewed with special emphasis on the hyperendemic foci, where there is serious visual handicap caused by the disease. These foci of blinding onchocerciasis lie primarily in the south-west of the country, along the rivers flowing north and east from the borders with the Central African Republic and Zaire. Nevertheless, at least one such focus is known also from the eastern part of the country close to the Ethiopian border.

In the foci with blinding forms of the disease which are often small villages situated not far from the rivers, the severity of ocular onchocerciasis equals that found in other African foci and, in certain cases (principally near Raga, Wau and Mvolo), may exceed it.

Only the Simulium damnosum s.l. species complex has been implicated in disease transmission and only the two dangerous, morphologically similar, savanna cystospecies, S. damnosum s.s. and S. sirbanum, have been identified from breeding sites close to known onchocerciasis foci. Near the Uganda and Zaire borders it is likely that other, less anthropophilic cytospecies occur. Different Onchocerca-Simulium complexes, composed of different parasite strains with different pathogenicities transmitted by different vector species, may be responsible for the different degrees in severity of the disease found in the three main areas of onchocerciasis in north, east and south-west Sudan. In the main foci of blinding onchocerciasis in south-west Sudan, however, there is no evidence that the strain of O. volvulus differs significantly from that found in the main foci in the Sudan savanna of west and central Africa. In these latter foci the clinical characteristics are: few nodules on head and body, heavy infections with microfilariae in the eyes and many ocular lesions, particularly in the anterior segment (Duke, 1976a; Muller, 1979).

The localized, focal distribution of the communities seriously afflicted by blinding onchocerciasis suggests that a strategy of tackling the disease on a focus by focus basis may prove optimal. A control scheme designed to treat all the vector breeding sites with insectcide, as in west Africa (Walsh et al., 1979), would receive extensive invasion from the Zaire/Congo river basin and the headwaters of the White and Blue Niles in neighbouring countries. While some foci are situated beside major river rapids, with vector breeding only controllable by regular insecticide treatments, several foci have been identified close to removable man-made objects which provide excellent breeding sites at certain water levels (e.g. causeways). The destruction of such breeding sites should be considered since localized vector control may produce substantial reductions in onchocerciasis transmission (Baker & Abdelnur, 1984).

ACKNOWLEDGEMENTS

Information on onchocerciasis in Sudan has been culled from a wide variety of both published and unpublished material. We are most grateful to the authors of the unpublished documents for giving us access to them and for their agreement to letting us reproduce a summary of the results in the present document.

We believe that all the authors quoted would wish to join in paying tribute to the many hundreds of workers, be they vector collectors, laboratory assistants, medical assistants, public health officers or others, who have worked long and hard in conditions of some personal risk to collect the data presented here.

We also wish to thank Professor Barrie Jones, Dr Charles Mackenzie and Dr Graham White for commenting on drafts of this paper and Dr Stefanie Meredith who kindly identified larvae collected in southern Sudan.

RESUME

L'ONCHOCERCOSE AU SOUDAN : AIRE DE DISTRIBUTION DE LA MALADIE ET DE SES VECTEURS

Ce document décrit la distribution de l'onchocercose et de ses vecteurs au Soudan en mettant l'accent plus particulièrement sur les foyers d'hyperendémicité où cette maladie provoque des troubles graves de la vue. Ces foyers d'onchocercose entraînant la cécité (typhlogène) se trouvent principalement dans le sud-ouest du pays, le long des fleuves qui coulent vers le nord et l'est à partir des frontières de la République centrafricaine et du Zaïre. Cependant, on connaît au moins un autre foyer dans la partie orientale du Soudan, non loin de la frontière éthiopienne.

Dans les foyers où la maladie revêt la forme typhlogène, qui sont souvent de petits villages situés non loin des cours d'eau, la gravité de l'onchocercose oculaire ne le cède en rien à celle qu'on constate dans d'autres foyers d'Afrique et, dans certains cas (principalement près de Raga, Wau et Mvolo), elle est peut-être encore pis.

Seul le complexe des espèces Simulium damnosum s.l. a été impliqué dans la transmission de la maladie et, dans des gîtes larvaires situés à proximité des foyers connus d'onchocercose, on a seulement identifié les deux espèces cytotaxonomiques savanicoles S. damnosum et S. sirbanum qui sont dangereuses et de morphologie identique. Il est probable que d'autres espèces cytotaxonomiques, moins anthropophiles, soient présentes près des frontières de l'Ouganda et du Zaïre. Peut-être différents complexes Onchocerca-Simulium composés de souches parasitaires différentes douées d'une pathogénicité différente et transmises par différentes espèces de vecteurs sont-ils responsables des différents degrés de gravité de la maladie observés dans les principaux périmètres onchocerquiens du nord, du sud et du sud-ouest du Soudan. En revanche, dans les principaux foyers d'onchocercose typhlogène du sud-ouest du Soudan, rien ne porte à croire que la souche d'O. volvulus diffère notablement de celle qu'on trouve dans les principaux foyers des savanes soudaniennes de l'Afrique de l'Ouest et de l'Afrique centrale. Dans ces derniers foyers, les caractéristiques cliniques sont les suivantes : peu de nodules sur la tête et le corps, fortes infections dues à des microfilaires dans les yeux, et nombreuses lésions oculaires, en particulier dans le segment antérieur.

La répartition localisée et par foyers des collectivités gravement atteintes par l'onchocercose typhlogène permet de supposer que la stratégie optimale consisterait à s'attaquer à la maladie foyer par foyer. En effet, un projet de lutte conçu pour traiter aux insecticides la totalité des gîtes larvaires du vecteur, comme c'est le cas en Afrique de l'Ouest, entraînerait une invasion massive à partir du bassin hydrographique Congo/Zaïre et du cours supérieur du Nil Blanc et du Nil Bleu dans les pays voisins. Bien que quelques foyers soient situés à proximité de rapides importants, où la reproduction du vecteur ne pourrait être combattue que par des traitements réguliers aux insecticides, on a recensé plusieurs foyers proches d'ouvrages artificiels pouvant être éliminés et qui constituent d'excellents gîtes larvaires quand l'eau atteint certains niveaux (par exemple des radiers). Il faut envisager la destruction de tels gîtes larvaires car une lutte antivectorielle localisée peut entraîner une réduction substantielle de la transmission de l'onchocercose.

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TABLE 1. SIMULIUM DAMNOSUM S.L. LOCALITIES IN SUDAN

Site	Location	Collection	Coordinates
1 Abongara	River Sue south of Wau	T	7°41'N, 28°03'E
2 Abu Asha	Blue Nile near Wad Medani	L	14°20'N, 33°35'E
3 Abu Dis	Nile upstream from Abu Hamed	GO	19°08'N, 33°36'E
4 Abu Fatima	Nile 3rd cataract	L	19°41'N, 30°24'E
5 Abu Hamed	Nile 4th - 5th cataract	LO	19°32'N, 33°20'E
6 Abu Hashim	Nile near Abu Hamed	O	18°57'N, 33°36'E
7 Abu Haraz	Blue Nile near Wad Medani	L	14°28'N, 33°31'E
8 Abu Usher	Blue Nile downstream from Wad Medani	L	14°55'N, 33°14'E
9 Abu Zogoli	Blue Nile Sennar-Damazine	O	11°50'N, 34°23'E
10 Agok	River Bussere south of Wau	T	7°38'N, 28°01'E
11 Akanda	River Bussere south of Wau	T	7°26'N, 27°49'N
12 Aluk	Pongo river	L	8°43'N, 27°24'E
13 Amadi	Yei river	L	5°32'N, 30°20'E
14 Aramularo (K)	Gel river (Wau-Tonj road)	L	7°03'N, 29°08'E
15 Argo	Nile north of Dongola	LO	19°32'N, 30°27'E
16 Asal	Nile 6th cataract	O	16°14'N, 32°37'E
17 Atbara	Nile north of Khartoum	LO	17°42'N, 34°00'E
18 Bandula	River Sue south of Wau	L	6°20'N, 27°45'E
19 Banga	River Sue north of Yambio	L	4°46'N, 28°51'E
20 Beka Canal	Blue Nile near Wad Medani	V	14°25'N, 33°30'E
21 Biri	River Biri Wau-Raga road	OT	7°47'N, 26°09'E
22 Bissellia	River Getti Wau-Raga road	OT	7°46'N, 27°41'E
23 Bo	River Sue tributary south of Wau	LOT	6°48'N, 27°53'E
24 Bussere	River Bussere south of Wau (causeway and school)	OT	7°32'N, 27°56'E
25 Dabaka	Nile near 6th cataract	O	16°15'N, 32°40'E
26 Dagash	Nile near Abu Hamed	O	19°22'N, 33°26'E
27 Damazine	Blue Nile near Roseires dam	LO	11°50'N, 34°23'E
28 Debba	Nile Karim-Dongola	L	18°02'N, 30°57'E
29 Deleiba	Boro river north-east of Raga	T	8°49'N, 26°02'E
30 Delgo	Nile downstream from Dongola	O	20°08'N, 30°37'E

31 Dongola	Nile near 3rd cataract	L	19°10'N, 30°27'E
32 Duma	River Sue tributary north of Tembura	LT	5°51'N, 27°34'E
33 Ed Daba	Nile Karima-Dongola	O	18°02'N, 30°57'E
34 Ed Damer	Nile Shendi-Atbara	O	17°35'N, 33°56'E
35 El Bageir	Nile Shendi-Atbara	O	17°20'N, 33°50'E
36 El Basabir	Nile Shendi-Khartoum	O	16°30'N, 32°55'E
37 El Bellal	Nile 4th cataract	L	18°49'N, 32°03'E
38 El Ghaba	Nile 10 km west of Abu Hamed	A	19°33'N, 33°14'E
39 El Mahmiya	Nile Shendi-Atbara	O	17°11'N, 33°54'E
40 El Ushura	Nile Abu Hamed-Atbara	O	18°27'N, 33°40'E
41 Farajok	Imatong mountains	L	3°57'N, 32°31'E
42 Fareig	Nile downstream from Dongola	O	19°40'N, 30°25'E
43 Gallabat	River Atbara near Ethiopian border	L	12°57'N, 36°08'E
44 Genneti	Nile Karima-Dongola	O	17°57'N, 31°14'E
45 Getti	River Getti Wau-Aweil road	O	7°58'N, 27°51'E
46 Goleid	Nile Karima-Dongola	O	18°N, 31°05'E
47 Goshibi	Nile Karima-Dongola	O	18°N, 31°06'E
48 Gossinga	Rivers Raga and Sopo north-west of Raga	O	8°39'N, 25°57'E
49 Gureir	Nile Karima-Dongola	O	18°16'N, 31°42'E
50 Hagar El Asal	Nile 6th cataract	O	16°25'N, 32°49'E
51 Hagarel	Nile Shendi-Atbara	O	16°25'N, 32°49'E
52 Hamdab	Nile 4th cataract	LO	18°38'N, 32°03'E
53 Hassaheisa	Blue Nile near Wad Medani	V	14°44'N, 33°18'E
54 Hussein Nare	Nile Karima-Dongola	O	18°N, 31°05'E
55 Ibba	River Ibba Yambio-Maridi road	T	4°47'N, 29°08'E
56 Kabushiya	Nile Shendi-Atbara	O	16°52'N, 33°40'E
57 Kabodi (I)	Nile 3rd cataract	L	19°46'N, 30°20'E
58 Kaheila	Nile near Abu Hamed	O	19°25'N, 32°50'E
59 Kajo Kaji	West of White Nile near Ugandan border	L	3°52'N, 31°40'E
60 Karaba	Nile 5th cataract	O	18°32'N, 33°40'E
61 Karima	Nile below 4th cataract	LO	18°32'N, 31°48'E
62 Kashm El Girba	River Atbara south-east of Kassala	M	14°58'N, 35°57'E

63 Kawa	Nile near Dongola	L	19°10'N, 30°27'E
64 Khandaque	Nile Karima-Dongola	O	18°37'N, 30°34'E
65 Khartoum	Junction of White and Blue Niles	L	15°33'N, 32°35'E
66 Khogali	River Sue south of Wau	L	6°20'N, 27°45'E
67 Khor Shammam	River Raga north-east of Raga	OT	8°35'N, 25°47'E
68 Kit (R)	Near Nile south of Juba	W	4°42'N, 31°46'E
69 Kuru	River Kuru on Wau-Raga road	LOT	7°43'N, 26°27'E
70 Liwollo	Near Kajo Kaji	L	3°45'N, 31°30'E
71 Lubu	River Sue near Duma	L	5°50'N, 27°35'E
72 Maignbara	River Sue north-west of Yambio	L	5°05'N, 28°13'E
73 Maridi	Large town east of Yambio	L	4°55'N, 29°30'E
74 Maruki	River Sue south of Wau (near Bo)	LO	6°42'N, 28°00'E
75 Mbungu (R)	River Sue tributary Tembura-Yambio road	T	5°28'N, 27°38'E
76 Merowe	Nile near 4th cataract	LO	18°27'N, 32°49'E
77 Mograt (I)	Opposite Abu Hamed	GO	19°30'N, 33°20'E
78 Mokakene (K)	On Tembura-Yambio road	L	5°08'N, 28°00'E
79 Mundri	River Yei south of Amadi	LT	5°22'N, 30°19'E
80 Mureibiya	White Nile near Kosti	L	14°30'N, 32°10'E
81 Mvolo	River Naam Rumbek-Mundri road	LT	6°04'N, 29°55'E
82 Nadi	Nile below 5th cataract	LO	18°39'N, 33°43'E
83 Nimule	White Nile on Uganda border	M	3°35'N, 32°04'E
84 Ngohalima	River Bussere south of Wau	T	7°31'N, 27°55'E
85 Ngosulugu	River Bussere south of Wau	T	7°28'N, 27°48'E
86 Ngueni (K)	River Sue tributary north of Tembura	L	5°50'N, 27°35'E
87 Nkape	River Ibba (falls) south of Tonj	L	5°46'N, 28°35'E
88 Nummatina	River Bussere south of Wau	T	7°14'N, 27°38'E
89 Nyalero	River Bussere south of Wau	T	7°31'N, 27°57'E
90 Nyiduik	River Sue south of Wau	T	7°32'N, 28°08'E
91 Nyikijo	River Sue south of Wau	T	7°38'N, 28°06'E
92 Nyikakok	River Jur north of Wau	T	7°56'N, 28°01'E
93 Nyinchon	River Jur north of Wau	T	7°47'N, 28°01'E
94 Nuri	Nile 4th cataract	L	18°34'N, 31°54'E

95	Paye	River Yei Rumbek-Yirol road	T	6°31'N, 30°24'E
96	Peile	River Sue north of Bo (inland)	L	7°07'N, 27°56'E
97	Pochala	River Sobat near Ethiopian border at Nasir	L	7°09'N, 34°11'E
98	Pongo Aweil	River Pongo saw mill on Wau-Aweil road	O	8°43'N, 27°24'E
99	Pongo Nuer	River Pongo saw mill on Wau-Raga road	T	15°53'N, 32°35'E
100	Qubba	Nile 6th cataract	O	6°55'N, 27°57'E
101	Raffili	River Sue south of Wau near Bo	L	8°26'N, 25°46'E
102	Raga	River Raga 300 km west of Wau	OT	8°26'N, 25°46'E
103	Ramage	Near Kajo Kaji	L	3°55'N, 31°40'E
104	Rame	River Sue south of Bo (inland)	L	7°19'N, 27°57'E
105	Ringasi	River Sue tributary Yambio-Tembura road	T	4°54'N, 28°10'E
106	Saad El Fanti	Nile downstream from Dongola	O	19°40'N, 30°25'E
107	Sabaloka	Nile 6th cataract	GO	16°16'N, 32°40'E
108	Sabu	Nile 3rd cataract	L	19°44'N, 30°23'E
109	Sahaba	Nile Karim-Dongola	O	18°30'N, 30°40'E
110	Senango Faki	River Sue north of Yambio	L	5°02'N, 28°26'E
111	Sennar	Blue Nile Dam	L	13°31'N, 33°38'E
112	Shambat	Nile north of Khartoum	L	15°41'N, 32°34'E
113	Shendi	Nile between Atbara and Khartoum	O	16°41'N, 33°22'E
114	Shereik	Nile below 5th cataract	LO	18°46'N, 33°34'E
115	Simit	Nile downstream from Dongola	O	19°45'N, 30°23'E
116	Sopo	River Sopo Raga-Wau road	OT	8°02'N, 26°02'E
117	Sue	River Sue Yambio-Maridi road	T	4°46'N, 28°51'E
118	Sue	River Sue near Tembura	O	5°50'N, 27°50'E
119	Tangasi	Nile upstream from Dongola	L	18°27'N, 30°43'E
120	Tonj	River Ibba on Wau-Rumbek road	LOT	7°17'N, 28°39'E
121	Tore	River Tore Yei-Maridi road	T	4°31'N, 30°10'E
122	Tumbus	Nile 3rd cataract	L	19°49'N, 30°17'E
123	Uli (I)	Nile 4th cataract	L	18°46'N, 32°03'E
124	Um Shigil	Nile Shendi-Atbara	O	17°00'N, 33°45'E
125	Ushmati	Nile downstream from Dongola	O	19°30'N, 30°25'E
126	Wadi Arud	River Atbara near Ethiopian border	L	13°39'N, 36°16'E

127 Wad Medani	Blue Nile between Sennar and Khartoum	L	14°24'N, 33°30'E
128 Wau	Town on river Jur (Bussere/Sue confluence)	LOT	7°42'N, 27°58'E
129 Witu (R)	Near river Tapari east of Amadi	L	5°30'N, 30°46'E
130 Yabus (K)	Ethiopian border east of Malakal	L	9°57'N, 33°58'E
131 Yei	River Yei near Ugandan border	LT	4°09'N, 30°40'E

Key to:

Site

(I) = Island

(K) = Khor (small stream)

(R) = River

Collection

A = recorded by Anderson et al. (1974)

G = recorded by Gassouma (1972)

L = recorded by Lewis (1948, 1953a, 1953b, 1956)

M = recorded by Marr (1977)

O = recorded in Onchocerciasis Control Project records (mainly 1964-1974)

T = recorded by UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (see Baker & Abdenur, 1984)

V = recorded by Ovazza (1967, 1970)

W = recorded by Woodruff (pers. comm., 1984)

TABLE 2. ONCHOCERCIASIS FOCI IN SUDAN

		Discovered by (see key)	Coordinates
Northern Sudan			
Abu Hamed - Sheriek	River Nile	M	19°32'N - 18°46'N 33°20'E - 33°34'E
El Ghaba	River Nile 10 km west of Abu Hamed	O	19°33'N, 33°14'E
Karima	River Nile	Onc	18°32'N, 31°48'E
Mogal	River Nile, Mograt Island by Abu Hamed	O	19°30'N, 33°20'E
Eastern Sudan			
Akobo	Upper Sobat (Akobo) - Ethiopian border	B	7°47'N, 33°01'E
Birkait Nurein	River Atbara near Ethiopian border	A	13°40'N, 36°15'E
Mushra Ghanam	River Atbara near Ethiopian border	A	13°40'N, 36°15'E
Pibor	River Pibor (upper Sobat river)	B	6°50'N, 33°09'E
Umm Kharaeet	River Atbara near Ethiopian border	G	13°40'N, 36°15'E
Wad Kaoli	River Atbara near Ethiopian border	A	13°40'N, 36°15'E
Yabus (Khor)	Ethiopian border south of Damazine	AS	9°57'N, 33°58'E
Southern and western Sudan			
Abongara	River Sue south-east of Wau	T	7°41'N, 28°03'E
Abuul	River Sue south-east of Wau	T	7°18'N, 28°08'E
Agok	Leprosy centre south of Wau	TO	7°38'N, 28°01'E
Aguur	South-west of Tonj	T	7°04'N, 28°30'E
Akanda	River Bussere south-west of Wau	On	7°26'N, 27°49'E
Allel	River Yei west of Yirol	B	6°38'N, 30°25'E
Amadi	River Yei north of Mundri	E	5°32'N, 30°20'E
Angbanga	Near Raga (across river Raga)	On	8°26'N, 25°46'E
Aweil	North-west of Wau	O	8°42'N, 27°20'E
Bagari	Inland from river Bussere south-west of Wau	O	7°32'N, 27°42'E
Bahr el Girindi	River Yei north of Mundri	Br	6°06'N, 30°09'E

Bazia	Inland from river Sue south of Wau	K	7°07'N, 27°56'E
Bissellia	River Getti west of Wau	O	7°46'N, 27°41'E
Bo	River Bo south of Wau	K	6°48'N, 27°53'E
Buduge	River Kit south of Juba	O	4°40'N, 31°45'E
Bussere	River Bussere south-west of Wau	O	7°32'N, 27°56'E
Chalcow	River Kuru west of Aweil	O	8°47'N, 26°51'E
Deleiba	River Boro north-east of Raga	OnT	8°49'N, 26°02'E
Duma	Inland from river Sue north of Tembura	On	5°51'N, 27°04'E
Gossinga	Inland from river Boro/Sopo north-east of Raga	S	8°39'N, 25°57'E
Iwatoko	River Yei north of Yei	E	4°30'N, 30°30'E
Kafia Kingi	Upper Bahr El Arab	Onc	9°16'N, 24°25'E
Kangi	Inland from river Pongo south-west of Aweil	On	8°11'N, 27°38'E
Khorgana	Inland from river Pongo west of Wau	K	7°46'N, 27°06'E
Khor Shammam	River Raga north-east of Raga	S	8°35'N, 25°47'E
Kolye	River Kit South of Juba	O	4°40'N, 31°45'E
Lado	River Nile north of Juba	O	5°05'N, 31°33'E
Lali	East of Mvolo	Br	6°09'N, 30°03'E
Lerowa	Imatong mountains	E	3°55'N, 32°30'E
Logo	River Kit south of Juba	O	4°40'N, 31°45'E
Lori	East of Mvolo	Br	6°05'N, 29°55'E
Madol	North-east of Aweil	O	9°03'N, 27°43'E
(Maridi)	River Naam (? no longer a focus)	M	4°55'N, 29°30'E
Mbiri	River Sue north-east of Tembura	Ti	5°50'N, 27°50'E
Mijiki	River Tapari north-west of Juba	G	5°43'N, 30°51'E
Moruko	River Sue south of Bo	Ti	7°19'N, 27°57'E
Muke	East of Mvolo	Br	6°15'N, 29°50'E
Mundri	River Yei	L	5°22'N, 30°19'E

Mvolo	River Naam	L	6°02'N, 29°53'E
Ngohalima	River Bussere south-west of Wau	OT	7°31'N, 27°55'E
Nimule	River Nile, Uganda border	M	3°35'N, 32°04'E
Nummatina	River Bussere/Nummatina confluence south-west of Wau	O	7°14'N, 27°38'E
Nyalero	River Bussere south-west of Wau	T	7°37'N, 27°57'E
Nyikijo	River Sue south-west of Wau	O	7°38'N, 28°06'E
Nyinakok	River Jur north of Wau	O	7°56'N, 28°01'E
Nyinalel	River Jur north of Wau	O	7°55'N, 28°00'E
Nyinchon	River Jur north of Wau	O	7°47'N, 28°01'E
Paye	River Yei south-west of Yirol	T	6°31'N, 30°24'E
Peile	Inland from River Sue south of Wau (by Bazia)	K	7°07'N, 27°56'E
Pongo Aweil	River Pongo South-east of Aweil	O	8°43'N, 27°24'E
Pongo Nuer	River Pongo west of Wau	O	7°47'N, 27°16'E
Radom	Bahr El Arab	Onc	9°58'N, 24°53'E
Raga	River Raga	ST	8°26'N, 25°46'E
Sopi	East of Mvolo	Br	6°14'N, 29°55'E
Sopo	River Sopo south-east of Raga	On	8°02'N, 26°02'E
Tali Post	River Tapari (on road to Tindalo)	G	5°55'N, 30°44'E
Titribi	Bahr El Arab near Radom	Onc	9°58'N, 24°53'E
Tokiman	River Kit south of Juba	O	4°40'N, 31°45'E
Tonj	River Ibba	On	7°17'N, 28°39'E
Wan Alel	River Ibba north of Tonj	B	7°30'N, 28°49'E
Wau	River Jur	KO	7°42'N, 27°58'E
Wau Canning Factory	River Bussere south of Wau	OT	7°40'N, 28°01'E
Wulu	Near Mvolo	E	6°25'N, 29°35'E
Yeri	Between Mvolo and Mundri	E	5°50'N, 30°05'E
Yiri	Near Mvolo	Br	6°15'N, 29°50'E

Key to:

Focus discovered by

A	=	Abdalla (1974) or Abdalla & Abu Bakr (1975)
B	=	Bloss (1949)
Br	=	Bridger (1978)
E	=	Enarson (1976, 1977)
G	=	Gobel (pers. comm.)
K	=	Kirk (1947, etc.)
L	=	Lewis (1948-1956)
M	=	Marr (1977)
O	=	Onchocerciasis Control Project (1961-1963)
On	=	Onchocerciasis Control Project (1964-1974)
Onc	=	Onchocerciasis Control Project (1973, 1976)
S	=	Satti (1948, 1973)
T	=	UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (see Baker & Abdelnur, 1984)
Ti	=	Tizazu & Mburu (1984)

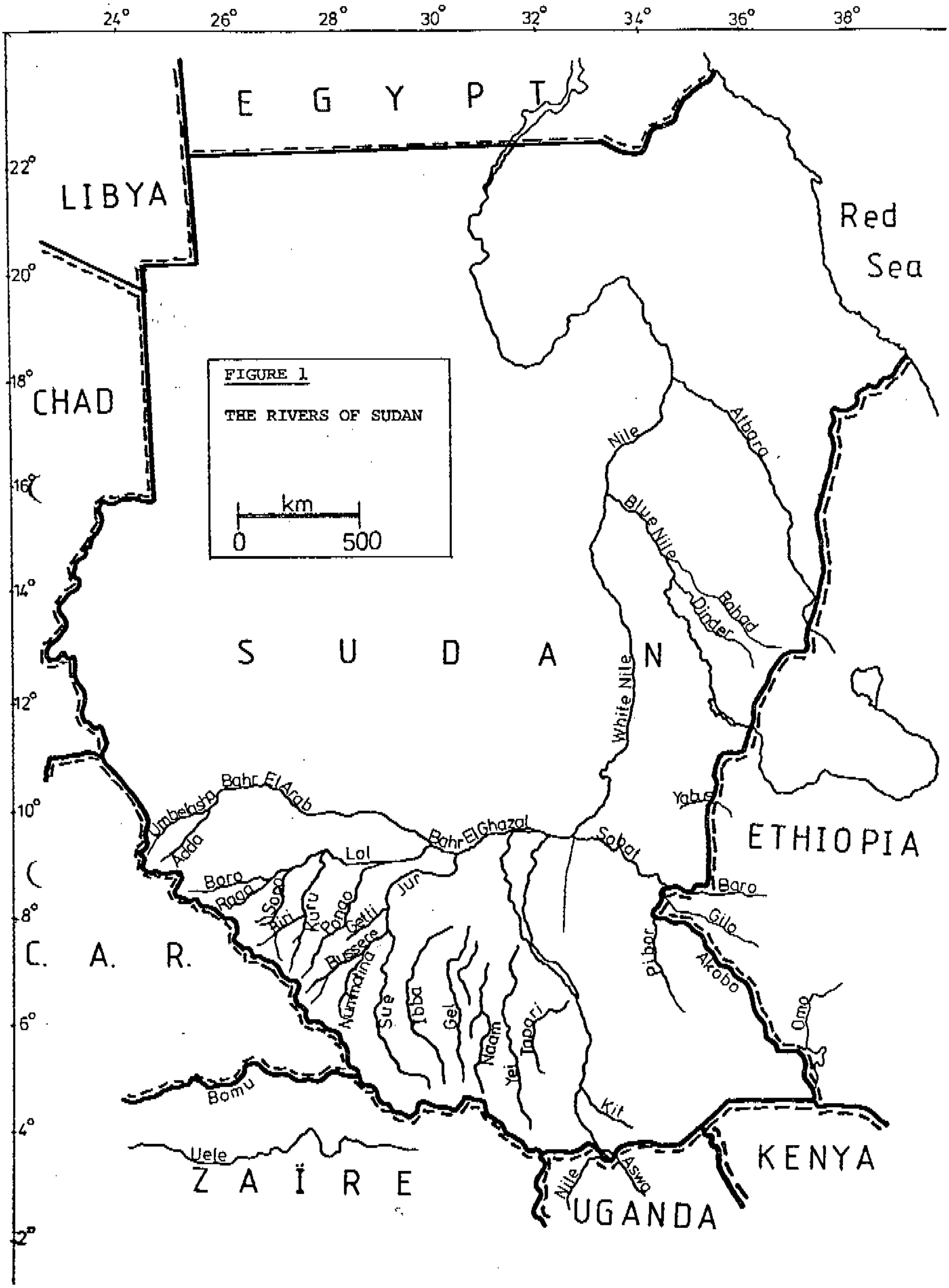


FIGURE 1
THE RIVERS OF SUDAN
km
0
500
24°
26°
28°
30°
32°
34°
36°
38°
22°
20°
18°
16°
14°
12°
10°
8°
6°
4°
2°
E G Y P T
LIBYA
CHAD
C. A. R.
S U D A N
ETHIOPIA
KENYA
UGANDA
Z A Ï R E
Red
Sea
Nile
Atbara
Blue Nile
Rahad
Dinder
White Nile
Bahr El Arab
Umbelasha
Adda
Bahr El Ghazal
Lol
Boro
Raga
Sopo
Pongo
Kuru
Getti
Busseri
Numatina
Jur
Sue
Ibba
Gel
Naam
Yei
Tapari
Sobat
Yabus
Baro
Gilo
Pibor
Akobo
Omo
Kit
Aswa
Nile
Bomu
Uele

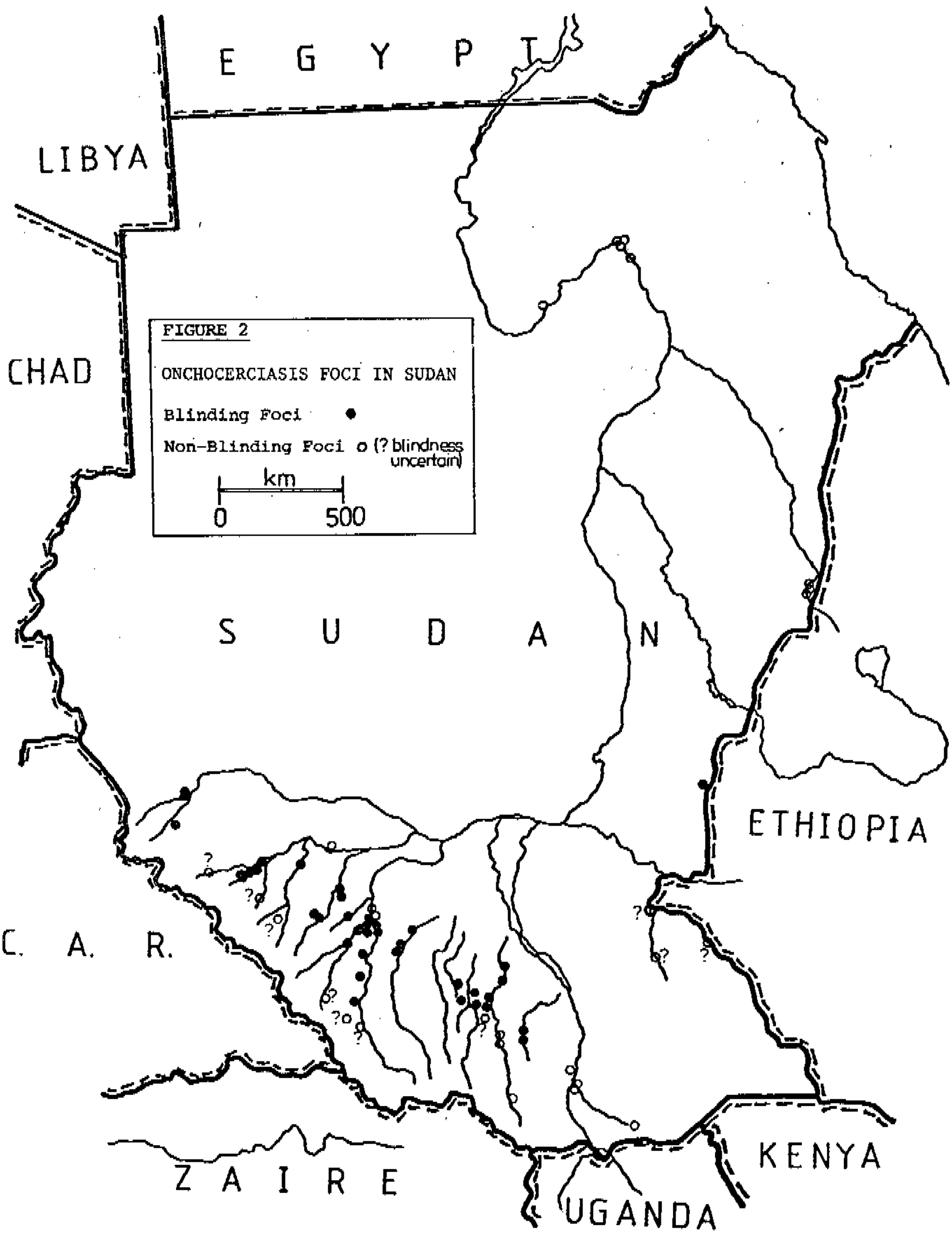
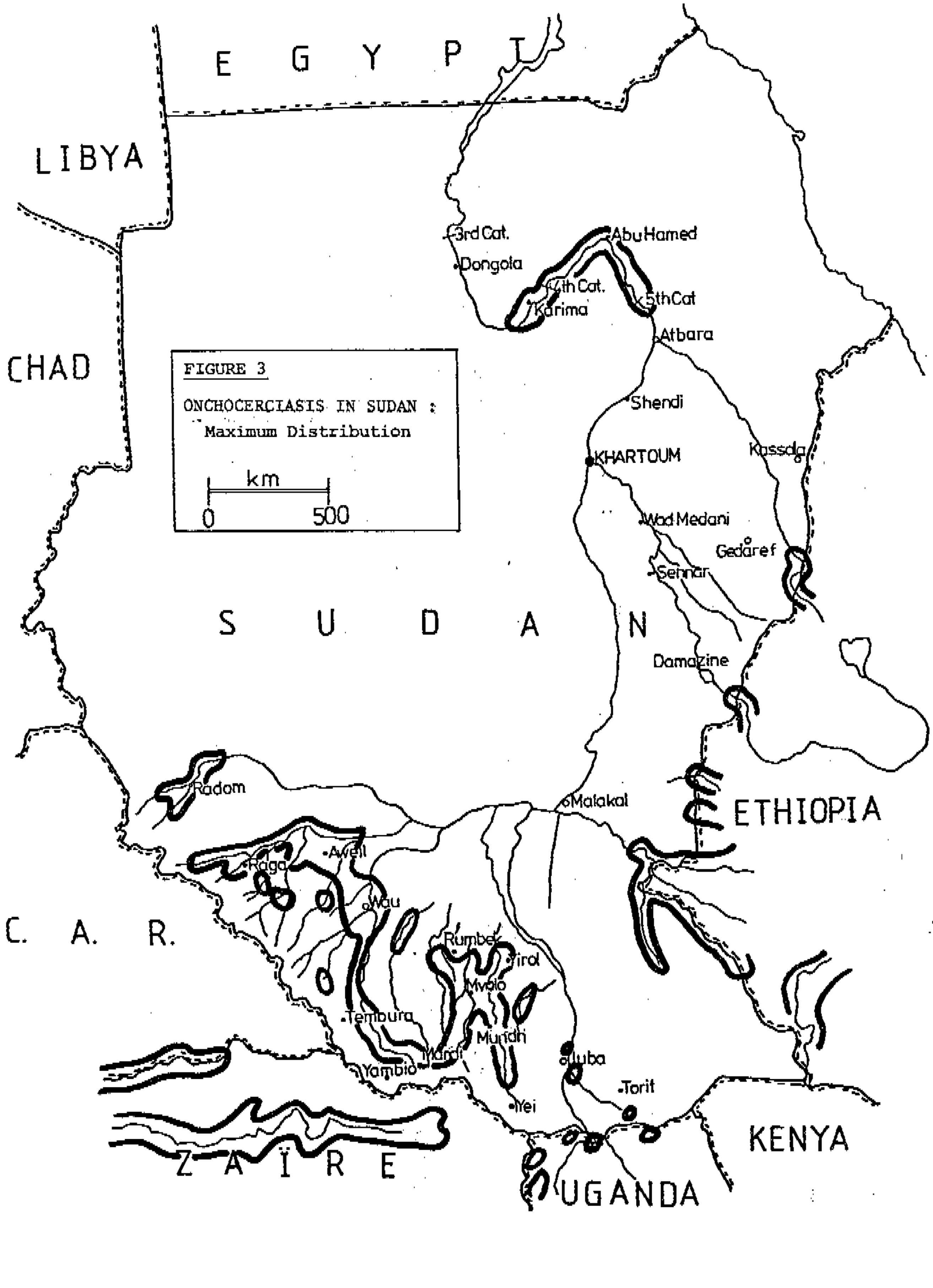
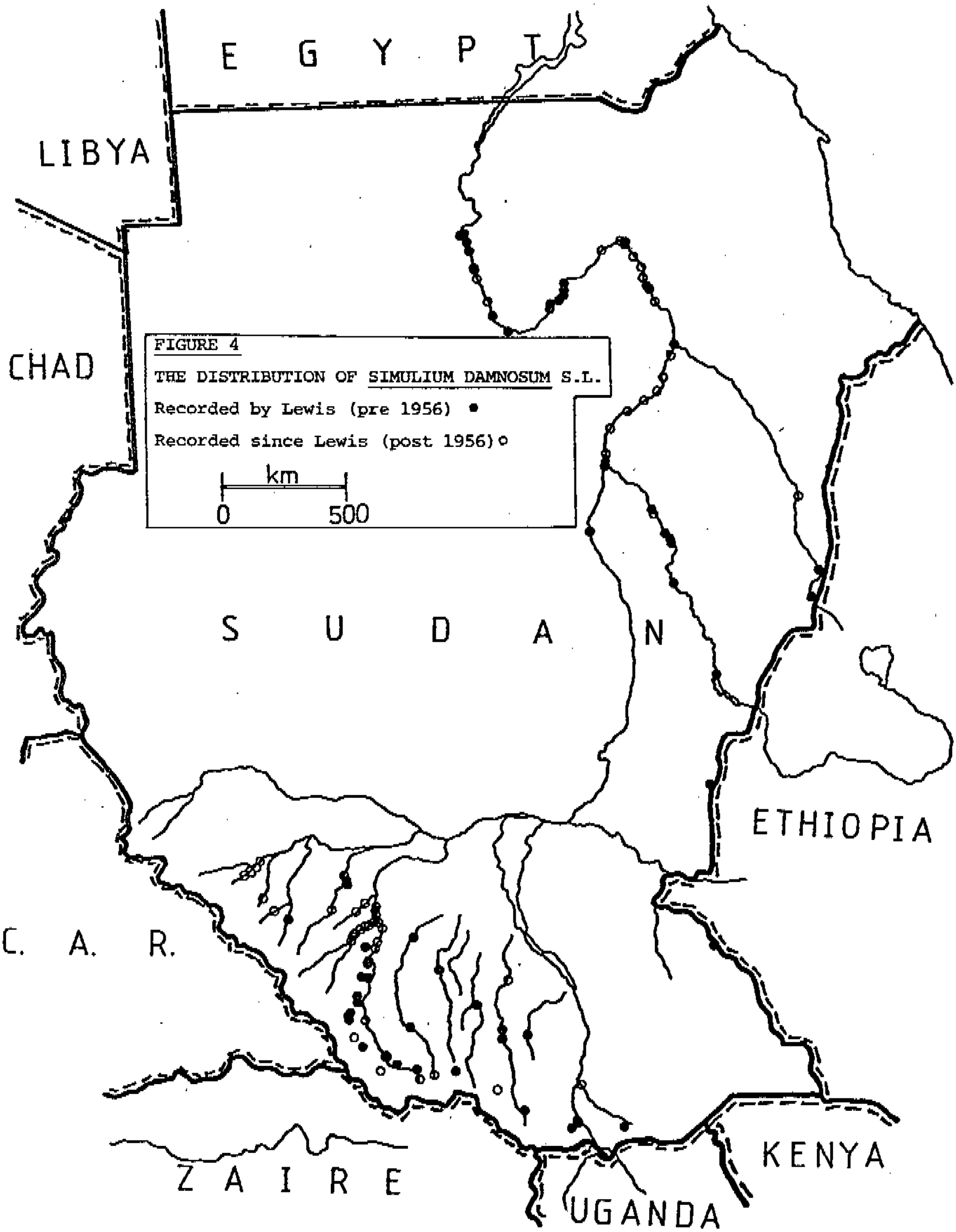


FIGURE 2
ONCHOCERCIASIS FOCI IN SUDAN
Blinding Foci ●
Non-Blinding Foci o (? blindness uncertain)
km
0
500
EGYPT
LIBYA
CHAD
SUDAN
ETHIOPIA
C. A. R.
ZAIRE
UGANDA
KENYA


EGYPT
LIBYA
CHAD
SUDAN
ETHIOPIA
C. A. R.
ZAÏRE
UGANDA
KENYA
3rd Cat.
Dongola
Abu Hamed
4th Cat.
Karima
5th Cat
Atbara
Shendi
KHARTOUM
Kassala
Wad Medani
Gedaref
Sennar
Damazine
Radom
Malakal
Raga
Aweil
Wau
Rumbek
Yirol
Mvolo
Tembura
Maridi
Yambio
Mundri
Juba
Torit
Yei
FIGURE 3
ONCHOCERCIASIS IN SUDAN : Maximum Distribution
km
0
500


E G Y P T
LIBYA
CHAD
FIGURE 4
THE DISTRIBUTION OF SIMULIUM DAMNOSUM S.L.
Recorded by Lewis (pre 1956) ●
Recorded since Lewis (post 1956) ○
km
0
500
S U D A N
ETHIOPIA
C. A. R.
KENYA
Z A I R E
UGANDA

= = =